DE BEERS SNAP LAKE MINE

AIR QUALITY, METEOROLOGICAL MONITORING, AND EMISSIONS REPORTING

2012 ANNUAL REPORT

Submitted to:

De Beers Canada Inc.
Yellowknife, Northwest Territories

July 2013 **13-1349-0001/3300**

EXECUTIVE SUMMARY

The Snap Lake Mine is a diamond mine owned and operated by De Beers Canada Inc. (De Beers). The mine is located approximately 220 km northeast of Yellowknife, 30 km south of MacKay Lake and 100 km south of Lac de Gras. Final regulatory approvals for construction and operation of the Mine were granted in May 2004, and construction began in April 2005. Mining began in 2007.

Air Quality and Meteorological Monitoring

The principal objective of the Air Quality, Meteorological Monitoring and Emissions Reporting Annual Summary is to comply with the Surveillance Network Program (SNP) described in Section D of the SNP, Appendix to Water License MV2001L2-0002, Article VI Section 6.3 items d and e and Article VI Section 7.2 part a) of the Environmental Agreement, and related corporate commitments.

This report provides the results of the air quality and meteorological monitoring programs that were active at Snap Lake during 2012. This document fulfills the annual reporting requirements outlined in the Air Quality and Emissions Management and Monitoring Plan (De Beers 2008). Changes to the original Plan (De Beers 2005) were made in 2007 and 2008 to align with design recommendations from the Government of the Northwest Territories' (GNWT) Ministry of Environment and Natural Resources and Environment Canada (GNWT and Environment Canada 2006).

What was monitored in 2012?

In 2012, the monitoring program involved the following components:

- **Meteorological monitoring** – Hourly measurements of wind speed, wind direction, solar radiation, temperature, relative humidity, and rainfall were collected from instruments mounted on a 10 metre (m) tower and a 3 m tripod.
- **Particulate monitoring** – 24-hour average values of total suspended particulate (TSP), particulate matter nominally less than or equal to 2.5 (micrometres) µm aerodynamic diameter ($PM_{2.5}$), and particulate matter nominally less than or equal to 10 µm aerodynamic diameter (PM_{10}) sampled once every six days between January and December.
- **Passive gas monitoring** – Passive gas sampling began in January and continued through December; monthly samples were collected for nitrogen dioxide (NO_2) and sulphur dioxide (SO_2).

What were the results of the 2012 Meteorological and Air Quality Monitoring Program?

The results of the 2012 monitoring program were:

- **Meteorological monitoring** – Wind speed and wind direction data from 2012 showed less wind from the northwest than in 2011, but the predominant wind remained from the east and east-southeast. Overall, the precipitation at Snap Lake was lower than the 30 year Yellowknife climate normals (1971 to 2000) (Environment Canada 2012). Annual average temperatures were within the range of those observed in the past five years with the exception of July, August, and September, wherein the temperature was higher than normal. The relative humidity followed the same pattern as the previous five years, as did precipitation.
- **Particulate monitoring** – Consolidation of the 2012 particulate monitoring data indicates notable challenges with the particulate monitoring program in 2012. In January 2013, the dichotomous $PM_{10}/PM_{2.5}$ Partisol located south of the runway was replaced to improve the quality of data. There was only one occurrence recorded above the GNWT Ambient Air Quality Standard (AAQS) for all particulate monitoring in 2012. The occurrence was a TSP 24-hour concentration of 145.2 micrograms per cubic metre ($\mu g/m^3$) which was above the objective of 120 $\mu g/m^3$ regulated by the GNWT (GNWT 2011). The occurrence was recorded on November 11, 2012 south of the runway.
- **Passive monitoring** – The highest monthly NO_2 concentration was 13.0 $\mu g/m^3$ observed during the May to June period at the passive monitoring site located just west of the tank farm. This peak concentration falls well below the maximum desirable annual level of 60 $\mu g/m^3$ set forth in the GNWT AAQS (GNWT 2011). The highest SO_2 concentration monitored during 2012 was 0.8 $\mu g/m^3$. The occurrence was observed during the November to December period at the passive monitoring site located west of the tank farm. This peak concentration falls well below the maximum annual average objective of 30 $\mu g/m^3$ regulated by the GNWT (GNWT 2011).
- **Snap Lake Mine emissions** – Fuel consumption was approximately 31,769 cubic metres of diesel with a sulphur content of not more than 15 parts per million by weight. The furnaces did not burn waste oil in 2012, but rather diesel fuel. Emission rates were lower in 2012 than 2011 despite an increase in fuel consumption. The emission reduction was primarily due to increased fuel consumption in equipment that has lower emission ratings and decreased fuel consumption in equipment with higher emissions. SO_2 and particulate emissions decreased due to diesel being used in the furnaces instead of waste oil which has higher sulphur content. Emissions remained below the 2007 Air Modelling Update.
- **Greenhouse gas emissions** –Total greenhouse gas emissions (GHGs) were estimated based on fuel consumption. The reported total includes calculated emissions for methane, carbon dioxide, and nitrous oxide. The carbon dioxide equivalent (CO_2e) releases from the Project in 2012 were 88.63 kilotonnes CO_2e. GHG emissions have increased since 2005 due to increased fuel consumption and were highest in 2012.

- **Dioxins and Furans** – Although not a regular component of the Air Quality and Emissions Management and Monitoring Plan, a dioxin and furan monitoring program measuring emissions from the on-site incinerators was undertaken in 2012. The total dioxins and furans measured was 18,787 picograms of international toxicity equivalents per reference cubic metre (pg I-TEQ/Rm^3). This result is above the Canada-Wide Standard (CWS) of 80 pg I-TEQ/Rm^3. The incinerators have been locked out and are no longer in use. A replacement pair of incinerators capable of meeting the CWS has been installed and is operational.

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ACRONYMS

AAQS	Ambient Air Quality Standards
AQEMMP	Air Quality and Emissions Management and Monitoring Plan
AQMP	Air Quality Monitoring Program
BC	British Columbia
CCME	Canadian Council of Ministers of the Environment
CH_4	methane
CI	continuous improvement
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
De Beers	De Beers Canada Inc.
Dichot Partisol	dichotomous partisol sampler
e.g.	for example
EAR	Environmental Assessment Report
EMP	Emissions Management Plan
EMS	Environmental Management System
ENR	Environment and Natural Resources
GHG	greenhouse gas
GNWT	Government of Northwest Territories
Golder	Golder Associates Ltd.
Hill Station	Hill meteorological monitoring station
I-TEQ	International Toxic Equivalents
KCAC	Keeping Clean Air Clean
Lake Station	Lake hydro-meteorological monitoring station
Mine	Snap Lake Mine
MVEIRB	Mackenzie Valley Environmental Impact Review Board
N_2O	nitrous oxide
NAAQO	National Ambient Air Quality Objectives
NAD	North American Datum
NAPS	National Air Pollution Surveillance
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NWT	Northwest Territories

O_2	oxygen
Partisol	Partisol Sampler – a particulate monitoring unit
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzofurans
PM_{10}	particulate matter nominally less than or equal to 10 micrometres (µm) aerodynamic diameter
$PM_{2.5}$	particulate matter nominally less than or equal to 2.5 µm aerodynamic diameter
QA/QC	quality assurance/quality control
SLEMA	Snap Lake Environmental Monitoring Agency
SNP	Surveillance Network Program
SO_2	sulphur dioxide
TSP	total suspended particulate
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator geographic coordinate system

UNITS

%	percent
±	plus or minus
°C	degrees Celsius
µg/m³	micrograms per cubic metre
µm	micrometre
km	kilometre
km/h	kilometres per hour
kt	kilotonne
kt/yr	kilotonnes per year
kW/m^2	kilowatts per square metre
L	litre
L/yr	litres per year
lb/cycle/unit	pounds per cycle per unit
m	metre
m^3	cubic metre
mg	milligrams
mm	millimetre
º	degrees
pg I-TEQ/Rm³	picograms per international toxicity equivalents per reference cubic metre
ppm	parts per million
t	tonnes
t/d	tonnes per day
W/m^2	watts per square metre

1 INTRODUCTION

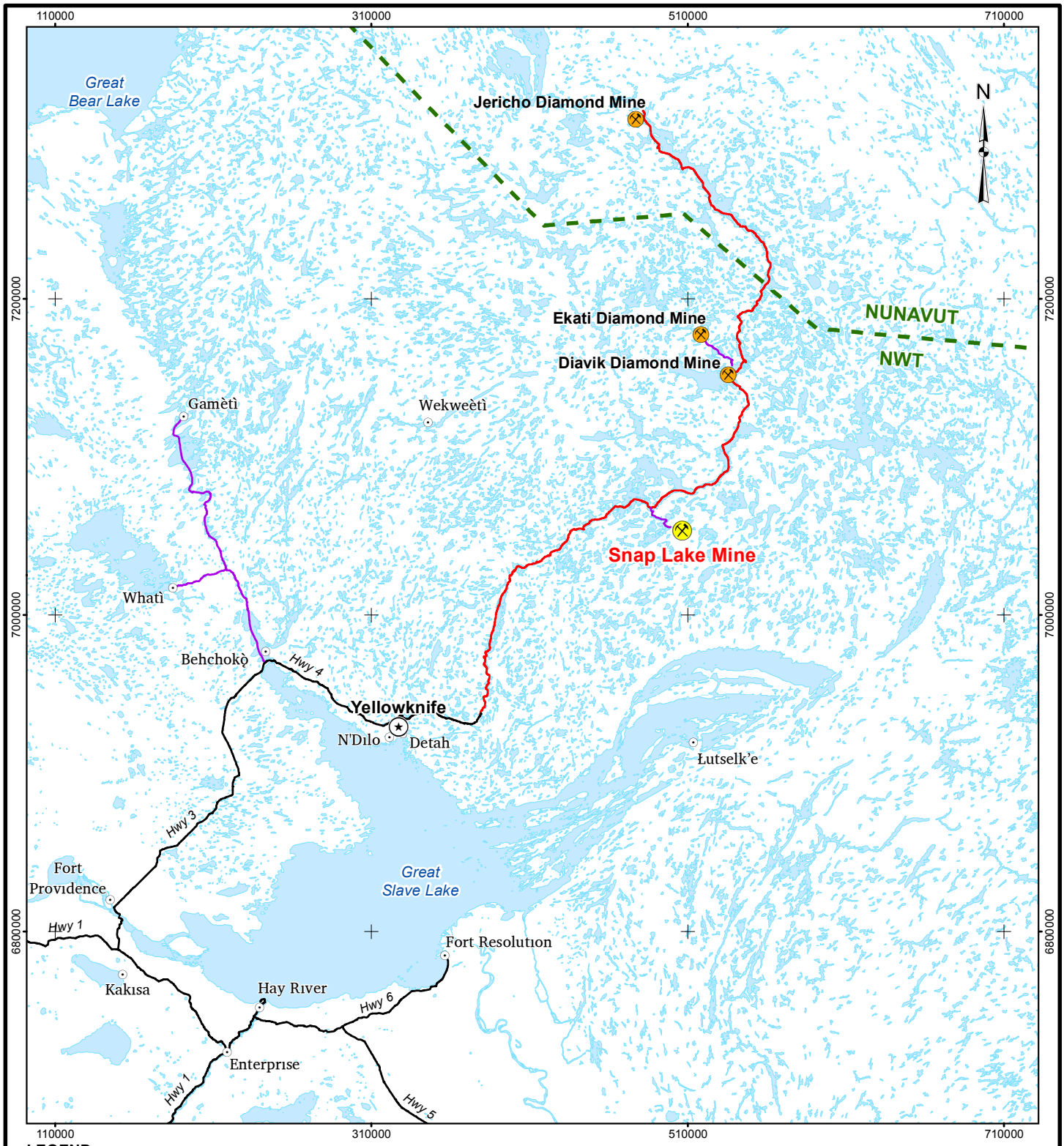
1.1 BACKGROUND

De Beers Canada Inc. (De Beers) owns and operates the Snap Lake Mine (Mine) in the Northwest Territories (NWT). The Mine is located approximately 220 kilometres (km) northeast of Yellowknife, 30 km south of MacKay Lake, and 100 km south of Lac de Gras where the Diavik Diamond Mine and the Ekati Diamond Mine are located (Figure 1-1). Final regulatory approvals for construction and operation of the Mine were granted in May 2004, and construction began in April 2005. The first diamonds were recovered in August 2007, and commercial production was achieved in early 2008. The Mine officially opened on July 25, 2008.

The Mine includes the development of underground workings, a kimberlite storage facility (the North Pile), mine facilities and accommodations, an airstrip, water treatment facilities, fuel and ammonium nitrate storage facilities, and a winter access road spur off the Tibbitt-to-Contwoyto winter road.

De Beers has conducted ambient air quality and meteorological monitoring at the Mine since 1998 when the Advanced Exploration Program began. The programs reflect a commitment by De Beers to identify and mitigate air impacts during planning, construction, and operation of the Mine (De Beers 2002a). Golder Associates Ltd. (Golder) has assisted De Beers with their air quality and meteorological monitoring needs since 1998.

This report provides the results of the air quality and meteorological monitoring programs that were active at the Mine during 2012. It fulfills the annual reporting requirements outlined in the Air Quality and Emissions Management and Monitoring Plan (AQEMMP) (De Beers 2008). Changes to the original AQEMMP (De Beers 2005) were made in 2007 and then in 2008 to incorporate design recommendations from the Government of the Northwest Territories (GNWT) Ministry of Environment and Natural Resources (ENR) and Environment Canada (GNWT and Environment Canada 2006).



LEGEND

- SNAP LAKE MINE
- EXISTING MINE
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- EXISTING WINTER ROAD
- TIBBITT-TO-CONTWOYTO WINTER ROAD
- WATERCOURSE
- WATERBODY
- TERRITORIAL/PROVINCIAL BOUNDARY

100 0 100

SCALE 1:3,500,000 KILOMETRES

REFERENCE

Base data source: The Atlas of Canada
Datum: NAD83 Projection: UTM Zone 12

PROJECT

De Beers
GROUP OF COMPANIES

TITLE

LOCATION OF SNAP LAKE MINE

Golder Associates

PROJECT NO. 13-1349-0001			FILE No.	
DESIGN	AO	08 Apr. 2013	SCALE AS SHOWN	REV. 0
GIS	CW	08 Apr. 2013		
CHECK	LK	08 Apr. 2013		
REVIEW	ME	08 Apr. 2013		

FIGURE: 1-1

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1.2 LEGISLATION, REGULATORY AND POLICY REQUIREMENTS

An Environmental Assessment Report (EAR) for the Mine (De Beers 2002a) was completed and submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) in February 2002. The Board in turn completed a review and recommended that the Mine proceed subject to the implementation of measures to mitigate environmental impacts (MVEIRB 2003). MVEIRB's report and recommendation were submitted to the Minister of Indian and Northern Affairs Canada in July 2003 and received ministerial approval in October 2003. De Beers received the necessary Water License (MV2001L2-0002), Land Use Permit, Land Lease, and Environmental Agreement in May 2004 to begin construction and operation of the Mine.

De Beers must meet the following requirements regarding air quality, meteorological monitoring, and emissions monitoring:

- develop an Air Quality Monitoring Program (AQMP), as outlined in Article VII, Section 7.2 item a of the Environmental Agreement;
- develop an Emissions Management Plan (EMP), as outlined in Article VI, Section 6.3 items d and e and Article VII, Section 7.2 item a) of the Environment Agreement; and
- meet the meteorological monitoring requirements specified in the General Conditions (Part B) and the SNP section of the Water Licence (MV2001L2-0002).

1.3 SCOPE

An initial draft of the AQMP was prepared in September 2003 and was updated in September 2005 based on feedback from the GNWT and Environment Canada. A draft of the EMP was submitted to the Snap Lake Environmental Monitoring Agency (SLEMA), GNWT, and Environment Canada in February 2006. Upon receipt of feedback on this draft (GNWT and Environment Canada 2006), the AQMP and EMP were harmonized into one document, the AQEMMP, not only to demonstrate the linkages between the two monitoring programs but also because the data from the two programs will be presented together each year in the annual report. The AQEMMP was submitted for review in October 2007.

De Beers, ENR, and Golder met on March 6, 2008 to discuss the harmonized AQEMMP and comments made by ENR in February 2008. Subsequently, the AQEMMP was finalized (De Beers 2008) to reflect the comments made by ENR in a February 2008 letter (ENR 2008) and during the March 2008 meeting, as well as comments made by the Snap Lake Environmental Monitoring Agency in a letter submitted to De Beers in January 2008 (SLEMA 2008).

The overall purpose of this integrated AQEMMP is to provide an overview of the activities included in the air quality monitoring and emissions management plans, and also to provide a template for the annual monitoring reports. The AQEMMP is a "living" document that has been been adapted as the Mine has evolved, consistent with the Mine's Adaptive Management Plan (De Beers 2004).

An important component of the AQEMMP is the requirement for a comparison of annual monitoring data to emission estimates and dispersion modelling predictions presented in the EAR (De Beers 2002a). An Air Modelling Update was completed in 2007 (De Beers 2007). In the present report, the 2007 Air Modelling Update is referred to as a basis for comparison with monitoring data.

1.4 OBJECTIVES

This report has been developed to address the following objectives:

- demonstrate compliance with applicable Federal and Territorial ambient air quality standards;
- track trends in ambient air quality and emissions;
- provide information required for the EMS (De Beers 2002b) to protect air quality;
- verify the impact predictions made in the Air Modelling Update (De Beers 2007);
- outline response plans to respond to increasing trends, occurrences above the air quality criteria, or occurrences above emission estimates, and dispersion modelling predictions presented in the Air Modelling Update;
- provide data that can make a meaningful contribution to a regional cumulative effects monitoring data bank;
- identify strategies for emissions tracking and monitoring;
- document fuel use as it relates to air quality management; and
- facilitate data gathering necessary to develop an approach for emissions mitigation, which includes the fugitive dust abatement program.

To achieve these objectives, Sections 2 and 3 of this report concentrate on the following three main components:

- on-site meteorological monitoring;
- ambient monitoring of total suspended particulate (TSP) and fine particulate matter concentrations less than 10 micrometres (µm) (PM_{10}) and less than 2.5 µm ($PM_{2.5}$); and
- passive monitoring of sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).

Section 4 focuses on the following three components:

- emissions estimates;
- fuel use summary; and
- emissions mitigation strategies, including the fugitive dust abatement program.

1.5 METHODOLOGY AND APPROACH

De Beers has conducted ambient air quality and meteorological monitoring at the Mine site since 1998 when the Advanced Exploration Program began. De Beers understands the need for adaptive management of the monitoring programs and acknowledges that the monitoring sites may change as the Mine evolves. However, an effort will be made to maintain consistency in the monitoring locations, as this is an important consideration in conducting trend analyses.

Monitoring activities occur both on-site and off-site. In this regard, on-site monitoring is defined as monitoring that occurs within the active mine area, whereas “off-site” monitoring occurs outside of the active mine area (Section 2).

The focus of the AQEMMP is off-site monitoring for consistency with the applicable ambient air quality standards, which are based on off-site concentrations measured at or beyond the facility boundary. This off-site monitoring is important because it provides an indication of the ambient concentrations of air emissions to which the public, or other components of the receiving environment, may be exposed. The effectiveness of the AQEMMP is dependent, in part, on selecting appropriate criteria against which Mine emissions and the resulting ambient air concentrations should be compared. Currently no provision for air quality is included in permits for mines in the NWT, and there is no requirement to monitor for compliance within permit limits. In lieu of air quality permit requirements, the Mine is required to comply with the relevant NWT Ambient Air Quality Standards (AAWQS) for TSP, $PM_{2.5}$ (24-hour and annual), NO_2 and SO_2 (1-hour, 24-hour and annual) (GNWT 2011). Table 1-1 presents the relevant air quality criteria.

Table 1-1 Relevant Ambient Air Quality Criteria

Parameter	NWT Standards	Canada-Wide Standards[b]	National Air Quality Objectives[c]		Other Criteria
			Desirable	Acceptable	
SO_2 [µg/m³]					
1-Hour	450[a]	—	450	900	450[e]
24-Hour	150[a]	—	150	300	125[e]
Monthly	—	—	—	—	30[e]
Annual	30[a]	—	30	60	20[e]
NO_2 [µg/m³]					
1-Hour	400[a]	—	—	400	300[e]
24-Hour	200[a]	—	—	—	—
Annual	60[a]	—	60	100	45[e]
TSP [µg/m³]					
24-Hour	120[a]	—	—	120	100[e]
Annual[d]	60[a]	—	60	70	60[e]
PM_{10} [µg/m³]					
24-Hour	—	—	—	—	50[f]
Annual	—	—	—	—	—
$PM_{2.5}$ [µg/m³]					
24-Hour	30[a]	30	—	—	25[f]
Annual	—	—	—	—	8[f]

[a] Source: GNWT 2011.

[b] Source: CCME 2000.

[c] Source: Environment Canada 2011.

[d] As a geometric mean.

[e] Source: Government of Alberta 2013.

[f] Source: Government of British Columbia 2009.

µg/m^3 = micrograms per cubic metre; SO_2 = sulphur dioxide; NO_2 = nitrogen dioxide; TSP = total suspended particulate; PM_{10} =particulate matter nominally less than or equal to 10 micrometres aerodynamic diameter; $PM_{2.5}$ = particulate matter nominally less than or equal to 2.5 micrometres aerodynamic diameter.

In addition to demonstrating that Mine emissions and ground-level concentrations are consistent with the applicable regulatory criteria, it is De Beers' intent to manage emissions and ground-level concentrations in keeping with the principles of "Continuous Improvement" (CI) and "Keeping Clean Areas Clean" (KCAC), as described in the Canada-Wide Standards for Particulate Matter and Ozone (CCME 2000). Therefore, the ambient air quality monitoring results and trends in emissions are important components of the AQEMMP, as discussed in Sections 2, 3, and 4.

De Beers has incorporated a number of design features that demonstrate their commitment to KCAC and CI. These include, but are not limited to, the following:

- selection of highly-efficient combustion equipment;
- underground and wet primary ore crushing;
- conveyor-based, covered ore transport systems;
- short haul route to tailings facility;

- investigation of alternate energy sources to offset diesel combustion;
- modern incineration facilities and waste segregation policies;
- worker education;
- on-site recycling programs; and
- development of management plans to guide actions and documentation needs regarding air quality.

Implementation of these policies and practices demonstrates De Beers' ongoing commitment to reducing emissions through the use of the best available, economically feasible technology and systems.

2 METEOROLOGICAL MONITORING

2.1 OBJECTIVE

Meteorological data were measured at Snap Lake during 2012 to contribute to the maintenance of an accurate record of weather conditions at the site. The data may also be used to support future air quality dispersion modelling. Temperature, relative humidity, solar radiation, and precipitation data may contribute to a regional data bank. Furthermore, precipitation data may be used in hydrological studies.

As indicated in the 2006 annual report, De Beers installed a hydro-meteorological monitoring station to provide data specifically for the calculation of lake evaporation. This station is located northeast of the tank farm and collects meteorological data from the lake-side including total precipitation (rain and snow).

2.2 MONITORING STATION LOCATIONS

The hill meteorological monitoring station (Hill Station) is located on an elevated point of land west of the water management pond at Universal Transverse Mercator [UTM] 506052E, 7052492N North American Datum (NAD) 83 (Zone 12N). The Hill Station is shown in Figure 2-1 which also displays the locations of the passive monitoring and particulate monitoring sites. Rainfall, temperature, wind, relative humidity, and solar radiation data were collected at the Hill Station in 2012. Data were collected from instruments mounted on a 10 metre (m) tower. Details of each of the sensors installed at the Hill Station to collect meteorological data is provided in Table 2-1. Summaries of monitoring results for each parameter are provided in the present section. Figure 2-2 is a photograph of the Hill Station with a view beyond to the north.

The lake hydro-meteorological monitoring station (Lake Station) is located northeast of the construction camp at UTM 506484E, 7053277N NAD 83 (Zone 12N). Temperature, wind, relative humidity, and net solar radiation data were collected at the Lake Station in 2012. Snow/rainfall data for 2012 were not collected due to a hardware malfunction. The hardware was sent to the vendor for repair, has been reinstalled, and has been operational as of January 2013. Details of each of the sensors installed at the Lake Station to collect meteorological data are provided in Table 2-2. Summaries of monitoring results for each parameter are provided in the present section. A photograph of the Lake Station is shown in Figure 2-3.

Figure 2-1 Air Quality and Meteorological Monitoring Stations

1. TSP Partisol 1, Dichotomous $PM_{10}/PM_{2.5}$ Partisol 1, Runway Passive Monitoring Site;
2. TSP Partisol 2, Dichotomous $PM_{10}/PM_{2.5}$ Partisol 2, Ammonium Nitrate Fuel Oil Area Passive Monitoring Site;
3. West Shore Snap Lake Passive Monitoring Site;
4. North Shore Snap Lake Passive Monitoring site;
5. TSP Partisol 3, Wetlands Passive Monitoring Site;
6. Tank Passive Monitoring Site;
7. Landfarm Passive Monitoring Site;
8. Hill Monitoring Station; and,
9. Lake Monitoring Station.

Table 2-1 Hill Meteorological Monitoring Station Components

Parameter	Instrumentation
Temperature	Temperature sensor is housed in a radiation shield that is mounted on the tower at approximately 2 m above ground level
Air temperature -55°C to +50°C	Campbell Scientific YSI 44002A thermistor
Winds	Anemometer is located at 10 m above the ground (avoids some of the effects of surface friction consistent with many other sites in North America)
Wind speed in kilometres per hour [km/h]	R.M. Young 05103 Wind Monitor, mounted at a height of 10 m
Wind direction (°)	R.M. Young 05103 Wind Monitor
Standard deviation of wind direction (°)	R.M. Young 05103 Wind Monitor (calculated internally in the datalogger using the Yamartino algorithm)
Solar Radiation	Device mounted at 2.5 m on the meteorological station tower
Incoming solar radiation (kW/m²)	Licor LI 200S Silicon Pyranometer
Precipitation	Device mounted at 2.5 m on the meteorological station tower
Rainfall (mm)	Texas Electronics: TE525 WS Tipping Bucket Rain Gauge
Relative Humidity	Relative humidity sensor housed in a radiation shield mounted at approximately 2 m above the ground at the meteorological station
Relative humidity (%)	Vaisala capacitive relative humidity sensor
Data Storage and Retrieval	
Datalogger	Campbell Scientific CR1000 (Cold Spec)
Power supply	Solar panel and battery back-up
Instrument mounting	Campbell Scientific UT30 tower (10 m high)

° = degrees; °C = degrees Celsius; kW/m² = kilowatts per square metre; mm = millimetres; % = Percent; m = metre.

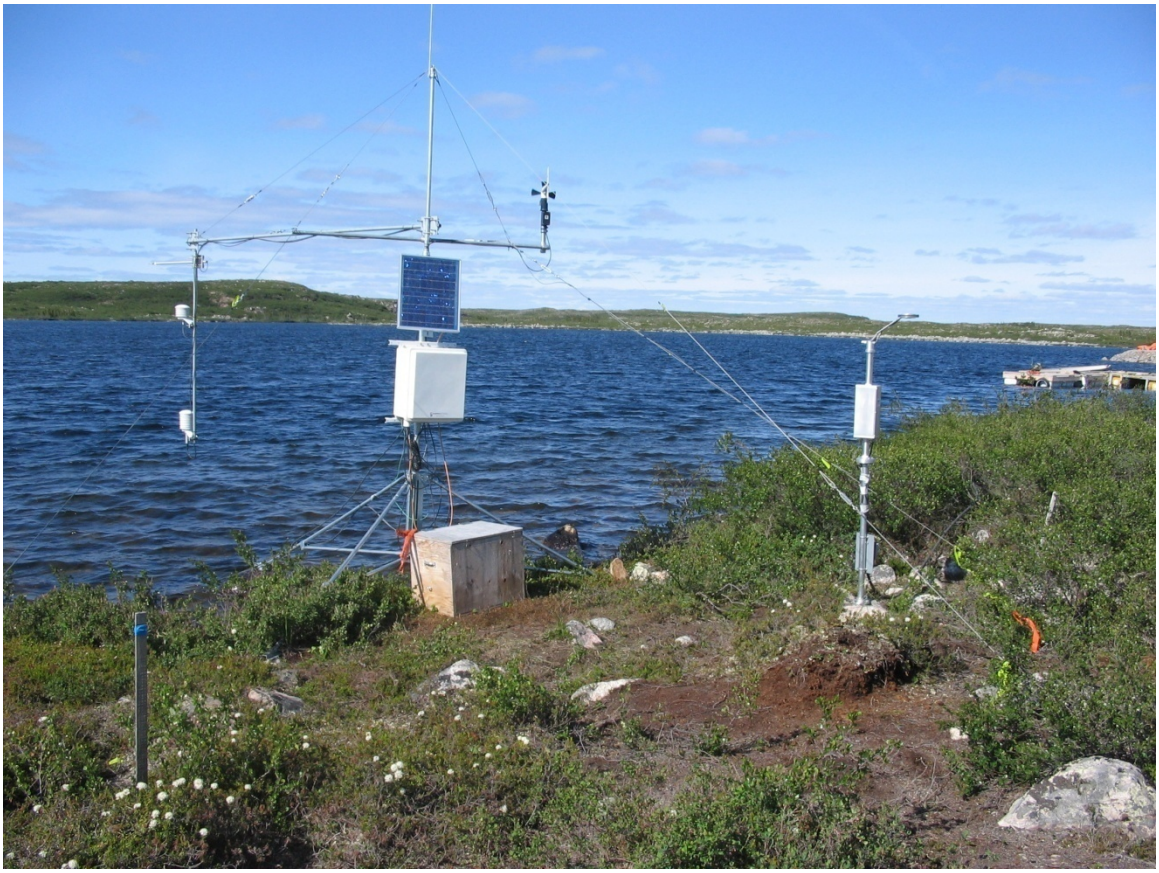
Figure 2-2 Hill Meteorological Monitoring Station

Table 2-2 Lake Meteorological Monitoring Station Components

Parameter	Instrumentation
Temperature	Four temperature sensors are installed at the station. Two are model 107L installed on the lake bed at nominally 1 and 2 m depths. A third 107L is mounted in a radiation shield at nominally 2 m above water surface. The fourth temperature sensor is a component of the combination Campbell Scientific model HMP45C212 temperature/relative humidity sensor. It is mounted in a radiation shield at nominally 1 m above the water surface.
Wind	Anemometer is located at 2.5 m above the ground (avoids some of the effects of surface friction consistent with many other sites in North America)
Wind speed (km/h)	R.M. Young 05103 Wind Monitor, mounted at a height of 2.5 m above the ground
Wind direction (°)	R.M. Young 05103 Wind Monitor
Standard deviation of wind direction (°)	R.M. Young 05103 Wind Monitor (calculated internally in the datalogger using the Yamartino algorithm)
Solar Radiation	Device mounted at 2.5 m above the water surface
Net solar radiation in (kW/m²)	Kipp & Zonen NR lite
Precipitation	Total precipitation sensor mounted at 2 m above the ground surface
Total precipitation (mm)	Yankee Environmental Systems TPS3100
Relative Humidity	Relative humidity sensor was housed in a radiation shield mounted at approximately 1 m above the water
Relative humidity (%)	Campbell Scientific model HMP45C212 temperature/relative humidity sensor
Water level	Keller 500C water bourne pressure transducer
Data Storage and Retrieval	
Datalogger	Campbell Scientific CR1000(Cold Spec)
Power supply	Solar panel and battery back-up
Instrument mounting	Campbell Scientific cm10 3 m tripod

km/h = kilometres per hour; ° = degrees; kW/m² = kilowatts per square metre; mm = millimetre; % = percent; m = metre.

Figure 2-3 Lake Meteorological Monitoring Station



2.3 MONITORING METHODS

Meteorological monitoring is being conducted at the site using a Campbell Scientific-based system. For the Hill Station, sensors are mounted on a 10 m tower while the Lake Station sensors are mounted on a 3 m tripod. Both stations are consistent with current accepted practice in Canada. The stations operate independently using a combination battery/solar panel power supply. A radio link permits communications between the Hill Station and the on-site De Beers' environmental technician's office.

2.3.1 Monitoring Frequency

Meteorological monitoring was conducted year-round throughout 2012. Meteorological data were measured continuously and recorded hourly. The data were downloaded approximately monthly by De Beers' site staff.

2.3.2 Monitoring Parameters

The Hill Station tower system continuously measured the following meteorological parameters:

- wind speed at 10 m above the ground;
- wind direction at 10 m above the ground;
- temperature at 2 m above the ground;
- relative humidity at 2 m above the ground;
- solar radiation at 2.5 m above the ground; and
- rainfall at 2 m above the ground.

The Lake Station tower system continuously measured the following meteorological parameters:

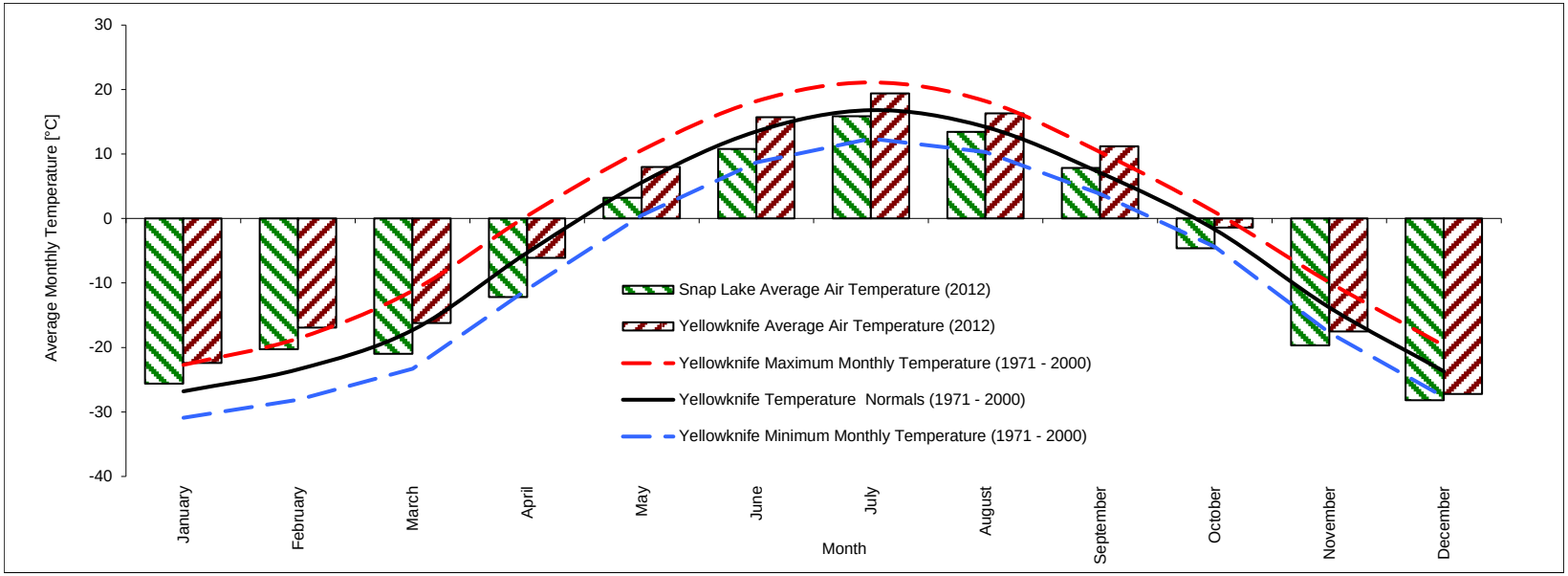
- wind speed at 2.5 m above the ground;
- wind direction at 2.5 m above the ground;
- temperature at 1 m and 2 m above the ground and 1 m and 2 m below the water;
- relative humidity at 1 m above the water;
- solar radiation at 2.5 m above the water; and
- precipitation at 2 m above the ground.

2.4 TEMPERATURE

2.4.1 Hill Station Temperature Results

The Hill Station hourly temperature values were measured for the entire year, with a data recovery rate of 98.4 percent (%). A summary of temperature data at Snap Lake is presented in Figure 2-4. Monthly mean temperatures ranged from -28.2 degrees Celsius (°C) in December to +15.9°C in July. The annual average temperature at Snap Lake in 2012 was -6.7°C, which was 1.2°C warmer than in 2011 (-7.9°C) and 0.9°C warmer than the 2004-2011 average (-7.6°C). The 1971 to 2000 long-term data for Yellowknife are also provided for comparison in Figure 2-4 (Environment Canada 2012).

Figure 2-4 2012 Hill Station Temperature Summary



ºC = degrees Celsius.

2.4.2 Lake Station Temperature Results

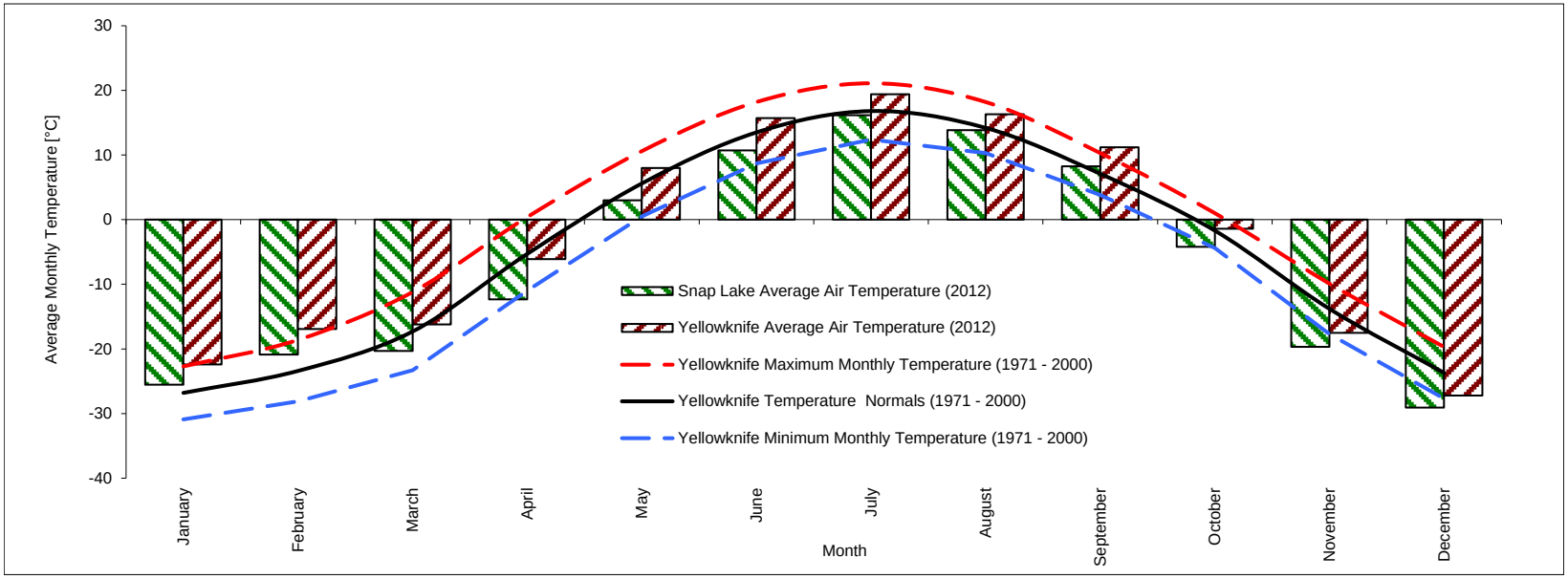
The Lake Station hourly temperature values were measured for the entire year, with a data recovery rate of 94.0%. A summary of temperature data at Snap Lake is presented in Figure 2-5. Monthly mean temperatures ranged from -29.1°C in December to +16.2°C in July. The annual average temperature at Snap Lake in 2012 was -6.7°C, which was 0.7°C warmer than in 2011 (-7.4°C) and 2.2°C colder than the 2008-2011 average (-4.5°C). The 1971 to 2000 long-term data for Yellowknife are also provided for comparison in Figure 2-5 (Environment Canada 2012).

2.4.3 Discussion

The average annual temperature of -6.7°C in 2012 for Snap Lake Hill Station was 2.1°C colder than the annual temperature of -4.6°C for Yellowknife during 1971 to 2000. The Lake Station data for Snap Lake were similar to the Hill Station data. The maximum difference between the stations was in November where the Hill station was 0.9°C warmer than the Lake Station.

The 2012 monthly air temperature average in Yellowknife was warmer than the long-term average temperature except for April, November, and December (Environment Canada 2012). In 2012, Yellowknife was 1.5°C warmer (-3.1°C) than the long-term average of -4.6°C (1971 to 2000).

Figure 2-5 2012 Lake Station Temperature Summary



ºC = degrees Celsius.

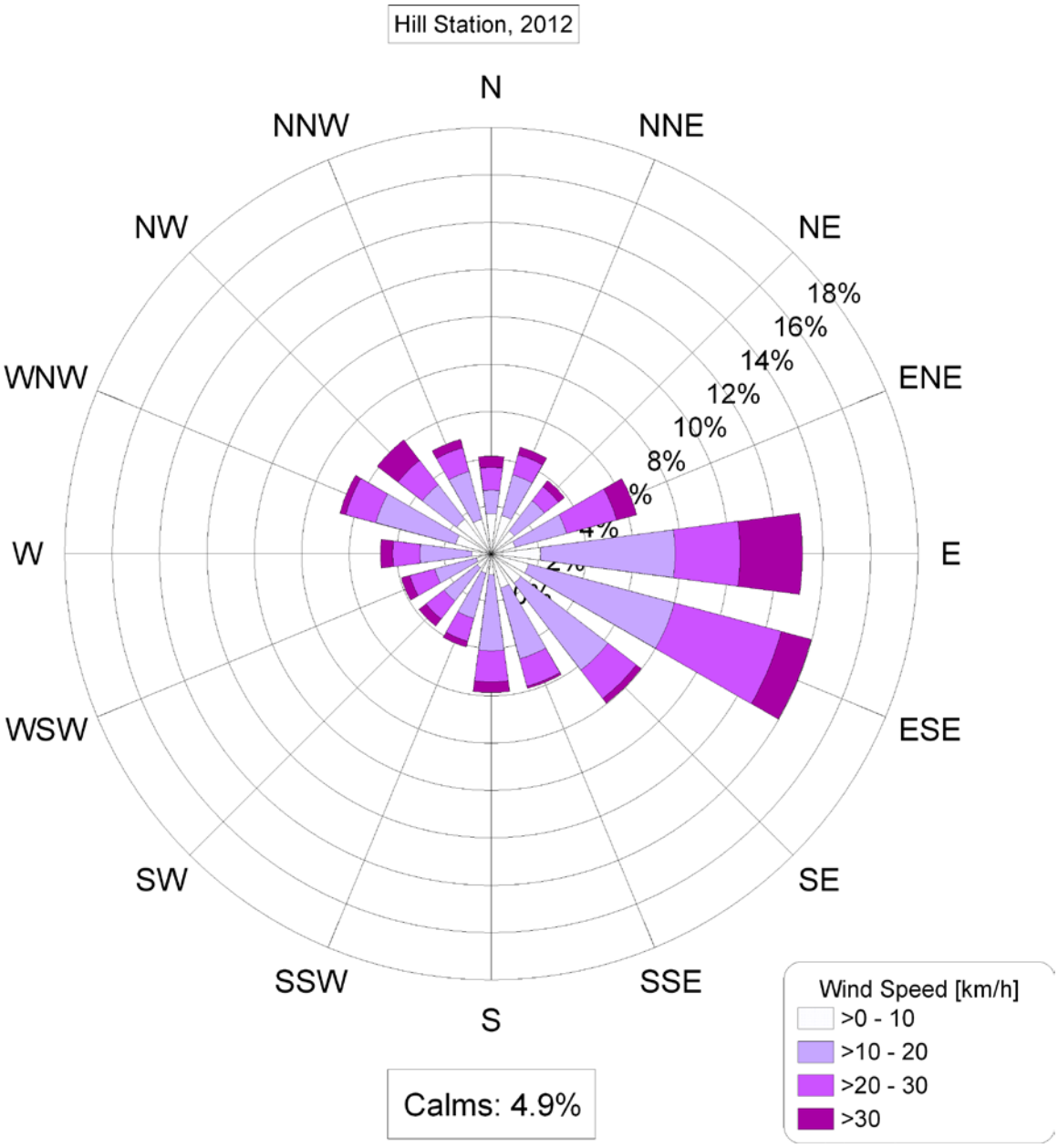
2.5 WIND SPEED AND WIND DIRECTION

2.5.1 Hill Station Wind Speed and Wind Direction Results

The Hill Station wind sensor service factor (operational uptime) for 2012 was 0.92; a factor of 1 would mean full data recovery for the year. A windrose showing frequencies of wind direction and wind speed for 2012 is presented in Figure 2-6. The predominant winds were from the east-southeast and the east with calm conditions occurring 4.9% of the time. Calm conditions refer to wind speeds less than 3.6 kilometres per hour (km/h).

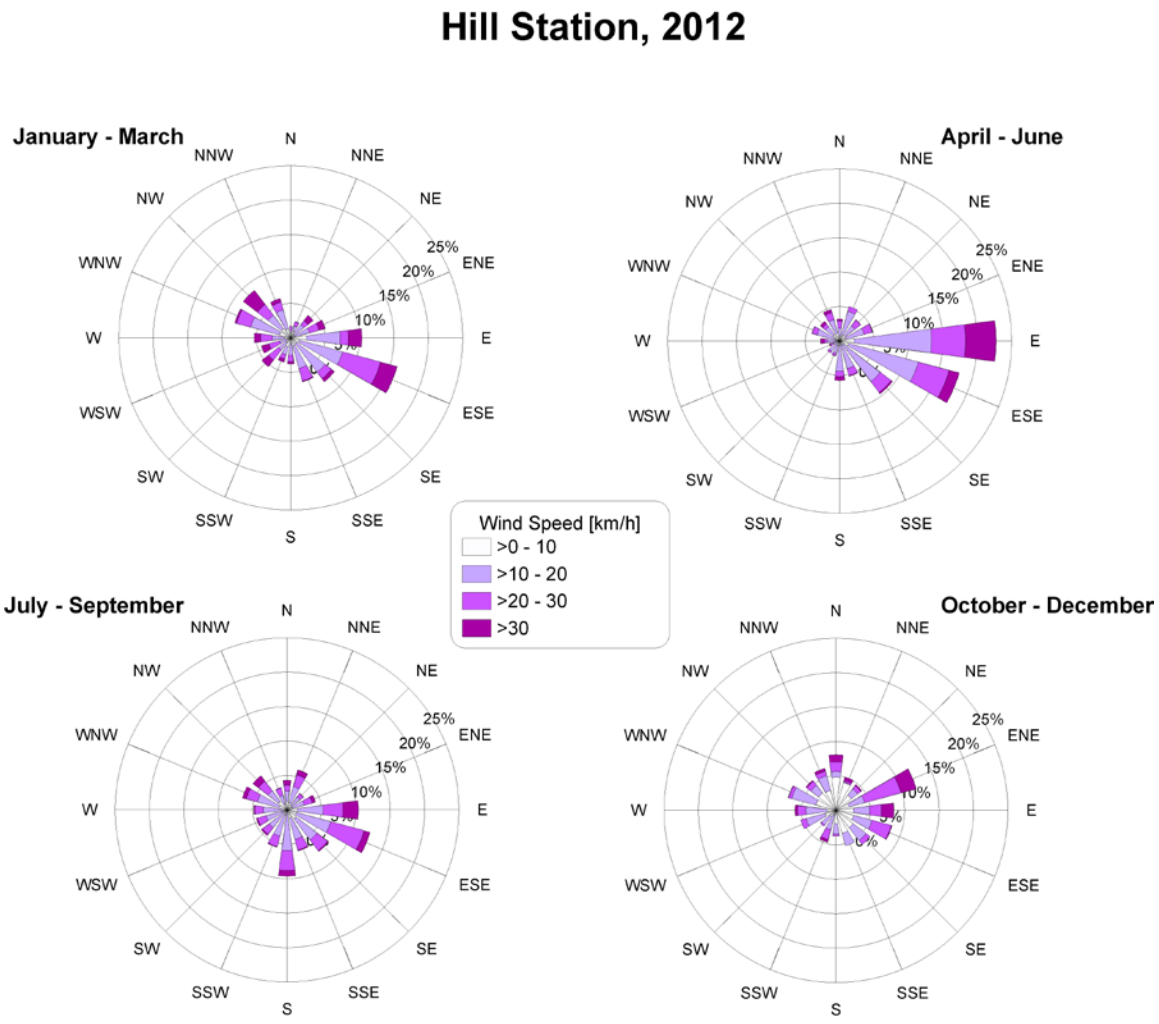
A series of windroses representing the four quarterly records of wind at Snap Lake is shown in Figure 2-7. The quarterly figure shows January through March, April through June, July through September, and October through December 2012 data in separate windroses. The January to March windrose shows that winds were predominantly from the east-southeast direction. During April to June, the winds were predominantly from the east and east-southeast directions. The windrose for the July to September quarter shows predominance from the east-southeast direction. For October to December, winds were predominantly from the east-northeast and not from the northwest where they are usually predominant at this time of the year.

Figure 2-6 2012 Hill Station Annual Wind Speed and Wind Direction Summary



km/h = kilometres per hour; % = percent.

Figure 2-7 2012 Hill Station Quarterly Wind Speed and Wind Direction Summary



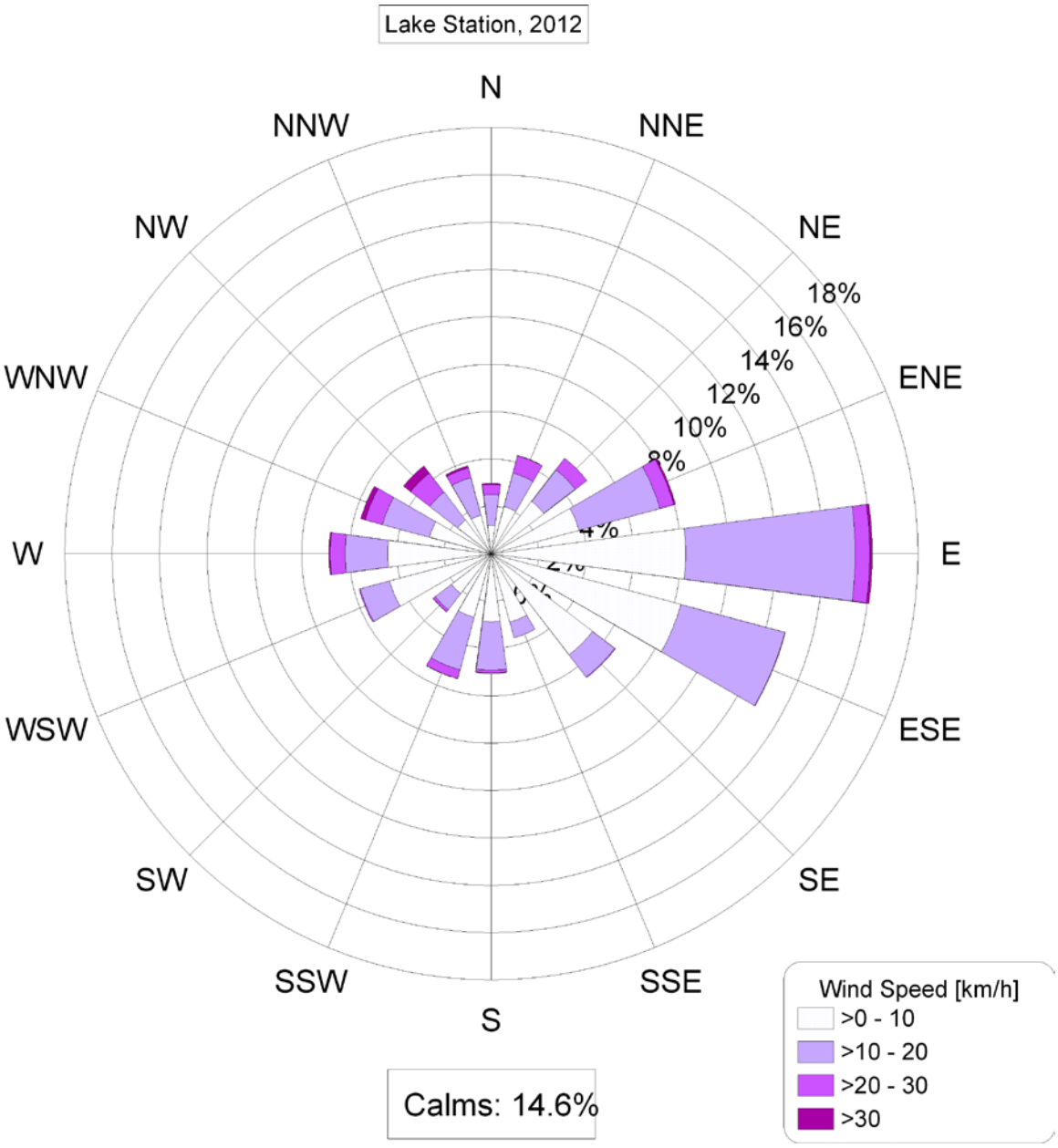
km/h = kilometres per hour; %= percent.

2.5.2 Lake Station Wind Speed and Wind Direction Results

The Lake Station wind sensor service factor for 2012 was 0.94. A windrose showing frequencies of wind direction and wind speed for 2012 is presented in Figure 2-8. The predominant winds were from the east and frequently from the east-southeast direction. Calm conditions occurred 14.6% of the time. Most of the calm conditions occurred during winter conditions; frost may have affected the equipment and overstated the amount of calm conditions. Wind from the northwest was less prevalent than in previous years.

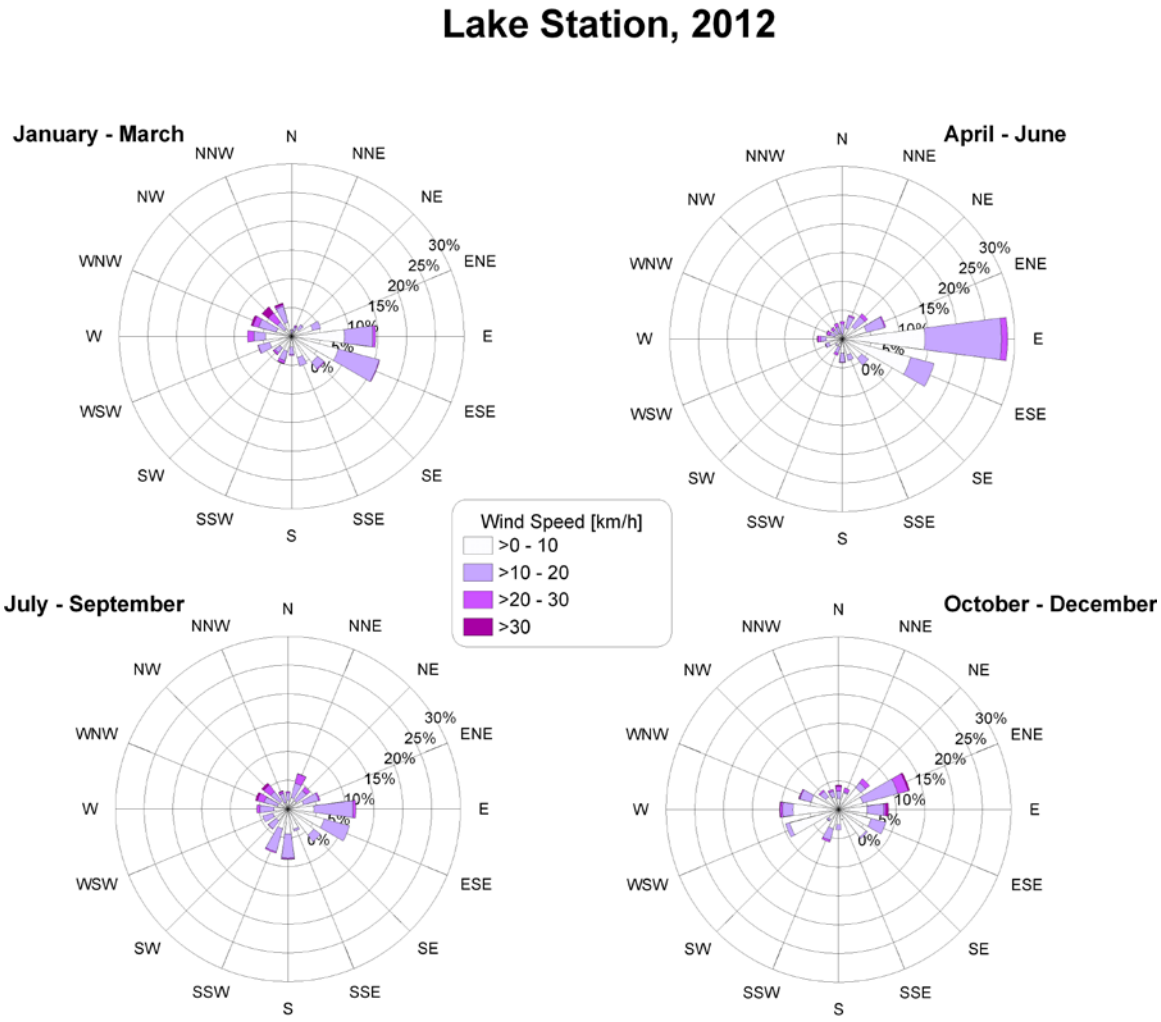
A series of windroses representing the four quarterly records of wind at Snap Lake is shown in Figure 2-9. The quarterly figure shows January through March, April through June, July through September, and October through December 2012 data in separate windroses. The January to March windrose shows that winds were predominantly from the east-southeast with secondary winds from the east direction. During April to June, the winds were predominantly from the east direction. The windrose for the July to September quarter shows no predominance, but more frequent wind from the east and east-southeast directions. For October to December, winds were predominant from the east-northeast direction.

Figure 2-8 2012 Lake Station Annual Wind Speed and Wind Direction Summary



km/h = kilometres per hour; %= percent.

Figure 2-9 2012 Lake Station Quarterly Wind Speed and Wind Direction Summary



km/h = kilometres per hour; %= percent.

2.5.3 Discussion

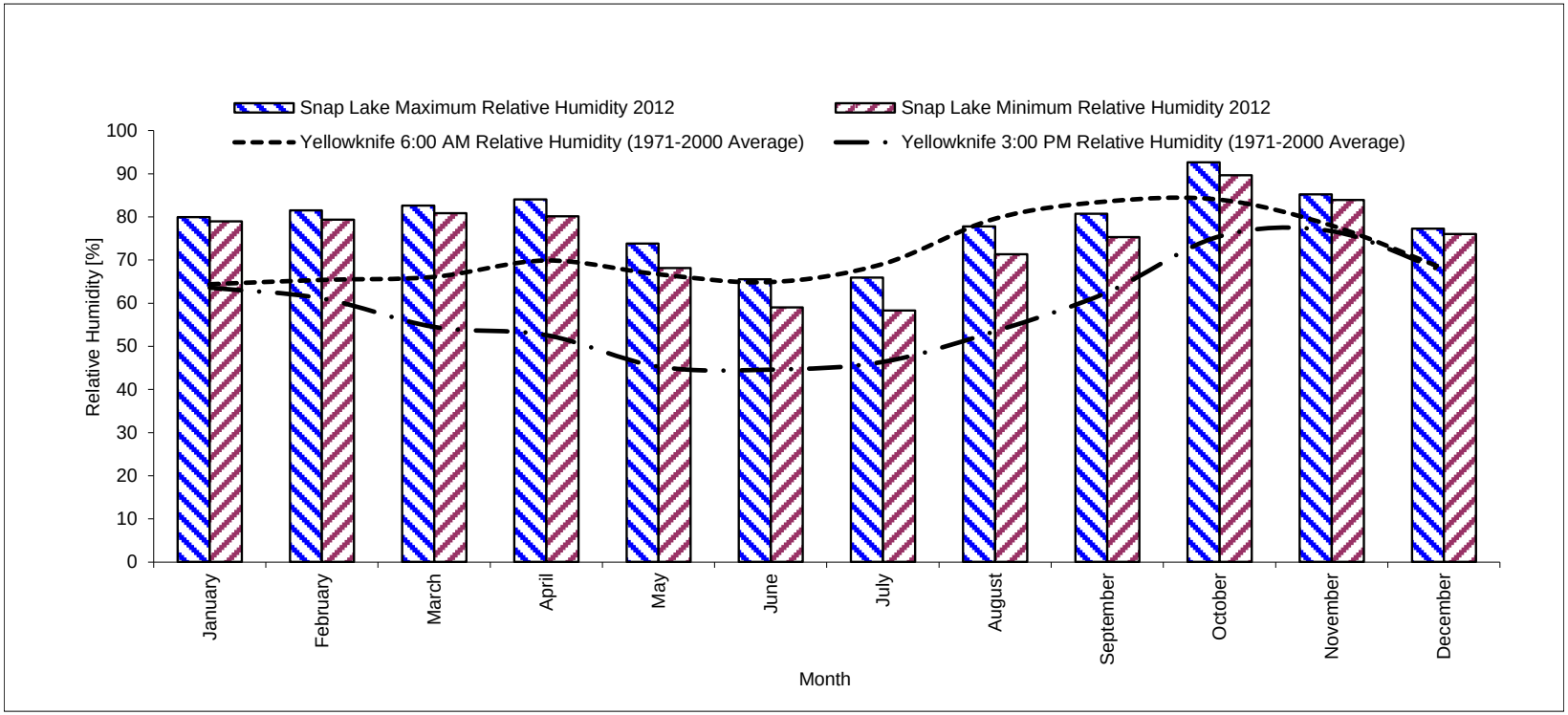
The Hill Station annual windrose shows a similar pattern as in previous years' monitoring with a high frequency of winds from the east-southeast, but less than in previous years from the west-northwest and northwest. The Lake Station annual windrose shows a similar pattern as in previous years' monitoring with a high frequency of winds from the east for the Lake Station. The quarterly windroses illustrate a more diverse range in wind direction throughout the year but, as in previous years, winds from the east and southeast dominated for much of the year. Unlike the previous year, the winter period winds frequently were not predominant from the northwest. These variations can be attributed to the different seasonal weather patterns that occur because annual wind predominance is influenced by the pattern of large scale weather systems that move through the region.

2.6 RELATIVE HUMIDITY

2.6.1 Hill Station Relative Humidity Results

The Hill Station relative humidity values were measured for the entire year, and the sensor service factor was 0.98. Average monthly relative humidity values ranged from 62.0% in July to 91.2% in October. The mean monthly relative humidity at Snap Lake is presented in Figure 2-10. Long-term (1971 to 2000) data for Yellowknife are also provided for comparison (Environment Canada 2012).

Figure 2-10 2012 Hill Station Relative Humidity Summary



%=percent.

2.6.2 Lake Station Relative Humidity Results

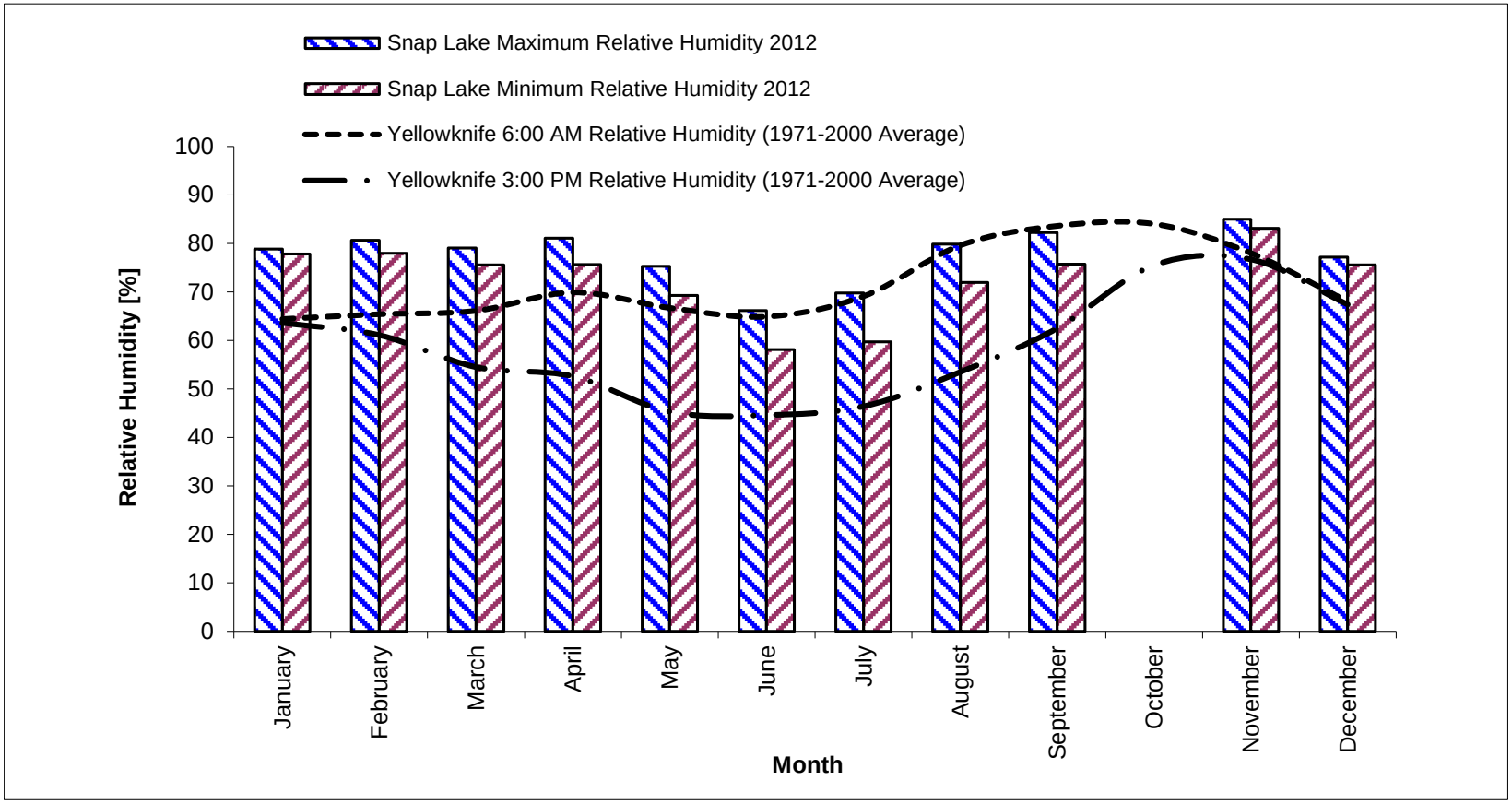
Lake Station relative humidity values were measured for the entire year, and the sensor service factor was 0.85. A hardware malfunction occurred at the end of September and resulted in data recorded as 0% for all of October. These data were removed from the data summary. The hardware at the Lake Station was repaired in early November. Average monthly relative humidity values ranged from 61.7% in June to 84.1% in November. The mean monthly relative humidity at Snap Lake is presented in Figure 2-11. Long-term (1971 to 2000) data for Yellowknife are also provided for comparison (Environment Canada 2012).

2.6.3 Discussion

Relative humidity is a measure of the amount of water vapour present in the air at a given temperature and pressure relative to the maximum amount of vapour that could be present at the same temperature and pressure. If the amount of vapour remains constant and the temperature rises, relative humidity will fall.

Long-term relative humidity averages are provided for 6:00 AM and 3:00 PM measurements (Environment Canada 2012) for Yellowknife. Morning humidity readings are typically higher than afternoon readings due to cooler temperatures, which result in the air having less ability to hold water. The 2012 data from the Hill and Lake Stations (Figures 2-10 and 2-11) show patterns and ranges consistent with those of the Yellowknife data. The fact that the relative humidity data are higher on average at Snap Lake than in Yellowknife could be attributed to overall slightly lower ambient temperatures but similar levels of absolute ambient moisture. The data in Figures 2-10 and 2-11 have a similar pattern and range between the Hill Station and the Lake Station. The Lake Station ranged from 2.5% higher to 4.3% lower than Hill Station.

Figure 2-11 2012 Lake Station Relative Humidity Summary



%=percent.

2.7 SOLAR RADIATION

2.7.1 Hill Station Solar Radiation Results

The Hill Station solar radiation sensor service factor for 2012 was 0.98. The monthly solar radiation summary is presented in Figure 2-12. Values ranged from a monthly average of 3.1 watts per square metre (W/m^2) in December to an average of 278.7 W/m^2 in June.

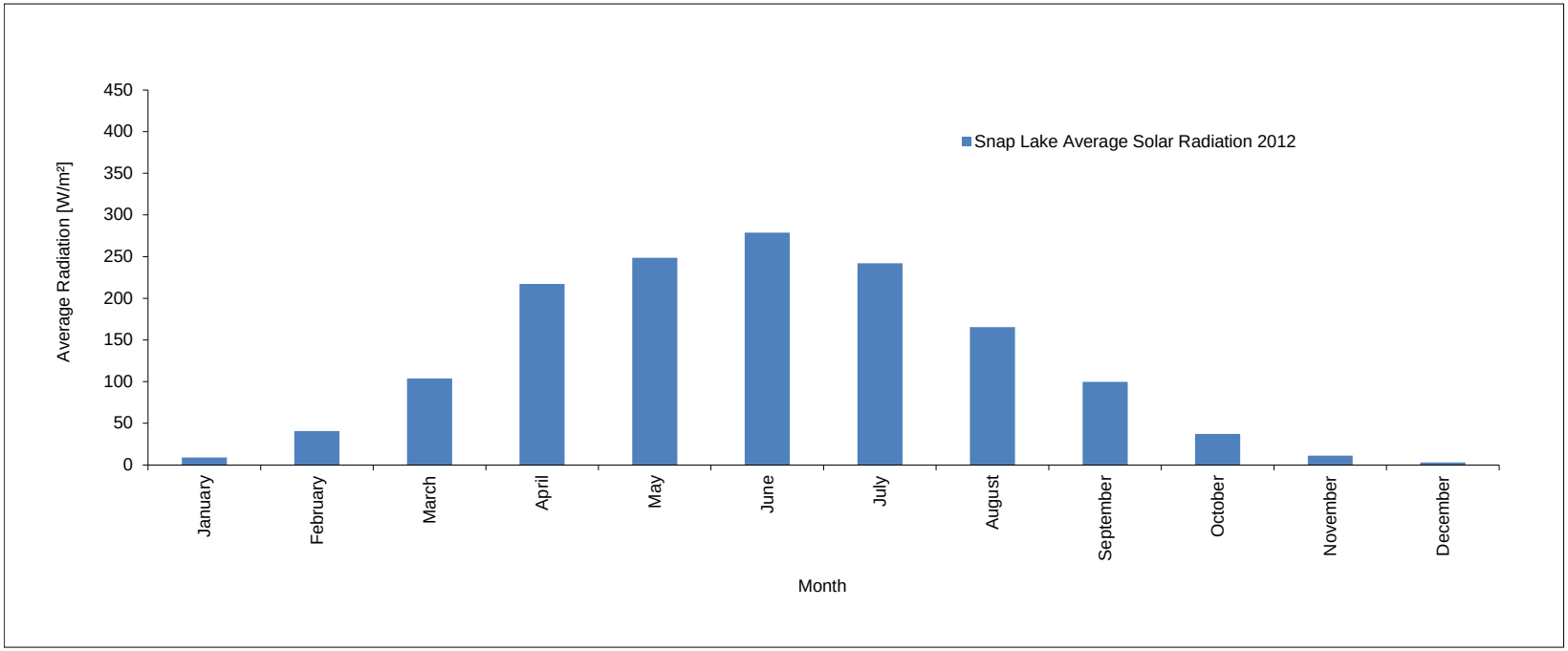
2.7.2 Lake Station Net Solar Radiation Results

The Lake Station net solar radiation sensor service factor for 2012 was 0.94. The monthly net solar radiation summary is presented in Figure 2-13. Values ranged from a monthly average of 15.4 W/m^2 in January to an average of 164.0 W/m^2 in June.

2.7.3 Discussion

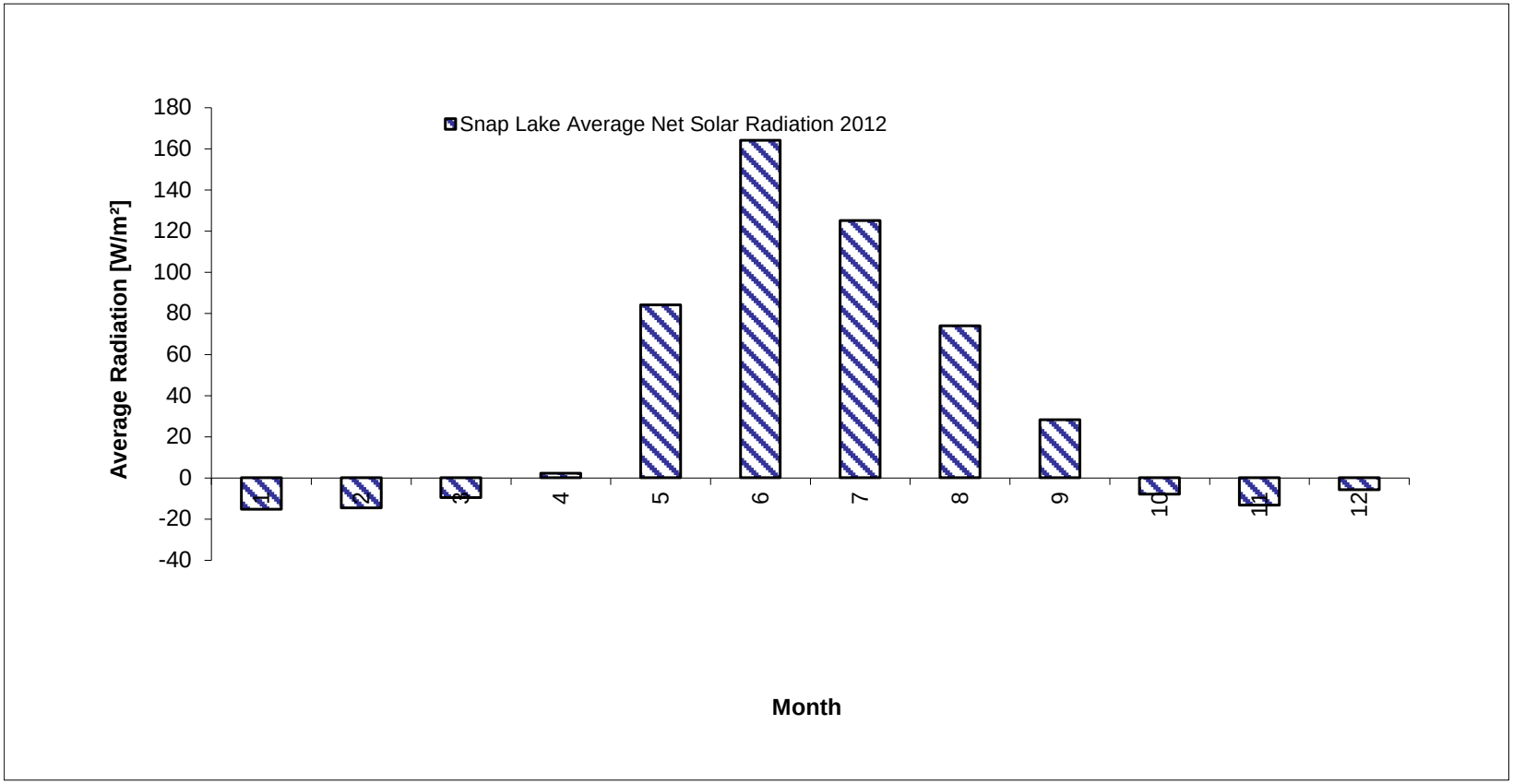
Solar radiation levels measured at the surface are a function of hours of sunlight and sun azimuth angle, as well as a function of local weather conditions including relative humidity, cloud cover, cloud type, and cloud depth. Changes in the weather variables may cause the annual peak to fluctuate from year to year. The peak solar radiation occurred in May for 2004, 2005, 2008, 2009, and 2011 and in June for 2006, 2007, 2010, and 2012. Even though the Hill Station and the Lake Station cannot be directly compared, Figures 2-12 and 2-13 show a similar pattern.

Figure 2-12 2012 Hill Station Solar Radiation Summary



W/m^2 = watts per square metre.

Figure 2-13 2012 Lake Station Net Solar Radiation Summary



W/m^2 = watts per square metre.

2.8 PRECIPITATION

2.8.1 Hill Station Precipitation Results

In general, rainfall is collected between April and October when temperatures exceed 0ºC. The Hill Station rainfall sensor was operational 98.4% of the time throughout the year. The highest monthly rainfall was 46.0 millimetres (mm) in August 2012. A comparative summary of the monthly rainfall readings for Snap Lake in 2012 versus the monthly rainfall for Yellowknife in 2012 and from 1971 to 2000 (Environment Canada 2012) is provided in Figure 2-14.

2.8.2 Lake Station Precipitation Results

The Lake Station precipitation sensor was not operational throughout 2012 due to defective hardware. The hardware was sent to the vendor for repair, has been reinstalled, and was functioning in January 2013.

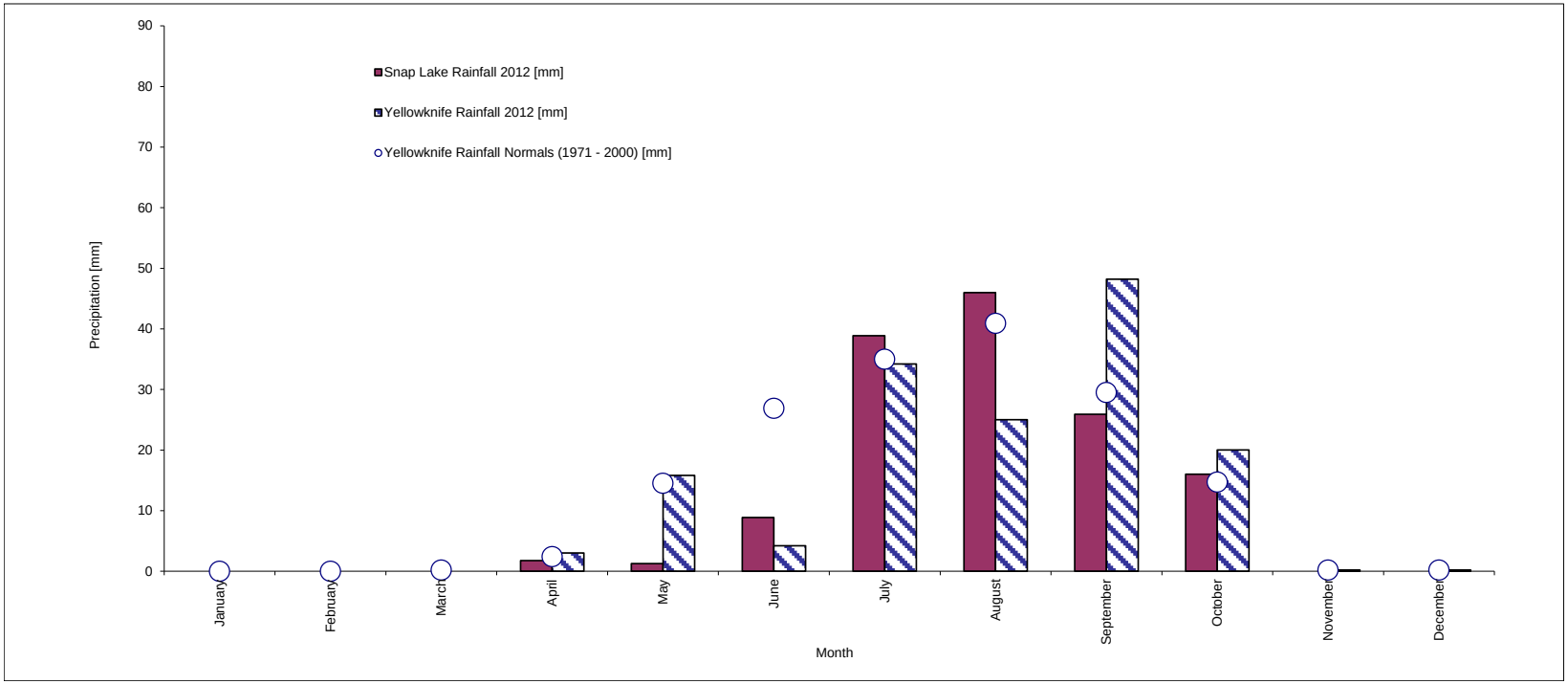
2.8.3 Discussion

The total annual rainfall recorded at the Hill Station for Snap Lake in 2012 was 138.9 mm, which is approximately 8.7% lower than the Yellowknife total for 2012 (150.8 mm) and 18.6% lower than the Yellowknife long-term (1971 to 2000) annual rainfall average of 164.5 mm. The monthly rainfall totals for most of the year at Snap Lake were lower than those for Yellowknife in 2012 except in June, July, and August where they were higher and January, February, and March where neither station observed rain.

The monthly rainfall observed at Yellowknife in 2012 was higher than the corresponding 1971 to 2000 monthly rainfall averages for the months of March, April, May, September, and October and lower for the months of June, July, and August.

The monthly rainfall observed at the Hill Station exceeded the 1971 to 2000 monthly averages for Yellowknife in the months of July, August, and October, but was lower than the 1971 to 2000 normals for Yellowknife for the months of March, April, May, June, September, November, and December (Figure 2-14).

Figure 2-14 2012 Hill Station Rainfall Summary



mm = millimetres.

3 AIR QUALITY MONITORING

3.1 INTRODUCTION

As indicated by the GNWT and Environment Canada (GNWT and Environment Canada 2006), one of the purposes of the AQEMMP should be to identify trends in ambient air quality and use this information to inform management decisions regarding emissions mitigation. This type of proactive management requires that a clear and well-documented system be established. This section provides details on how this system operates.

For the system to operate effectively the following parameters must be clearly defined:

- the methods for determining trends and identifying when emissions mitigation is necessary;
- the monitoring timeframe over which emissions mitigation decisions will be made; and
- the action levels at which emissions mitigation will be employed.

Each year the annual average concentrations of particulate are summarized as part of the annual report. Where applicable, the trend analysis that guides response planning incorporates shorter than annual monitoring periods. The particulate monitoring that is conducted at the Mine area permits direct comparison. For example, 24-hour criteria exist for $PM_{2.5,}$ PM_{10}, and TSP, against which the 24-hour monitoring data collected at the Mine area can be compared. To evaluate the magnitude and trends in concentrations, a series of pre-determined action levels have also be presented on the figure that presents the data observed over the course of the year. These action levels indicate a range or percent change (year to year) in concentrations at which emissions mitigation should be considered. A description of how the action levels should be applied to each of the compounds emitted by the Mine is provided below.

A systematic approach was taken to develop action levels for each compound based on the Air Modelling Update predictions (De Beers 2007), the applicable ambient air quality criteria, and a percent change (year to year) in measured concentrations. The action levels for SO_2, TSP, PM_{10}, and $PM_{2.5}$ are:

- Action Level I – annual concentrations below the maximum Air Modelling Update prediction or less than +10% year to year change.
- Action Level II – concentrations above the applicable short-term ambient air quality criteria, for example, 24-hour particulates, or above the maximum annual concentrations predicted in the Air Modelling Update but below 50% of the applicable ambient air quality criteria or from +10% to +20% year to year change.
- Action Level III – annual concentrations above 50% of the applicable ambient air quality criteria or more than +20% year to year change.

The above action levels are not applicable to NO_2, as the NO_2 concentrations predicted in the Air Modelling Update are high relative to the ambient air quality criteria and therefore require more proactive emissions management. This more proactive management entails setting the action levels for NO_2 to respond to a smaller percentage change in concentrations:

- Action Level I – concentrations below the maximum Air Modelling Update prediction or less than +5% year to year change.
- Action Level II – concentrations above the maximum Air Modelling Update prediction but below 90% of the applicable ambient air quality standard or from +5% to +10% year to year change.
- Action Level III – concentrations above 90% of the applicable ambient air quality standard or more than +10% year to year change.

The management action that will be implemented for each of the action levels is as follows:

- Action Level I – continue monitoring, no mitigation necessary.
- Action Level II – internal review, development of action plan, and implementation.
- Action Level III – external review, development of action plan, and implementation.

The criteria that will be used to trigger actions as defined above is indicated in Table 3-1. This is a general approach that can be applied to any of the monitored compounds. If either an internal or external review is necessary, then this will likely include a review of ambient monitoring data and emissions to determine whether the elevated concentrations or trends are related to Mine equipment or operations. In this manner, any potential issues can be resolved before the ambient air quality standards are reached, which is the primary benefit of this type of proactive management system.

Table 3-1 Criteria Used to Trigger Action Levels

Parameter	Criteria [µg/m³]	Source
Annual SO_2	30	NWT AAQS (GNWT 2011)
Annual NO_2	60	NWT AAQS (GNWT 2011)
24-Hour TSP	120	NWT AAQS (GNWT 2011)
Annual TSP	60	NWT AAQS (GNWT 2011)
24-Hour PM_{10}	50	Objective in British Columbia (Government of British Columbia 2009)
24-Hour $PM_{2.5}$	30	NWT AAQS (GNWT 2011)

SO_2 = sulphur dioxide; NO_2 = nitrogen dioxide; TSP = total suspended particulate; PM_{10} = particulate matter less than 10 microns diameter; $PM_{2.5}$ = particulate matter less than 2.5 microns diameter; µg/m³= micrograms per cubic metre, NWT = Northwest Territories, AAQS = Ambient Air Quality Standards.

3.2 ESTABLISHING THE ACTION LEVEL BASIS

The official starting point of the ambient air quality response plan was in 2007, and is the basis from which 2012 trends in SO_2, TSP, PM_{10}, and $PM_{2.5}$ concentrations are compared. The three air quality components that were examined in 2007, 2008, 2009, 2010, and 2011 were SO_2, NO_2, and TSP.

3.3 PASSIVE SO_2 AND NO_2 MONITORING

Sulphur dioxide and NO_2 emissions are generated by the combustion of diesel fuel and the incineration of solid waste material sources at the Mine. De Beers monitors these compounds on a monthly basis using passive sampling technology.

3.3.1 Monitoring Station Locations

In 2012, passive monitoring was conducted at the Mine at seven separate locations: four off-site locations situated to demonstrate that ambient ground level concentrations are consistent with the criteria; and, three on-site locations whose data will be used to make informed decisions about occupational health and safety levels. The off-site locations are:

- at the southeast end of the airstrip, co-located with three partisol samplers;
- south of the emulsion plant, co-located with three partisol samplers;
- at the west end of Snap Lake (distant reference site); and
- on the north shore of Snap Lake, adjacent to the Mine.

The on-site locations are:

- just west of the tank farm, co-located with TSP Partisol 3;
- immediately north of the fire hall, just west of the three large fuel storage tanks; and
- along the south edge of the road leading to the emulsion plant, north of the airstrip.

3.3.2 Monitoring Methods

Passive monitoring has been conducted to generate ambient air quality data for various compounds including SO_2 and NO_2. Sampling is conducted using “charged” cartridges containing material that is both reactive and selective to the target gases. After approximately 30 days of exposure beneath a rain shelter, the samples are retrieved from the field and sent to the

laboratory for analysis. Results are reported in parts per billion and can be nominally compared to the annual ambient air quality criteria for the respective compounds.

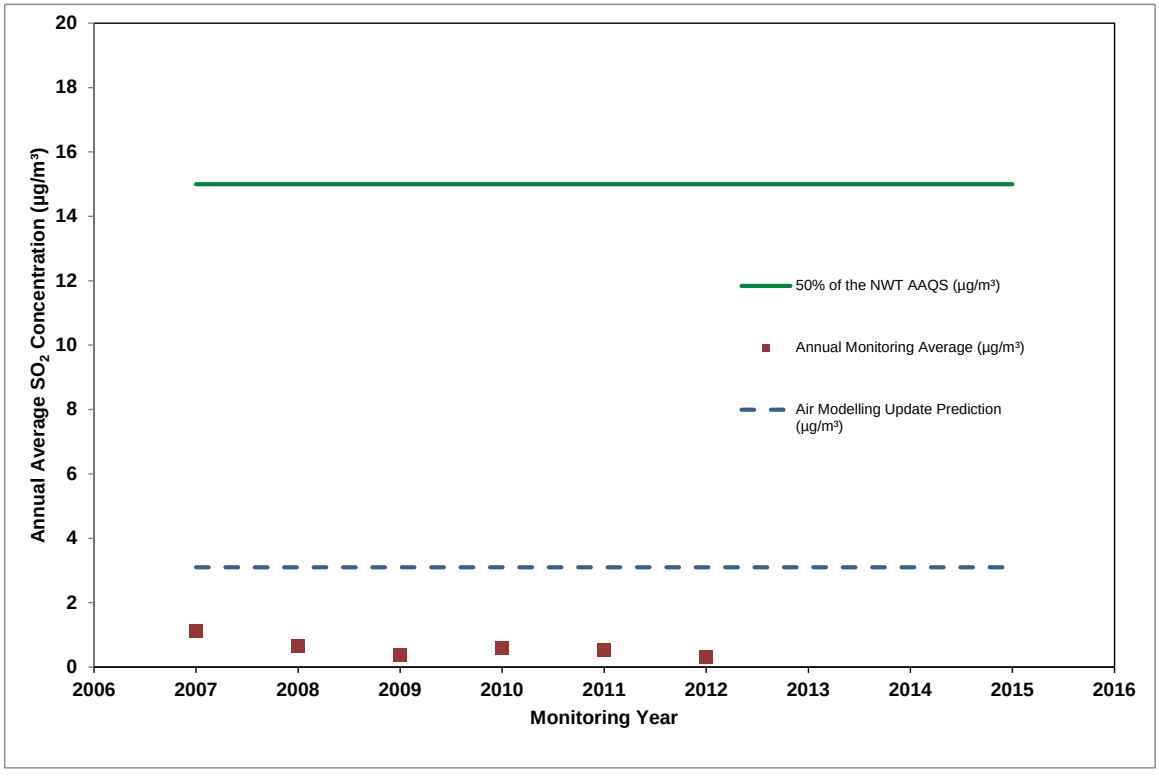
3.3.3 Monitoring Frequency

Sampling is conducted continuously, year-round with sample cartridges exposed to the environment for approximately 30 days before being sent to the laboratory for analysis.

3.3.4 Data Analysis

Figure 3-1 compares the 2008, 2009, 2010, 2011, and 2012 SO_2 passive monitoring data to the NWT AAQS for SO_2 and the Air Modelling Update Prediction. Based upon the 12 months of passive data collected during 2008, 2009, 2010, 2011, and 2012, a response consistent with Action Level I, as defined in Section 3.1, is appropriate.

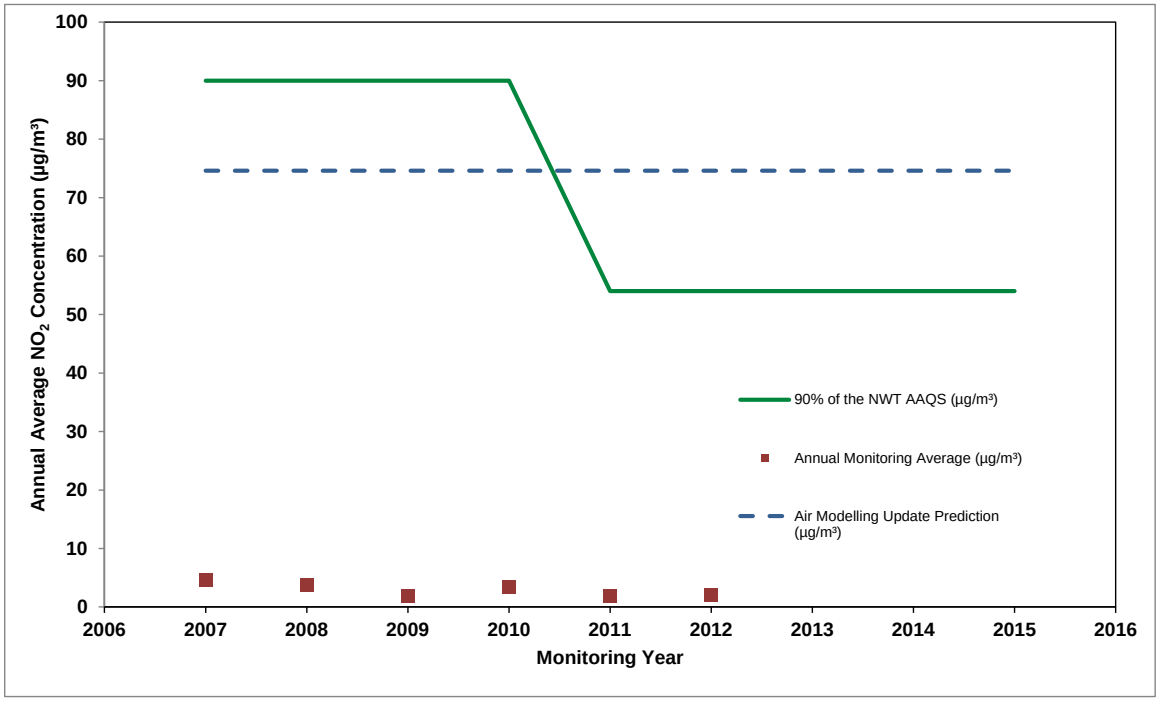
Figure 3-1 Annual Ambient SO2 Concentrations



µg/m^3 = micrograms per cubic metre; SO_2 = sulphur dioxide; NWT AAQS = Northwest Territories Ambient Air Quality Standard.

Comparisons of the 2008, 2009, 2010, 2011, and 2012 NO_2 passive monitoring data to 90% of the National Ambient Air Quality Objective, to the NWT AAQS, and to the 2007 Air Modelling Update Prediction are shown in Figure 3-2. Based upon the 12 months of passive NO_2 data collected in 2008, 2009, 2010, 2011, and 2012, a response consistent with Action Level I is appropriate as defined in Section 3.1. In 2011, the NWT introduced a standard for annual NO_2 of 60 µg/m³ (GNWT 2011). Prior to 2011, the National Ambient Air Quality Objectives (NAAQO) of 100 µg/m³ (Environment Canada 2011) was used to compare the measured annual ambient NO_2 concentrations.

Figure 3-2 Annual Ambient NO_2 Concentrations



µg/m^3 = micrograms per cubic metres;%= percent; NO_2 = nitrogen dioxide; NAAQO = National Ambient Air Quality Objective.

3.4 TOTAL SUSPENDED PARTICLES, PM_{10}, AND $PM_{2.5}$ MONITORING

Suspended particulate matter (fine dust) emissions are generated by wind erosion of local landscapes, movement of vehicles/equipment, airstrip activities, construction activities, the combustion of diesel fuel, and the incineration of solid waste materials.

Particles small enough to readily enter the lungs and bronchi of the lower respiratory tract are of most potential concern. These particles are typically $PM_{2.5}$. However, there is also evidence linking inhalable particles, or PM_{10}, to health concerns. The TSP, PM_{10}, and $PM_{2.5}$ monitoring was

carried out in 2012 to address the AQEMMP requirements outlined in Article VI, Section 6.3 (item e) (ii & iii) of the Environmental Agreement:

6.3 (e) DBCMI shall prepare and provide to the Parties and the Monitoring Agency an Air Quality and Emission Management annual report summarizing and analyzing the emissions and ambient monitoring information, including:

(ii) Comparisons of ambient air quality and deposition monitoring results to previous years, the predictions of the Environmental Assessment Report dispersion modeling and all applicable federal and territorial ambient air quality criteria, standards, objectives and guidelines;

(iii) Analysis of emissions and ambient air quality trends and effectiveness of strategies employed to minimized emissions.

It also fulfills the requirements ascribed to the AQEMMP in Article VI, Section 7.2 item of the Environmental Agreement for the Mine:

7.2 (a) The Air Quality Monitoring Program shall include but not be limited to:

(i) Monitoring total suspended particulate (TSP), PM_{10} and $PM_{2.5}$.

(ii) Monitoring of fugitive dust to determine the effects of dust deposition on the surrounding environment.

(iii) Documentation of quality assurance and quality control (QA/QC) procedures used to ensure valid data collection.

(iv) Contingency plans to respond to increasing trends or exceedances of air quality criteria/dispersion modelling predictions.

3.4.1 Monitoring Station Locations

On-site monitoring locations were selected during early construction to provide a conservative management approach to monitoring ambient particulate concentrations. These locations were selected based on areas of maximum particulate predictions produced by the dispersion modelling assessment. The demonstration of compliance with ambient air quality benchmarks at these locations can be extrapolated to represent compliance at off-site locales.

The locations for both on-site and off-site monitoring stations for the ambient particulate monitoring program are provided in Figure 2-1. The off-site locations were selected because they provide a representative estimate of particulate concentrations away from major Mine activities. The availability of electrical power was also a key consideration for these locations. TSP Partisol 3 (on-site) was specifically added to provide additional information to De Beers about

on-site particulate levels, and to provide information to occupational health and safety planning personnel. Partisol 3 moved slightly east in 2011 to accommodate ongoing construction.

Two PM_{10} and $PM_{2.5}$ Partisols are located off site, directly adjacent to the facility boundary. These locations were identified as areas of potentially higher off-site particulate concentrations by dispersion modelling predictions.

The two off-site particulate monitoring locations border the explosives emulsion plant and airstrip, situated just outside the active mine area. Both of these locations have a TSP Partisol sampler (Partisol), co-located with a PM_{10} and $PM_{2.5}$ dichotomous partisol sampler (Dichot Partisol). These locations are intended to be permanent and should not need to be moved in the future. Establishing permanent locations is an important part of producing consistent data suitable for comparison purposes over time.

3.4.2 Monitoring Methods

Partisols and Dichot Partisols operate on the principle that a stream of ambient air at a controlled flow rate is drawn through a size-selective inlet and then through a pre-weighed filter for a pre-determined time period. The exposed filter is shipped to a laboratory where it is re-weighed. The TSP, PM_{10}, and $PM_{2.5}$ concentrations can be determined using the measured volume of air and the weight difference between the pre-weighed and exposed filter.

The TSP Partisols at Snap Lake collect particulate with a nominal aerodynamic diameter of 100 µm or smaller. The collection of TSP provides a good measure of airborne particulate, and the 24-hour and annual average concentrations are subject to the GNWT ambient air quality standards of 120 and 60 µg/m³ respectively (GNWT 2011).

The Partisol sampling system has a number of operational advantages when compared to other samplers. This type of monitoring is a United States Environmental Protection Agency (USEPA) reference method for quantifying ambient PM_{10} and $PM_{2.5}$ concentrations. The collection of $PM_{2.5}$ is also subject to a standard in the NWT (GNWT 2011).

Monitoring technology continuously and evolves. De Beers has installed a demonstration particulate sampler for $PM_{2.5}$ that samples continuously. Based on an evaluation of the test results, De Beers may opt to replace the aging Partisols with new samplers in 2013.

3.4.3 Monitoring Frequency

The monitoring of TSP was carried out according to the National Air Pollution Surveillance (NAPS) schedule. This schedule follows a monitoring cycle where a single 24-hour sample is collected every sixth day. The schedule has been followed at the Mine since April 2000 when the original High-Volume monitoring program began.

Particulate sampling is now being conducted year-round. Sampling during extreme winter conditions (-20°C and colder with winds greater than 15 km/h) typically occurs between the months of October and April. The Partisols allow for some snow to be drawn through the inlet, resulting in a void sample and possible damage to the electronic components of the sampler. A small amount of data loss is expected during the winter as ambient conditions exceed the normal operating range expected for the equipment. Climate-controlled shelters installed by De Beers in the spring of 2008 to contain the Partisol sampling equipment have minimized but not eliminated this problem.

Sampling in accordance with the NAPS schedule provides consistency between the Snap Lake particulate monitoring stations and stations at other facilities across the country. In addition, by operating on a six-day cycle, different days are sampled each week, which allows for the monitoring of differing production intensities or other operational variability.

3.4.4 Data Analyses

The TSP data from the three monitoring locations were analyzed to identify potential air quality concerns, for example, increasing trends, or measured concentrations above the 2007 Air Modelling Update predictions and applicable ambient air benchmarks.

Analysis of temporal trends helps to identify consistent patterns in the measured particulate concentrations on an annual basis. The response planning and action levels to deal with increasing trends are described in Section 3.1. Managing trends in ambient particulate concentrations on an annual basis is appropriate given the scale of the Mine and the long-term nature of the monitoring program (i.e., through closure).

In addition to the annual trend analysis, ongoing visual observation at the Mine is intended to assist in quickly identifying any abnormal high-dust events and trigger, if necessary, remedial actions. The potential cause(s) of such events and the mitigation action(s) available is to be evaluated and implemented as appropriate, and data collected during periods of station malfunction are to be excluded from analyses.

3.4.5 Total Suspended Particles Monitoring Results

Of the 136 TSP samples collected, 114 had measureable particulate. A value of one-half the detection limit was used for samples that were below the detection limit. Data from the partisols recorded flow rates greater than zero 43% of the time for TSP.

Where flow rates were recorded as zero and measureable particulate had accumulated during the sampling, it was assumed that only the flow record was incomplete. Design flow rates were used to derive concentration data from the measured mass in these cases.

The TSP monitoring results from each location are provided in Table 3-2 and Figures 3-3, 3-4, and 3-5. The maximum recorded TSP concentration was 134.2 µg/m³ at TSP Partisol 1 on November 11, 2012. This occurrence was above the 24-hour objective of 120 µg/m^3 regulated by the GNWT (2011). The average concentration over the monitoring period was 7.5 µg/m³. This represents a 17.7% increase from the 2011 average of 6.3 µg/m³. Because the annual average has changed between 10 and 20%, Action Level II would be triggered. However, Figure 3-6 compares the 2012 TSP data to one-half of the annual NWT Standard and the 2007 Air Modelling Update Prediction. Based upon the data collected, Action Level III is in fact appropriate for TSP based upon the criteria defined in Section 3.1. Details of the response, which at this action level require external review, development of an action plan, and implementation, are provided in Section 3.4.8.

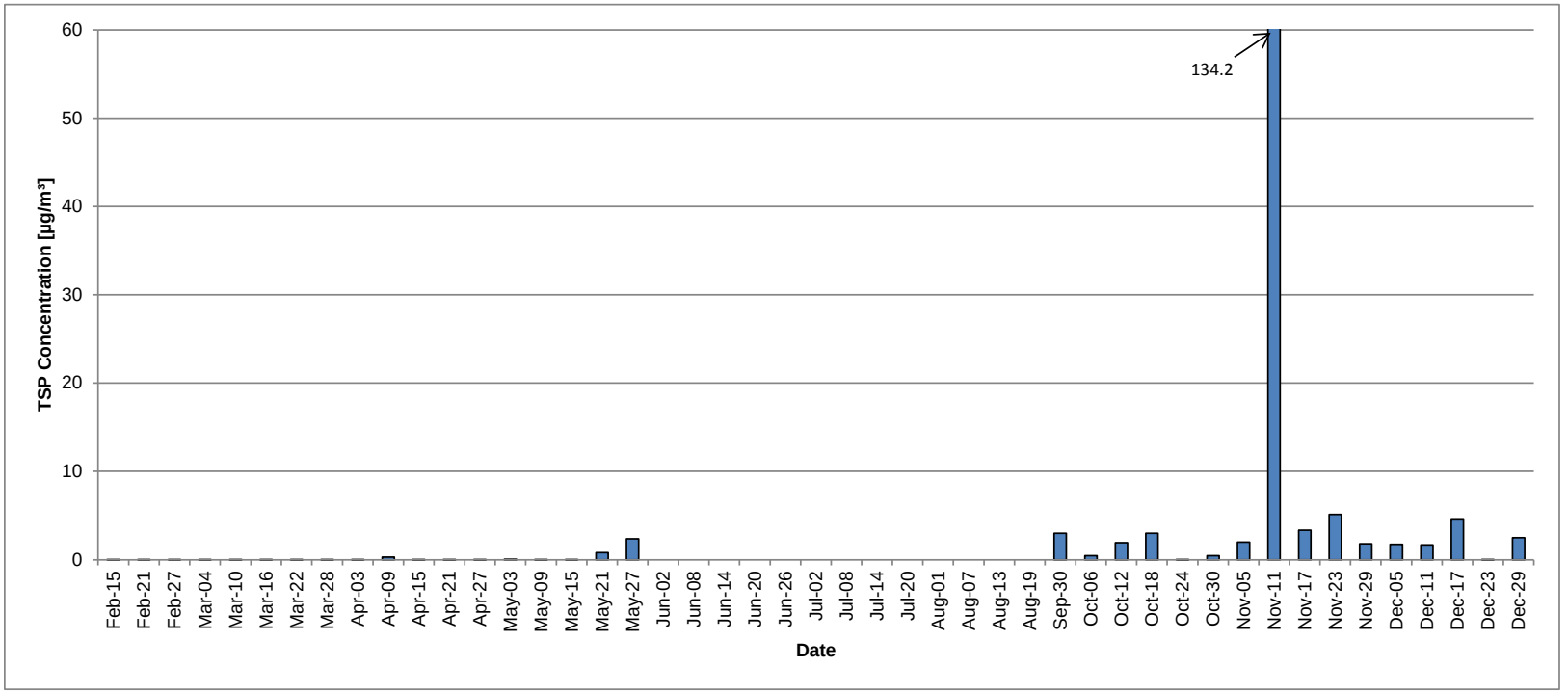
Table 3-2 Snap Lake Total Suspended Particulate Concentrations [µg/m³]

Compound	Monitoring Sites	Applicable Guideline		Air Modelling Update[(a)]		2012	
		24-Hour	Annual	Hourly	Annual	24-Hour Max	Annual Average
TSP	TSP Partisol 1	120	60	145.2	18.7	134.2	4.8
	TSP Partisol 2					47.1	5.9
	TSP Partisol 3					59.6	10.6

(a) Excluding active mine area.

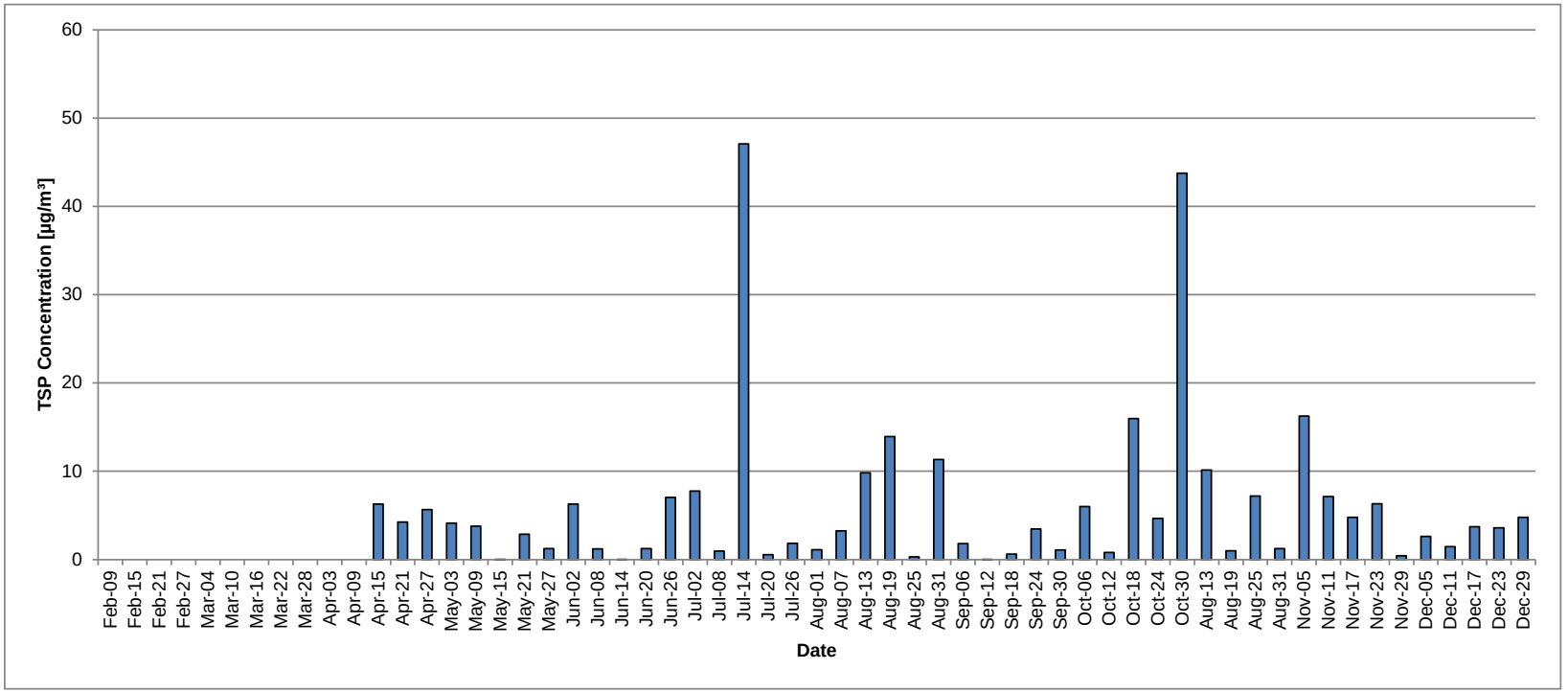
µg/m^3 = micrograms per cubic metre; TSP= total suspended particulate; max= maximum.

Figure 3-3 2012 Total Suspended Particulate (TSP) Concentrations at TSP Partisol 1



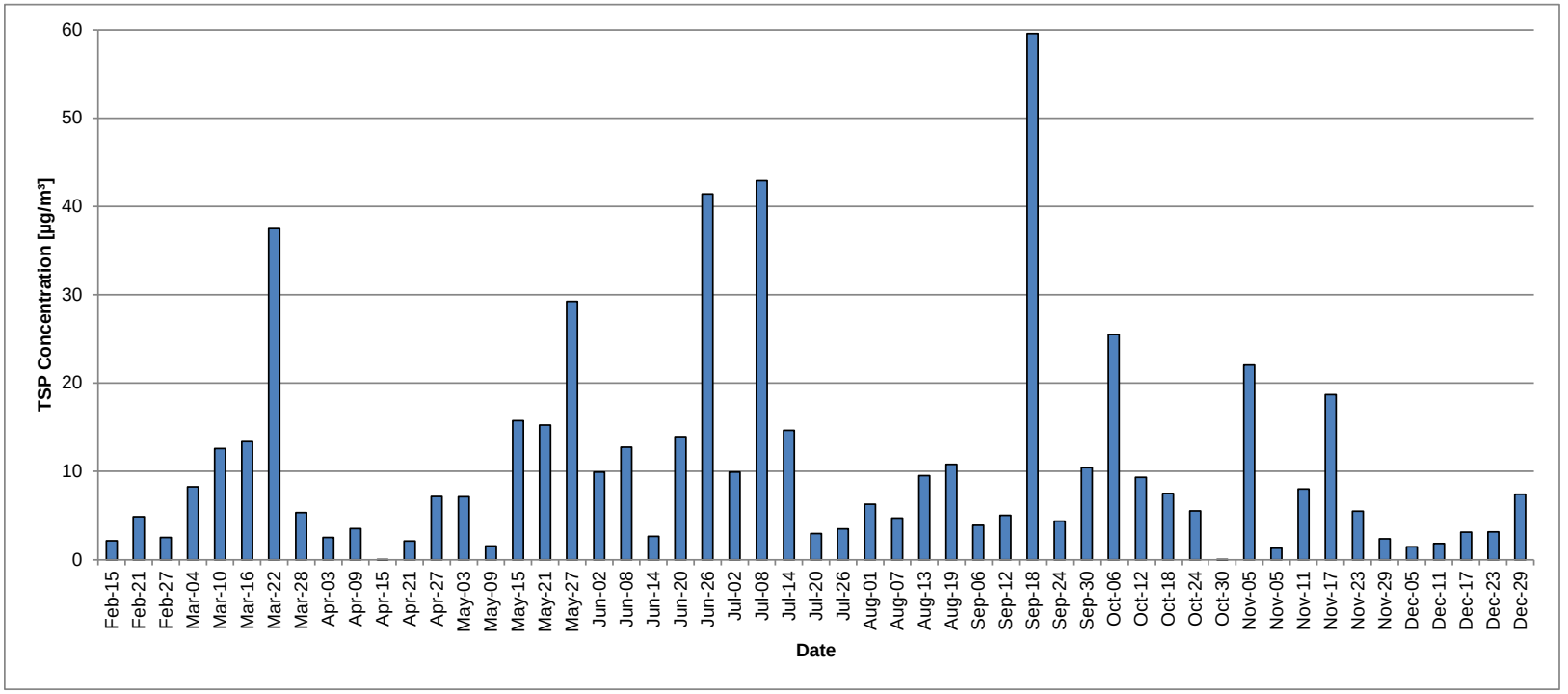
µg/m^3=micrograms per cubic meter.

Figure 3-4 2012 Total Suspended Particulate (TSP) Concentrations at TSP Partisol 2



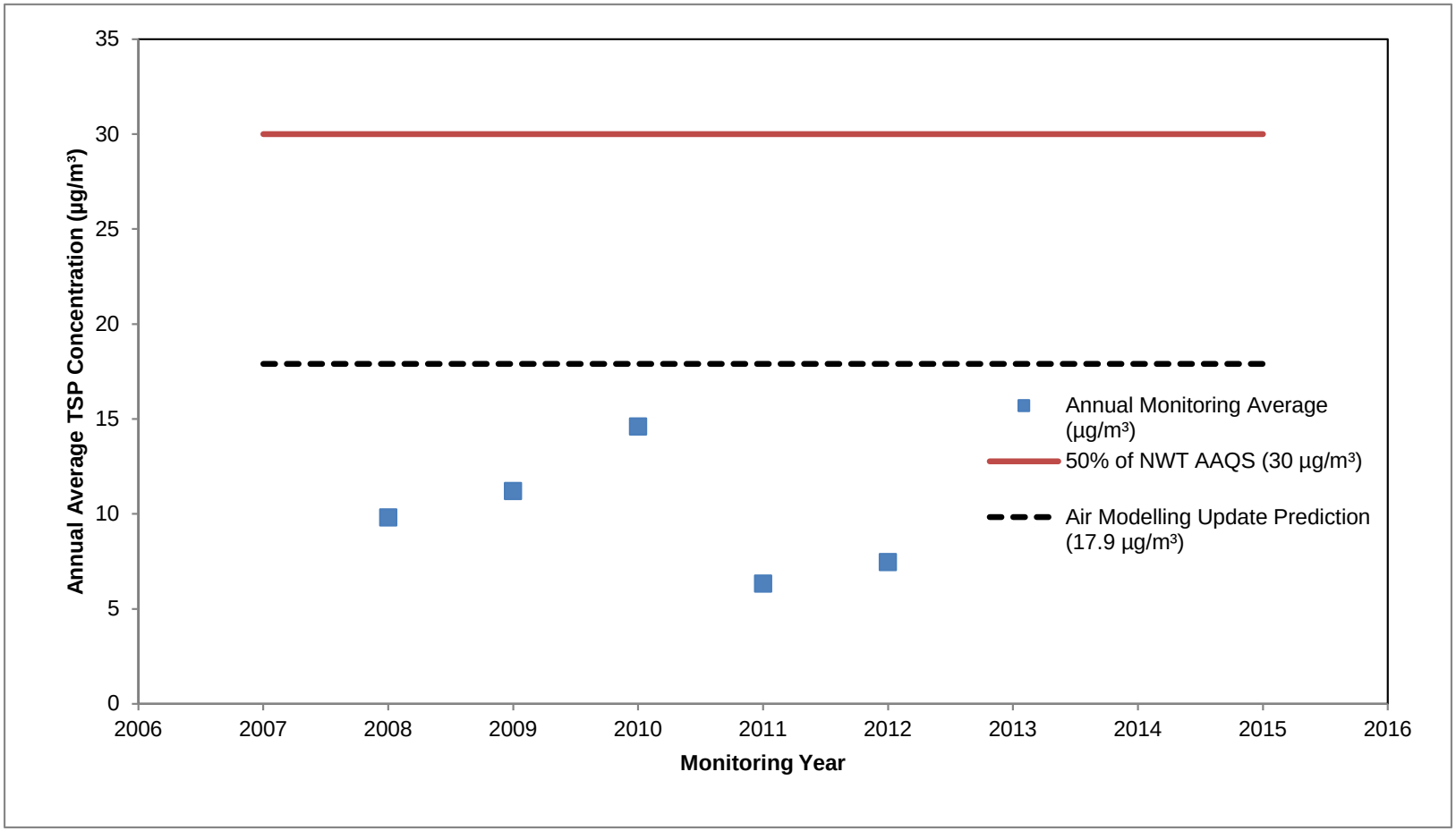
µg/m^3=micrograms per cubic meter.

Figure 3-5 2012 Total Suspended Particulate (TSP) Concentrations at TSP Partisol 3



µg/m^3=micrograms per cubic meter.

Figure 3-6 Action Levels for Annual Ambient Total Suspended Particulate Concentrations



µg/m³ = micrograms per cubic metre; TSP = total suspended particulate; NWT AAQS = Northwest Territories Ambient Air Quality Standard.

3.4.6 PM_{10} Monitoring Results

Of the 69 fine particulate samples and 69 coarse particulate samples collected, 35 fine particulate and 22 coarse particulate samples showed masses below the laboratory detectable limit. The fine and coarse portions of particulate are both required to calculate PM_{10} concentrations. A value of one-half the mass detection limit was used for samples that were below the detection limit. The flow data required for calculating PM_{10} were not always recorded by the sampling equipment. Where flow rates were recorded as zero and particulate had accumulated during the sampling, it was assumed that only the flow record was incomplete. Design flow rates were used to derive concentration data from the measured mass in these cases.

Four data points showed PM_{10} concentrations in excess of the co-located TSP data measured during the same monitoring period. These outlier PM_{10} data points were discarded because, by definition, TSP concentrations must exceed co-located PM_{10} measurements taken during the same time period. This left a total of 65 samples measured at two locations with reported PM_{10} concentrations for 2012.

The PM_{10} monitoring results from each location are provided in Table 3-3 and Figures 3-7 and 3-8. The maximum recorded PM_{10} concentration was 17.2 µg/m³ at Dichot Partisol 1 south of the runway on June 14, 2012. The average PM_{10} concentration from the samples above the analytical detection limits over the monitoring period was 2.4 µg/m³. The 24-hour concentration guideline for PM_{10} is 50 µg/m³ (Government of British Columbia 2009). All measurements in 2012 were or below this guideline. Because PM_{10} concentrations decreased in 2012 compared to 2011 this is an Action Level I event, which means that monitoring will continue and no mitigation is necessary.

A comparison the 2010 PM_{10} data to one-half of the British Columbia (BC) AAQO Standard and the 2007 Air Modelling Update prediction is shown in Figure 3-9. Based upon the data collected, Action Level I is appropriate for PM_{10}.

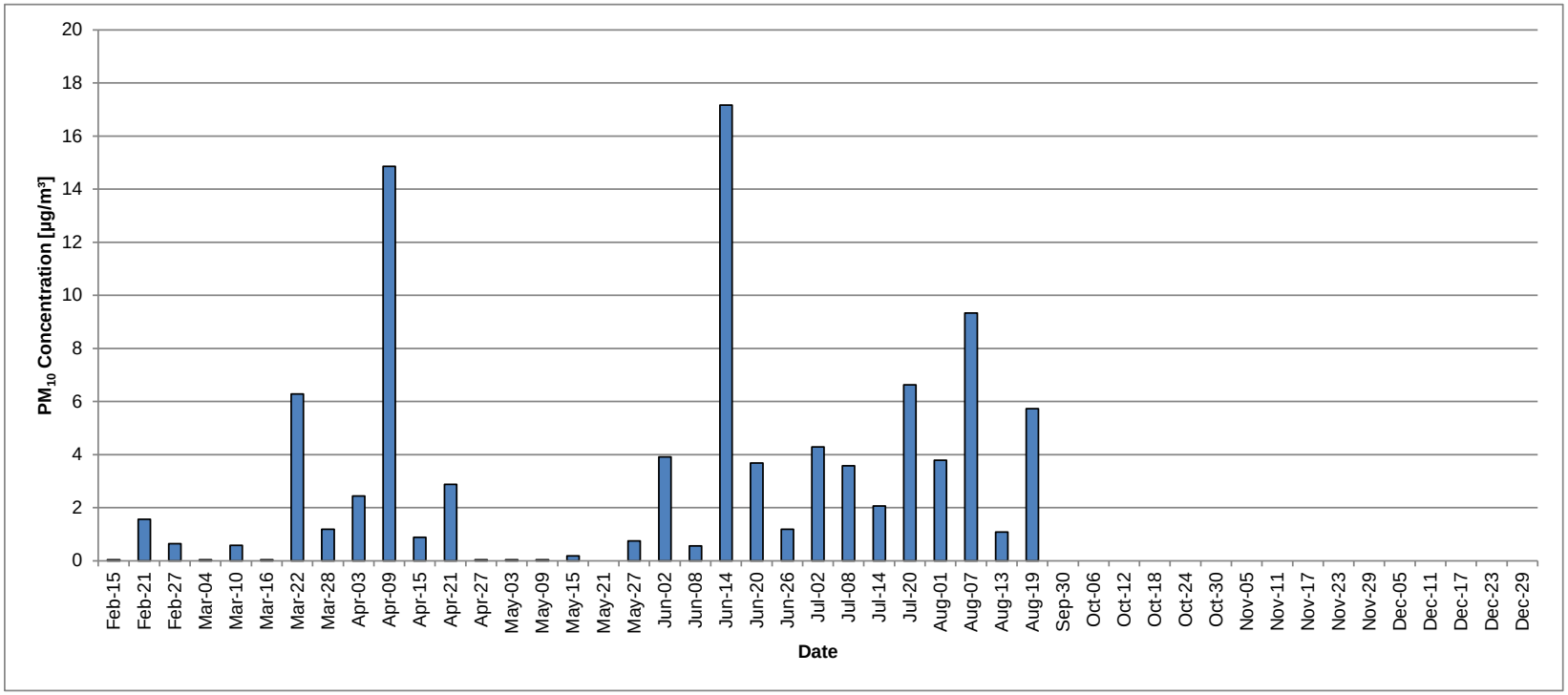
Table 3-3 Snap Lake PM_{10} Concentrations [µg/m³]

Compound	Monitoring Sites	Applicable Guideline		Air Modelling Update[(a)]		2012	
		24-Hour	Annual	Hourly	Annual	24-Hour Max	Annual Average
PM_{10}	Dichot Partisol 1	50	—	46.3	6.2	17.2	3.2
	Dichot Partisol 2					11.4	1.8

(a) Excluding active mine area.

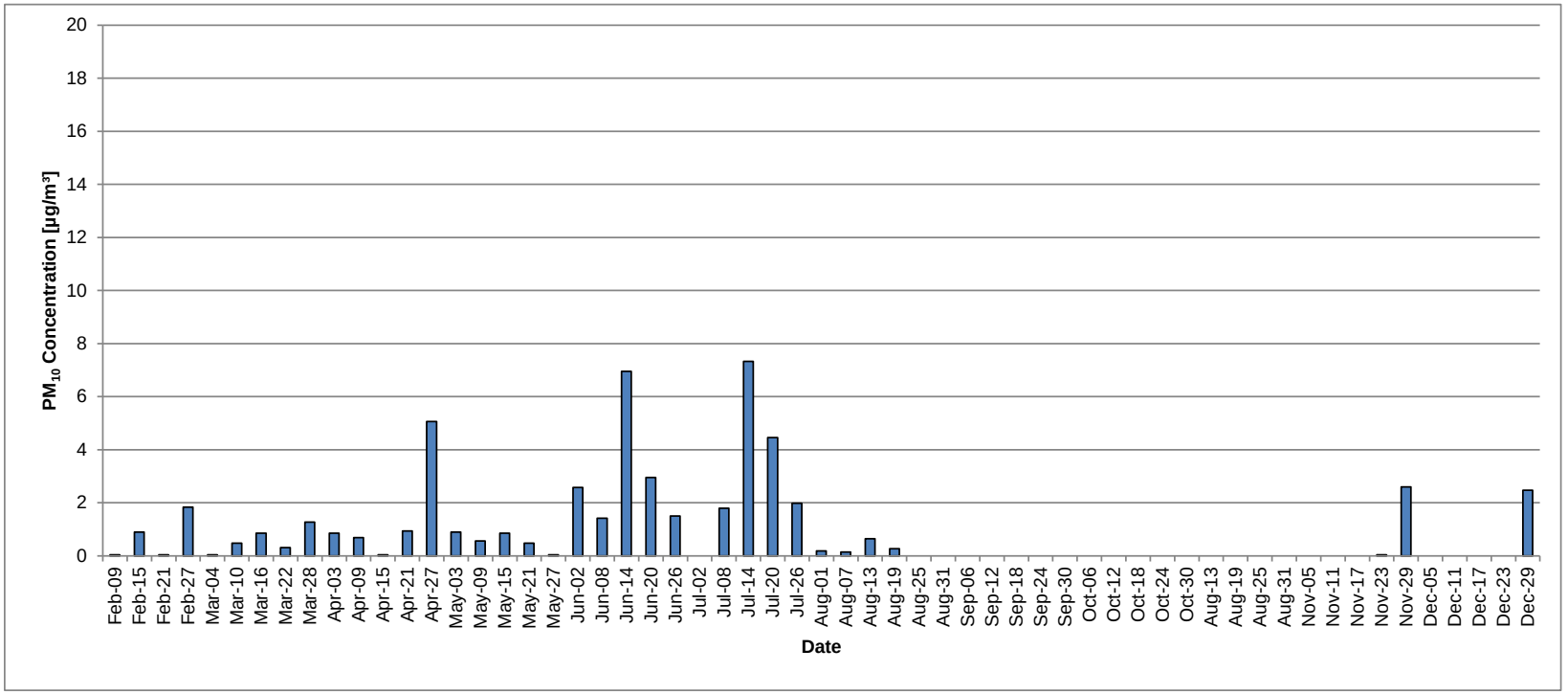
µg/m³ = micrograms per cubic metre; PM_{10}= particulate matter less than 10 microns diameter; max= maximum.

Figure 3-7 2012 PM_{10} Concentrations at Dichotomous Partisol Station 1



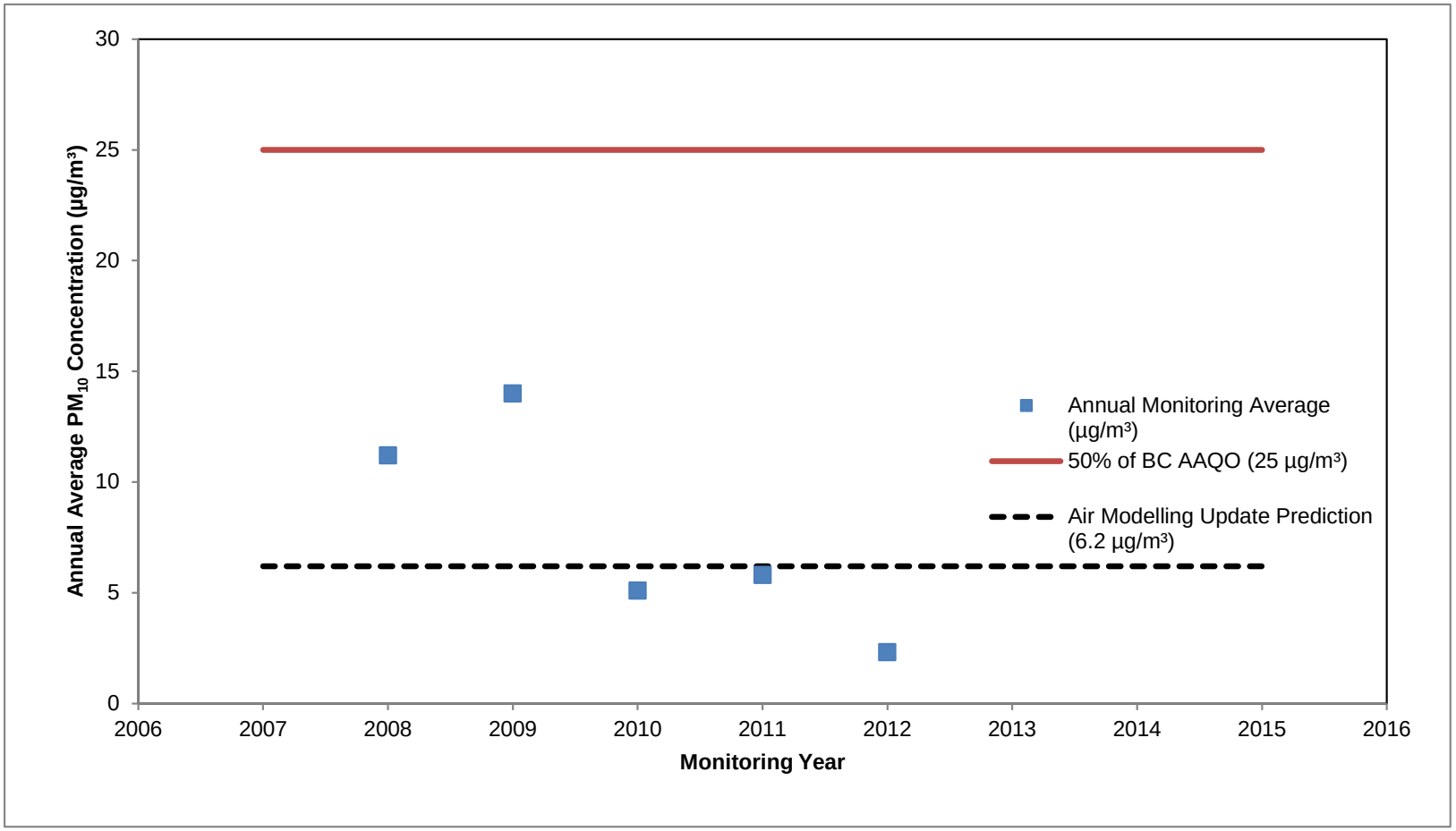
PM_{10}= particulate matter less than 10 microns diameter; $\mu g/m^3$ = micrograms per cubic metre.

Figure 3-8 2012 PM_{10} Concentrations at Dichotomous Partisol Station 2



PM_{10}= particulate matter less than 10 microns diameter; $\mu g/m^3$ = micrograms per cubic metre.

Figure 3-9 Action Levels for Annual Ambient PM_{10} Concentrations



µg/m³ = micrograms per cubic metre; PM_{10}= particulate matter nominally less than or equal to 10 microns (µm) aerodynamic diameter; BC AAQO = British Columbia Ambient Air Quality Objective.

3.4.7 $PM_{2.5}$ Monitoring Results

Of the 69 samples collected, 35 had observed values below the laboratory detectable limit (50% of total samples). A value of one-half the mass detection limit was used for samples that were below the detection limit. Flow data from the partisols were not recorded for $PM_{2.5}$. To account for the missing flow data (expected as a result of aging equipment), it was assumed that the actual flow though the sampler was per the equipment design and was not recorded. Concentration data, therefore, are the product of the actual mass accumulation on the filter and an assumed correct flow rate. Four $PM_{2.5}$ values that used the assumed flow rate resulted in concentrations in excess of the co-located TSP concentrations that were measured concurrently. Since, by definition, TSP concentrations must exceed co-located $PM_{2.5}$ measurements taken at the same time these anomalous $PM_{2.5}$ data points were discarded.

The $PM_{2.5}$ monitoring results for each location are provided in Table 3-4 and Figures 3-10 and 3-11. The maximum recorded $PM_{2.5}$ concentration was 6.3 µg/m³ at Dichot Partisol 1 on August 19, 2012. The average $PM_{2.5}$ concentration was 1.0 µg/m³. The annual average concentration was lower than the 2010 average of 2.5 µg/m³. Because the annual average concentration dropped in 2012 relative to the previous year, this is classed as an Action Level I event, which means that monitoring will continue and no mitigation is necessary.

A comparison the 2012 $PM_{2.5}$ data to one-half of the NWT Standard and the 2007 Air Modelling Update prediction is shown in Figure 3-12.

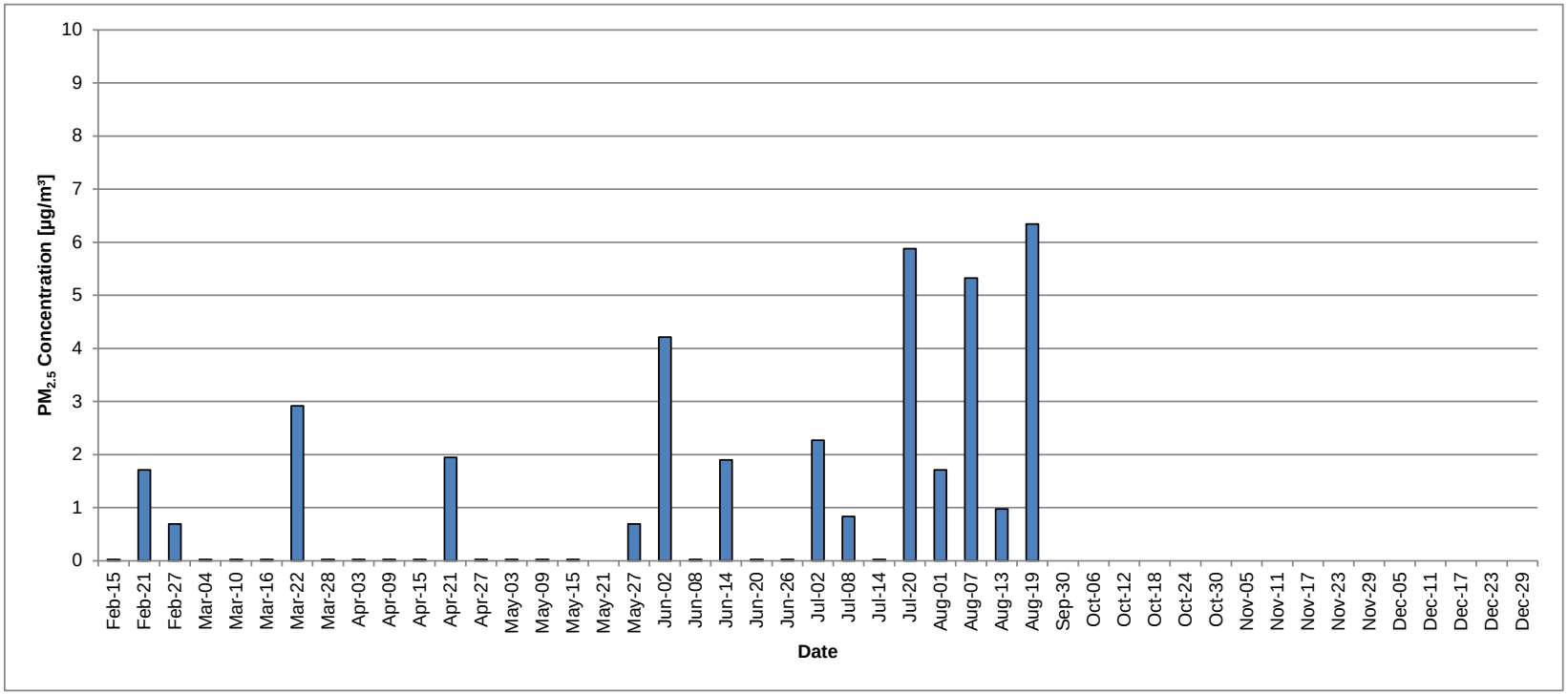
Table 3-4 Snap Lake $PM_{2.5}$ Concentrations [µg/m³]

Compound	Monitoring Sites	Applicable Guideline		Air Modelling Update[(a)]		2012	
		24-Hour	Annual	Hourly	Annual	24-Hour Max	Annual Average
$PM_{2.5}$	Dichot Partisol 1	30	—	24.3	6.2	6.3	1.3
	Dichot Partisol 2					4.4	0.6

(a) Excluding active mine area.

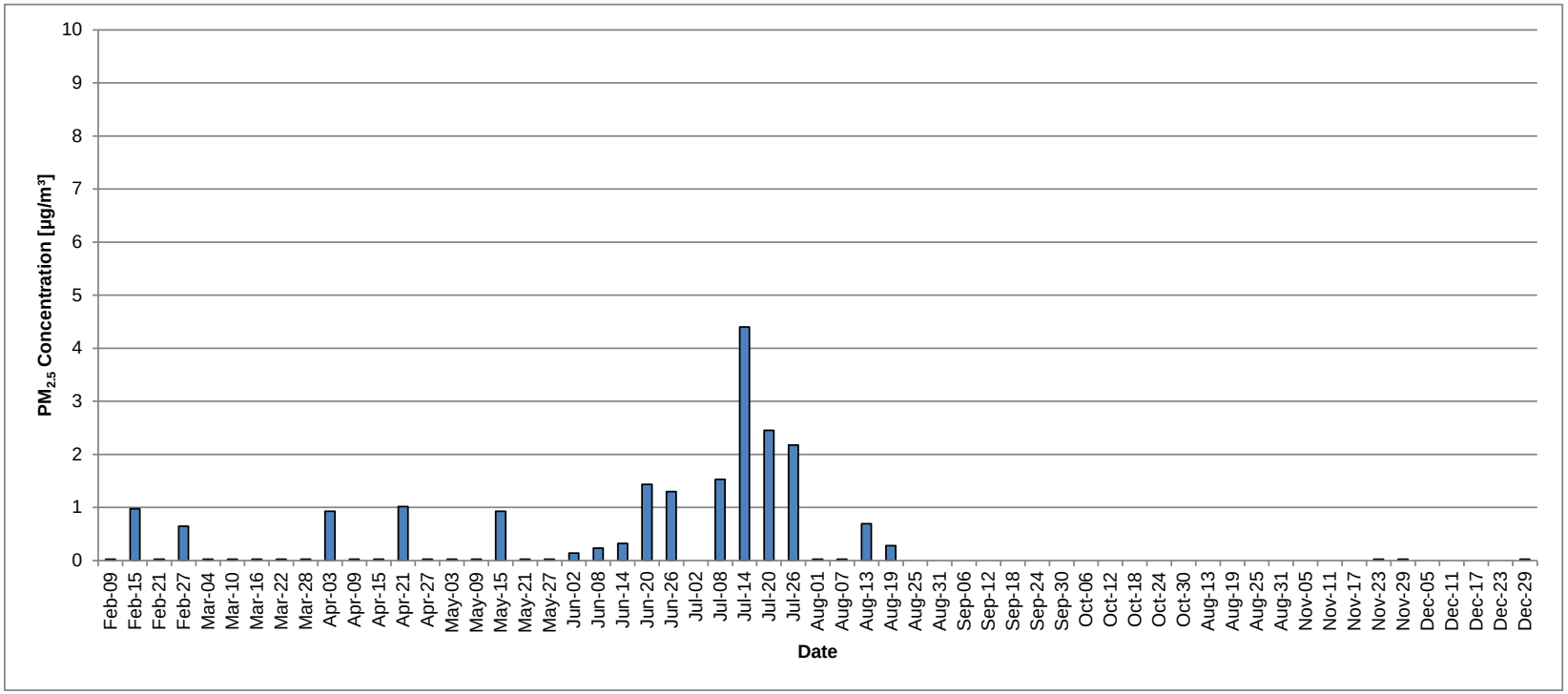
µg/m^3 = micrograms per cubic metre; $PM_{2.5}$= particulate matter less than 2.5 microns diameter; max= maximum.

Figure 3-10 2012 $PM_{2.5}$ Concentrations at Dichotomous Partisol Station 1



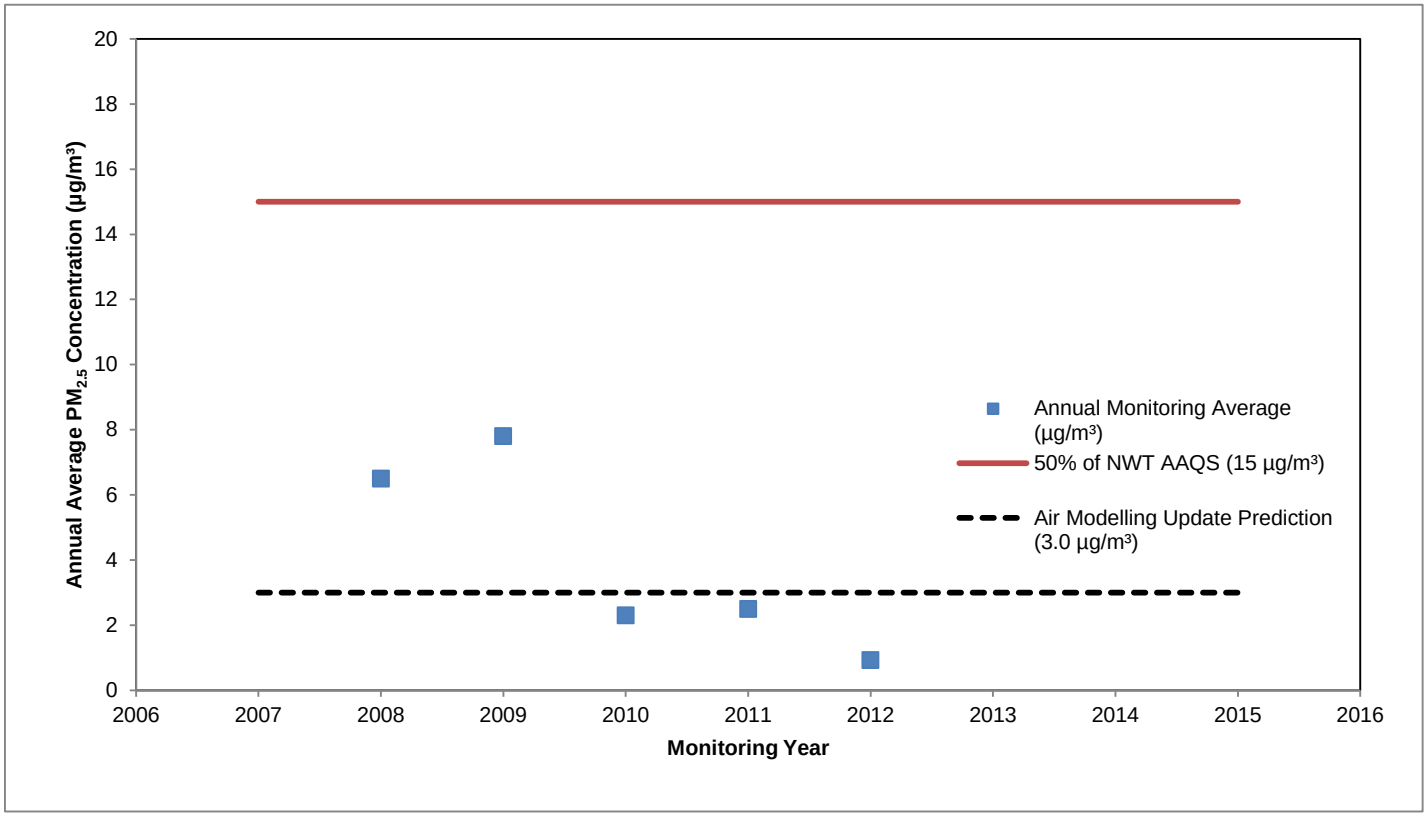
$PM_{2.5}$= particulate matter less than 2.5 microns diameter; $\mu g/m^3$ = micrograms per cubic metre.

Figure 3-11 2012 $PM_{2.5}$ Concentrations at Dichotomous Partisol Station 2



$PM_{2.5}$= particulate matter less than 2.5 microns diameter; $\mu g/m^3$ = micrograms per cubic metre.

Figure 3-12 Action Levels for Annual Ambient $PM_{2.5}$ Concentrations



µg/m³ = micrograms per cubic metre; $PM_{2.5}$= particulate matter nominally less than or equal to 2.5 microns (µm) aerodynamic diameter; NWT AAQS = Northwest Territories Ambient Air Quality Standard.

3.4.8 Discussion

The 2012 particulate monitoring program saw poor data recovery over the course of the year relating to flow rates and samples measured above the detection limit. Ongoing technical issues with the equipment over 2011 and 2012 have cast doubt on the accuracy of the data collected. The Dichot Partisol 1 located south of the runway was replaced in 2013 with a demonstration Thermo Scientific Model 5014i continuous particulate monitor. The data from the new monitoring equipment will be evaluated and the other aging Partisols will be considered for replacement.

Concentrations calculated for particulate mass measured by the laboratory, which was missing a corresponding air sample volume (one of the issues with the samplers), was estimated by using the typical sample volume for TSP, PM_{10}, and $PM_{2.5}$ of 24 cubic metres (m^3), 2.4 m^3, and 21.6 m^3 respectively. Approximately 57% of the TSP volumes, 64% of the PM_{10} volumes, and 100% of the $PM_{2.5}$ volumes had to be estimated for the samples – accordingly, the majority of the 2012 particulate data are estimated rather than measured and are thus of lower accuracy. Additionally, with the majority of samples, the laboratory was not able to detect particulate mass on the filters and in these cases reported a non-detect. These non-detects were included in the statistics and calculated at half the detection limit (detection limit = 0.001 µg/m³).

The average 24-hour TSP concentration over the monitoring period was 7.5 µg/m³, including samples that resulted in concentrations below the detectable limit of 0.001 milligram (mg). One occurrence was recorded above the NWT 24-hour TSP standard of 120 µg/m³ (GNWT 2011) at TSP Partisol 1 located south of the runway. The annual average TSP values were highest in the wetlands at TSP Partisol 3. This point is most central to site operations and is considered on-site, so it would be expected to record higher concentrations than at the other two, more remote sites.

Per the criteria for evaluating the concentration data prescribed in the AQEMMP, the exceedance of the 24-hour TSP standard compels a Level III response. A Level III response means an external investigation of the issue, followed by the development and implementation of an action plan to address the high concentration. De Beers will initiate this process by June 30, 2013 and will implement the resulting action plan by September 30, 2013.

The average PM_{10} concentration over the monitoring period was 2.4 µg/m³, including samples that resulted in concentrations below the detectable limit of 0.001 mg. No occurrences were recorded above the 24-hour PM_{10} objective of 50 µg/m³ (Government of British Columbia 2009). Three samples were excluded due to the PM_{10} concentration exceeding the TSP concentration.

The average $PM_{2.5}$ concentration over the monitoring period was 1.0 µg/m³, including samples that resulted in concentrations below the detectable limit of 0.001 mg. No occurrences were recorded above the NWT 24-hour $PM_{2.5}$ standard of 30 µg/m³ (GNWT 2011). Four samples were excluded due to the $PM_{2.5}$ concentration being larger than the co-located and concurrently sampled TSP concentration.

4 SUMMARY OF 2012 EMISSIONS

4.1 INTRODUCTION

The AQEMMP is used to coordinate the monitoring of emissions from the Mine, which were compared to the Air Modelling Update (De Beers 2007). The three main components of the emissions summary, and the sections in which they are discussed, are as follows:

- emissions estimates (Section 4.2);
- fuel use summary (Section 4.3); and
- emissions mitigation strategies, which include the dust abatement program (Section 4.4).

4.2 EMISSION ESTIMATES

The emissions estimate component of the 2012 Annual Report has the following objectives:

- to demonstrate De Beers' commitment to ongoing monitoring of emissions at the Mine site;
- to provide an overview of the appropriate methods for calculating emissions from the Mine;
- to show that Mine emissions do not exceed those modelled in the Air Modelling Update (De Beers 2007); and
- to demonstrate De Beers' commitment to minimizing emissions.

4.2.1 Types of Emissions

4.2.1.1 Combustion Emissions

Combustion is the process of burning fuels of various types, and using the energy released to produce electricity, space or process heating, or to facilitate on-site transportation and incineration. The six primary combustion sources at the Mine are:

- power generators;
- mine air heaters;
- underground fleet;
- surface fleet;
- incinerators; and
- furnaces.

Compounds such as SO_2, oxides of nitrogen (NO_X), particulates, and greenhouse gases (GHGs) are common combustion by-products from Mine sources. These by-products are the subject of regulatory guidance which limits the release amounts of the compounds to protect the receiving environment. De Beers has committed to meet the relevant GNWT standards, NAAQO, and Canada-wide standards that apply to these compounds. The applicable criteria are provided in Table 1-1.

In addition to the ambient air quality criteria for common combustion compounds which include SO_2, NO_X, and suspended particulates, there also exist Canada-Wide Standards for other combustion by-products, such as dioxins, furans, and mercury that may be released during on-site waste incineration (CCME 2001). A summary of the Canada-Wide Standards for dioxins, furans, and mercury is presented in Table 4-1. These apply to municipal waste incineration at new facilities such as the Mine. Meeting the Canada-Wide Standards often requires the utilization of best available control techniques, such as a waste diversion program.

Table 4-1 Canada-Wide Standards for Municipal Waste Incineration Emissions

Municipal Waste Incineration Compound	Emission Limit
Dioxins and Furans[(a)]	80 picograms of International Toxic Equivalents (I-TEQ) per cubic metre
Mercury[(b)]	20 micrograms per cubic metre ($\mu g/m^3$)

(a) CCME 2001; corrected to 11% of oxygen (O_2) content.

(b) CCME 2003.

By calculating and reporting annual combustion emissions, De Beers can determine whether operational emissions remain below the estimates provided in the Air Modelling Update (De Beers 2007) in addition to meeting the Canada-Wide Standards.

4.2.1.2 Fugitive Emissions

Fugitive emissions are substances that are released to the atmosphere without passing through a stack, vent, or functionally equivalent opening. Fugitive emissions are expected as a result of Mine construction and operation activities and are expected to consist primarily of fugitive dust.

Fugitive dust emissions can result from Mine sources through either mechanical or natural processes. Examples of mechanical processes that can generate fugitive dust include crushing, materials handling, vehicle fleet operation, heavy equipment operation, vegetation removal, and the take-off and landing of aircraft from the airstrip. The main natural process that generates fugitive dust is wind erosion. The two main potential fugitive emission sources at the Mine are:

- the roads and airstrip; and
- the North Pile.

4.3 FUEL USE AND WASTE SUMMARY

Fuel use and emissions data collected to date are compared with the EAR (De Beers 2002a) and the 2007 air modelling update emission predictions in this section. Comparing fuel usage in the Air Modelling Update (Table 4-2) shows that total fuel consumption and therefore emissions at the Mine were well below the amounts used to predict ground-level concentrations. In other words, the fuel use estimated in the assessment and used to make the predictions markedly exceeded the actual fuel consumption at the Mine in 2012. Thus, 2007 modeling was conservative and over-predictive.

Table 4-2 Diesel Fuel Consumption Comparisons

Source	Diesel Consumption Rate [L/yr]						
	Air Modelling Update (De Beers 2007)	2007	2008	2009	2010	2011	2012
Power Generators[(a)]	28,319,000	5,782,945	15,761,482	19,886,852	25,094,725	26,309,858	23,447,183
Mine Heaters and Incinerators	11,318,000	5,376,223	2,585,818	745,100	568,868	631,236	3,264,199
Fleet	7,225,000	6,832,013	2,438,514	3,823,752	3,071,664	3,819,252	4,697,621
Furnaces[(b)]	-	-	-	-	159,198	311,780	359,892
Total	**46,862,000**	**17,991,181**	**20,785,814**	**24,455,704**	**28,894,456**	**31,072,126**	**31,768,895**

(a) Includes pumps, compressors, welders, and other equipment.

(b) Furnaces are using waste oil, not diesel fuel, but are included in the total.

L/yr = litres per year.

The monthly fuel usage for the Mine combustion sources, identified in Section 4.2.1, and comparisons of these values to the 2007 Air Modelling Update (De Beers 2007) is reported in Table 4-3.

A breakdown of the monthly solid waste incineration in metric tonnes at the Mine and comparison to the monthly allocations as outlined in the 2007 Air Modelling Update is provided in Table 4-4. Such tables allow for year by year comparisons of the monthly and annual fuel usage so that trends can be identified in the annual reports. The total monthly fuel usage for all months was below the allowed monthly fuel usage as defined in the 2007 Air Modelling Update. A scale is now being used to weigh the waste being taken to the incinerators; a daily estimate was used for missing data. Monthly waste incineration was lower for all months in 2012 compared to the monthly values used in the 2007 Air Modelling Update (Table 4-4).

Table 4-3 2012 Monthly Fuel Usage from Major Combustion Sources

Month	Power Generation[a] [m³]	Mine Heaters [m³]	Mobile Fleet [m³]	Incineration [m³]	Furnaces[b] [m³]	Total [m³]	Air Modelling Update (De Beers 2007) [m³]
January	1,957	467	360	19	89	2,891	3,905
February	1,892	531	388	21	53	2,884	3,905
March	2,080	510	426	24	35	3,075	3,905
April	1,970	353	335	10	14	2,683	3,905
May	1,950	213	382	14	14	2,572	3,905
June	1,775	41	326	10	9	2,161	3,905
July	1,742	0	352	13	0	2,106	3,905
August	1,742	0	408	15	1	2,165	3,905
September	1,836	0	415	17	9	2,277	3,905
October	2,002	60	464	25	10	2,562	3,905
November	2,116	298	475	28	61	2,979	3,905
December	2,386	572	367	22	65	3,412	3,905
Total	23,447	3,045	4,698	219	360	31,769	46,862

[a] Includes pumps, compressors, welders, and other equipment.

[b] Furnaces are using waste oil, not diesel fuel, but are included in the total.

m³ = cubic metres.

Table 4-4 2012 Monthly Waste Tonnage Burned

Month	Waste Tonnage Burned 2009 [t]	Waste Tonnage Burned 2010 [t]	Waste Tonnage Burned 2011 [t]	Waste Tonnage Burned 2012 [t]	Air Modelling Update (De Beers, 2007) [t]
January	98.24	15.17	51.41	15.00	27.31
February	75.52	13.71	27.02	16.29	25.55
March	54.75	15.17	42.79	14.49	27.31
April	33.26	14.69	18.21	14.37	26.43
May	34.17	15.49	16.93	15.24	27.31
June	23.30	13.46	15.27	13.73	26.43
July	30.45	15.52	24.41	18.70	27.31
August	15.03	14.71	29.65	14.32	27.31
September	21.66	15.42	77.32	15.24	26.43
October	33.68	15.26	28.52	15.59	27.31
November	40.13	14.61	20.23	15.25	27.31
December	36.15	15.10	20.80	12.96	27.31
Total	**496.30**	**178.31**	**373.28**	**181.19**	**323.33**

t = tonnes.

De Beers used two EcoWaste Solutions model CA 600 incinerators, which are rated for a maximum loading of 750 pounds per cycle per unit (lb/cycle/unit) with an average of 5 hours/cycle (including holding, heating, and cooling times). Taking into account these operational parameters, as well as the monthly tonnage burned (Table 4-4), the average incinerator loading factor per cycle is 80% of the maximum rating. An 80% loading factor assumes that each incinerator cycled 24 hours per day and for 365 days in 2012.

4.3.1 Incinerator Stack Testing Results

Stack testing of the Mine's incinerator in accordance with stack testing protocols as outlined in the Canadian-Wide Standards for Dioxins and Furans (CCME 2001) occurred in August 2012. A summary of the thermal oxidizer stack testing results and comparison of these findings to the Canada-Wide Standards for Dioxins and Furans from municipal waste incineration emissions is provided in Table 4-5.

Table 4-5 2012 Incinerator Stack Testing Results

Component	CCME Canada-Wide Standard [pg I-TEQ/Rm³][(a)]	Average Stack Testing Results [pg I-TEQ/Rm³]
Total PCDD[(b)]	80	1,880[(c)]
Total PCDF[(b)]		16,907[(c)]
Total		**18,787**

(a) Volume referenced to 25 degrees Celsius, 760 millimetres mercury & 11% of oxygen (O_2) content.

(b) Polychlorinated dibenzo-para-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF).

(c) Average of three stack test results.

CCME = Canadian Council of Ministers of the Environment; pg I-TEQ/Rm³ = picograms of international toxicity equivalent per reference cubic metre.

As shown in Table 4-5, the sum total of all polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) compounds was found to exceed the CCME Canada-Wide Standard for total PCDD and PCDF incinerator emission concentrations. The incinerators have since been locked out and will not be put back into service. Two new incinerators have beeninstalled and are in operation.

4.4 EMISSIONS MITIGATION STRATEGIES

A number of mitigation measures will be integrated into the operations phase of the Mine to minimize air emissions. For other compounds released from the Mine, particularly combustion compounds such as SO_2, NO_X, particulate, dioxins, furans, and mercury, the following mitigation measures are used:

- fuel conservation measures to reduce SO_2, NO_X, and particulate emissions;
- CCME-compliant equipment to reduce NO_X emissions;
- waste diversion methods to minimize dioxins, furans, and mercury emissions from the incinerator (see details in Section 3.1 of the Domestic Waste and Sewage Management Plan, De Beers 2006);
- operation of combustion equipment, particularly the incinerator, at optimal conditions (e.g., manufacturer recommended temperature, pressure, and other parameters); and
- regular maintenance of the vehicle fleet and limiting of engine idling.

4.5 FACILITY EMISSIONS

4.5.1 Methods

This section describes the three methods that were used to estimate operations emissions (depending on the compounds):

- using a mass balance approach;
- using an emission factor approach (published or calculated); or
- using available intermittent source stack testing data.

The mass balance approach is based on the law of conservation of mass in a system. Essentially, if there is no accumulation within the system, then all the materials that go into the system must come out. Fuel analysis data are a good example of the mass balance approach in predicting emissions. For example, if the sulphur content of a fuel is known, then the emissions of sulphur (in the form of SO_2) can be calculated by assuming that all of the sulphur in the gas is emitted from the system.

The second approach is the use of emission factors. Emission factors are available for many emission source categories and are based on the results of source tests performed at one or more facilities within an industry. An emission factor is the contaminant emission rate relative to the level of source activity. Generic emission factors are commonly used when site-specific source monitoring data are unavailable.

Source-specific stack testing data are appropriate for emission sources or compounds that may be difficult to characterize using either mass balance or emission factors. A stack test measures the amounts of specific compounds present in the stack exhaust gas.

The methods that were used for estimating emissions were:

- SO_2 – mass balance approach;
- NO_X – emission factor approach;
- particulates – emission factor approach;
- GHGs – emission factor approach; and
- dioxins, furans and mercury – stack testing approach.

The following sections provide the data from the emissions calculations based on each of the aforementioned approaches.

4.5.2 Emission Calculation Results

Article VI Section 7.2 (part a item i) of the Environmental Agreement requires annual estimation of emissions from the facility, apportioned by major sources. Emission estimates of NO_X, SO_2, and particulate matter (apportioned into TSP, PM_{10} and $PM_{2.5}$) are required.

Emission calculations are based on fuel consumption and emission factors for the equipment at the Mine. The emission factors used are consistent with those used to develop the emissions profile that was simulated in the EAR (De Beers 2002a) and the 2007 modelling update (De Beers 2007). Data provided by De Beers in 2013 indicate a diesel consumption of 31,768,895 litres (L) with a maximum sulphur content of 15 parts per million (ppm) by weight. The 2012 emission estimates of the Mine are presented in Table 4-6.

Table 4-6 2012 Estimated Emission Rates

Source	Diesel Consumption [L/yr]	Emission Rates [t/d]				
		SO_2	NO_X	TSP	PM_{10}	$PM_{2.5}$
Power Generators[(a)]	23,447,183	0.002	3.328	0.072	0.060	0.058
Mine Heaters/Incinerators	3,264,199	0.000	0.021	0.004	0.002	0.002
Fleet	4,697,621	0.000	0.632	0.023	0.023	0.023
Furnaces[(b)]	359,892	0.000	0.002	0.000	0.000	0.000
Total	31,768,895	0.002	3.983	0.100	0.085	0.083

(a) Includes pumps, compressors, welders, and other equipment.

(b) Furnaces used diesel fuel this year, not waste oil.

L/yr = litres per year; SO_2 = sulphur dioxide; NO_X = oxides of nitrogen; TSP = total suspended particulate; PM_{10} =particulate matter nominally less than or equal to 10 micrometres aerodynamic diameter; $PM_{2.5}$ = particulate matter nominally less than or equal to 2.5 micrometres aerodynamic diameter; t/d = tonnes per day.

The 2012 emission rates in tonnes per day (t/d) from the EAR (De Beers 2002a) are compared with the emission rates for the years 2006 to 2011 in Table 4-7. Overall, the emission rates in 2012 were lower than 2011 even though fuel consumption increased approximately 700,000 L. The decrease in emissions in sulphur dioxide and particulate is attributed to burning diesel fuel instead of waste oil in the furnaces. Particulate and NO_X emissions also decreased due to the decreased fuel consumption of the power generators (approximately 3,000,000 L) and the increased fuel consumption of the mine heaters and fleet (approximately 3,500,000 L). Even though total fuel consumption increased, the overall emission factors for the mine heaters and fleet were lower than the power generator, resulting in less emissions overall. The particulate emission factors for the power generators were refined, resulting in lower emission factors. Even without the lower emission factors, a decrease in particulate emissions would still have occurred.

Table 4-7 Estimated Emission Rates Comparisons

Compound	Sources	Air Modelling Update (De Beers 2007)	2006	2007	2008	2009	2010	2011	2012
SO_2 (t/d)	Power Generators[(a)]	0.085	0.014	0.033	0.005	0.001	0.002	0.002	0.002
	Mine Heaters and Incinerators	0.171	0.003	0.035	0.001	0.000	0.000	0.000	0.000
	Fleet	0.048	0.007	0.032	0.001	0.000	0.000	0.000	0.000
	Furnaces	-	-	-	-	-	0.015	0.030	0.000
	Subtotal	*0.304*	*0.024*	*0.068*	*0.007*	*0.002*	*0.017*	*0.032*	*0.002*
NO_X (t/d)	Power Generators[(a)]	6.215	1.151	0.958	2.612	2.822	3.561	3.734	3.328
	Mine Heaters and Incinerators	0.658	0.012	0.035	0.017	0.005	0.004	0.004	0.021
	Fleet	1.763	0.897	1.563	0.558	0.514	0.413	0.514	0.632
	Furnaces	-	-	-	-	-	0.001	0.002	0.002
	Subtotal	*8.636*	*2.06*	*2.557*	*3.187*	*3.342*	*3.979*	*4.254*	*3.983*
TSP [t/d]	Power Generators[(a)]	0.064	0.036	0.027	0.073	0.088	0.111	0.117	0.072
	Mine Heaters and Incinerators	0.032	0.002	0.025	0.035	0.001	0.001	0.001	0.004
	Fleet	0.229	0.033	0.032	0.002	0.019	0.015	0.019	0.023
	Furnaces	-	-	-	-	-	0.005	0.009	0.000
	Subtotal	*0.325*	*0.071*	*0.084*	*0.110*	*0.108*	*0.132*	*0.145*	*0.100*
PM_{10} (t/d)	Power Generators[(a)]	0.053	0.03	0.022	0.060	0.073	0.091	0.096	0.060
	Mine Heaters and Incinerators	0.027	0.001	0.020	0.035	0.001	0.000	0.000	0.002
	Fleet	0.102	0.033	0.026	0.002	0.019	0.015	0.019	0.023
	Furnaces	-	-	-	-	-	0.004	0.007	0.000
	Subtotal	*0.182*	*0.064*	*0.068*	*0.097*	*0.092*	*0.111*	*0.123*	*0.085*
$PM_{2.5}$ (t/d)	Power Generators[(a)]	0.051	0.029	0.018	0.050	0.070	0.089	0.093	0.058
	Mine Heaters and Incinerators	0.024	0.001	0.017	0.008	0.000	0.000	0.000	0.002
	Fleet	0.068	0.033	0.021	0.002	0.019	0.015	0.019	0.023
	Furnaces	-	-	-	-	-	0.003	0.006	0.000
	Subtotal	*0.143*	*0.063*	*0.057*	*0.059*	*0.090*	*0.107*	*0.118*	*0.083*

[(a)] Includes pumps, compressors, welders, and other equipment.

SO_2 = sulphur dioxide; NO_X = oxides of nitrogen; TSP = total suspended particulate; PM_{10} =particulate matter nominally less than or equal to 10 micrometres aerodynamic diameter; $PM_{2.5}$ = particulate matter nominally less than or equal to 2.5 micrometres aerodynamic diameter; t/d = tonnes per day.

4.6 GREENHOUSE GAS EMISSIONS

Greenhouse gases are emitted from the combustion sources at the Mine. Article 7.2 (part a item i-D) of the Environmental Agreement requires reporting of GHG emissions from Mine activities and specifies that GHGs must be apportioned as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Estimates of the Mine's GHG emissions in 2012 were based on emission factors published by Environment Canada (2010) and on fuel consumption data listed in Table 4-2. Because each reported GHG has a different Global Warming Potential, emissions of CH_4 and N_2O were converted to a CO_2e. GHG emissions are reported in kilotonnes (kt) CO_2e per year. The 2012 GHG emissions due to fuel combustion at the Mine are presented in Table 4-8. The total GHG emissions were estimated to be 88.63 kt CO_2e.

The GHG emissions have increased since 2005 due to increased fuel consumption and were highest in 2012 (Table 4-9).

Table 4-8 2012 Lake Greenhouse Gas Emissions

Source	CO_2	CH_4	N_2O	Total CO_2e
Global Warming Potential	1	21	310	—
Emissions (kt/yr)	84.601	0.004	0.013	88.629

kt/yr = kilotonnes per year; CO_2 = carbon dioxide; CH_4 =methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent.

Table 4-9 Annual Snap Lake Greenhouse Gas Emission Comparisons (2005 to 2012)

Compound	2005	2006	2007	2008	2009	2010	2011	2012
CO_2 (kt/yr)	24.72	44.13	49.11	55.35	65.13	76.95	82.75	84.60
CH_4 (kt/yr)	0.03	0.05	0.05	0.00	0.00	0.00	0.00	0.00
N_2O (kt/yr)	1.12	2.00	2.23	0.02	0.01	0.01	0.01	0.01
Total CO_2e (kt/yr)	**25.87**	**46.18**	**51.39**	**62.51**	**68.23**	**80.61**	**86.68**	**88.63**

kt/yr = kilotonnes per year; CO_2 = carbon dioxide; CH_4 =methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent.

5 CONCLUSIONS

Meteorological data collected were wind speed, wind direction, temperature, relative humidity, solar radiation, and rainfall. The Hill Station data were collected with a 98% retrieval rate for solar radiation, temperature, relative humidity, and precipitation and a 92% retrieval rate for wind. The Lake Station data were collected with a greater than 93% retrieval rate for solar radiation, temperature, and wind and an 85% retrieval rate for relative humidity; however, precipitation data from that station were not available throughout 2012 due to defective hardware. The hardware was sent to the vendor for repair, has been reinstalled, and was functioning in January 2013.

Particulate monitoring was completed in 2012 with data being collected for TSP, PM_{10}, and $PM_{2.5}$. However, the data from the particulate monitoring sites are suspect. Only one occurrence was above the NWT AAQS for TSP. An external review of the data and the development and implementation of an action plan for the high TSP value has been recommended. In order to improve the particulate data quality, the Dichot Partisol 1, located south of the runway was replaced in January 2013 with a demonstration continuous monitor. The data from this monitor will be summarised in the 2013 annual report.

The passive monitoring of SO_2 and NO_2 in 2012 indicated concentrations well below applicable criteria. SO_2 decreased by 43% from 2011, from 0.5 µg/m³ to 0.3 µg/m³. Observed NO_2 was similar to 2011.

A comparison of air emission rates (SO_2, NO_X, and particulates) showed that 2012 emission totals were lower than those reported in 2011, despite the overall increased fuel consumption. Emissions decreased due to three factors: fuel being used by equipment that has lower emission ratings; diesel instead of waste oil being used in some space heating furnaces; and, lower emission factors used for calculating particulate matter for power generation. Even if the particulate matter emission factors did not change, overall emissions for particulates would still have decreased. All emission rates are still considerably lower than those used in the EAR (De Beers 2002a) and in the 2007 Air Modelling Update.

The average monthly waste tonnage burned in 2012 decreased from 2011 and was found to be about 44% less than the 2007 Air Modelling Update. A review of the solid waste incineration records and the incinerator stack testing data demonstrated that concentrations observed during the 2012 testing were above Canada-wide Standards for dioxins and furans (CCME 2001). As a result of the stack testing, the incinerators have been locked out and will not be put back into service. Two new incinerators have been installed and are operational.

Greenhouse gas emissions increased in 2012 to a total of 88.6 kt CO_2e. This is the highest greenhouse gas emission total reported to date from the Snap Lake Mine. The increased GHG emissions are a direct result of the increased fuel consumption in 2012.

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7 CLOSURE

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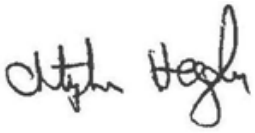

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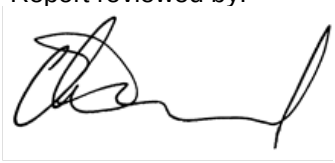

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9 GLOSSARY

adaptive management	The exact definition of adaptive management varies among monitoring components, but typically adheres to having four themes as follows (WLWB 2010): 1) learning in order to reduce management uncertainties; 2) using what is learned to change policy and practice; 3) focusing on improving management; and 4) doing the above in a formal, structured, and systematic way.
ambient	Existing or present in the surrounding air.
ambient air quality objectives	Levels of concentration or deposition of specific chemicals or materials that are established to safeguard the health of ecosystem components (most often sensitive humans or vegetation).
dioxins	A variety of chemical compounds that can be described by the chemical formula: $C_4H_4O_2$.
emission	Release of substances to the atmosphere (can be fugitive emission, stack emission, diesel exhaust, mechanical, ground disturbance, etc.).
emission factor	An estimate or statistical average of the rate at which a contaminant is released to the atmosphere as a result of some activity, such as combustion or industrial production, divided by the level of that activity. The emission factor, therefore, relates the average quantity of each contaminant emitted according to an appropriate base quantity. Emission factors are usually expressed as a weight of contaminant divided by a unit weight, volume, distance or duration of associated activity that emits the pollutant (e.g., kg of SO_2 emitted per kilometre travelled).
furans	One of a group of colorless, volatile, heterocyclic organic compounds containing a ring of four carbon atoms and one oxygen atom.
greenhouse gas (GHG)	An atmospheric gas that causes heat in the form of thermal infrared radiation emitted from the Earth to be partially trapped within the atmosphere.

I-TEQ	International Toxic Equivalency Quotients (relative to 2,3,7,8 tetrachlorodibenzo-para-dioxin) are internationally established multiplication factors that are used to collectively express the toxicity of various dioxins, furans, and co-planar PCBs (polychlorinated biphenyls) to humans, mammals, fish, and birds relative to the most toxic of these substances: 2,3,7,8-tetrachlorodibenzo-para-dioxin. The multiplication factors range from 0.000001 to 1.000000.
kimberlite	Igneous rocks that originate deep in the Earth's mantle and intrude the Earth's crust. These rocks typically form narrow pipe-like deposits that sometimes contain diamonds.
nitrogen oxides (NO_X)	A measure of the oxides of nitrogen comprised of nitric oxide (NO) and nitrogen dioxide (NO_2).
particulate matter (PM)	A mixture of small particles, e.g., dust and soil.
PM_{10}	Airborne particulate matter with a mean aerodynamic diameter less than 10 µm (microns). This represents the fraction of airborne particles that can be inhaled into the upper respiratory tract.
$PM_{2.5}$	Airborne particulate matter with a mean aerodynamic diameter less than 2.5 µm (microns). This represents the fraction of airborne particles that can be inhaled deeply into the pulmonary tissue.
probable effect levels	Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely but not certain to occur.
quality assurance (QA)	Management and technical practices designed so that the data generated are of consistent high quality. They include standardization and review by field and office personnel of procedures used in the collection, transport, and analyses of samples.
quality control (QC)	Internal techniques used to measure and assess data quality, including samples that are used to detect and reduce systematic and random errors that may occur during field sampling and laboratory procedures.
relative humidity	The ratio of the amount of water vapour actually present in the air to the greatest amount possible at the same temperature.
standard deviation (SD)	A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.
standard error (SE)	The standard deviation (positive square-root of the variation) of the errors associated with a series of measurements.

total suspended particulate (TSP)	The fraction of airborne particulates that will remain airborne after their release into the atmosphere; the average diameter is nominally 100 µm (micrometres) and below.
windrose	A diagram showing wind speed and direction distribution for a particular location.