2 AIR QUALITY

2.1 Introduction

The air quality baseline section presents a summary of baseline information compiled from literature and field studies. It describes information on the air quality study areas, with focus on the components of concern that are assessed in Volume 5, Biophysical Impact Assessment.

The air quality baseline section addresses the interrelated subjects of:

- ambient air quality
- air emissions
- climate and meteorology

Ambient air quality is measured according to the concentration of airborne constituents, e.g., aerosols or gases, in the environment, or the rate at which these constituents are deposited. Air emissions are releases of gases or particles to the atmosphere that can contribute to changes in air quality. They can result from:

- natural sources, e.g., decomposition of organic matter
- human activities, e.g., vehicle exhausts

Climate is a measure of the long-term averages, i.e., normals, of key atmospheric variables, including temperature, precipitation and wind. In contrast, meteorology refers to the variability in these atmospheric variables. An understanding of this variability is important in determining how emissions might affect air quality. Regulatory agencies have established standards and guideline values to which ambient measurements can be compared to determine the air quality.

An airshed is the space in which air emissions interact and in which air quality models might meaningfully predict potential changes in air quality. Three airsheds were used in this study (see Section 2.2.1, Study Areas).

2.1.1 Baseline Study Objectives

The objectives of the air baseline section are to provide information on:

- ambient air quality data
- existing emissions data
- existing greenhouse gas (GHG) emissions data
- climatic data
- meteorological data

Ambient air quality data includes the current ambient concentrations or deposition rates for selected air constituents near the project. This data establishes the existing conditions to which predicted concentrations might be compared, and determines the effect on air quality of existing air emissions from sources in the region but not associated with the project. Climatic conditions near the project are defined by the long-term averages and extremes of temperature and precipitation. Meteorology describes the hour-to-hour variations wind, temperature, precipitation and other parameters that describe the assimilative capacity of the environment. These are incorporated into air quality models in the impact assessment to describe the physical characteristics of the atmosphere and predict how project emissions are dispersed. From this it can be determined how air quality might change.

2.2 Methods

Figure 2-1 illustrates the methods used for the air quality baseline study.

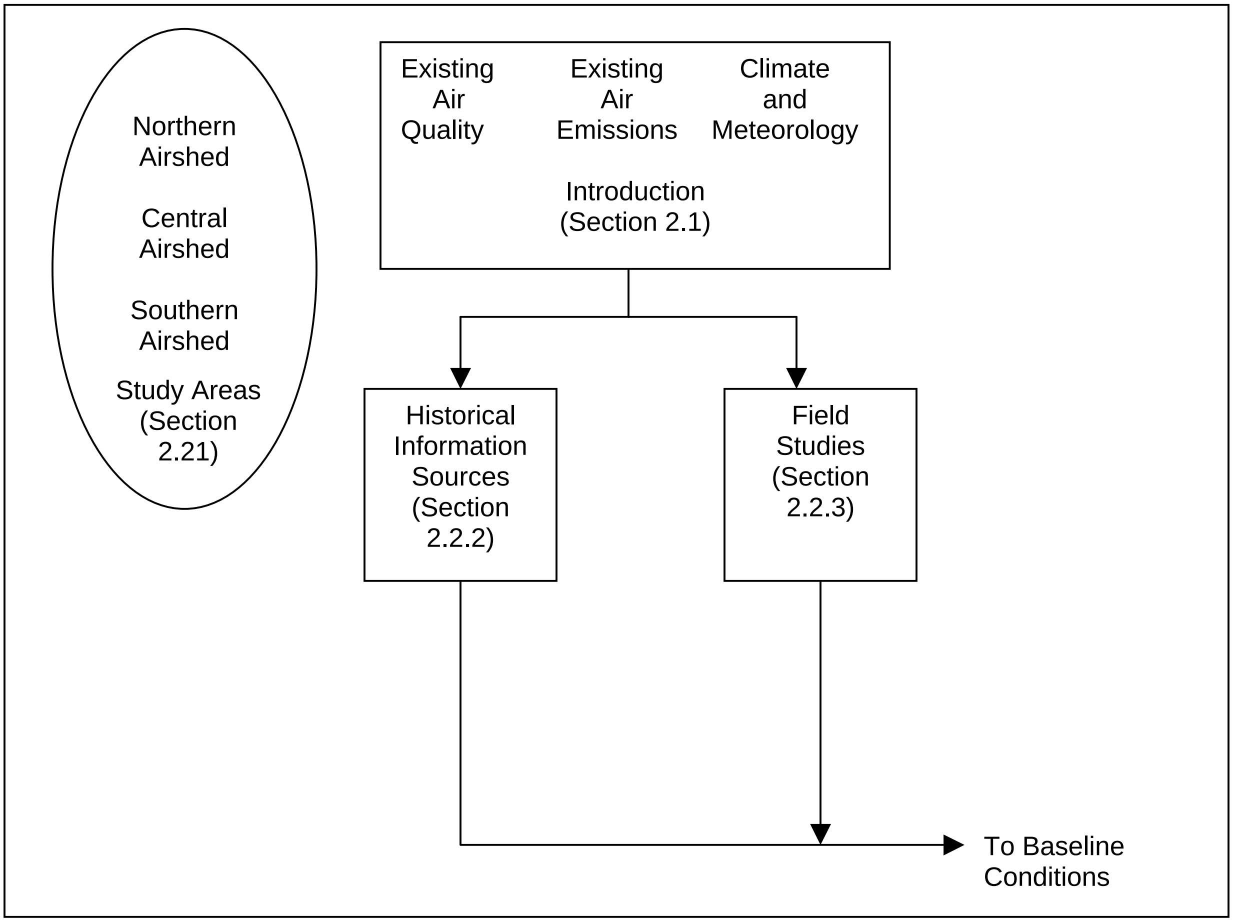

Figure 2-1: Methods for Air Quality Baseline Study

2.2.1 Study Areas

Three airsheds, or regional study areas (RSAs), were defined that cover most of the project's large spatial extent. These airsheds represent the areas over which model predictions were made, and within which emissions from different facilities interact. Emissions from within one airshed were not considered to interact with emissions from the other airsheds. The three airsheds are:

- northern airshed – a 150 by 200 km area that includes the production area and the Inuvik area facility (see Figure 2-2)

- central airshed – a 250 by 375 km area that covers the northern part of the pipeline corridor, including:
  - the Little Chicago compressor and pumping station
  - the Norman Wells compressor facility (see Figure 2-3)
- southern airshed – a 300 by 500 km area that covers the southern part of the pipeline corridor and includes the following:
  - Blackwater River and Trail River compressors
  - Trout River heater station
  - NOVA Gas Transmission Ltd. (NGTL) interconnect facility (see Figure 2-4)

The organization of the baseline data as presented here is based on the three RSAs.

Within these RSAs, local study areas (LSAs) were defined near each of the project facilities. Most project emission effects are expected to occur in these LSAs. Each LSA is 20 by 20 km and is centred on a facility, except for the Inuvik area facility LSA, which measures 32 km east to west and 20 km north to south and which extends to the west to enclose the town of Inuvik.

2.2.2 Historical Information Sources

Historical information was gathered for the following baseline components:

- air quality
- existing emissions
- GHG emissions
- climate and meteorology

Figure 2-5 shows the locations of stations used as sources for baseline air quality monitoring, climate and meteorological data.

2.2.2.1 Air Quality

Key findings of the gap analysis conducted by AGRA (2000) suggest that no long-term historic air quality measurements have been made near the project. The limited data that does exist to describe the baseline air quality conditions is from short-duration monitoring programs that were conducted either many years ago or in areas that are not near the proposed project facilities.

A short-term monitoring program was completed near the project in 1972 and 1973 near Inuvik and Richards Island (Slaney 1973a, 1973b).

Figure 2.2 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 2.3 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 2.4 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 2.5 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

The Government of the Northwest Territories (GNWT) has also conducted ambient air quality monitoring. Most of this data has been collected in and around Yellowknife, although recent monitoring was done in more remote areas. SO_2 has been monitored at Fort Liard since 2000 (GNWT 2003). In 2003, a monitoring station was installed in Inuvik to measure SO_2, NO_2 and $PM_{2.5}$.

Measurements have also been conducted on precipitation to determine the presence of acid compounds. A Canadian air and precipitation monitoring station has been in operation at the Northwest Territories Power Corporation's Snare Rapids hydroelectric site since 1989. The data from this site indicates levels of sulphate, nitrate and potential acid input (PAI) in the region. This data is considered to be an improvement on the short-term precipitation data collected in Fort Simpson in 1978 and in Inuvik in 1981. The long-term measurements of precipitation chemistry from Snare Rapids are considered to be more representative than the short-term readings, and provide the information most representative of the conditions in the Mackenzie Valley region.

2.2.2.2 Existing Emissions

Information about community and industrial air emissions was obtained from published data and combined with statistical information on community traffic volumes, heating needs and transportation activities. The estimates for existing air emissions were made using published literature and expert judgment, and included calculated values for aviation activities, marine sources, communities and other industrial activities.

2.2.2.3 Greenhouse Gas Emissions

The baseline quantities of GHG emissions were compiled from previous studies. The GHG emissions for the Northwest Territories and Canada were taken from federal inventory and GHG outlook documents produced by Environment Canada (2002; 2003) and Natural Resources Canada (NRC 1999). To determine the existing levels of GHG emissions from aviation activities, marine sources, communities and other industrial activities within 50 km of the project, published information on community traffic volumes, heating needs and transportation activities was used. This information was combined with emission factors from published guidance documents.

2.2.2.4 Climate

Long-term climate data was compiled from data collected at Meteorological Services of Canada (MSC) stations in the region. Where available, climate normals from 1961 to 1990 were obtained. In addition, the current climate conditions and historical climate trends were derived from historical temperature and precipitation data collected from 1951 to 2000 for 16 stations (see Table 2-1).

Table 2-1: Climate Data Stations Used for the Baseline Setting Information

Station Name	Administrative Region[1]	Airshed[2]
Sachs Harbour	Inuvialuit Settlement Region	–
Cape Parry	Inuvialuit Settlement Region	–
Komakuk Beach	Inuvialuit Settlement Region	–
Tuktoyaktuk	Inuvialuit Settlement Region	Northern airshed
Shingle Point	Inuvialuit Settlement Region	–
Inuvik	Inuvialuit Settlement Region, Gwich'in Settlement Area	Northern airshed
Aklavik	Gwich'in Settlement Area	Northern airshed
Fort McPherson	Gwich'in Settlement Area	–
Fort Good Hope	Sahtu Settlement Area	Central airshed
Norman Wells	Sahtu Settlement Area	Central airshed
Wrigley	Deh Cho Region	Southern airshed
Fort Simpson	Deh Cho Region	Southern airshed
Hay River	Deh Cho Region	–
Fort Liard	Deh Cho Region	Southern airshed
Fort Nelson, British Columbia	Northeastern British Columbia	–
High Level, Alberta	Northwestern Alberta	–

NOTES:
– Data from that station was not used to determine current conditions
1 Stations used to characterize the current and historic climatic conditions for the regions
2 Stations used to characterize climate in the airsheds

The current climatic conditions were based on the averages for the five-year period from 1996 to 2000. A five-year average was selected as a reliable representation of the current conditions. This is consistent with guidelines for using meteorological data in air assessments. Available data for the full 50-year period was used to determine the historic trends for the past 30 years, from 1971 to 2000.

Some of the climate normals and meteorological data has been subdivided into the following four seasons:

- December, January and February
- March, April and May
- June, July and August
- September, October and November

Although these four quarters do not directly relate to the seasonal weather patterns observed, these groupings are used by convention in Canada.

2.2.2.5 Meteorology

Whereas climate describes the long-term atmospheric conditions, meteorology describes the variability in atmospheric parameters that can affect dispersion. The dispersion models used in the air quality assessment require five years of hourly meteorological data for each of the three airsheds, including:

- temperature
- precipitation
- wind speed and direction
- atmospheric stability and turbulence
- mixing height

The stations for collecting the meteorological data used for modelling emission sources in the three airsheds were selected based on:

- proximity to the project components
- length of record and suitability of data for dispersion modelling

Of the available stations, Inuvik, Norman Wells and Fort Simpson were selected. Table 2-2 summarizes the sources of hourly meteorological data used to define the baseline setting and to provide input data for dispersion modelling.

Table 2-2: Meteorological Data Used for the Baseline Setting

Station Name	Airshed	Period of Record
Inuvik	Northern airshed	1994–1998
Norman Wells	Central airshed	1997–2001
Fort Simpson	Southern airshed	1997–2001

2.2.3 Field Studies

2.2.3.1 Monitoring and Sampling Methods

Passive and continuous monitoring was conducted as part of field studies for this baseline. In passive monitoring, gas or vapour pollutant samples are collected from the atmosphere by diffusion through a static air layer or by permeation through a membrane. Sampling can range from days to weeks. This method, when used over months or years, provides a relatively long-term measure of ambient levels of the compounds being monitored. Given the good air quality in the region, integrated passive sampling provides a good measure of long-term ambient concentrations.

Continuous monitoring requires an electronic instrument equipped with a pump. The pump draws an ambient air sample into a chamber, and a measuring device estimates the concentration of the compound being monitored. This estimate is then converted into an hourly value. A continuous program in a clean remote area often measures emissions from its own power source, i.e., typically a diesel generator, rather than the true background levels. Continuous monitoring was done at Norman Wells because:

- one of the proposed project facilities will be located close to the town
- emissions from a oil processing facility in the community are considered part of the background readings

SUMMA canisters were used to monitor volatile organic compounds (VOCs). They are specialized stainless steel containers each fitted with a pressure valve. The valve is opened manually and a sample of ambient air is drawn into the device for a set time, e.g., one hour. The valve is then closed and the container is sent to a certified laboratory, e.g., Maxxam Analytics Inc., for analysis of select VOCs. A key benefit of using the SUMMA sampling method is that laboratories can detect very small concentrations with specialized analytical equipment, e.g., a gas chromatograph. The SUMMA sampling method provides a representative estimate of the existing background VOC levels in the region. Although the results of the VOC analysis include 39 separate compounds, the air quality assessment focused on the following four, which are considered most relevant to oil and gas operations:

- benzene
- toluene
- ethylbenzene
- xylene

Although benzene is considered to be an important parameter on its own, the remaining compounds are usually discussed collectively as BTEX, i.e., benzene, toluene, ethylbenzene and xylene.

2.2.3.2 Production Area

As no human activity likely to affect air quality occurs near the production facilities, e.g., hunting and fishing activities, ambient concentrations of air compounds are expected to be low, at or below the level of detection for most compounds. However, a limited VOC monitoring program between September and December 2002 at Taglu and Parsons Lake, involving the collection of three short-term samples, i.e., for one hour, using SUMMA canisters was undertaken to capture background VOC levels, which might have resulted from exploration activities in the area. A separate VOC monitoring program was not completed at Niglintgak because it is so close to Taglu and baseline conditions were assumed the same in both areas.

The information available from the MSC was considered suitable for describing the meteorological and climatic conditions in the production area. No additional meteorological and climate monitoring was done.

2.2.3.3 Pipeline Corridor

The baseline air-monitoring program along the pipeline corridor involved monitoring for sulphur dioxide (SO_2), nitrogen dioxide (NO_2), oxides of nitrogen (NO_X) and ozone (O_3) in Inuvik and Norman Wells. These field studies extended over a 12-month period between September 2001 and August 2002 to allow data to be collected for all seasons. These sites were selected based on their proximity to communities and the potential for adverse air quality effects associated with project activities.

Inuvik Monitoring

The monitoring program at Inuvik was conducted east of the town, at a fixed location between the proposed facility and the town. The passive monitoring equipment, installed in August 2001, measured monthly values of SO_2, NO_2, NO_X and O_3. The program lasted 12 months. The location was selected so that it could be accessed all year.

Oxides of nitrogen, i.e., NO_X and NO_2, were monitored, as they will be emitted from the proposed combustion equipment. Although SO_2 emissions from the project are unlikely, SO_2 monitoring was included. Ozone, although not directly emitted from the project, was included in the field studies. The closest other source of ambient O_3 data is in Fairbanks, Alaska, 700 km southwest of Inuvik.

Norman Wells Monitoring

A combination of passive monitoring, involving monthly measurements, and continuous monitoring, involving hourly measurements, was used in Norman Wells to measure SO_2, NO_2, NO_X and O_3. The monitoring program in Norman Wells was conducted west of the town, near the proposed compressor station. Short-term monitoring, i.e., hourly averages, in Norman Wells allowed direct comparisons between continuous measurements and the passive monitoring results, and between measured values and short-term guideline values.

2.3 Baseline Conditions

2.3.1 Air Quality

The compounds of interest included those that might be generated by the project or that might be formed as a by-product of project emissions, including:

- sulphur dioxide (SO_2)
- oxides of nitrogen (NO_x)
- nitrogen dioxide (NO_2)
- ozone (O_3)
- carbon monoxide (CO)
- volatile organic compounds (VOCs), which include benzene and the subset of VOCs collectively referred to as BTEX
- respirable particulate matter, which is smaller than 2.5 µm in diameter, is referred to as $PM_{2.5}$
- compounds whose deposition might contribute to acidification in the environment, including sulphates and nitrates, which can be collectively evaluated as potential acid input (PAI)

Table 2-3 provides the relevant ambient air quality guideline values for most of these compounds. As the Northwest Territories has not yet established guideline values or standards for all of the compounds of interest, the table also includes available criteria established by other Canadian or North American jurisdictions.

The baseline air quality data used for the assessment was taken from a combination of data gathered through field monitoring and data compiled from previous studies. The following tables list the data sources used to define the baseline air settings for the facilities in the northern (see Table 2-4), central (see Table 2-5) and southern (see Table 2-6) airsheds. For CO, the background concentrations were assumed to be zero because of the lack of anthropogenic emission sources, such as vehicles, in the area. Background levels of $PM_{2.5}$ were assumed to be zero for the same reason. Although natural sources of $PM_{2.5}$, such as fires and wind blown dust, can occur in the area, they are highly seasonal and difficult to quantify.

Table 2-3: Ambient Air Quality Guideline Values

Parameter	Northwest Territories Standard[1] (µg/m³)	Federal Air Quality Objectives[2]			Other Criteria (µg/m³)
		Desirable (µg/m³)	Acceptable (µg/m³)	Tolerable (µg/m³)	
Sulphur dioxide (SO_2)					
1-hour maximum	450	450	900	N/A	N/A
24-hour maximum	150	150	300	800	N/A
Annual average	30	30	60	N/A	N/A
Nitrogen Dioxide (NO_2)					
1-hour maximum	N/A	N/A	400	1,000	N/A
24-hour maximum	N/A	N/A	200	300	N/A
Annual average	N/A	60	100	N/A	N/A
Carbon Monoxide (CO)					
1-hour maximum	N/A	15,000	35,000	N/A	N/A
8-hour maximum	N/A	6,000	15,000	20	N/A
Particulate Matter ($PM_{2.5}$)					
24-hour maximum	30	N/A	N/A	N/A	N/A
Benzene					
1-hour[3] maximum	N/A	N/A	N/A	N/A	30
Toluene					
1-hour[4] maximum	N/A	N/A	N/A	N/A	1,880
Ethyl-benzene					
1-hour[5] maximum	N/A	N/A	N/A	N/A	4,000
Xylene					
1-hour[4] maximum	N/A	N/A	N/A	N/A	2,079
BTEX					
1-hour[6] maximum	N/A	N/A	N/A	N/A	30
Ozone (O_3)					
1-hour maximum	N/A	100	160	N/A	N/A
8-hour maximum[7]	N/A	N/A	N/A	N/A	126
Annual average	N/A	N/A	30	N/A	N/A

NOTES:
N/A = not applicable
1 Ambient air standards in the Northwest Territories (RWED 2002)
2 Federal ambient air quality objectives as presented in *The Clean Air Act* (Environment Canada 1981)
3 Alberta Ambient Air Quality Guidelines (AENV 2000)
4 Texas Natural Resource Conservation Commission environmental screening levels (TNRCC 2000)
5 Ontario ambient air quality criteria (Ontario Ministry of the Environment 2001)
6 The Alberta Ambient Air Quality Guidelines (AENV 2000) for benzene have been chosen as an applicable guideline for BTEX in this assessment
7 *Canada-Wide Standards for Particulate Matter (PM) and Ozone by Year 2010* (CCME 2000)

Table 2-4: Baseline Air Data Sources for the Northern Airshed

Parameter	Niglintgak	Taglu	Parsons Lake	Inuvik Area Facility
Sulphur dioxide (SO_2)	Inuvik[1]	Inuvik[1]	Inuvik[1]	Inuvik[1]
Nitrogen dioxide (NO_2)	Inuvik[1]	Inuvik[1]	Inuvik[1]	Inuvik[1]
Carbon monoxide (CO)[4]	Assumed zero	Assumed zero	Assumed zero	Assumed zero
Particulate matter ($PM_{2.5}$)[4]	Assumed zero	Assumed zero	Assumed zero	Assumed zero
Benzene	Taglu[2]	Taglu[2]	Parsons Lake[3]	Parsons Lake[3]
Total BTEX[5]	Taglu[2]	Taglu[2]	Parsons Lake[3]	Parsons Lake[3]
PAI[6]	Snare Rapids	Snare Rapids	Snare Rapids	Snare Rapids
Sulphate deposition[6]	Snare Rapids	Snare Rapids	Snare Rapids	Snare Rapids
Nitrate deposition[6]	Snare Rapids	Snare Rapids	Snare Rapids	Snare Rapids
Ozone (O_3)	Inuvik[1]	Inuvik[1]	Inuvik[1]	Inuvik[1]

NOTES:
1 Passive monitoring results from the field studies at Inuvik
2 SUMMA canister field monitoring program at Taglu
3 SUMMA canister field monitoring program at Parsons Lake
4 Results assumed to be zero based on the absence of emission sources
5 Total BTEX represents the sum of the benzene, toluene, ethylbenzene and xylene
6 Results based on wet deposition monitoring data for Snare Rapids, Northwest Territories (GNWT 2003; Golder and Conor Pacific 1998)

Table 2-5: Baseline Air Data Sources for the Central Airshed

Parameter	Little Chicago	Norman Wells
Sulphur dioxide (SO_2)	Norman Wells[1]	Norman Wells[1]
Nitrogen dioxide (NO_2)	Norman Wells[2]	Norman Wells[2]
Carbon monoxide (CO)[4]	Assumed zero	Assumed zero
Particulate matter ($PM_{2.5}$)[4]	Assumed zero	Assumed zero
Benzene	Parsons Lake[3]	Parsons Lake[3]
Total BTEX[5]	Parsons Lake[3]	Parsons Lake[3]
PAI[6]	Snare Rapids	Snare Rapids
Sulphate deposition[6]	Snare Rapids	Snare Rapids
Nitrate deposition[6]	Snare Rapids	Snare Rapids
Ozone (O_3)	Norman Wells[2]	Norman Wells[2]

NOTES:
1 Passive monitoring results from field studies at Norman Wells
2 Continuous monitoring results from field studies at Norman Wells
3 SUMMA canister field monitoring program at Parsons Lake
4 Results assumed to be zero based on the absence of emission sources
5 Total BTEX represents the sum of the benzene, toluene, ethylbenzene and xylene
6 Results based on wet deposition monitoring data for Snare Rapids, Northwest Territories (GNWT 2003; Golder and Conor Pacific 1998)

Table 2-6: Baseline Air Data Sources for the Southern Airshed

Parameter	Blackwater River	Trail River	Trout River	NGTL Interconnect Facility
Sulphur dioxide (SO_2)	Norman Wells[1]	Norman Wells[1]	Norman Wells[1]	Norman Wells[1]
Nitrogen dioxide (NO_2)	Norman Wells[2]	Norman Wells[2]	Norman Wells[2]	Norman Wells[2]
Carbon monoxide (CO)[4]	Assumed zero	Assumed zero	Assumed zero	Assumed zero
Particulate matter ($PM_{2.5}$)[4]	Assumed zero	Assumed zero	Assumed zero	Assumed zero
Benzene	Parsons Lake[3]	Parsons Lake[3]	Parsons Lake[3]	Parsons Lake[3]
Total BTEX[5]	Parsons Lake[3]	Parsons Lake[3]	Parsons Lake[3]	Parsons Lake[3]
PAI[6]	Snare Rapids	Snare Rapids	Snare Rapids	Snare Rapids
Sulphate deposition[6]	Snare Rapids	Snare Rapids	Snare Rapids	Snare Rapids
Nitrate deposition[6]	Snare Rapids	Snare Rapids	Snare Rapids	Snare Rapids
Ozone (O_3)	Norman Wells[2]	Norman Wells[2]	Norman Wells[2]	Norman Wells[2]

NOTES:
NGTL = NOVA Gas Transmission Limited
1 Passive monitoring results from field studies at Norman Wells
2 Continuous monitoring results from field studies at Norman Wells
3 SUMMA canister field monitoring program at Parsons Lake
4 Results assumed to be zero based on the absence of emission sources
5 Total BTEX represents the sum of the benzene, toluene, ethylbenzene and xylene
6 Results based on wet deposition monitoring data for Snare Rapids, Northwest Territories (GNWT 2003; Golder and Conor Pacific 1998)

2.3.1.1 Sulphur Dioxide

The SO_2 data collected in the field-monitoring program near Inuvik and in Norman Wells supplements the limited information from previous studies. Short-term monitoring results near Inuvik and Richards Island in 1972 and 1973 (Slaney 1973a, 1973b) indicated levels were low, i.e., below the method detection limits, ambient SO_2 levels. This is consistent with the field monitoring program results in Table 2-7. However, observations made by the Government of the Northwest Territories in Fort Liard (GNWT 2003), indicated that the monthly SO_2 concentrations in that community were higher, ranging from 5 to 6 µg/m³, but still well below the annual Northwest Territories standard of 30 µg/m³.

2.3.1.2 Nitrogen Dioxide

The ambient NO_2 data collected in the field-monitoring program near Inuvik and in Norman Wells supplements the limited information from previous studies. The short-term monitoring completed in 1972 and 1973 (Slaney 1973a, 1973b) near Inuvik and Richards Island indicated levels were low, i.e., below the method detection limits, ambient levels of NO_2. This finding is consistent with the field monitoring program results listed in Table 2-8.

Table 2-7: Baseline Ambient Sulphur Dioxide Measurements

Monitoring Date	Duration (days)	Monitored SO_2		
		Inuvik	Norman Wells[1]	
		Passive (ppb)	Continuous (ppb)	Passive (ppb)
August 28, 2001 to October 5, 2001	38	0.1	0.0	0.2
October 5, 2001 to October 31, 2001	26	0.1	0.0	0.2
October 31, 2001 to December 4, 2001	34	0.1	0.0	0.2
December 4, 2001 to January 7, 2002	34	0.2	0.0	0.1
January 7, 2002 to February 5, 2002	29	0.2	0.0	0.2
February 5, 2002 to March 7, 2002	30	0.3	0.0	0.2
March 7, 2002 to April 2, 2002	26	0.2	0.0	0.2
April 2, 2002 to May 3, 2002	31	0.2	0.0	0.1
May 3, 2002 to June 3, 2002	31	<0.1	0.0	0.1
June 3, 2002 to July 11, 2002	38	<0.1	0.0	0.2
July 11, 2002 to August 12, 2002	32	N/A	0.0	0.1
August 12, 2002 to September 4, 2002	23	0.1	0.0	0.1
Annual average (ppb)		0.2	0.0	0.2
Annual average (µg/m³)		0.4	0.0	0.4
Annual Northwest Territories annual standard (µg/m³)[2]		30	30	30

NOTES:
ppb = parts per billion
N/A = not applicable
1 The continuous and passive SO_2 monitoring results from Norman Wells are effectively the same, given the monitoring methods used
2 Ambient air quality standards in the Northwest Territories (RWED 2002)

2.3.1.3 Carbon Monoxide

Carbon monoxide in the environment typically results from partial or incomplete combustion, usually from vehicle exhaust. Given the absence of anthropogenic sources such as vehicles near the proposed project facilities, background CO levels were assumed to be zero for the air quality assessment.

Table 2-8: Baseline Ambient Nitrogen Dioxide Measurements

Monitoring Date	Duration (days)	Monitored NO_2		
		Inuvik	Norman Wells	
		Passive (ppb)	Continuous (ppb)	Passive (ppb)
August 28, 2001 to October 5, 2001	38	<0.1	0.0	0.1
October 5, 2001 to October 31, 2001	26	0.3	0.1	0.6
October 31, 2001 to December 4, 2001	34	0.3	0.2	0.8
December 4, 2001 to January 7, 2002	34	0.3	0.6	1.5
January 7, 2002 to February 5, 2002	29	0.6	1.6	2.1
February 5, 2002 to March 7, 2002	30	0.8	0.7	1.7
March 7, 2002 to April 2, 2002	26	1.0	2.3	2.4
April 2, 2002 to May 3, 2002	31	0.4	0.2	0.8
May 3, 2002 to June 3, 2002	31	0.3	0.2	0.9
June 3, 2002 to July 11, 2002	38	0.1	0.1	0.7
July 11, 2002 to August 12, 2002	32	–	0.0	0.5
August 12, 2002 to September 4, 2002	23	1.2	0.0	0.4
Annual average (ppb)		0.4	0.5	1.0
Annual average (µg/m³)		0.8	0.9	2.0
Annual federal acceptable objective (µg/m³)[1]		100	100	100

NOTES:
ppb = parts per billion
– = results were not available because of bad weather
1 Federal Ambient Air Quality Objectives as set out in *The Clean Air Act* (Environment Canada 1981)

2.3.1.4 Respirable Particulate Matter

Fine particulate matter includes particles that have a mean diameter of less than 2.5 µm and are referred to as $PM_{2.5}$. There is currently no ambient $PM_{2.5}$ monitoring data available in the region. The only other $PM_{2.5}$ data in the region comes from the GNWT facility in Yellowknife, where between 2000 and 2002, the average $PM_{2.5}$ levels ranged from 3 to 5 µg/m³ (GNWT 2001, 2002, 2003). Although ambient $PM_{2.5}$ levels can be affected by natural sources such as fires and windblown dust, most $PM_{2.5}$ is from combustion emissions. Because there are virtually no combustion sources near the proposed facilities, background $PM_{2.5}$ levels were assumed to be effectively zero in the air quality assessment.

2.3.1.5 Volatile Organic Compounds

VOCs come from either natural, i.e., biogenic, or human, i.e., anthropogenic, sources. Biogenic VOC sources include coniferous trees and decaying vegetation. Anthropogenic sources include fugitive emissions and leaks from motor vehicles, and oil and gas operations. Given the absence of human activity near the planned facilities, background VOC levels are expected to be low, at or below detection limits.

To evaluate these levels, a limited VOC monitoring program was conducted in the Taglu and Parsons Lake leases. During October, November and December 2002, SUMMA canisters were used to collect 1-hour grab samples of ambient air. The resulting samples were analyzed using the TO-14 method (U.S. EPA 1999). Although the results of the VOC analysis included 39 separate compounds, the air quality assessment focused on the concentration of benzene and total BTEX.

Table 2-9 summarizes the VOC monitoring results for Taglu and Table 2-10 summarizes the results for Parsons Lake. Data at other locations in the production area should be comparable to these values, though there might be elevated VOCs near Norman Wells where an existing oil processing facility is located.

Table 2-9: Baseline Volatile Organic Compound Measurements for Taglu

Compound Analyzed[1]	Detection Limit (ppb)	Concentration				Average Concentration (µg/m³)
		October 1, 2002 (ppb)	October 24, 2002[a] (ppb)	December 5, 2002[a] (ppb)	Average (ppb)	
Benzene	0.12	N/C	0.94	0.20	0.57	1.82
Toluene	0.08	N/C	0.12	0.37	0.25	1.06
Ethylbenzene	0.08	N/C	–	0.08	0.08	0.30
m/p-Xylene[2]	0.08	N/C	–	0.31	0.31	1.35
o-Xylene[3]	0.06	N/C	–	0.14	0.14	0.61
Total BTEX		N/C	1.06	1.10	1.35	4.30[2]

NOTES:
ppb = parts per billion
N/C = the October 1, 2002 sample was not collected because of bad weather conditions
– = value below the detection limit
a Individual 1-hour VOC samples were collected on October 24 and December 5
1 Analysis completed using the TO-14 method (U.S. EPA 1999)
2 The m-xylene, p-xylene and o-xylene isomers that are distinguished from each other by the position that the two methyl groups are attached to the benzene ring
3 Total BTEX in µg/m³ was calculated as the sum of benzene, toluene, ethylbenzene and xylene, assuming the molecular weight of benzene

Table 2-10: Baseline Volatile Organic Compound Measurements for Parsons Lake

Compound Analyzed[1]	Detection Limit (ppb)	Concentration: October 1, 2002 (ppb)	Concentration: October 24, 2002 (ppb)	Concentration: December 5, 2002 (ppb)	Concentration: Average (ppb)	Average Concentration (µg/m³)
Benzene	0.12	0.82	–	0.17	0.50	1.58
Toluene	0.08	0.23	–	0.19	0.21	0.91
Ethylbenzene	0.08	–	–	–	–	–
m/p-Xylene[2]	0.08	0.10	–	–	0.10	0.43
o-Xylene[3]	0.06	–	–	–	–	–
Total BTEX		1.15	N/A	0.36	0.81	2.92[2]

NOTES:
N/A = not applicable
ppb = parts per billion
– = value below the detection limit
1 The analysis was completed using the TO-14 method (U.S. EPA 1999)
2 The m-xylene, p-xylene and o-xylene isomers that are distinguished from each other by the position that the two methyl groups are attached to the benzene ring
3 Total BTEX in µg/m³ was calculated as the sum of benzene, toluene, ethylbenzene and xylene, assuming the molecular weight of benzene

2.3.1.6 Acid Deposition

The Government of the Northwest Territories has operated a Canadian Air and Precipitation Monitoring station at the Northwest Territories Power Corporation's Snare Rapids hydroelectric facility since 1989. Precipitation monitoring data from this site provided the background levels of sulphate and nitrate deposition, and therefore of the potential acid input (PAI) expected in the Mackenzie Valley region. The background sulphate deposition rate at that site is 0.96 kg/ha/a, and the nitrate deposition rate is 0.62 kg/ha/a. The wet sulphate and nitrate deposition at Snare Rapids is likely the result of long-range transport of industrial emissions from outside the region.

A background PAI value of 0.03 keq/ha/a was determined for this site. Because PAI comprises several chemical species, PAI is expressed in units of keq/ha/a, where keq refers to the number of equivalent hydrogen ions, i.e., 1 keq = 1 kmol H^+. For sulphur, each molecule is equivalent to two hydrogen ions. Each molecule of nitrogen is equivalent to one hydrogen ion.

2.3.1.7 Ozone

Although the short-term monitoring completed near Inuvik and Richards Island in 1972 and 1973 (Slaney 1973a, 1973b) indicated that ozone levels in the region were low, i.e., below the method detection limits, a field monitoring program was completed near Inuvik and Norman Wells to determine background ozone levels. The findings from the program indicated background levels were relatively high (see Table 2-11). These elevated ground-level ozone concentrations might, at first, seem to be higher than those expected for remote, rural areas. However, the ambient ozone concentrations from many rural sites in the northern hemisphere show consistently high monthly readings. These elevated ozone readings are thought to result from the intrusion of stratospheric ozone from weather systems passing through the region. The stratosphere, the region of the atmosphere containing the ozone layer, is closer to the ground at high latitudes than farther south.

Table 2-11: Baseline Ambient Ozone Measurements

Monitoring Date	Duration (days)	Monitored O_3		
		Inuvik	Norman Wells	
		Passive (ppb)	Continuous (ppb)	Passive (ppb)
August 28, 2001 to October 5, 2001	38	12.7	17.6	9.7
October 5, 2001 to October 31, 2001	26	20.5	25.3	11.8
October 31, 2001 to December 4, 2001	34	16.0	10.8	14.7
December 4, 2001 to January 7, 2002	34	19.5	20.4	15.6
January 7, 2002 to February 5, 2002	29	24.1	23.3	17.2
February 5, 2002 to March 7, 2002	30	31.7	31.3	24.6
March 7, 2002 to April 2, 2002	26	29.9	32.3	27.1
April 2, 2002 to May 3, 2002	31	28.2	35.9	26.1
May 3, 2002 to June 3, 2002	31	19.5	27.6	18.8
June 3, 2002 to July 11, 2002	38	22.1	25.2	20.2
July 11, 2002 to August 12, 2002	32	–	15.7	14.9
August 12, 2002 to September 4, 2002	23	36.5	15.3	13.5
Annual Average (ppb)		23.7	23.4	17.9
Annual Average (µg/m³)		46.5	45.9	35.1
Annual federal acceptable objective (µg/m³)[1]		29.4	29.4	29.4

NOTES:
ppb = parts per billion
– = results were not available because of bad weather
1 Federal ambient air quality objectives (Environment Canada 1981)

Table 2-12 compares the background ozone measurements from Inuvik and Norman Wells to available ozone guideline values. The table shows that the maximum short-term, i.e., 1-hour, ozone concentration in Norman Wells of 284.6 µg/m³ is higher than the federal acceptable objective of 160 µg/m³ (82 ppb). Although the maximum 8-hour ozone concentration in Norman Wells of 108.1 µg/m³ is less than the new Canada-wide standard (CCME 2000) of 126 µg/m³ (64 ppb), the annual average concentrations at both Inuvik and Norman Wells are higher than the federal acceptable objective of 29.4 µg/m³ (15 ppb). It is not unusual that ground-level ozone concentrations in these areas exceed guideline values, as ambient concentrations from rural sites in the northern hemisphere are consistently high. The elevated ozone levels are thought to result from the intrusion of stratospheric ozone, which is closer to the ground at the high latitudes in the North than farther south.

Table 2-12: Comparison Between Baseline Ozone Data and Guideline Values

Monitoring Area (type of monitoring)	Maximum Ambient Ozone Concentration			
	1-Hour (µg/m³)	**8-Hour** (µg/m³)	**Monthly**[1] (µg/m³)	**Average** (µg/m³)
Inuvik (passive)	N/A	N/A	71.6	46.5
Norman Wells (passive)	N/A	N/A	53.2	35.1
Norman Wells (continuous)	284.6	108.1	70.5	45.9
Guideline values	160 [2]	126 [3]	N/A	29.4[2]

NOTES:
N/A = not applicable
1 Monthly values based on the schedule for the passive sampling program, where the readings ranged from 23 to 38 days
2 Federal ambient air quality objectives (Environment Canada 1981)
3 *Canada-wide standards for Particulate Matter (PM) and Ozone by Year 2010* (CCME 2000)
There are no Northwest Territories standards for ozone.

2.3.2 Existing Emissions

Existing emission sources in the region might combine with emissions from the project and contribute to air quality. Existing emission sources were identified from various map and literature sources and the emissions were calculated. They were organized into four categories:

- aviation, including all air traffic, i.e., fixed-wing and rotary-wing aircraft
- marine sources, including seasonal river traffic on the Mackenzie River
- community sources, including local and highway traffic, vehicle refuelling and residential heating, including:
  - fuel oil
  - natural gas
  - wood combustion
- other industrial sources, including existing oil and gas operations

Although most of the project is in a region with no development or human habitation, some emissions do occur. These existing emissions affect air quality and air quality values discussed in the previous section. Table 2-13 summarizes the existing emissions, in tonnes per day, expected within 50 km of the project and includes values for aviation activities, marine sources, communities and other industrial activities.

Table 2-13: Summary of Existing Air Emissions by Activity

Source	Emission[1]					
	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)	Benzene (t/d)	BTEX (t/d)
Aviation	0.02	0.38	0.50	0.03	0.003	0.005
Marine	0.06	0.56	0.08	0.01	0.004	0.008
Communities	0.07	0.26	3.58	2.36	0.031	0.082
Power and Industrial	1.11	2.37	0.41	0.06	0.001	0.003
Total	1.26	3.58	4.57	2.46	0.039	0.097

NOTES:
1 Calculated using published emission factors, population data and fuel information
The numbers shown in this table have been rounded for presentation purposes. Therefore, the totals might not appear to equal the sum of the presented values.

The existing sources of emissions are not evenly distributed. Table 2-14 summarizes the existing emissions by region.

Table 2-14: Summary of Existing Air Emissions by Region

Administration Region	Emission					
	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)	Benzene (t/d)	BTEX (t/d)
Inuvialuit Settlement Region	0.03	0.43	0.83	0.49	0.007	0.018
Gwich'in Settlement Area	1.14	1.60	1.80	0.95	0.015	0.036
Sahtu Settlement Area	0.05	0.88	1.13	0.58	0.010	0.025
Deh Cho Region	0.04	0.67	0.81	0.43	0.008	0.018
Total	1.26	3.58	4.57	2.46	0.039	0.097

NOTES:
1 Calculated using published emission factors, population data and fuel information
The numbers shown in this table have been rounded for presentation purposes. Therefore, the totals might not appear to equal the sum of the presented values.

2.3.3 Greenhouse Gas Emissions

The baseline levels of GHG emissions in the Northwest Territories and Canada were compiled to provide a reference to which the project emissions can be compared. Potential GHG emissions were calculated from regional activities, from all four categories of existing emission sources.

GHG emissions include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). By using the relative GHG potentials of these compounds, it is possible to convert them into equivalent carbon dioxide (ECO_2) numbers so that the emissions can be totalled. Table 2-15 is a summary of the GHG emissions estimated to occur within 50 km of project activities.

The existing GHG emissions in the area are not evenly distributed. Table 2-16 shows the distribution of the GHG emissions in the region.

Because managing GHG emissions is a territorial and a national issue, it is important to know the existing levels of emissions nationally and territorially (see Table 2-17).

Table 2-15: Existing Greenhouse Gas Emissions by Activity

Activity	Emission			
	Carbon Dioxide CO_2 (kt/a)	**Methane CH_4** (kt/a)	**Nitrous Oxide N_2O** (kt/a)	**Equivalent Carbon Dioxide ECO_2[1]** (kt/a)
Aviation	–	–	–	–
Marine	–	–	–	–
Community	60.5	0.0	0.0	60.5
Power and Industrial	119.5	0.2	0.0	122.7
Total	180.0	0.2	0.0	183.2

NOTES:
– = not available
1 Equivalent CO_2 (ECO_2) emissions were calculated using GHG potentials of 1 for CO_2, 21 for CH_4 and 310 for N_2O (Environment Canada 2002)
The numbers shown in this table have been rounded for presentation purposes. Therefore, the totals might not appear to equal the sum of the presented values.

Table 2-16: Existing Greenhouse Gas Emissions by Region

Administrative Region	Emission			
	Carbon Dioxide CO_2 (kt/a)	**Methane CH_4** (kt/a)	**Nitrous Oxide N_2O** (kt/a)	**Equivalent Carbon Dioxide ECO_2[1]** (kt/a)
Inuvialuit Settlement Region	17.0	0.0	0.0	17.2
Gwich'in Settlement Area	37.6	0.1	0.0	40.5
Sahtu Settlement Area	108.1	0.0	0.0	108.4
Deh Cho Region	17.2	0.0	0.0	17.2
Total	180.0	0.2	0.0	183.2

NOTES:
1 Equivalent CO_2 (ECO_2) emissions were calculated using GHG potentials of 1 for CO_2, 21 for CH_4 and 310 for N_2O (Environment Canada 2002)
The numbers shown in this table have been rounded for presentation purposes. Therefore, the totals might not appear to equal the sum of the presented values.

Table 2-17: Existing National and Northwest Territories Greenhouse Gas Emissions

Reporting Year	GHG Emissions	
	Canada (kt/a of ECO_2)[1]	**Northwest Territories** (kt/a of ECO_2)
1995	673,000[2]	1,538[3]
2000	730,000[2]	1,607[3]
2005	728,000[3]	1,708[3]

NOTES:
1 Equivalent CO_2 (ECO_2) emissions were calculated using GHG potentials of 1 for CO_2, 21 for CH_4 and 310 for N_2O (Environment Canada 2002)
2 Canada's GHG Inventory, 1990 to 2001 (Environment Canada 2003)
3 Canada's Emissions Outlook (NRC 1999)

2.3.4 Climate

The climate, which describes long-term atmospheric conditions, was characterized by data collected at many weather stations in the region. The available data was processed to produce seasonal and annual values for the following specific climatic parameters:

- temperature, including mean, maximum and minimum
- precipitation, including rain, snow and total precipitation
- extreme temperature and precipitation events
- long-term trends in climatic parameters

2.3.4.1 Climate Normals

Climate data represents long-term observations of atmospheric parameters, such as temperature and precipitation. These can be reported as climate normals, which represent average climatic conditions over an extended period, usually 30 years. Table 2-18 summarizes temperature normals for the project area. In the table, the data is provided both on an annual and quarterly basis.

Table 2-19 summarizes the annual and quarterly precipitation normals available for the project area.

Visibility in the region is primarily affected by atmospheric humidity. The greater the humidity, the lower the visibility. Two humidity conditions that can affect visibility in the region are fog and ice fog. Fog is formed when moisture in the air condenses and can restrict aircraft and other transportation. Ice fog is a uniquely northern situation that occurs below -30°C. Ice fog events are typically associated with local temperature inversions. Table 2-20 summarizes the fog and ice fog events that have been observed.

Table 2-18: Summary of Available Temperature Normals

Parameter	Location	Temperature Normals				
		DJF (°C)	MAM (°C)	JJA (°C)	SON (°C)	Annual (°C)
Daily average temperature	Tuktoyaktuk (ISR)	-26.5	-15.7	8.5	-8.3	-10.5
	Aklavik (ISR)	-28.2	-11.9	11.7	-8.0	-9.1
	Inuvik (GSA)	-27.8	-13.0	11.6	-8.8	-9.5
	Fort McPherson (GSA)	-28.6	-11.0	12.6	-8.3	-8.8
	Fort Good Hope (SSA)	-29.1	-8.9	14.2	-7.2	-7.8
	Norman Wells (SSA)	-26.1	-6.6	14.9	-6.1	-6.0
	Wrigley (DCR)	-26.2	-3.9	15.4	-5.3	–
	Fort Simpson (DCR)	-24.2	-2.3	15.3	-3.8	-3.7
Daily maximum temperature	Tuktoyaktuk (ISR)	-21.3	-1.0	15.4	5.4	-6.9
	Aklavik (ISR)	-23.4	4.2	18.3	6.8	-5.0
	Inuvik (GSA)	-21.4	4.2	19.5	7.5	-4.5
	Fort McPherson (GSA)	-22.8	6.3	20.2	7.5	-4.1
	Fort Good Hope (SSA)	-23.8	10.0	22.6	10.4	-2.6
	Norman Wells (SSA)	-21.4	11.6	22.4	10.9	-1.1
	Wrigley (DCR)	-19.0	14.0	22.8	12.0	–
	Fort Simpson (DCR)	-16.4	15.0	23.4	13.2	1.9
Daily minimum temperature	Tuktoyaktuk (ISR)	-31.8	-29.6	0.8	-23.7	-14.3
	Aklavik (ISR)	-33.2	-27.6	4.9	-23.5	-13.1
	Inuvik (GSA)	-33.7	-30.3	4.5	-26.0	-14.6
	Fort McPherson (GSA)	-34.7	-28.6	5.9	-24.8	-13.6
	Fort Good Hope (SSA)	-35.0	-27.4	6.6	-24.7	-13.0
	Norman Wells (SSA)	-31.4	-25.1	8.0	-23.4	-10.9
	Wrigley (DCR)	-32.5	-23.1	7.9	-22.9	–
	Fort Simpson (DCR)	-31.3	-21.2	7.7	-21.1	-9.5

NOTES:
– = not available
DJF = December, January, February
MAM = March, April, May
JJA = June, July, August
SON = September, October, November
ISR = Inuvialuit Settlement Region
GSA = Gwich'in Settlement Area
SSA = Sahtu Settlement Area
DCR = Deh Cho Region

SOURCES: Environment Canada (1982, 1993)

Table 2-19: Summary of Available Precipitation Normals

Parameter	Location	Precipitation Normals				
		DJF (mm)	**MAM** (mm)	**JJA** (mm)	**SON** (mm)	**Annual** (mm)
Precipitation[1]	Tuktoyaktuk (ISR)	20.3	17.0	61.1	43.7	142.1
	Aklavik (ISR)	27.4	27.1	91.8	61.5	207.8
	Inuvik (GSA)	43.5	42.5	100.2	71.3	257.4
	Fort McPherson (GSA)	73.4	61.7	90.0	118.5	343.6
	Fort Good Hope (SSA)	46.5	41.9	116.4	77.1	281.9
	Norman Wells (SSA)	51.1	45.7	142.6	77.1	316.6
	Wrigley (DCR)	29.1	39.8	158.6	88.1	–
	Fort Simpson (DCR)	56.3	63.8	148.3	92.0	360.5
Rainfall	Tuktoyaktuk (ISR)	0.1	2.3	58.7	14.1	75.4
	Aklavik (ISR)	0.1	1.8	89.2	14.1	105.2
	Inuvik (GSA)	0.2	6.5	92.3	16.9	116.0
	Fort McPherson (GSA)	0.0	2.1	89.2	18.3	109.6
	Fort Good Hope (SSA)	0.1	9.7	115.5	24.9	150.2
	Norman Wells (SSA)	0.2	12.3	141.2	29.3	183.2
	Wrigley (DCR)	0.0	21.7	158.6	32.1	–
	Fort Simpson (DCR)	0.3	24.8	147.7	36.7	209.7
Snowfall[2]	Tuktoyaktuk (ISR)	20.1	14.6	2.3	29.7	66.8
	Aklavik (ISR)	28.7	28.8	3.5	49.9	110.9
	Inuvik (GSA)	54.5	44.8	6.7	69.3	175.2
	Fort McPherson (GSA)	73.3	60.3	0.9	100.0	234.5
	Fort Good Hope (SSA)	46.4	32.2	0.8	52.2	131.6
	Norman Wells (SSA)	57.9	37.2	1.3	52.5	148.9
	Wrigley (DCR)	30.3	19.2	0.0	56.4	–
	Fort Simpson (DCR)	62.9	41.3	0.6	59.3	164.1

NOTES:
– = not available
DJF = December, January, February
MAM = March, April, May
JJA = June, July, August
SON = September, October, November
ISR = Inuvialuit Settlement Region
GSA = Gwich'in Settlement Area
SSA = Sahtu Settlement Area
DCR = Deh Cho Region

1 Precipitation is the combined rainfall and snowfall (as liquid water equivalent). Data is taken from the official climate normals produced by Environment Canada (1982, 1993). In some cases, the precipitation does not appear to equal the sum of the reported rainfall and snowfall.
2 Snowfall is provided in mm as a liquid water equivalent.

SOURCES: Environment Canada (1982, 1993)

Table 2-20: Summary of Available Fog and Ice Fog Data

Parameter	Location	Average				
		DJF	MAM	JJA	SON	Annual
Normal number of days with fog [1]	Inuvik (GSA)[3]	3	5	6	8	24
	Norman Wells (SSA)[4]	7	–	1	9	18
	Fort Simpson (DCR)[5]	1	–	4	13	20
Number of days with fog[2]	Inuvik (GSA)	5	13	22	22	60
	Norman Wells (SSA)	4	5	11	20	39
	Fort Simpson (DCR)	5	5	12	23	46
Fog frequency (number of hours)	Inuvik (GSA)	19	67	106	111	303
	Norman Wells (SSA)	21	17	45	110	192
	Fort Simpson (DCR)	25	19	51	137	232
Number days with ice fog[2]	Inuvik (GSA)	23	7	0	6	35
	Norman Wells (SSA)	20	3	0	5	28
	Fort Simpson (DCR)	6	0	0	2	9
Ice fog frequency (Number of hours)	Inuvik (GSA)	156	28	0	20	203
	Norman Wells (SSA)	161	8	0	19	187
	Fort Simpson (DCR)	25	1	0	6	31

NOTES:
– = not available
DJF = December, January, February
MAM = March, April, May
JJA = June, July, August
SON = September, October, November
GSA = Gwich'in Settlement Area
SSA = Sahtu Settlement Area
DCR = Deh Cho Region
DCR = Deh Cho Region
1 The days with fog in the climate normals include only days where the visibility is reduced to less than 1 km.
2 The number of days with fog and ice fog include all days when fog is recorded for at least 1 hour.
3 March through July data missing
4 January through June data missing
The data in this table was taken from the official climate normals produced by Environment Canada (1982, 1993). In some cases, the individual seasonal data reported by Environment Canada do not appear to add up to the reported annual averages.

SOURCES: Environment Canada (1982, 1993)

Climate extremes are often reported for some of the monitoring stations. Table 2-21 summarizes the temperature and precipitation climate extremes for the region.

Table 2-21: Summary of Available Extreme Climate Data

Parameter	Location	Climate Extreme				
		DJF	MAM	JJA	SON	Annual
Extreme maximum temperature (°C)	Tuktoyaktuk (ISR)	1.1	19.0	30.0	22.2	30.0
	Aklavik (ISR)	10.0	25.0	33.9	24.4	33.9
	Inuvik (GSA)	5.4	24.9	31.7	26.2	31.7
	Fort McPherson (GSA)	10.0	28.3	33.3	27.2	33.3
	Fort Good Hope (SSA)	6.7	27.2	34.4	28.3	34.4
	Norman Wells (SSA)	11.8	31.1	35.0	26.7	35.0
	Wrigley (DCR)	11.1	31.0	35.0	28.3	35.0
	Fort Simpson (DCR)	14.4	29.9	35.4	30.0	35.4
Extreme minimum temperature (°C)	Tuktoyaktuk (ISR)	-50.0	-45.0	-11.1	-38.9	-50.0
	Aklavik (ISR)	-52.2	-48.9	-11.1	-45.6	-52.2
	Inuvik (GSA)	-56.7	-50.6	-6.1	-46.1	-56.7
	Fort McPherson (GSA)	-55.6	-48.9	-6.7	-46.7	-55.6
	Fort Good Hope (SSA)	-55.6	-46.7	-5.6	-47.2	-55.6
	Norman Wells (SSA)	-54.4	-46.1	-6.1	-42.8	-54.4
	Wrigley (DCR)	-53.3	-46.7	-6.0	-48.0	-53.3
	Fort Simpson (DCR)	-53.3	-42.2	-3.7	-41.7	-53.3
Extreme daily precipitation (mm)	Tuktoyaktuk (ISR)	10.2	12.4	29.5	18.0	29.5
	Aklavik (ISR)	25.4	50.8	44.2	20.8	50.8
	Inuvik (GSA)	15.8	24.2	42.9	30.7	42.9
	Fort McPherson (GSA)	20.3	24.1	66.0	35.6	66.0
	Fort Good Hope (SSA)	13.7	18.5	59.2	27.4	59.2
	Norman Wells (SSA)	19.6	26.7	49.3	50.8	50.8
	Wrigley (DCR)	25.9	28.4	40.1	29.4	40.1
	Fort Simpson (DCR)	13.9	38.4	85.8	45.9	85.8

NOTES:
DJF = December, January, February
MAM = March, April, May
JJA = June, July, August
SON = September, October, November
ISR = Inuvialuit Settlement Region
GSA = Gwich'in Settlement Area
SSA = Sahtu Settlement Area
DCR = Deh Cho Region

SOURCES: Environment Canada (1982, 1993)

2.3.4.2 Climate Trends

The climate normals and current climate conditions cannot present a complete picture for climate. Information about past climate trends is also important in understanding how the climate of the region might be changing. Table 2-22 summarizes, by region the calculated climate trends for the 30-year period between 1971 and 2000.

Table 2-22: Summary of Historic Climate Trends

Administrative Region	Change in Climate Condition[1]			
	Average Temperature (°C)	**Minimum Temperature** (°C)	**Maximum Temperature** (°C)	**Total Precipitation** (mm)
Inuvialuit Settlement Region	+1.5	+2.5	+0.9	+5.2
Gwich'in Settlement Area	+2.0	+5.1	+0.1	+1.5
Sahtu Settlement Area	+1.3	+2.4	+0.3	-49.0
Deh Cho Region	+1.7	+4.2	+1.0	+5.1
Northwestern Alberta	+1.1	+2.3	+0.3	+9.2

NOTE:
1 The 30-year change in climate conditions was determined using the available 50-year climate dataset

The following figures illustrate the relationship between the calculated trends in annual temperatures for each region and the variability in average temperature from one year to the next. The figures also show the 95th percentile confidence limits around the calculated relationships. Trends in average temperature are given for the Inuvialuit Settlement Region (see Figure 2-6), the Gwich'in Settlement Area (see Figure 2-7), the Sahtu Settlement Area (see Figure 2-8), the Deh Cho Region (see Figure 2-9) and for Northwestern Alberta (see Figure 2-10).

To appreciate the historic changes in regional climate, it is important to understand the current climate conditions. The current climate will be different from the climate normals, which refer to long-term, i.e., 30-year, average conditions of temperature and precipitation. For this assessment, the current climate conditions are defined as the average conditions over the last five years of available data, i.e., 1996 through 2000. Table 2-23 provides a summary of the current climate by region.

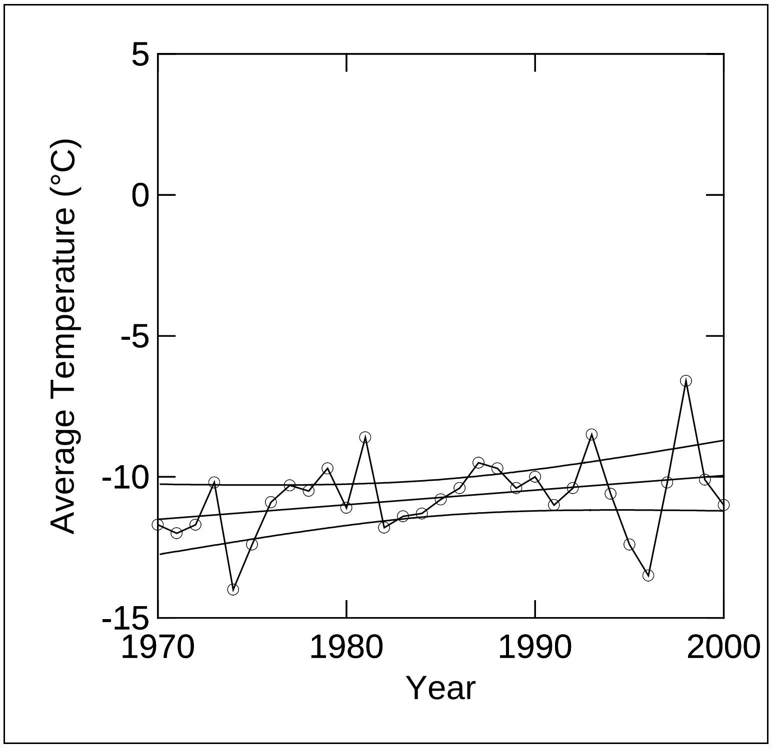

Figure 2-6: Trends in Average Temperature in the Inuvialuit Settlement Region

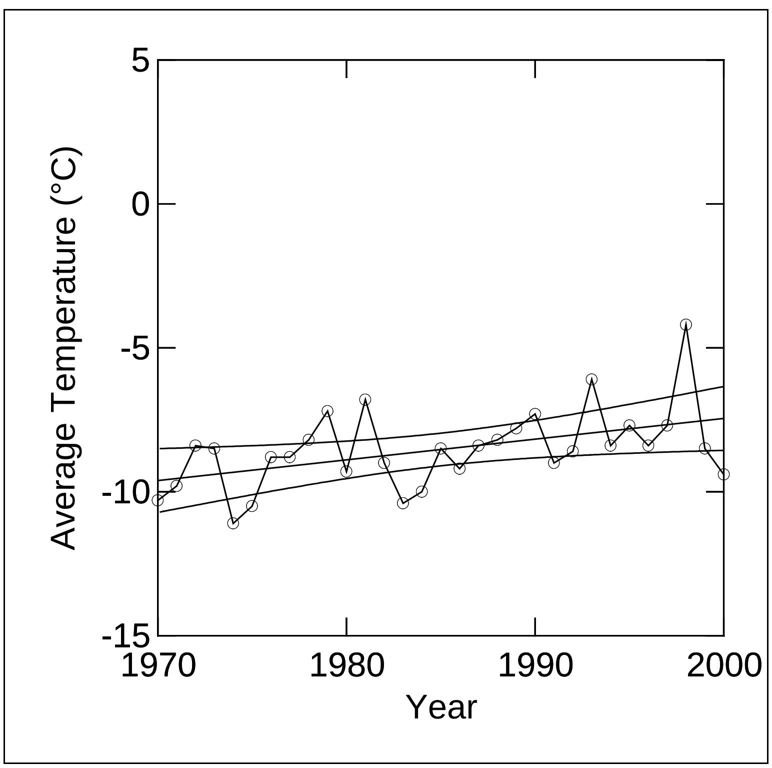

Figure 2-7: Trends in Average Temperature in the Gwich'in Settlement Area

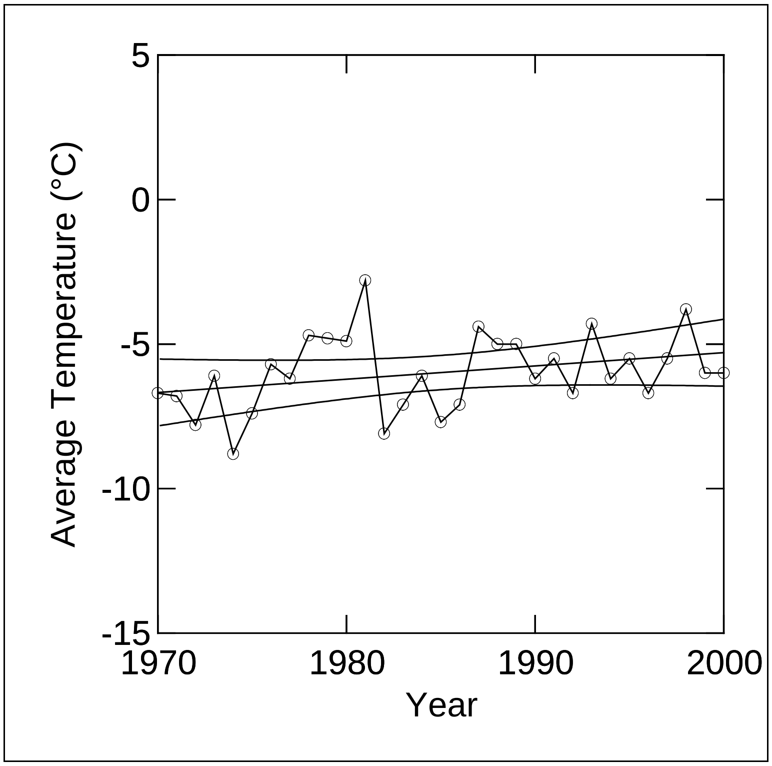

Figure 2-8: Trends in Average Temperature in the Sahtu Settlement Area

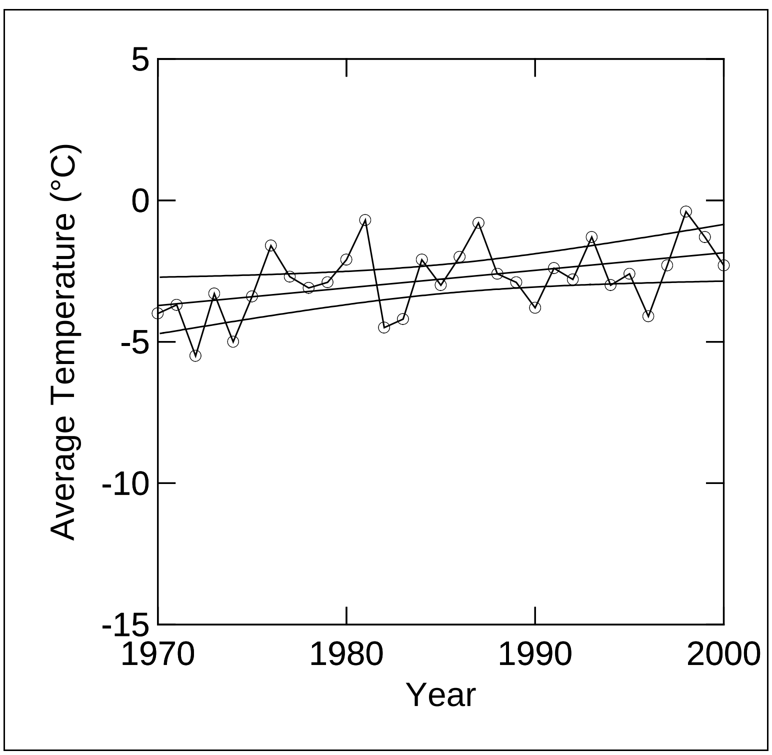

Figure 2-9: Trends in Average Temperature in the Deh Cho Region

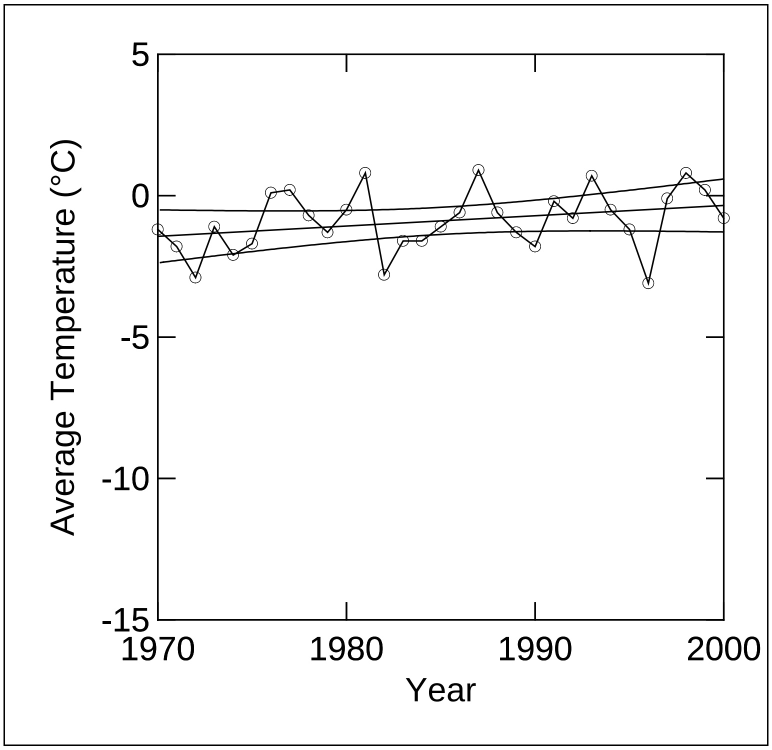

Figure 2-10: Trends in Average Temperature in Northwestern Alberta

Table 2-23: Summary of Current Climate Conditions by Region

Administrative Region	**Current Climate Condition**[1]			
	Average Temperature (°C)	**Minimum Temperature** (°C)	**Maximum Temperature** (°C)	**Total Precipitation** (mm)
Inuvialuit Settlement Region	-10.27	-32.63	14.34	190.98
Gwich'in Settlement Area	-7.63	-32.24	19.77	347.45
Sahtu Settlement Area	-5.61	-33.67	22.92	210.25
Deh Cho Region	-2.07	-30.06	23.46	390.81
Northwestern Alberta	-0.61	-29.67	23.41	317.62

NOTE:
1 Current conditions are determined as the average of the data from 1996 to 2000

2.3.5 Meteorology

The meteorological conditions near the project areas will determine how project emissions are transported in the atmosphere and, as a result, how project emissions might change the air quality. These meteorological conditions describe the assimilative capacity of the environment with respect to air emissions. The meteorological data used in this assessment was collected at established monitoring stations run by the MSC. Hourly meteorological data covering a five-year period was obtained from various stations and applied to the dispersion models run for the three airsheds as follows:

- data from the Inuvik station, in the Gwich'in Settlement Area, was used to describe the meteorological conditions in the northern airshed, which includes the production area and the northern end of the pipeline corridor
- data from the Norman Wells station, in the Sahtu Settlement Area, was used to describe the meteorological conditions in the central airshed, which covers the central part of the pipeline corridor
- data from the Fort Simpson station, in the Deh Cho Region, was used to describe the meteorological conditions in the southern airshed, which includes the facilities located near the southern end of the pipeline corridor

The dispersion models require five full years of hourly meteorological input data to simulate the dispersion and transport of project emissions. This section summarizes the meteorological data and compares it with the long-term climate data discussed in Section 2.3.4.2, Climate Trends. The specific parameters include:

- wind speed and direction
- temperature
- precipitation
- atmospheric stability and turbulence
- mixing height

Atmospheric stability can be viewed as a measure of the atmosphere's ability to disperse emissions. The amount of turbulence is important in determining how a plume is dispersed as it is transported by the wind. Turbulence can be generated either thermally or mechanically. Surface heating or cooling by radiation contributes to generating or suppressing thermal turbulence, and high wind speeds contribute to generating mechanical turbulence.

The Pasquill-Gifford (PG) stability classification is one method for classifying atmospheric stability. The classification ranges as follows:

- unstable, i.e., stability classes A, B and C
- neutral, i.e., stability class D
- stable, i.e., stability classes E and F

Unstable conditions are primarily associated with daytime heating that results in enhanced turbulence, i.e., enhanced dispersion. Stable conditions are associated primarily with nighttime cooling that results in suppressed turbulence, i.e., poorer dispersion. Neutral conditions are primarily associated with higher wind speeds or overcast conditions.

The mixing height is a measure of the depth of the atmosphere through which mixing of emissions can occur. The mixing height often exhibits a strong diurnal and seasonal variation. During the night, heights are lower, whereas during the day they are higher. Heights are typically lower in the winter and higher in the late spring and early summer.

2.3.5.1 Northern Airshed

Data from 1994 to 1998 at Inuvik was used to describe the meteorological conditions and dispersion in the northern airshed.

Winds

The hourly winds observed at Inuvik were predominantly from the east, and most of the strong winds were from the northwest. Prevailing winds were easterly during the fall, winter and spring seasons. Wind direction was more variable during the summer season.

Figure 2-11 summarizes the hourly winds observed at Inuvik, in the form of a wind rose. A wind rose is often used to illustrate the frequency of wind direction and the magnitude of the wind velocity. The lengths of the bars on the wind rose indicate the wind frequency and speed, and the direction from which the wind blows is illustrated by the orientation of the bar in 1 of 16 directions.

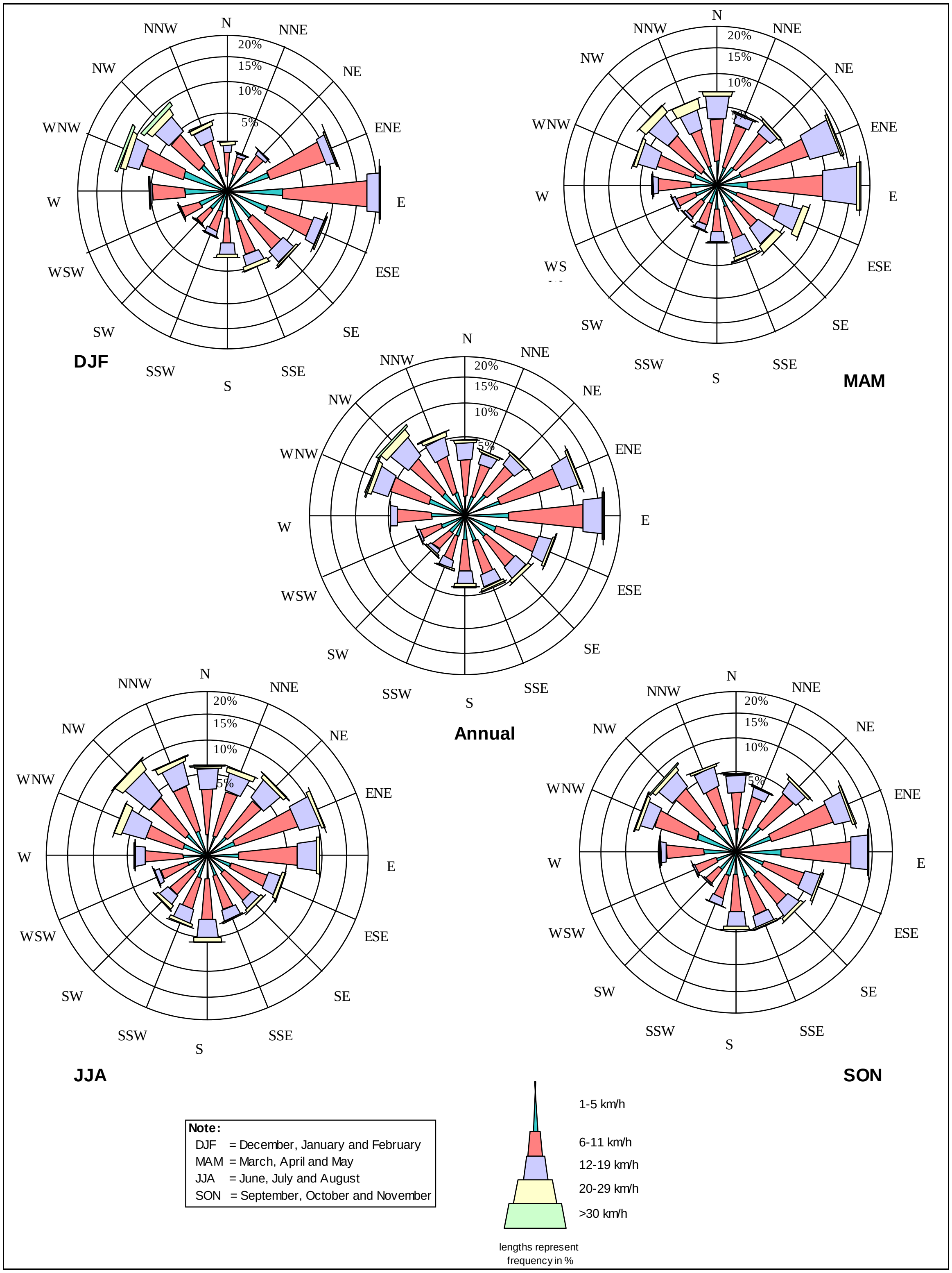

Figure 2-11: Summary of Hourly Winds at Inuvik (1994 to 1998)

Temperature

The average temperature of -7.0°C for the five years of meteorological data for Inuvik, used for the northern airshed modelling, is slightly higher than the long-term climate normal of -9.5°C. Although the warmest year was 1998, all five years had annual average temperatures exceeding the 30-year climate normals. Figure 2-12 is a monthly summary of the observed temperatures overlain with the climate normal data for comparison. Although the figure illustrates monthly temperature averages, hourly temperature data was used for the dispersion modelling.

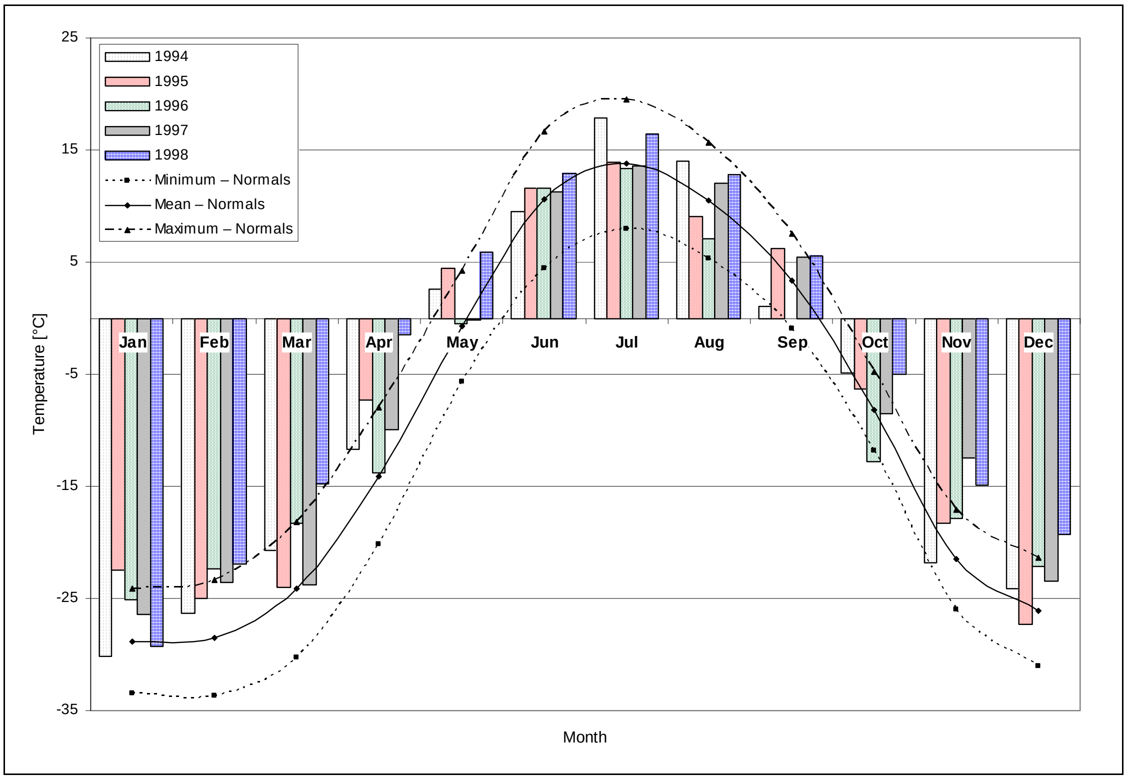

Figure 2-12: Summary of Hourly Temperatures at Inuvik (1994 to 1998)

Precipitation

Although a full five years of meteorological data was obtained for Inuvik, one year and five months of precipitation data, from August 1995 to December 1996, was missing from the dataset. The missing data was replaced using typical precipitation rates from the climate normals. These rates were applied randomly to the individual hours and then adjusted to ensure that the total precipitation in each month was consistent with the climate normals.

There is high annual variability in precipitation in Inuvik. In 1994, rainfall was normal, but the total precipitation amount was above normal. Both rainfall and total precipitation were slightly above the climate normals in 1997. In 1998, rainfall was above normal, but the total precipitation was about normal. Because of the precipitation replacement method discussed previously for 1995 and 1996, the total precipitation was close to normal. There was also a large variation in monthly precipitation totals. Most of the precipitation occurred as rain in the summer, July and August. Figure 2-13 summarizes the hourly precipitation data for Inuvik.

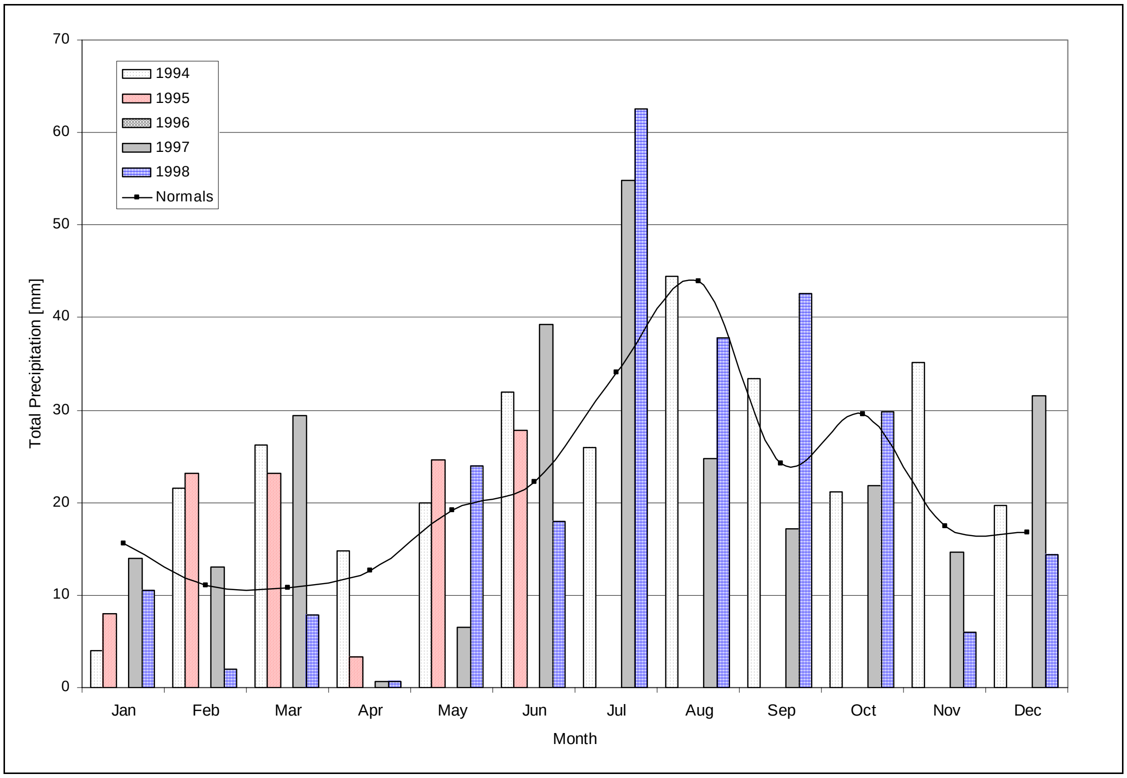

Figure 2-13: Summary of Hourly Precipitation at Inuvik (1994 to 1998)

Atmospheric Stability

Unstable conditions, classes A, B and C, of the Pasquill-Gifford scheme, occur in Inuvik about 20% of the time, neutral conditions, class D, occur about 46% of the time, and stable conditions, classes E and F, occur about 34% of the time. Figure 2-14 shows the frequency of stability classes.

Mixing Height

Average mixing heights in Inuvik are typically higher during the summer, at about 1,500 m. The most frequent mixing heights are in the 300 to 900 m range. These occur about 40% of the time. Mixing heights less than 300 m occurred only 4% of the time at Inuvik. Mixing heights greater than 3,000 m occur about 1% of the time. Figure 2-15 summarizes the mixing height conditions for Inuvik.

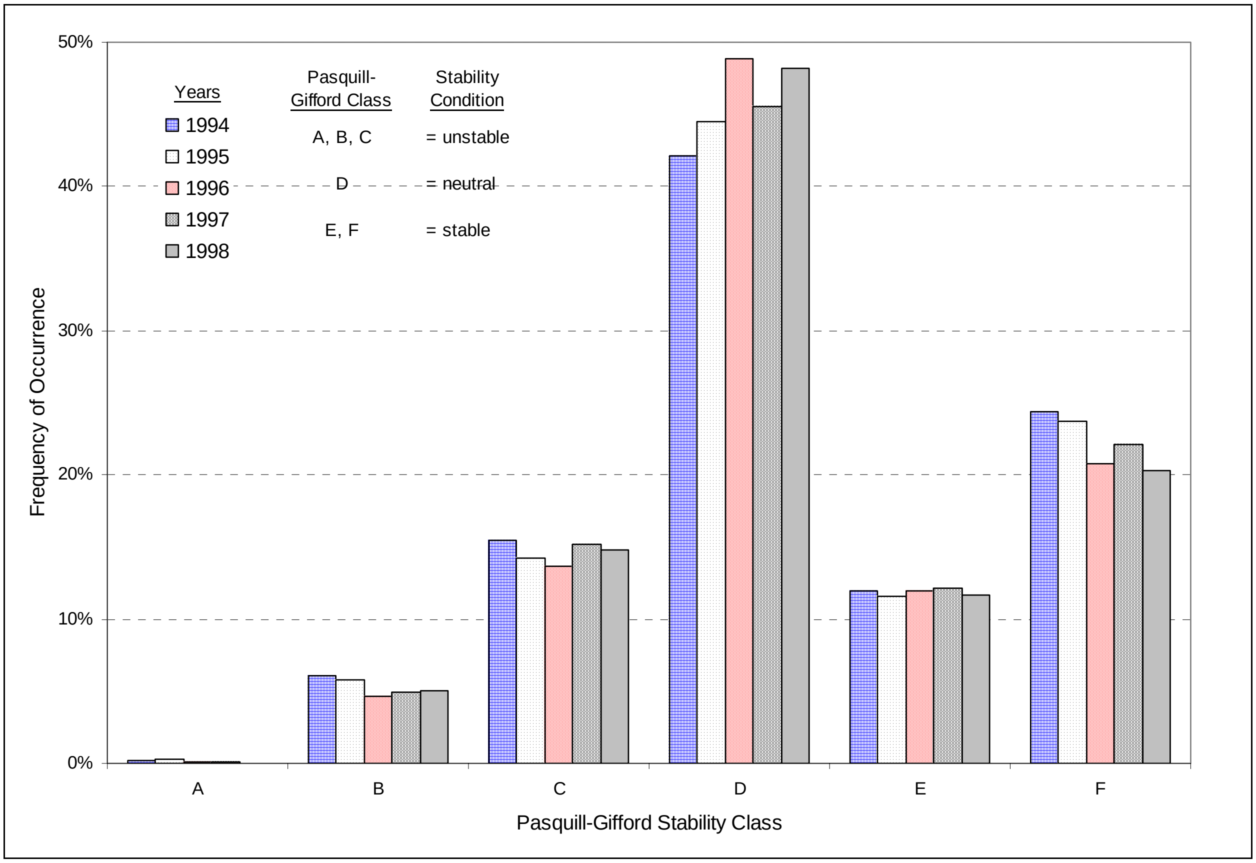

Figure 2-14: Summary of Hourly Stability Conditions at Inuvik (1994 to 1998)

2.3.5.2 Central Airshed

Hourly meteorological data from 1997 to 2001 at Norman Wells was used to describe the meteorological conditions and dispersion in the central airshed.

Winds

Winds at Norman Wells reflect the channelling effect of the Mackenzie River Valley in which the town is located, with a strong west-northwest and east-southeast component. The west-northwest component is predominant in all seasons. The southeast component is more dominant than the east-southeast component during the spring and summer. The reverse is true during the fall and winter. See Figure 2-16, which presents the annual and quarterly wind roses derived from the hourly data from Norman Wells.

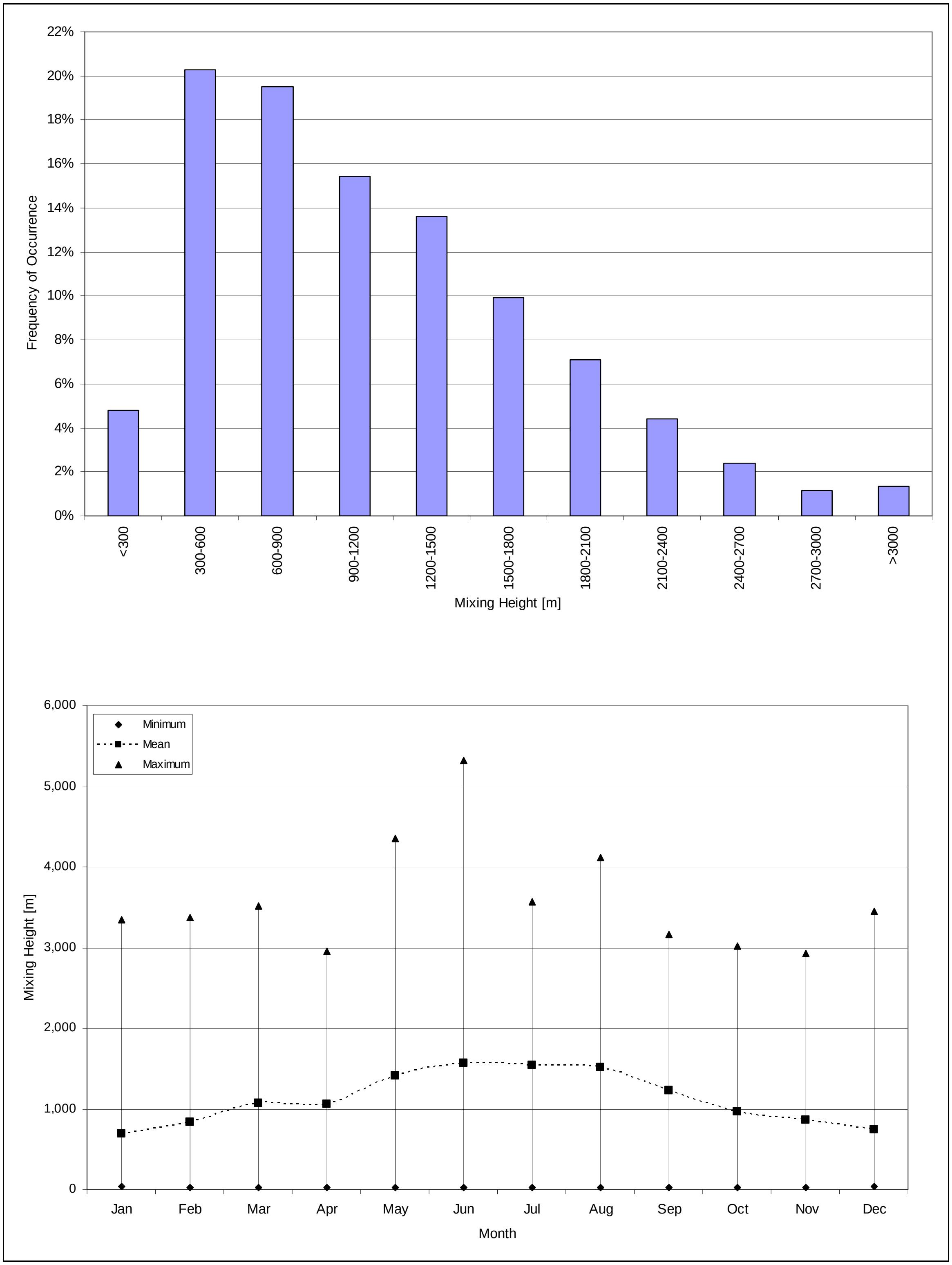

Figure 2-15: Summary of Hourly Mixing Heights at Inuvik (1994 to 1998)

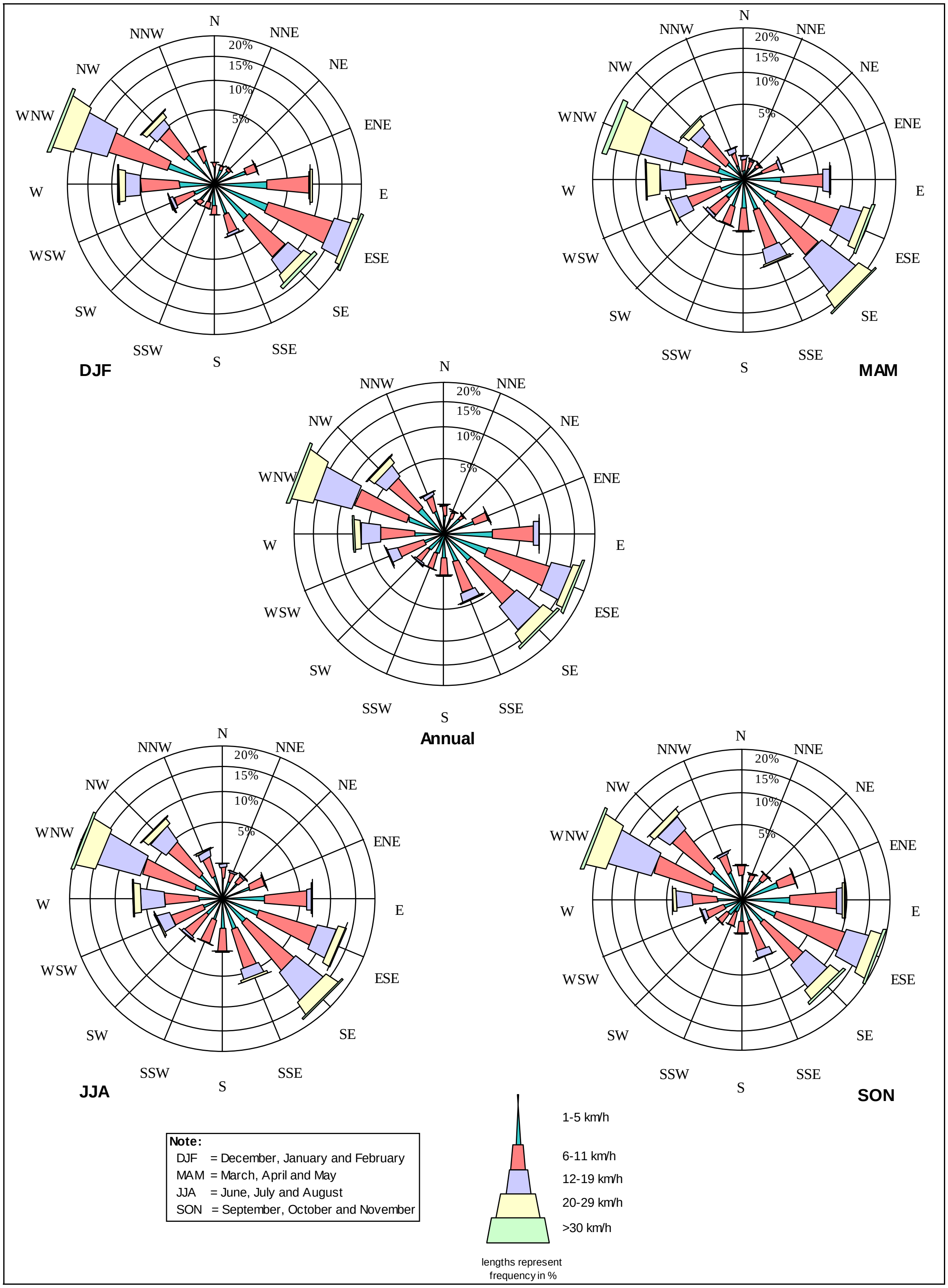

Figure 2-16: Summary of Hourly Winds at Norman Wells (1997 to 2001)

Temperature

The average temperature of -4.6°C for the five years of meteorological data used for Norman Wells was slightly higher than the long-term climate normal of -6.0°C. The warmest year was 1998, but all five years had annual average temperatures exceeding the 30-year climate normals. Figure 2-17 is a monthly summary of the observed temperatures overlain with the climate normals for comparison. Although the figure illustrates monthly temperature averages, hourly temperature data was entered in the dispersion modelling.

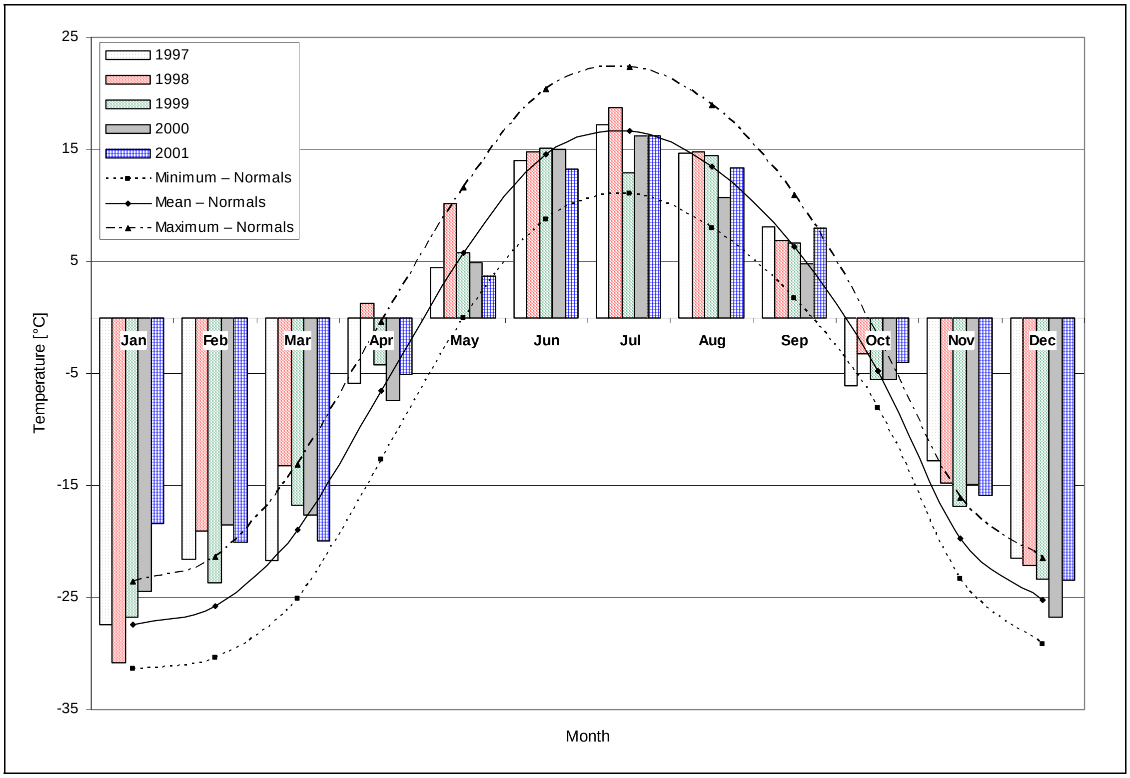

Figure 2-17: Summary of Hourly Temperatures at Norman Wells (1997 to 2001)

Precipitation

Total precipitation in Norman Wells during the five years analyzed was below the climate normal average. In 1997, total precipitation and rainfall were closest to normal. In 1999, the least precipitation occurred: 62 mm below normal. The other years had close to normal rainfall but below normal total precipitation.
Figure 2-18 summarizes the hourly precipitation observations at Norman Wells from 1997 through 2001.

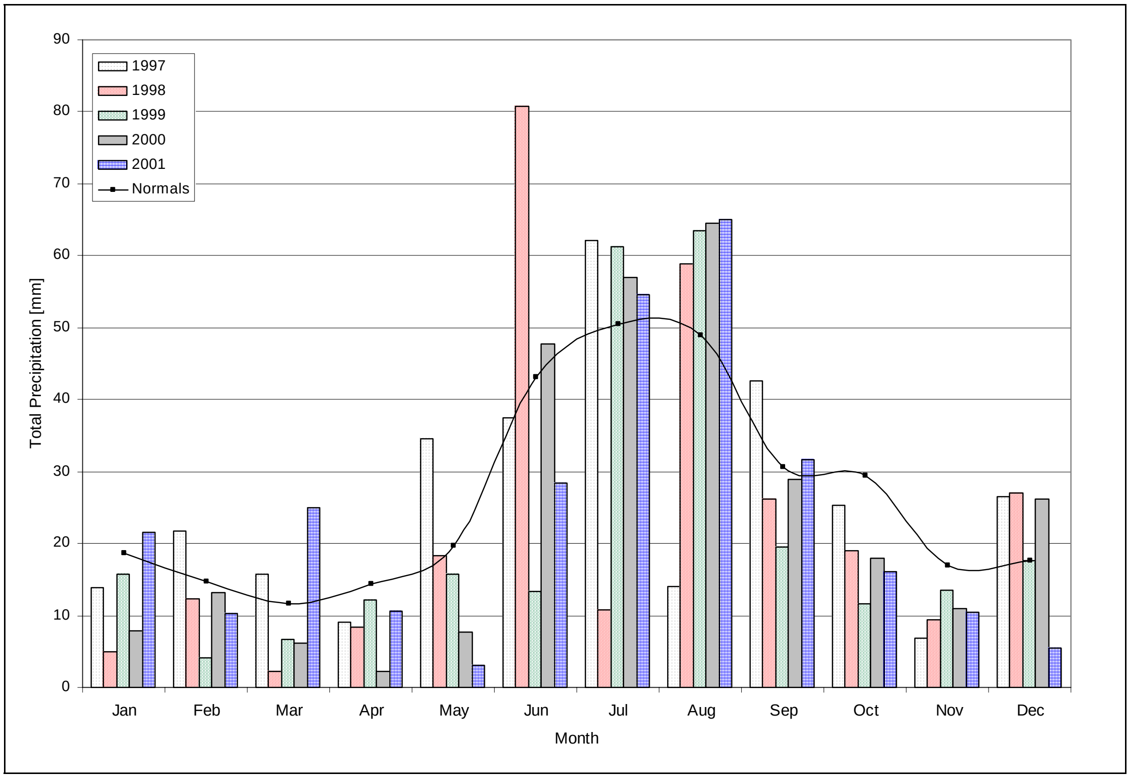

Figure 2-18: Summary of Hourly Precipitation at Norman Wells (1997 to 2001)

Atmospheric Stability

Unstable conditions, i.e., classes A, B and C of the Pasquill-Gifford scheme, occur in Norman Wells about 21% of the time, neutral conditions, class D, occur about 42% of the time, and stable conditions, classes E and F, occur about 37% of the time. Figure 2-19 shows the frequency of stability classes observed at Norman Wells from 1997 to 2001.

Mixing Height

Average mixing heights at Norman Wells increased from about 800 m in the winter to about 1,600 m in the summer. Mixing heights between 300 and 600 m occurred most frequently occurring about 20% of the time. Figure 2-20 summarizes the mixing height conditions for Norman Wells.

2.3.5.3 Southern Airshed

Hourly meteorological data for 1997 to 2001 at Fort Simpson was selected to describe the meteorological conditions and dispersion in the southern airshed.

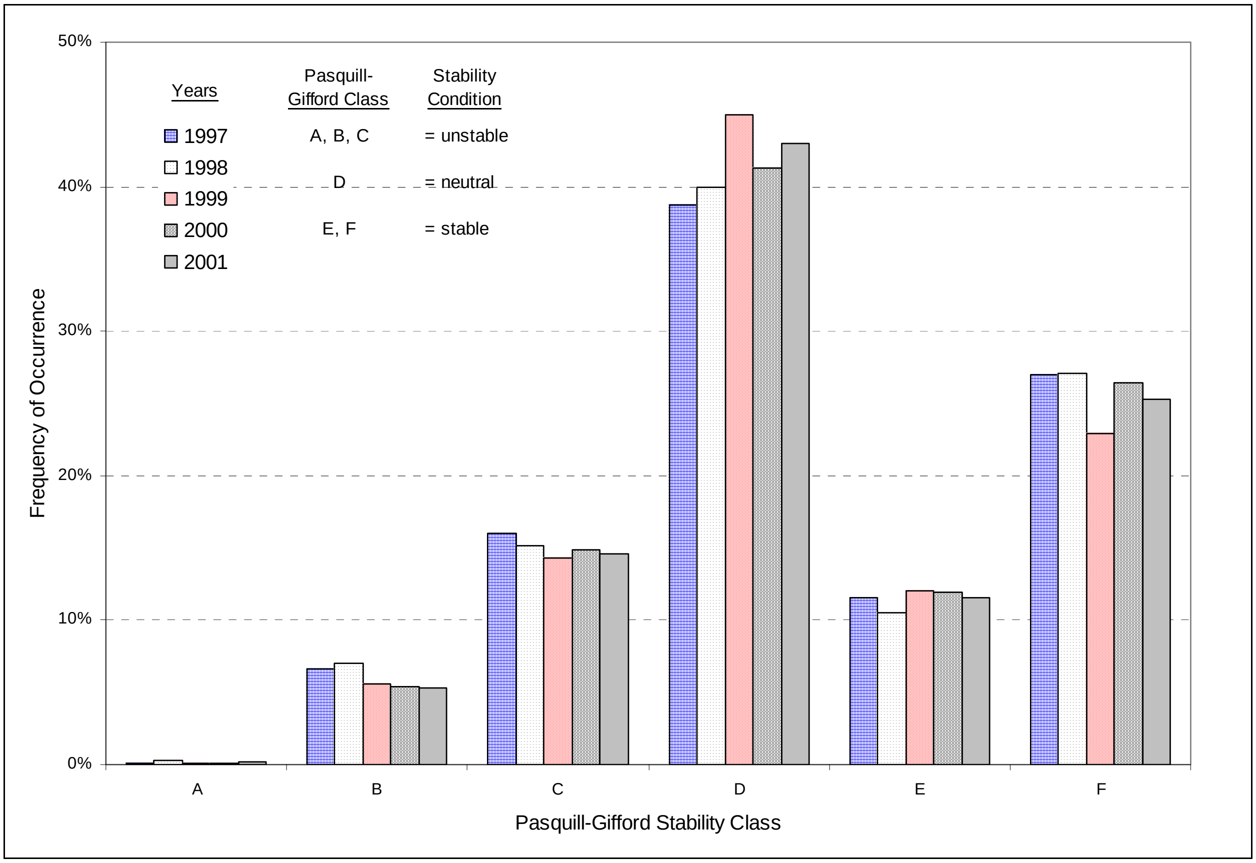

Figure 2-19: Summary of Hourly Stability Conditions at Norman Wells (1997 to 2001)

Winds

The winds at Fort Simpson are greatly influenced by the Mackenzie Valley, with prevailing winds blowing from the north-northwest throughout the year. The strongest winds, i.e., more than 20 km/h, are from the northwest and north-northwest during the fall and winter. Figure 2-21 provides annual and quarterly wind rose summaries of the hourly wind data for Fort Simpson.

Temperature

For the five years of data from Fort Simpson, the annual average temperature of -1.9°C was above the 30-year climate normal of -3.7°C. Although the warmest year at Fort Simpson was 1998, with an average temperature of -1.0°C, and all five years had annual average temperatures that exceeded the long-term normals. Figure 2-22 is a monthly summary of the observed temperatures overlain with the climate normal data for comparison.

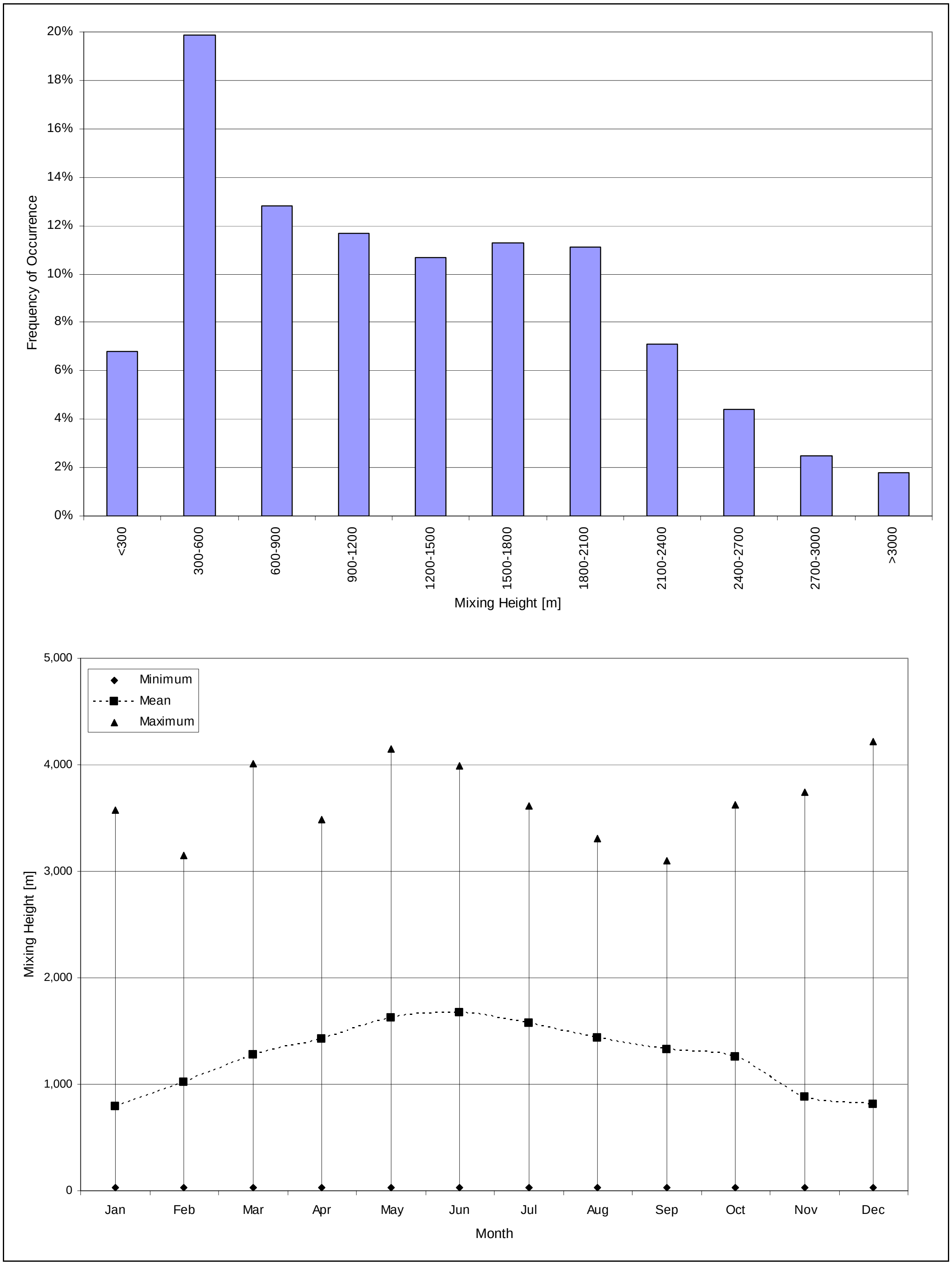

Figure 2-20: Summary of Hourly Mixing Heights at Norman Wells (1997 to 2001)

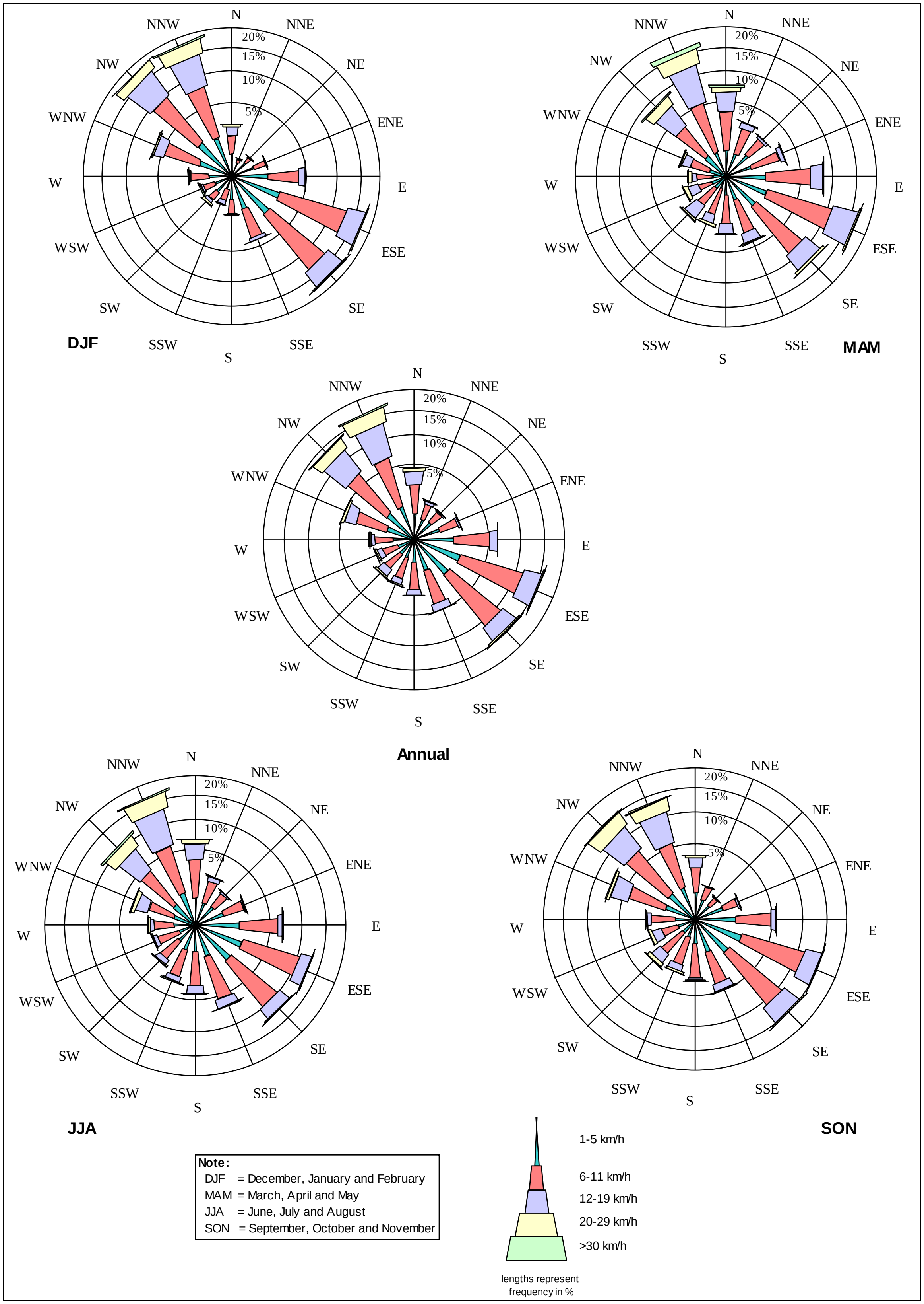

Figure 2-21: Summary of Hourly Winds at Fort Simpson (1997 to 2001)

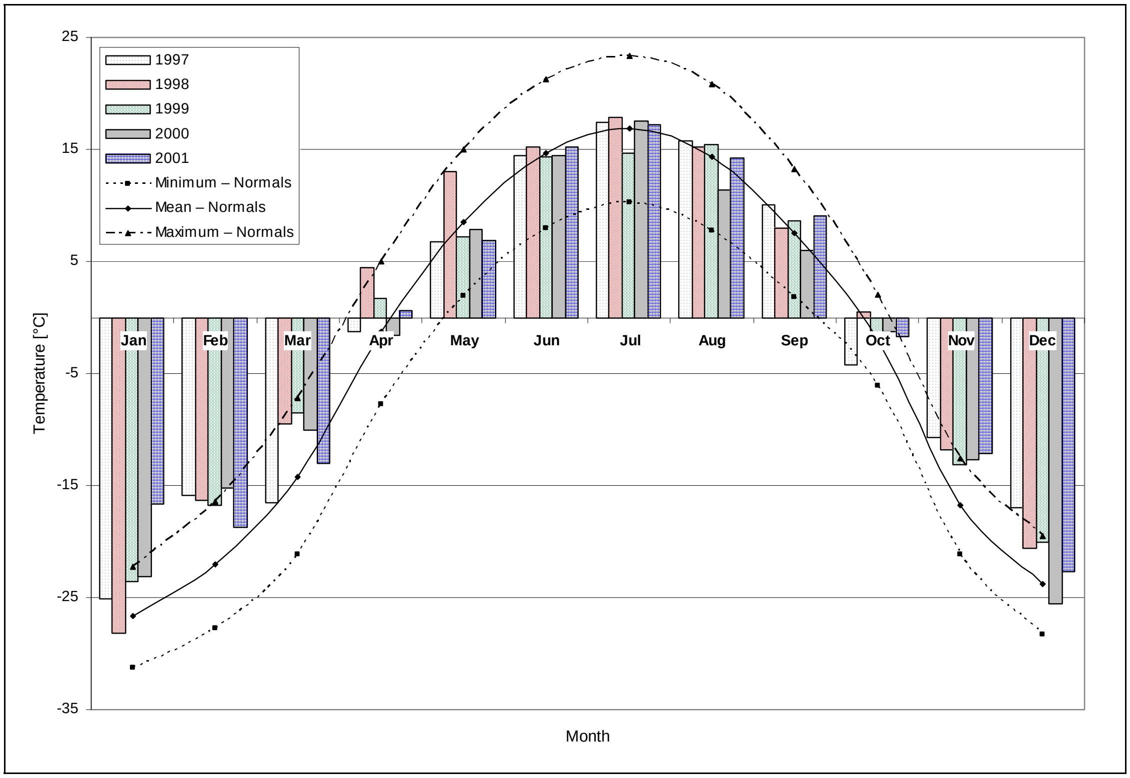

Figure 2-22: Summary of Hourly Temperatures at Fort Simpson (1997 to 2001)

Precipitation

The average annual precipitation in Fort Simpson over the five years of hourly data was 432.1 mm, which was higher than the 360.5 mm climate normal. The greatest amount of precipitation, i.e., 480 mm, was recorded in 1997 and 2000 had the least precipitation, i.e., 384 mm. Most precipitation falls as rain. Figure 2-23 summarizes the hourly precipitation observations at Fort Simpson from 1997 through 2001.

Atmospheric Stability

Unstable conditions, i.e., classes A, B and C, occur in Fort Simpson about 24% of the time, neutral conditions, i.e., class D, occur about 39% of the time, and stable conditions, i.e., classes E and F, occur about 37% of the time. Figure 2-24 shows the frequency of stability classes observed at Fort Simpson from 1997 to 2001.

Mixing Height

Average mixing heights at Fort Simpson increased from about 900 m in the winter to almost 2,000 m in the summer. Mixing heights below 1,800 m occur about 75% of the time. Mixing heights above 3,000 m occur about 3% of the time. Figure 2-25 summarizes the mixing height conditions for Fort Simpson.

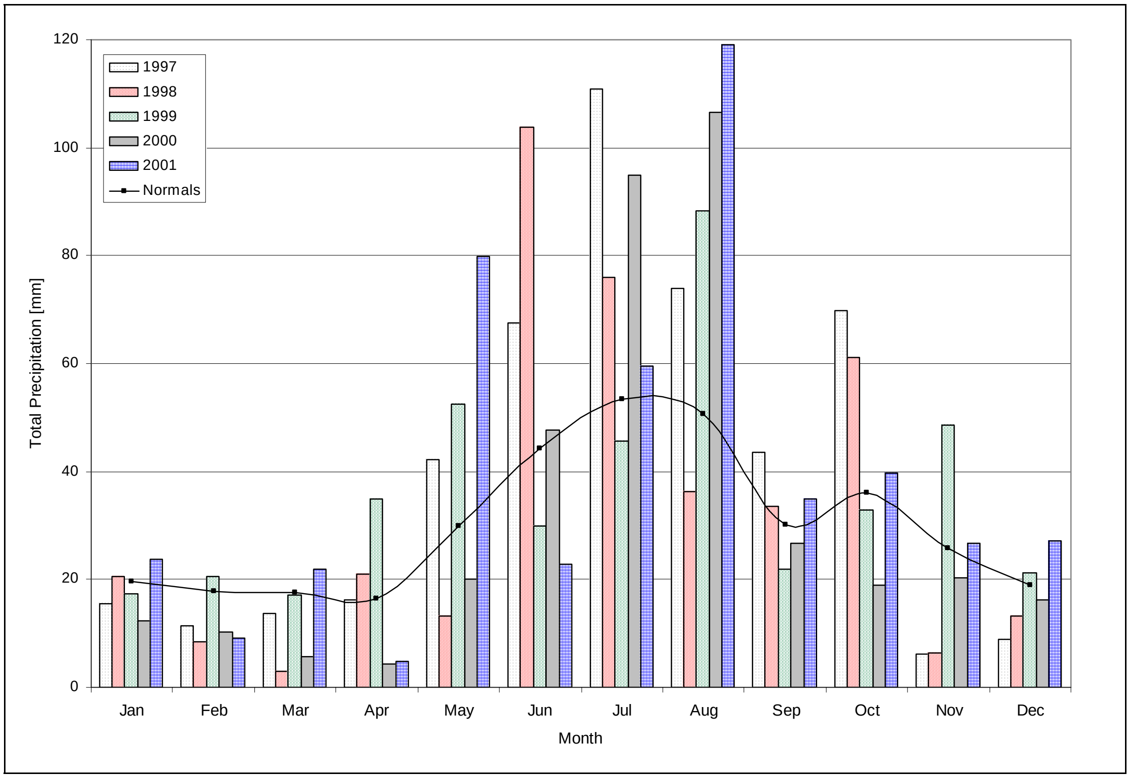

Figure 2-23: Summary of Hourly Precipitation at Fort Simpson (1997 to 2001)

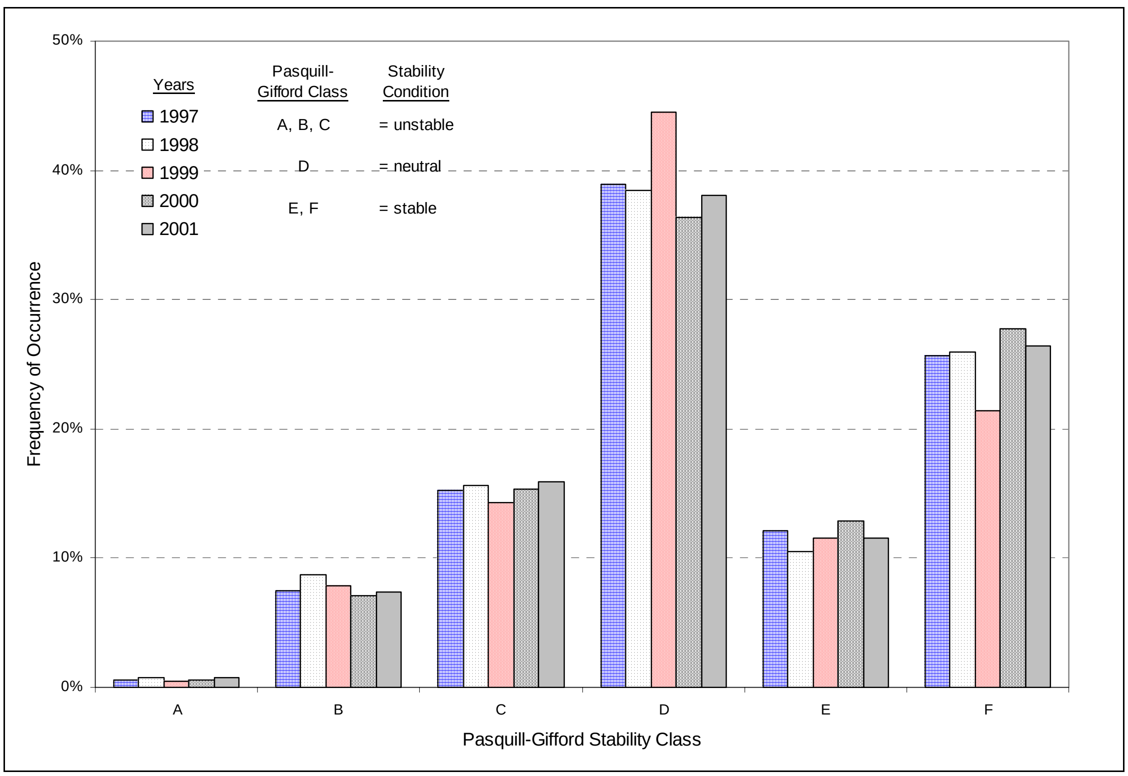

Figure 2-24: Summary of Hourly Stability Conditions at Fort Simpson (1997 to 2001)

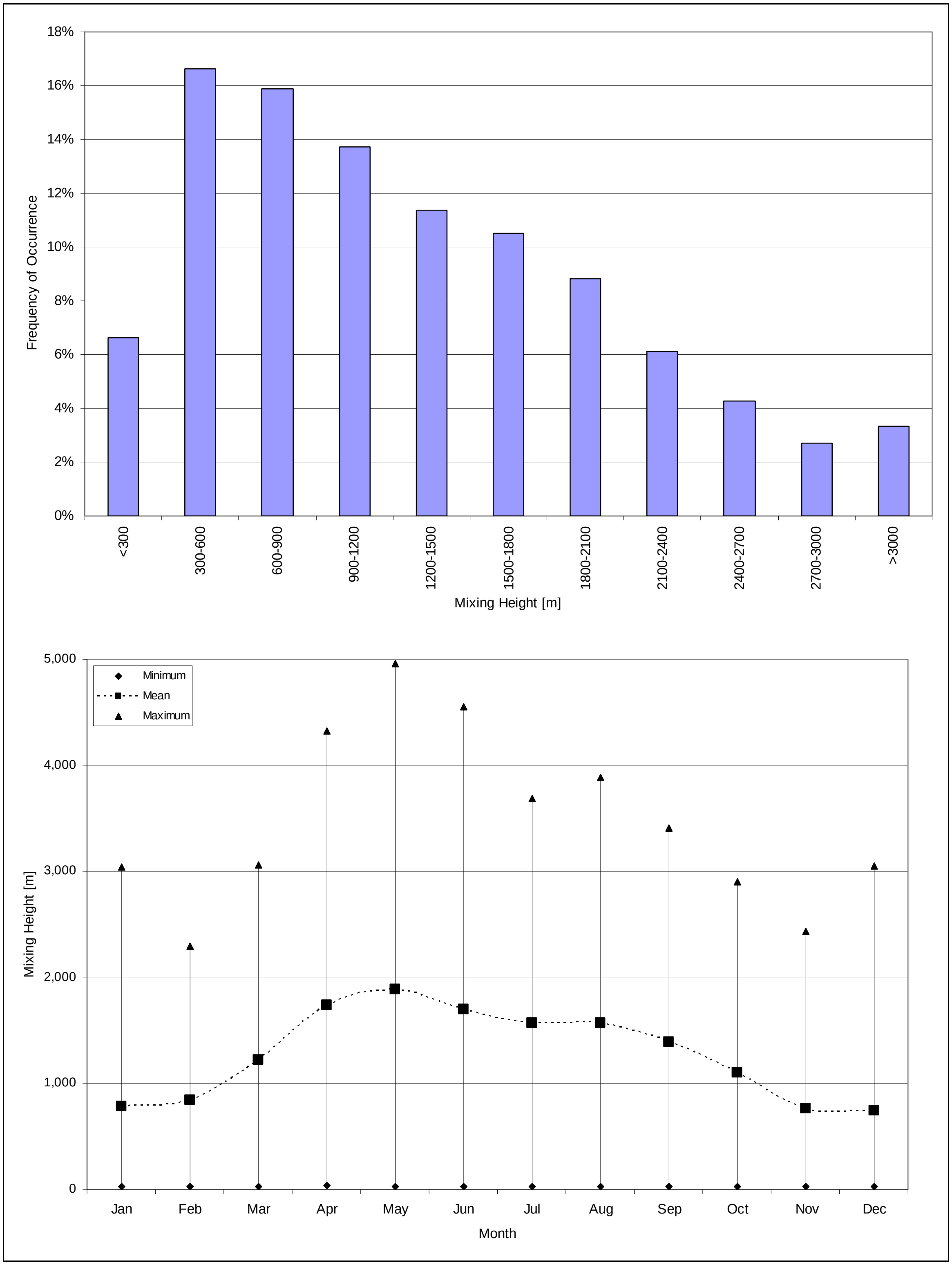

Figure 2-25: Summary of Hourly Mixing Heights at Fort Simpson (1997 to 2001)

References

AGRA Earth & Environmental Limited (AGRA). 2000. *Regulatory, Biophysical, Socio-Economic, Historical Resources and Geotechnical Review – Mackenzie Delta Gas Feasibility Study*. Calgary, Alberta.

Alberta Environment (AENV). 2000. *Alberta Ambient Air Quality Guidelines*. Environmental Protection and Enhancement Act.

Canadian Council of Ministers of the Environment (CCME). 2000. *Canada-Wide Standards for Particulate Matter (PM) and Ozone by Year 2010*. Accepted November 29, 1999 for Endorsement in May 2000.

Environment Canada. 1981. The Clean Air Act – Compilation of Regulations and Guidelines. *Air Pollution Regulations, Codes and Protocols Report: EPS–1–AP–81–1*. Air Pollution Control Division.

Environment Canada. 1982. *Canadian Climate Normals 1951–1980: Temperature and Precipitation*. Canadian Climate Program, Ottawa, Ontario.

Environment Canada. 1993. *Canadian Climate Normals 1961–90*. Minister of Supply and Services Canada. Ottawa, Ontario.

Environment Canada. 2002. *Canada's Greenhouse Gas Inventory, 1990–2000: Emission and Removal Estimation Practices and Methods*. Ottawa, Ontario.

Environment Canada. 2003. *Canada's Greenhouse Gas Inventory, 1990–2001: Emission and Removal Estimation Practices and Methods*. Ottawa, Ontario.

F.F. Slaney & Company Limited (Slaney). 1973a. *Interim Report – 1972 Environmental Field Program – Taglu-Richards Island, Mackenzie Delta. Part 5 – Meteorology and Climate – January 1973*. Prepared for Imperial Oil Limited. Calgary, Alberta.

F.F. Slaney & Company Limited (Slaney). 1973b. *Interim Report – 1972 Environmental Field Program – Taglu-Richards Island, Mackenzie Delta. Part 6 – Pollution Testing – January 1973*. Prepared for Imperial Oil Limited. Calgary, Alberta.

Golder Associates Ltd and Conor Pacific Environmental Technologies Inc. (Golder and Conor Pacific). 1998. *Technical Reference for the Meteorology, Emissions and Ambient Air Quality in the Athabasca Oil Sands Region*. Calgary, Alberta.

Government of the Northwest Territories (GNWT). 2001. *1999/2000 Northwest Territories Air Quality Report*. Environmental Protection Service. Department of Resources, Wildlife and Economic Development. Yellowknife, Northwest Territories.

Government of the Northwest Territories (GNWT). 2002. *2000/2001 Northwest Territories Air Quality Report*. Environmental Protection Service. Department of Resources, Wildlife and Economic Development. Yellowknife, Northwest Territories.

Government of the Northwest Territories (GNWT). 2003. *2001/2002 Northwest Territories Air Quality Report*. Environmental Protection Service. Department of Resources, Wildlife and Economic Development. Yellowknife, Northwest Territories.

Natural Resources Canada (NRC). 1999. *Canada's Emissions Outlook: An Update*. Prepared by the Analysis and Modelling Group of the National Climate Change Process.

Ontario Ministry of the Environment. 2001. *Summary of Point of Impingement Standards, Point of Impingement Guidelines, and Ambient Air Quality Criteria (AAQCs).* Prepared by Standards Development Branch of Ontario Ministry of the Environment.

Resources, Wildlife and Economic Development (RWED). 2002. *Guideline for Ambient Air Quality Standards in the Northwest Territories*. Government of the Northwest Territories, Environmental Protection Service.

Texas Natural Resource Conservation Commission (TNRCC). 2000. *Listing of Effects Screening Levels (ESLs) for Use in Texas*.

United States Environmental Protection Agency (U.S. EPA). 1999. *Compendium Method TO-14; Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specially Prepared Canisters With Subsequent Analysis by Gas*. United States Environmental Protection Agency, Office of Research and Development.