Ambient Air Quality Predictions for the Athabasca Oil Sands Region

May, 1996

Prepared for:

Suncor Inc.

Prepared by:

Golder Associates

BOVAR Environmental

952-2307

This report is one of a series of reports prepared for Suncor Inc. Oil Sands Group for the Environmental Impact Assessment for the development and operation of the Steepbank Mine, north of Fort McMurray, Alberta. These reports provided information and analysis in support of Suncor's application to the Alberta Energy Utilities Board and Alberta Environmental Protection to develop and operate the Steepbank Mine, and associated reclamation of the current mine (Lease 86/17) with Consolidated Tailings technology.

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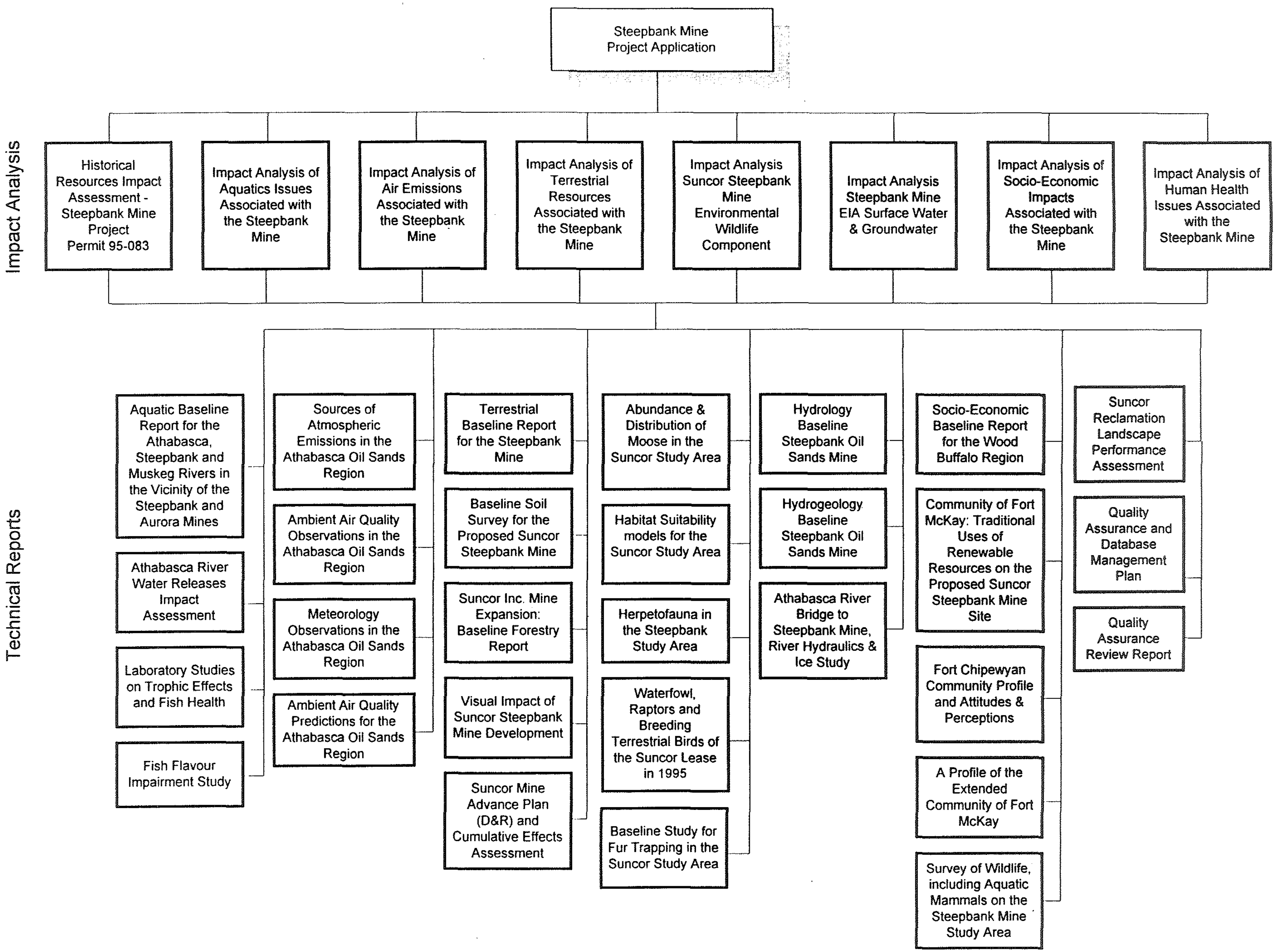

Reports Prepared for the Steepbank Mine Environmental Assessment

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AMBIENT AIR QUALITY PREDICTIONS IN THE ATHABASCA OIL SANDS REGION

(Report 4)

Prepared for:

Suncor Inc., Oil Sands Group
and
Syncrude Canada Ltd.

Prepared by:

BOVAR Environmental

May 1996
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Attention: **Peter Koning**
New Lease Environmental
Coordinator

Subject: **Air Quality Technical Report**

We are pleased to submit our report entitled *Ambient Air Quality Predictions in the Athabasca Oil Sands Region*. This report presents dispersion modelling predictions which complement regional monitoring observations.

If you have any questions regarding this report, please contact the undersigned at (403) 750-9335.

Yours sincerely,

BOVAR Environmental

Mervyn J.E. Davies
Manager, Air Quality Assessment

MJED/mp
Enclosure

c.c. Hal Hamilton, Golder Associates Ltd.
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ACKNOWLEDGEMENTS

This report was prepared for Suncor Inc. Oil Sands Group and Syncrude Canada Ltd. by BOVAR Environmental. The modelling was based on source information provided by both Suncor and Syncrude and the meteorological data collected by Suncor. The evaluation of the model predictions was based on comparing them with ambient air quality data collected by Suncor, Syncrude and Alberta Environmental Protection. Mr. Lawrence Cheng of Alberta Environmental Protection provided information regarding the Alberta Research Council RELMAP model.

This background report was prepared for the Suncor Steepbank Mine Environmental Impact Assessment (EIA) and for the Syncrude Aurora Mine EIA. Coordinators for the Steepbank Mine EIA are Don Klym from Suncor and Hal Hamilton from Golder Associates Ltd. Coordinators for the Aurora Mine EIA are Peter Koning from Syncrude and Judy Smith from BOVAR Environmental.

Principal investigator for this study was Mervyn Davies, Manager of BOVAR Environmental's Air Quality Assessment Group in Calgary. Mervyn was assisted by Michael Brennand and Nini van Steenbergen, both meteorologists, with the Air Quality Assessment group. Report typing and formatting was provided by Maureen Parsons.

1.0 INTRODUCTION

1.1 Background

Alberta produces a significant portion of Canada's energy requirements through the production of fossil fuels that include natural gas, conventional crude oil, synthetic crude oil and coal. The oil sands sector produces almost 25% of Canada's needs through the production of synthetic crude oil from bitumen. In 1994, Syncrude Canada received approval to increase crude oil production to 17.6 million m^3/a. Similarly, Suncor recently received approval for modifications to increase their bitumen throughput. Both Syncrude and Suncor have plans to develop new oil sands leases and to further increase SCO and bitumen production.

The development of new leases (e.g. SOLV-EX) and the continuing production at the existing extraction and upgrading facilities (e.g. Suncor and Syncrude) will have effects on the environment. In recognition of these effects, Suncor has proposed modifications to reduce SO_2 emissions to the atmosphere. As part of Syncrude's approval to increase SCO production, they are required to develop additional ambient air quality, sulphur deposition and biomonitoring programs. The objective of these programs is to ensure environmental quality is not compromised due to atmospheric emissions associated with their operations.

1.1.1 *Provincial Initiatives*

In response to the interest in atmospheric emissions in Alberta, several initiatives are underway to evaluate air quality management approaches in the province:

- The 1991 **Clean Air Strategy for Alberta** Report to the Ministers of the Environment and Energy presented a long-term framework for air quality management. This framework was developed through a multi-stakeholder consultation process. The report identified the vision and mission statements shown in Table 1.1 to provide the basis for future air quality management initiatives.

- In response to the 1991 Report, the **Clean Air Strategic Alliance (CASA)** was formed. CASA is a joint industry-government program which represents a partnership between government, industry, environmental and other key stakeholders. CASA is responsible for the strategic planning related to air quality issues in Alberta through a Comprehensive Air Quality Management System (CAQMS) for Alberta. The CAQMS allows regional stakeholders to design solutions specific to their regional air quality issues.

- In response to the CAQMS, the **West Central Regional Airshed Monitoring Committee (WCRAMC)** was established to design an environmental monitoring program for the West Central Zone of Alberta. The zone was developed in response to the zonal air quality management concept identified in the 1991 Report to the

Table 1.1 The Clean Air Strategy for Alberta vision and mission statements.

VISION STATEMENT
The air will be odourless, tasteless, look clear and have no measurable short- or long-term adverse effects on people, animals or the environment.
MISSION STATEMENT
Alberta's Clean Air Strategy is to provide guidelines for the management of emissions from human activity and encourage appropriate life-styles so as to protect human health and ecological integrity within a provincial, national and international context. *The strategy will be comprehensive but flexible and, through an ongoing consultative process, will employ a wide range of mechanisms available for implementing the strategy, including public education, market-based approaches, legislation, regulation, and research and development.*

Ministers and because of the relatively high interest of stakeholders in the area. The approach and concept for managing air quality in the West Central Zone was viewed as a prototype that could be used for other airshed zones in Alberta.

1.1.2 *Air Quality Management*

Air quality issues have been addressed in the oil sands region through a number of processes that include the following:

- **Regulatory:** Terms and conditions specified by Licences-to-Operate that were issued under the former Clean Air Act. With the introduction of the Alberta Environmental Protection and Enhancement Act (EPEA), these licences were renewed as Environmental Approvals (under EPEA).

- **EIAs:** Various impact assessments prepared for the development and expansion of existing and proposed oil sands developments have led to the collection of field data and associated air quality assessments.

- **Research:** The Alberta Oil Sands Environmental Research Program (AOSERP), a jointly funded federal and provincial program, conducted environmental and air quality research in the oil sands region from 1975 to 1981. The research program was continued by the Research Management Division of Alberta Environment from 1981 to 1986.

- **Multistakeholder:** Various groups such as the Fort McMurray Regional Air Quality Task Force (AQTF) have been formed to address industry, government and stakeholder issues related to air emissions and their potential effects.

Multistakeholder air quality issues in the oil sands area are currently addressed by the Regional Air Quality Coordinating Committee (RAQCC) which is comprised of government, industry and committee participation. RAQCC has been responsible for establishing a number of working groups to help evaluate air quality issues in the area.

1.1.3 *Background Reports*

Given that the oil sands will continue to play a significant role in Canada's energy requirements and that air quality issues associated with oil sands mining, extraction and upgrading operations have a multistakeholder interest and furthermore, in consideration of the recent initiatives associated with addressing air quality issues in Alberta, a series of background air quality reports have been prepared for the oil sands area. The purpose of these reports is to provide air quality baseline information to mid-1995. The specific reports are as follows:

- **Report 1 Source Characterization**

  To identify and quantify anthropogenic air emissions in the Fort McMurray - Fort McKay corridor that include industrial point, fugitive, traffic and residential sources. Emissions of interest include SO_2, NO_x, CO, VOC, TRS, particulates and CO_2.

- **Report 2 Ambient Air Quality Observations**

  To summarize ambient air quality monitoring undertaken in the Fort McMurray - Fort McKay airshed. The sources include quantification data from the Suncor, Syncrude and AEP networks as well as qualitative data associated with other monitoring programs.

- **Report 3 Meteorology Observations**

  To summarize the meteorological data that can be used to describe the transport, dispersion and deposition of emissions in the area. The focus is on the meteorological data collected by Suncor from the Lower Camp and Mannix towers. A review of the terrain in the region and its effect on meteorology will be provided.

- **Report 4 Air Quality Modelling**

  Concurrent sources, air quality and meteorological data are used to select an optimum dispersion modelling approach resulting in predictions which compare favourably with observations. The modelling will complement the monitoring by providing local and regional short- and long-term air quality changes associated with the current operation in the area.

These reports serve as background reports that can be used by industry to assist with future plant applications and by other stakeholders to assist with the review of these applications. Furthermore, these reports can also be used by RAQCC in support of other regional air quality related initiatives.

1.2 Report 4 (Air Quality Modelling)

1.2.1 *Objectives*

Air quality monitoring and modelling are complementary air quality management tools. Modelling can be used to predict air quality changes in locations where monitoring is not undertaken and can be used to predict air quality changes associated with source and emission changes. The objectives of this air quality modelling report are to:

- Select a model that can be used to predict short-term and long-term air quality changes from emission sources located in the Athabasca oil sands area.

- Compare the model predictions to ambient observations in order to obtain an understanding of model performance.

- Apply the model to current emission sources in the area to determine relative contributions from major sources and to determine regional concentration patterns.

- Apply the model to current emission sources in the area to determine regional deposition patterns.

- Discuss uncertainties associated with model predictions.

The end-product of Report 4 is a dispersion model whose performance has been evaluated and an understanding of regional concentration and deposition patterns.

1.2.2 *Approach*

The approach for selecting a model to apply to the oil sands sources was based on the use of existing models or modified existing models. The focus of this exercise was not viewed as a formal model development and evaluation program.

Models require data that characterize the emission sources, the terrain and the meteorology. These items have been discussed in Background Reports 1 and 3, respectively. To evaluate the model performance, ambient air quality data are required. These have been discussed in Background Report 2. The primary focus for the dispersion modelling was on data collected over the 20 month period November 1, 1993 to January 30, 1995. This period was determined by the availability of the meteorological data.

While this document will refer to differing computerized dispersion models, it is not intended to provide a formal documentation of the model uses.

1.2.3 *Definition of Terms*

Given the technical nature of this report, it is useful to confirm to the reader some of the terminology used to facilitate a common understanding. Table 1.2 provides definitions of technical terms used in the report.

Table 1.2 Definition of commonly used terms.

Term	Definition
Model	A model is a simplified representation of reality. It is simplified because we cannot deal with all the variables that affect the environment. Models are usually comprised of mathematical relationships between the important variables.
Dispersion Model	A set of mathematical relationships that are used to describe the rise of a plume and the subsequent dispersion of the plume as it is transported by the wind. When these relationships are coded for use by a computer, the model is referred to as a computer model. Computer models, like people, are given names (e.g., SCREEN3, ISCST3, ADEPT2).
Spatial Scale	Can be defined as the distance from the source to a receptor. Typical spatial scales are as follows: • Site specific: 0 to 250 m. • Local: 250 m to 20 km. • Mesoscale: 20 to 500 km. • Long-range: 500 to 1000 km • Hemispheric • Global The criteria delineating different scales can vary with practitioner.
Temporal Scale	Can be defined as the response time of an exposed receptor and/or the travel time from source to receptor. Typical temporal scales are: • Instantaneous (seconds to minutes) • Hourly (short-term) • Daily (short-term) • Seasonal (growing season) • Annual (chronic low-level exposures) Hourly, daily and annual from the basis of ambient air quality guidelines.
Deposition Velocity	A proportionally constant that can be used to convert an ambient concentration into a deposition flux. Deposition velocities vary with meteorology, pollutant and receptor activity. The latter will result in differing deposition velocities for different vegetation canopies.

Table 1.2 Concluded

Term	Definition
Stability Class	A method of classifying the level of turbulence in the atmosphere. Pasquill-Gifford (PG) stability classes range from unstable (Classes A, B and C) that can occur during the daytime through to neutral (Class D) that can occur day or night to stable (Classes E and F) that can occur at night.
STAR	Stability Array. A joint frequency distribution of wind speed (6 classes), wind direction (16 directions) and stability class (6 classes) whose sum for each season adds up to unity (1.000). STAR data are used by climatological models such as ADEPT2.
Terrain Effects	Terrain can influence the overall horizontal and vertical trajectory of a plume. Terrain can also increase turbulence levels due to its roughness.
Plume Rise	Gases exiting from a stack can rise due to momentum and/or buoyancy effects before the wind bends the plume over into a horizontal trajectory.
Location	The location of the maximum predicted concentrations relative to a given source is given in polar coordinates: distance and angle. The distance is expressed in kilometres (km) from the source and the angular value is based on direction. A 90° direction indicates a location to the east of the source; a 180° direction indicates a location to the south of the source; and so on.

1.2.4 *Report Organization*

This report is organized into the following sections:

Section	Content
2	An overview of dispersion models and a summary of the models that have been applied to the Athabasca oil sands area.
3	Identification of the models that are applied for this assessment and an indication of model performance.
4	Provides model predictions of ambient SO_2 concentrations resulting from intermittent and continuous SO_2 releases.
5	Provides model predictions of the deposition of sulphur compounds resulting from continuous sources.
6	Provides model predictions of ambient NO_x concentrations resulting from point sources.
7	Provides model predictions of ambient CO concentrations resulting from point sources.
8	Provides model predictions of ambient particulate concentrations from major combustion sources.
9	Provides model predictions of hydrocarbon concentrations from the major fugitive sources.
10	Provides the summary and comments.
11	Identifies references.

The documentation of computer files used for the modelling analysis is presented in the Appendix.

2.0 DISPERSION MODEL OVERVIEW

Air quality simulation (or dispersion) models are used to predict ambient air quality under a wide range of meteorological conditions. These models provide a scientific means of relating industrial emissions to changes in ambient air quality and are comprised of mathematical equations to simulate transport, dispersion, transformation and deposition processes in the atmosphere. Models can address a wide range of spatial (short range and long range) and temporal (1 hour to annual) scales.

Dispersion modelling and ambient air quality monitoring from complementary tools that can be used for air quality assessments. Monitoring data are not usually sufficient as a sole basis for determining the adequacy of an air quality management plant for the following reasons:

- Models can be used to calculate the effect of a single source amid numerous sources, whereas monitoring may not discriminate between different sources.
- For a new source, modelling is the only way to obtain estimates of air quality changes since the appropriate monitoring data do not exist for a source that has not yet been built.
- Modelling calculations can be made at thousands of locations for less than the cost of measurements at one location. Monitoring observations, because of economic reasons, have limited spatial and/or temporal coverage.
- Models can be used to forecast changes associated with modifying a source. This can allow the effectiveness of alternate control technologies to be evaluated.
- Models can be used to estimate the effects of accidental releases of toxic or flammable gases.

Because of these advantages, considerable weight has been accorded to model predictions in terms of selecting emission control approaches and technology. As model predictions can have significant impacts on project costs; the selection, application and interpretation of results require careful consideration.

2.1 Model Types

Dispersion models can be classified by the type of meteorological data required by the model. Four types of models frequently used include:

- **Event.** These models calculate ambient concentrations for a single meteorological event. The event mode is usually used to either help explain a single observation or to help determine model performance.

- **Screening.** These models calculate concentrations for a wide range of meteorological conditions. The meteorological conditions are either pre-selected by the model, or are user-defined. These models are primarily designed to determine maximum short-term (i.e., one-hour) average concentrations, which usually occur within 10 km of the source.

- **Climatological.** These models use summarized long-term meteorological data to calculate long-term (i.e., seasonal or annual) average concentrations and depositions. The summarized meteorological data are typically in the form of a joint frequency distribution of wind speed, wind direction, and stability class. These models can be used to predict annual average concentrations and depositions out to distances of 50 to 100 km.

- **Sequential Time Series.** These models are used to simulate air quality changes on an hour-by-hour basis using a representative year of hourly average meteorological data (8670 h). These models create an hourly average concentration file for all source/ receptor combinations. The hourly average concentration file can then be used to determine average concentrations for periods that are multiples of one-hour (e.g., 24 h).

Most air quality models are based on Gaussian shaped plume assumptions. The Gaussian plume model, in its simplest form, simulates the rise of a hot buoyant plume from a single stack and the associated dispersion over flat terrain under uniform wind speed conditions. Modified algorithms are often used to account for momentum plume rise and changes in the air flow and turbulence due to the presence of irregular terrain.

2.2 Limitations

Compared to other engineering disciplines and their associated calculations, the uncertainties associated with dispersion modelling can be relatively large. The accuracy with a model is usually determined by comparing model predictions for a given meteorological condition with concurrent ambient air quality observations. These uncertainties can include:

- The source conditions may be well defined for a large isolated rural source with a continuous stack emission monitor. For a facility with numerous emission sources, the source conditions may not be as well known.

- The difficulty in defining transport winds that can vary with height above the ground, with geographical location and with time. The concentration for a receptor located off the plume centreline will be much less than the value for a receptor located directly below the centreline.

- The difficulty in defining the turbulence that can also vary with height, geographical location and time. For models that use six discrete turbulence classes, an error of one category can result in a difference in the calculation of 50% or more at a given receptor.

- The limitations of the model physics to simulate behaviour of the atmosphere for the given source conditions, meteorology and terrain type.

- The uncertainties associated with the ambient observations. For example, while the accuracy may be ± 5% at span; the accuracy may decrease to ± 100% for concentrations near the threshold.

- In some cases, the ambient observations may not exist due to the lack of an appropriate monitoring technology (e.g., dry deposition measurements).

The most difficult task for a model is the ability to accurately predict a short-term (i.e., one-hour average) concentration for a given meteorological condition at a single receptor. The comparison between observations and predictions for this case are said to be "paired in time and space". Other comparisons are only paired in space or in time. Needless to say, the evaluation of a dispersion model performance is not a trivial exercise.

Irrespective of how well a model mimics reality, there will be some uncertainty that can arise from model physics, model input or irreducible error due to the random nature of atmospheric turbulence processes. The uncertainty in model predictions range from ± 10% for the ideal dispersion case (Pasquill and Smith 1983) to ± 200% for tall stack Gaussian model predictions (Smith 1981). The U.S. EPA indicates that models can usually predict the highest concentrations to within ± 40% (not in time or space). Despite the seemingly high uncertainty with model predictions, better decision-making can arise from model predictions that are within a factor of two, than can be developed in the absence of any data.

For example, in the vicinity of an SO_2 emitting source, acute ambient SO_2 concentrations of 300 ppb (0.3 ppm) can occur. The background pristine SO_2 concentration is typically in the 0.3 ppb range. These extremes represent a range of 1000 to one. A model uncertainty by a factor of two is certainly an improvement.

In many cases, the data sets to evaluate the models are very limited or event do not exist. An example of the former is a lack of concurrent meteorological information for a given source/ receptor event. An example of the latter is the lack of dry deposition measurements. Regardless of the reason, many of the model evaluations are based on "scientific faith". That is, specific components that have been tested are extrapolated and integrated into a given model.

By definition, air quality models can only approximate atmospheric processes and simplifications are made to describe real phenomena. Potential areas for the improvement of model predictions (minimizing reducible errors) is in the use of representative meteorological data and updated model physics to address the transport, dispersion, transportation and deposition processes.

2.3 Application of Models

In order to help assess impacts of atmospheric emissions on the environment as a result of industrial development in northeastern Alberta, it is important that the dispersion models incorporate the following features:

- A sequential time series approach that will allow multiple averaging periods and allow frequency analyses to be undertaken.

- Ability to recognize the effects of terrain on air flow and turbulence (e.g., the Athabasca River Valley, Birch Mountains, Muskeg Mountains, etc.).

- Recognition of the seasonal and diurnal variability of the receptor (e.g., vegetation) to uptake these emissions.

- Ability to correctly simulate ambient concentration observation trends (e.g., large concentrations occurring during the day).

In addition, the application and interpretation of dispersion models require the following information:

- **Source data.** Since sequential time series models can predict concentrations on an hourly basis, hourly emission data can be incorporated for both continuous and intermittent sources.

- **Meteorological data** are required to describe the transport and dispersion. Specific parameters required include plume level wind speed, wind direction, turbulence, and vertical temperature gradients in addition to mixing heights.

- **Ambient concentration data** for concurrent periods to allow the model performance to be evaluated.

- **Additional data** that can be related to vegetation sensitivity. These data may be related to meteorological parameters such as temperature, relative humidity, solar radiation, surface wetness or to soil conditions such as moisture content or temperature.

In addressing the impacts associated with exposures to ambient concentrations; the first challenge is to identify and quantify the exposure; the second challenge is to relate this to an impact. Both the Interim Acid Deposition Critical Loadings Task Group (1990) and Alberta Environment (1990) have proposed interim target loadings to address the effect of SO_2 emissions on the acidification of surface waters and soils, respectively. As these target loadings are based on expected impacts, the model estimates of loadings can be correlated to an impact.

2.4 History of Dispersion Modelling Assessments in the Oil Sands Region

A number of dispersion modelling assessments have been conducted in the last 10 years to estimate ambient air quality changes in the Athabasca oil sands area. Table 2.1 provides a chronological summary of the dispersion modelling exercises that have been conducted with respect to:

- **Supporting Group.** The sponsoring or company that commissioned the study.
- **Authorship.** The group or company that carried out the dispersion modelling work.
- **Model.** The "trade name" of the dispersion model(s) that was (were) used in the study.
- **Model type** as described in Section 2.1.2 (Event, Screening Climatological or Time Series).
- **Spatial scale** as described in Section 2.1.1 (Site specific, Local, Mesoscale, or Long-range).
- **Temporal scale** as described in Section 2.1.1 (Instantaneous, Hourly, Daily, Seasonal, or Annual).
- **Prediction** refers to the contaminant predicted by the model (e.g., SO_2 and NO_2 concentrations and/or sulphate and nitrate depositions).
- **Comments** refer to unique features of the study.

Most of the studies that were undertaken focus on sulphur compound emissions (namely SO_2) but NO_2 concentrations or sulphate and/or nitrate deposition have also been addressed.

2.5 Current Status of Regulatory Models

Alberta Environmental Protection (AEP) has historically provided industry with the tools (models) and corresponding guidelines (e.g., Standards and Approvals Division 1989 and 1990). The AEP models have included STACKS2, SEEC and PLUMES2 for estimating short-term air quality changes and SULDEP3 and ADEPT2 for estimating long-term air quality and deposition changes.

Alberta Environmental Protection have replaced their dispersion models with U.S. EPA equivalents. Air and Water Approvals Division (1994) issued draft guidelines outlining the application of the U.S. EPA models to the Alberta regulatory framework. These guidelines recommend the following models:

Table 2.1 Summary of dispersion model assessments and evaluation in the Athabasca Oil Sands Area.

Supporting Group	Reference	Model	Type	Spatial Scale	Temporal Scale	Prediction	Comments
Syncrude	Concord (1992*b*)	ISCON ADEPT2	Time Series Climatological	Local Mesoscale	Hourly Daily Annual	SO_2 concentrations. Wet/dry total sulphate deposition.	Model application for the Syncrude ERCB application.
Suncor	Concord (1992*a*)	ISCON ADEPT2	Timer Series Climatological	Local Mesoscale	Hourly Daily Annual	SO_2 concentrations. Wet/dry/ total sulphate deposition.	Model application. Intermittent and continuous sources were evaluated. The ISCON model is a modified version of ISCST.
OSLO	Concord (1991)	ISCON ADEPT	Time Series Climatological	Local Mesoscale	Hourly	SO_2 concentrations.	Model application for the OSLO Environmental Impact Assessment.
Research Management Division	Cheng *et al.* (1990)	MESOPUFF II RELMAP SERTAD	Lagrangian Time Series Statistical Climatological	Mesoscale to long-range	Monthly Seasonal Annual	Dry/wet/total sulphur deposition; SO_2 and sulphate concentrations.	Model performance evaluation. Twice-daily data input.
ADRP	G.E. McVehil (1990)	COMW	Climatological	Mesoscale	Seasonal Annual	SO_2, NO_x and sulphate concentrations. Wet/dry/total deposition of a range of species.	Model application to determine provincial loadings and depositions.
Suncor	Envirodyne (1990)	SUNDISP	Event	Local	Hourly	SO_2 concentrations.	Model performance evaluation.
Research Management Division	Davies and Fung (1989)	LERTAD	Lagrangian Time Series	Mesoscale to long-range	Daily	SO_2 sulphate concentrations and wet/dry depositions.	Model performance evaluation. LERTAD is a modified version of MESOPUFF II.
Suncor	Shekar (1989)	ISCST	Event	Local	Peak Concen-trations	Odour strength.	Odour assessment associated with fugitive hydrocarbon emissions.
Suncor	Suncor (1988)	ISCST ADEPT	Time Series Climatological Event	Local to Mesoscale	Annual Daily Hourly	SO_2 concentrations. Frequency of one-hour SO_2 concentration exceedences. Wet and dry sulphur and total depositions.	Model application for the debottlenecking EIA application. ISCST was modified to account for elevated terrain.

Table 2.1 Concluded.

Supporting Group	Reference	Model	Type	Spatial Scale	Temporal Scale	Prediction	Comments
Syncrude	Western Research (1988)	STACKS2 PLUMES2	Event	Local to Mesoscale	Hourly	SO_2 concentrations. NO_x concentrations. CO concentrations.	Model application.
AQTF	AQTF (1987)	FREDIS	Time Series	Local	Annual	Dry SO_2 deposition.	Model application.
Syncrude	Dabbs (1987)	FREDIS	Time Series	Local to Mesoscale	Annual Seasonal	SO_2 concentrations. Total sulphate deposition.	Model application.
Research Management Division	Nosal (1985)	FREDIS	Time Series	Local	Annual Seasonal	SO_2 concentrations.	Model evaluation to determine applicable to vegetation sensitivity.
Syncrude	Dabbs (1985)	FREDIS	Time Series	Local to Mesoscale	Annual Hourly	SO_2 concentration. Sulphate deposition. Particulate deposition.	Model application to evaluate vegetation effects.
Suncor	Slawson and Hitchman (1984)	NUMDIS	Event	Local	Hourly	SO_2 concentration.	A model development and evaluation program.
OSESG	MEP (1982)	TRANS	Time Series	Long-range	Annual	SO_2 concentration. Sulphate concentrations. Wet and dry deposition. NO_2 concentration. Nitrate concentration. Wet and dry nitrate deposition.	Model application. Up to 14 existing and proposed oil sands facilities for the years 1967 to 2017 were evaluated.
Atmospheric Environment Services	Kociuba (1982)	LRTAP	Time Series	Long-range	Daily Monthly Total	SO_2 and sulphate concentrations. Dry and wet deposition fluxes.	Model assessment. Input data every 6 hours.
Research Management Division	Davison *et al.* (1981*a,b,c*)	FREDIS	Time Series	Local	Hourly Annual	SO_2 concentration.	A model development and evaluation program.

- For screening assessments, SCREEN2 for single source, ISCST2 for multiple sources located in non-complex terrain and CTSCREEN for multiple sources located in complex terrain.

- For refined assessments, ISCST2 for flat or simple terrain and either RTDM3.2 or COMPLEX-I for complex terrain.

The screening assessment is based on using pre-determined wind speed, wind direction and PG stability class combinations. Screening models are suitable only for calculating hourly average concentrations. Longer term averages can then be estimated from the predicted hourly values using empirical conversion factors. The refined assessment is based on using the models in a sequential time series mode. This approach allows daily and annual average concentrations to be rigourously calculated in addition to the hourly values.

Since this Alberta Environmental Protection guideline was released, the U.S. EPA has updated the SCREEN2 model (now called SCREEN3), and the ISCST2 model (now called ISCST3). The new ISCST3 model also incorporates the COMPLEX-I algorithms which allows the model to be used in simple or complex terrain. ISCST3 also incorporates the calculation of dry and wet deposition primarily for the removal of particulates.

3.0 MODEL SELECTION

This section provides the rationale for selecting the models that are applied to the emission sources associated with Suncor's and Syncrude's operations. The performance of the model is also discussed.

3.1 Model Selection

The models required to assess air quality in the Athabasca oil sands region should have the ability to address temporal scale ranging from one hour to one year and to address spatial scales out to 50 km and beyond. For this assessment, the following models were used:

- **SCREEN3** was applied to individual point sources assuming flat terrain. The model is easy to run and can only be applied to a single source. The application of this model allows the relative contribution for each source to be qualitatively assessed.

- **ISCST3** is the work-horse of the U.S. EPA models and has the ability to address point, line, area, volume and open pit sources; can predict concentrations for time periods ranging from 1 hour to 1 year; and can also be used to predict deposition of particulates.

- **ISC3BE** is a modified version of the ISCST3 model. Being based on ISCST3, the model has the flexibility to simulate air quality changes from multiple areas for a wide range of meteorology conditions.

- **ADEPT2** was applied to predict annual average SO_2 concentrations and deposition. This model has been frequently used in Alberta for this type of application.

As ISC3BE is a non-standard model and is the primary model used for this assessment, further discussion describing the changes and the model performance is provided.

3.1.1 *SCREEN3*

The SCREEN3 model is a simple Gaussian plume model that uses the Pasquill-Gifford dispersion coefficients to characterize atmospheric turbulence and the Briggs relationships to determine plume rise. Basic model assumptions are provided in Table 3.1. The model and corresponding documentation are available through the U.S. EPA **O**ffice of **A**ir **Q**uality **P**lanning and **S**tandards (OAQPS) network of electronic bulletin boards known as the **T**echnology **T**ransfer **N**etwork (TTN). The model specifically is available from the **S**upport **C**entre for **R**egulatory **M**odels (SCRAM) bulletin board.

In the U.S., the SCREEN3 model predictions are deemed to correspond to hourly average concentrations. Alberta Environmental Protection (AEP), however, assumes the SCREEN3 model predictions correspond to 10-minute average concentrations. AEP states that the

Table 3.1 Assumptions incorporated into the U.S. EPA SCREEN3 model.

Item	Assumption
Gaussian Plume Model	The concentration distribution through a plume cross-section is assumed to be Gaussian in the horizontal and vertical. The cross-sectional area increases with increasing distance and atmospheric stability. The model calculates the maximum concentration that occurs below the plume centreline.
Plume Rise	The plume will rise above the stack tip due to momentum and buoyancy effects. The methods for calculating plume rise are based on the recommendations of Briggs (1975) and are the same as those assumed by other models such as ISCST3. Unlike ISCST3, however, the model explicitly accounts for flare stacks.
Meteorology	The model examines a wide range of atmospheric stability class and wind speed combinations (54) to identify the combination that results in the maximum ground-level concentration (i.e., worst case conditions). Limited mixing conditions are assumed for certain meteorological combinations.
Receptors	A pre-selected array of 50 distances, ranging from 100 m to 50 km, can be used. An interation routine is used to determine the maximum concentration and the associated distance to the nearest meter.

SCREEN3 predictions should be multiplied by a factor of 0.55 to provide an hourly average prediction (AEP 1994). For the model predictions presented in this report, the 0.55 factor was not used.

3.1.2 *ISCST3*

The ISCST3 (Industrial Source Complex, Short Term, Version 3) model can be used in event, screening or sequential time series modes. General features of the model include:

- Ability to predict concentrations from a wide range of source types: point sources, volume sources, area sources and open pit sources. The model can be applied to single or multiple sources.

- The effects of buoyancy induced turbulence and the aerodynamic wake effects of adjacent buildings on dispersion can be addressed.

- The model predicts concentrations, dry deposition and wet deposition.

- The model can account for simple, intermediate and complex terrain.

- When used in the sequential time series mode, the model has the ability to predict values for time periods that range from one hour to one year.

Table 3.2 summarizes the input requirements for the ISCST3 model in terms of control, source, receptor, meteorological and output parameters. Because of the flexibility by the model, it has become the "work-horse" model. The model, like SCREEN3, is available from the SCRAM (Support Centre for Regulatory Models) bulletin board.

3.1.3 *ISC3BE*

The ISC3BE designation was used to distinguish the modified model from the original ISCST3 version. The modifications are based on an earlier study undertaken for Suncor (Concord Environmental 1992*a*). Features of the modified model include:

- The modified model does not assume the same plume rise as ISCST3. For neutral and unstable conditions, the plume rise is taken as 87% of that predicted by ISCST3. This is equivalent of using a 1.4 coefficient in the "2/3 law" plume rise calculation instead of the 1.6 coefficient used in ISCST3. For stable conditions, the plume rise is taken as 69% of that predicted by ISCST3. This is equivalent of using 1.8 coefficient in the calculation of stable plume rise instead of 2.6. The selection of the 1.4 and 1.8 coefficients is based on an analysis of photograph data collected in 1976 and 1977 (Davison and Leavitt 1979). This modification will have the effect of increasing ground-level concentrations since the plume will be closer to the ground.

Table 3.2 Input requirements for the ISCST3 dispersion model.

Category	Description
Control	• Title • Select output units • Select averaging time • Select output parameters (concentration, deposition) • Select rural or urban dispersion • Identify output file names
Source	• Source locations • Source types • Source characterization (stack height, diameter, exit velocity, temperature, emission rate) • Building dimensions • Source grouping
Receptor	• Polar or Cartesian grid system • Discrete receptor locations • Locations
Methodology	• Anemometer height • Meteorological file (wind speed, wind direction, temperature, PG stability class, mixing height) • Default wind profile experiments, temperature gradients
Output options	• First highest, second highest values • Maximum 50 tables • Specify plot files

- The modified model uses vertical plume spread coefficients recommended by Briggs (1973) for rural areas instead of the Pasquill-Gifford values used by ISCST3.

- The modified model assumes several changes with respect to the horizontal plume rise coefficients. These are:

  - The use of the relationships proposed by Briggs (1973) for rural areas instead of the Pasquill Gifford values.

  - The Briggs stability dependent coefficients of 220, 160, 110, 80, 60, 40 were modified to 220, 160, 110, 80, 80, 80 for receptors located in the valley (that is, for receptor elevations less than 270 m).

  - For non-valley receptors, the coefficients of 220, 160, 110, 80, 110 and 160 were used to account for the increased horizontal plume spreads observed under stable conditions (Slawson *et al.* 1979).

  - For non-valley receptors and distances greater than 10 km, the effect of increased meander due to wind shear for longer travel times was accounted for by further increasing the Briggs coefficients by a factor of $(x/10)^{0.5}$, where x = distance in km. Briggs forced his plume spreads to increase as $x^{0.5}$ for large travel times while field studies have indicated that the lateral dispersion is proportional to $x^{0.8}$ or $x^{1.2}$ for large travel distances (Draxler 1984). The use of the $(x/10)^{0.5}$ correction factor forces Briggs' values to converge to $x^{1.0}$ at these large distances. Models that do not account for wind shear enhanced turbulence for distances beyond 10 km may over-estimate concentrations (Davison and Leavitt 1979). Draxler (1984) indicates "any approach that considers wind shear at these distances is likely to provide more realistic estimates than those from extrapolation of short-term data beyond their range of applicability".

- The modified model uses the same "half height" type of approach as the ADEPT2 model for unstable and neutral conditions. Specifically, terrain correction coefficients of 0.8, 0.7, 0.6 and 0.5 are used for PG stability classes A through D, respectively. For stable atmospheric conditions (PG stability class E and F), the neutral coefficients (0.5) were used.

The net effect of these changes is the modified model allows for larger horizontal plume spreads under stable conditions for valley receptors. The horizontal plume spreads are increased further for stable conditions for non-valley receptors. For longer travel times/downwind distances meander due to wind shear was assumed to further enhance the plume spreads. The net effect of enhancing the horizontal spread will be to decrease the predicted values.

The selection of the above parameters represents a series of modifications that were designed to tune or "force" the ISCST3 model to bias the prediction of maximum concentrations during daytime and ensure the number of predicted exceedence values were similar to what was observed.

A more rigorous approach reviewing alternate plume spread relationships may have been preferable in retrospect, but the objective was not to engage in the development of a new model. In essence, the modifications have produced a new model and the modifications were undertaken to account for physically realistic phenomenon.

While the model tuning was based on using reasonable algorithms, the U.S. EPA (1990) indicates that the tuning or calibration of short-term models is of "questionable benefit". On an operational basis, however, the tuning did produce model predictions that were more comparable to the observations than were otherwise available.

3.1.4 *ADEPT2*

ADEPT2 (Alberta **Dep**osition model with **T**errain-Version **2**) is a climatological dispersion model that can be used to estimate seasonal and annual average concentrations and deposition of sulphur compounds. While Alberta Environmental Protection no longer provides technical support for the models, they have indicated that the model predictions will still be accepted.

The features common to the original ADEPT and the new ADEPT2 version of the model:

- Dry deposition is estimated using the deposition velocity concept.
- Wet deposition is estimated using a reversible scavenging concept.
- Airflow trajectory changes due to complex terrain are based on stability dependent correction factors.
- Seasonal and annual joint frequency distributions of wind direction, wind speed and atmospheric stability are required.
- Multiple conventional and sour gas flare stacks can be evaluated.

The chemistry in the ADEPT and ADEPT2 models is limited to SO_2 sources and does not account for NO_x emissions.

Specific improvements incorporated into the ADEPT2 code are as follows:

- SO_2 to sulphate (SO_4^{-2}) conversion is incorporated, allowing the model results to be extrapolated to larger distances (up to 300 km).
- A resistance analog approach is used to estimate seasonal deposition velocities for different vegetation canopies.

Specific vegetation canopies addressed by the ADEPT2 model are as follows:

- Urban
- Agriculture
- Range
- Agriculture-range mixture
- Deciduous forest
- Coniferous forest
- Forested swamp
- Swamp
- Water

A uniform deposition canopy is assumed for each model run. The ADEPT2 code also has an output option that provides concentration and deposition values in a format that can be readily adapted for input into objective analysis and plotting packages.

Table 3.3 summarizes the input parameters required by the ADEPT2 model and the values adopted for application to the oil sands region. A STAR data set was derived for each of the three meteorological data sets. The ADEPT2 model assumes that the wind speeds are observed at 10 m and scales the winds from this level to stack height for assessment purposes. This scaling portion of the ADEPT2 code was modified to allow the user to assume any anemometer height.

3.2 ISC3BE Evaluation Approach

The ISC3BE model evaluation was based on using the model to predict ambient SO_2 concentrations at the ambient air quality monitoring trailer locations using meteorological data collected in the vicinity of the oil sands plants. The model predictions were then compared to the observations at each of the monitoring sites. The focus of the evaluation was to compare large one-hourly average predictions with large one-hourly average observations.

The comparison was based on the meteorological data collected over the 20 month period November 1993 to June 1995. Current source and air quality data from the source period were used.

3.2.1 *Source Data*

For the evaluation, only the three main continuous sources of SO_2 emissions were used: Suncor Powerhouse, Suncor Incinerator and the Syncrude main stack. Table 3.4 summarizes the source and emission parameters for these stacks. The exit velocities and temperatures are based on stack surveys conducted over the November 1993 to June 1995 period. Similarly, the SO_2 emission values are based on CSEM observations over the same period. As was indicated in Background Report 1, the SO_2 emission data exhibit day-to-day variability. An hour-by-hour

Table 3.3 Input requirements for the ADEPT2 dispersion model.

Category	Description
Stack parameters	• Total flow rate, SO_2 flow rate, exit temperature, stack diameter, stack height
Terrain data	• Tree canopy height and land use
Meteorology	• Precipitation rate, mixing height, plume rise constants, potential temperature gradients, ambient temperature • SO_2 to SO_4^{-2} conversion rates
Dry deposition[a]	• Deposition velocities
Wet deposition	• Background pH • Time fraction of precipitation
STAR data	• Joint frequency distribution of wind direction, wind speed and PG stability class on a seasonal basis

[a] ADEPT2 was modified to allow the user to specify deposition velocities as a function of season and stability class (see Section 5).

Table 3.4 Source parameters used to evaluate the performance of the ISC3BE model.

		Suncor Powerhouse	**Suncor Incinerator**	**Syncrude Main**
Base elevation	(m)	259	259	304
Stack height	(m)	106.7	106.7	183
Stack diameter	(m)	5.8	1.8	7.9
Exit velocity	(m/s)[a]	22.3	18.5	27.2
Exit temperature	(°C)[a]	256	489	239
SO_2 emission	(t/d)[b]			
Maximum		259	50	294
99%		255	48	275
95%		250	44	263
90%		243	42	257
50%		217	24	227
Approved		259	51	292

(a) Based on 1994 stack surveys.

(b) Based on daily values from November 1, 1993 to June 30, 1995 (20 months).

variability also exists that is not reflected in Table 3.2. For the purpose of comparing the model prediction with observations, the 99 percentile SO_2 emission values were used.

Part of the comparison uses air quality data from 1977 and 1978 (see Section 3.2.5). During the period when high SO_2 events were observed at Birch Mountain, only Suncor was operating and the respective Powerhouse and Incinerator emissions during these events were 245.6 and 16.5 t/d, respectively.

3.2.2 *Terrain / Receptor Data*

The terrain elevation data identified in Background Report 2 were used. The terrain grid data are required to allow the vertical plume trajectory to be modified and to specify a receptor location where concentrations and depositions are to be calculated. The terrain/receptor grid data used for the assessment, however, are limited to the locations where the current ambient air quality monitoring stations are located. These stations are identified in Table 3.5. The Birch Mountain station has been included in the table as it is the only elevated site where ambient air quality data from an elevated location are available.

3.2.3 *Meteorological Data*

Meteorological data are collected at multiple elevations on the communication towers located at Lower Camp (within the valley) and Mannix (above the valley). The data collected for the period November 1, 1993 to June 30, 1995 were summarized in Background Report 3. For this assessment, the following were used:

- **Wind direction:** Both Lower Camp 167 m and Mannix 75 m wind directions were used. The wind directions were converted to reflect the direction the wind is blown to which is required by both ISCST3 and ISC3BE.

- **Wind speed:** Both Lower Camp 167 m and Mannix 75 m wind speeds were used.

- **Ambient temperature:** From the 20 m level of both towers were used.

- **PG stability class:** The criteria for determining PG class were based on vertical wind direction fluctuation (σ_ϕ) using observations from Mannix 20 m level. The criteria were modified to account for an observation height of 20 m and a surface roughness of 1 m. A day-night criteria were superimposed to ensure unstable conditions did not occur during the day or stable conditions did not occur during the night.

- **Mixing height:** Based on net radiation data from Mannix and Mannix 20 m level wind speeds and a surface roughness of 1 m. The selected hourly value was based on the maximum of the convective and mechanical values for that hour.

Table 3.5 Terrain/receptor parameters used to evaluate the performance of the ISC3BE model.

Monitoring Site	Location[a]		Elevation (m ASL)	Location Relative to Athabasca Valley
	North	East		
Suncor				
Mannix (#2)	-3857	-482	334	Above
Lower Camp (#4)	3290	-1828	245	Within
Fina Airstrip (#5)	-748	3476	323	Above
Poplar Creek (#9)	-7253	1362	245	Within
Athabasca Bridge (#10)	15 060	-7350	238	Within
Syncrude				
AQS1 (Mine South)	-914	-7444	306	Above
AQS2 (Fort McMurray)	-21 916	1917	339	Above
AQS3 (Mildred Lake)	5303	-5303	319	Above
AQS4 (Tailings North)	16 714	-9650	265	Above
AQS5 (Tailings East)	11 268	-8804	274	Above
AEP				
FMMU (Fort McMurray)	-34 143	11 093	254	Within
FRMU (Fort McKay)	20 372	-9070	244	Within
AOSERP				
Birch Mountain	77 163	-19 340	795	Elevated

[a] Relative to the Suncor Powerhouse (North = 0, East = 0). The UTM coordinates of this stack are (N 6317526, E 471078).

No attempt was made to interpolate or replace missing data. The model therefore does not provide predictions for these periods. The meteorological parameters that depend on PG stability class and the values used for the assessment are shown in Table 3.6. Differences between the two sets are noted.

Figure 3.1 presents a summary of the meteorological data. Both locations show a bias to north-northeasterly or south-southeasterly winds reflecting the orientation of the Athabasca River Valley. Wind speeds occur most frequently in the 5 to 20 km/h range. Near neutral (PG stability class D) conditions were predicted to occur most frequently. Mixing heights were estimated to range from a typical value of 400 m during the night to up to 1000 m during the day.

3.2.4 *Ambient Air Quality Data*

The ambient air quality data from the stations listed in Table 3.5 were used to evaluate the model. Only data from the period November 1, 1994 to June 30, 1995 were used (except for Birch Mountain). Table 3.7 lists the maximum, the 5th highest and the 10th highest concentrations observed at each site and the number of hours when 0.17 ppm was exceeded as a one-hour average.

Figure 3.2 shows a composite frequency distribution when the observed concentrations were greater than 0.17 ppm (N = 119 h). The occurrence of incidents associated with concentrations in excess of 0.3 ppm, tend to occur infrequently. The figure also shows the diurnal distribution of these SO_2 events. These events are typically biased to occur during the middle of the day and not during the night. This is similar to the findings of Strosher and Peters (1980).

The Birch Mountain data are not included in Figure 3.2. The high values at this location occurred during the morning or nighttime period. These conditions were likely associated with stable atmospheric conditions, which in contrast to the other stations occurred during daytime convective conditions.

3.2.5 *Performance Evaluation Criteria*

The performance of a dispersion model in predicting spatial and temporal distributions of pollutant concentrations depends on the physical realism of the model and the quality of the input data (source, terrain and meteorology). Since models use simplified mathematical representations of the physical and stochastic nature of the atmosphere, there is little reason to expect predicted values to agree well with corresponding observations. This is particularly true for the prediction of extreme values (Rao and Visalli 1981). Detailed formal model evaluation approaches have been proposed (Bencala and Seinfeld 1979). These types of approaches, however, results in a "large complex batch of statistics" that are "relatively indigestible" (Smith 1986).

Table 3.6 Meteorological conditions used to evaluate the performance of the ISC3BE model.

PG Stability Class	Wind Profile Exponent		Vertical Potential Temperature Gradient (K/m)	
	Lower Camp[a]	Mannix[b]	Lower Camp[a]	Mannix[c]
A	0.12	0.21	-	-
B	0.07	0.21	-	-
C	0.10	0.23	-	-
D	0.28	0.40	-	-
E	0.59	0.62	0.03	0.04
F	0.57	0.50	0.04	0.05

[a] Based on 167 and 100 m levels.
[b] Based on 75 and 20 m levels.
[c] Based on 75 and 45 m levels.

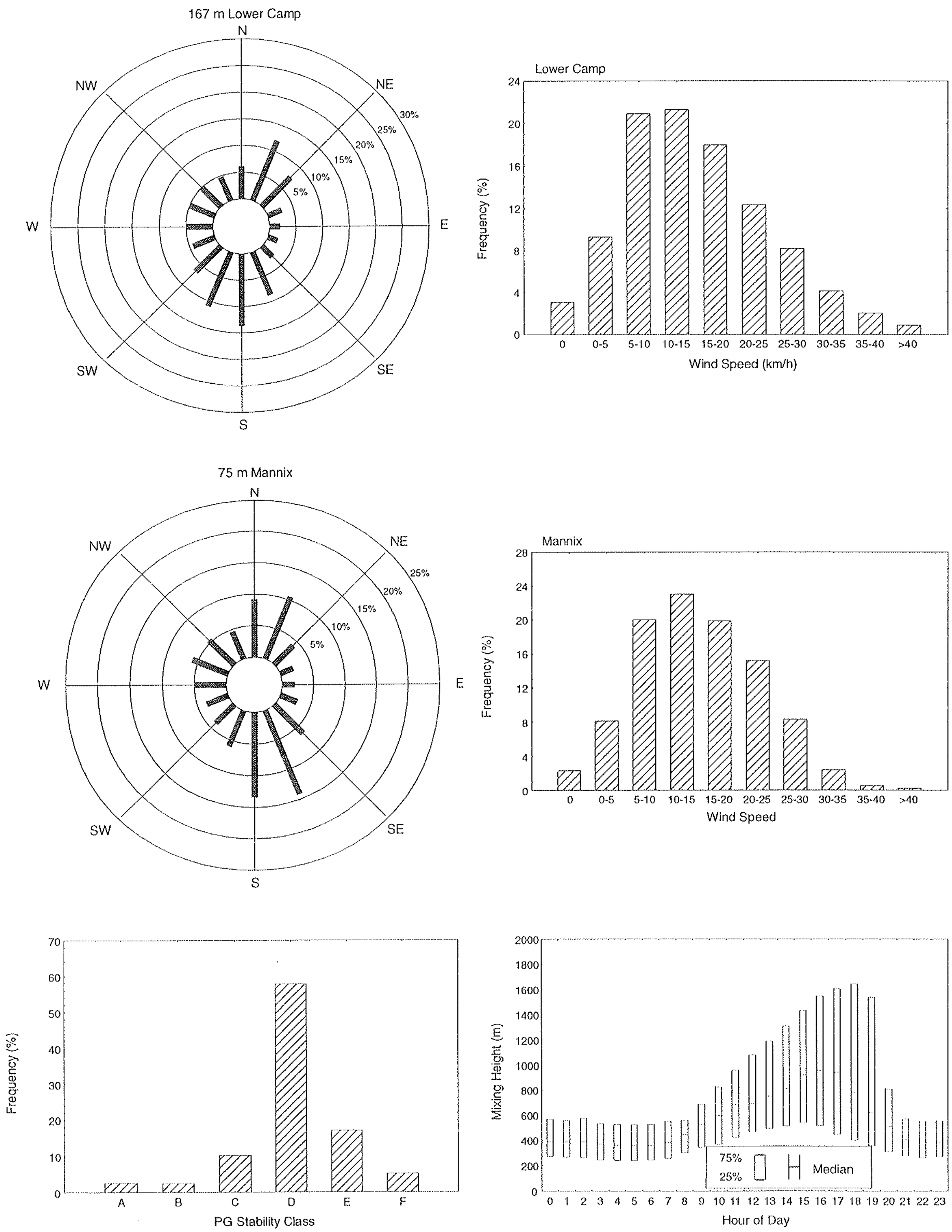
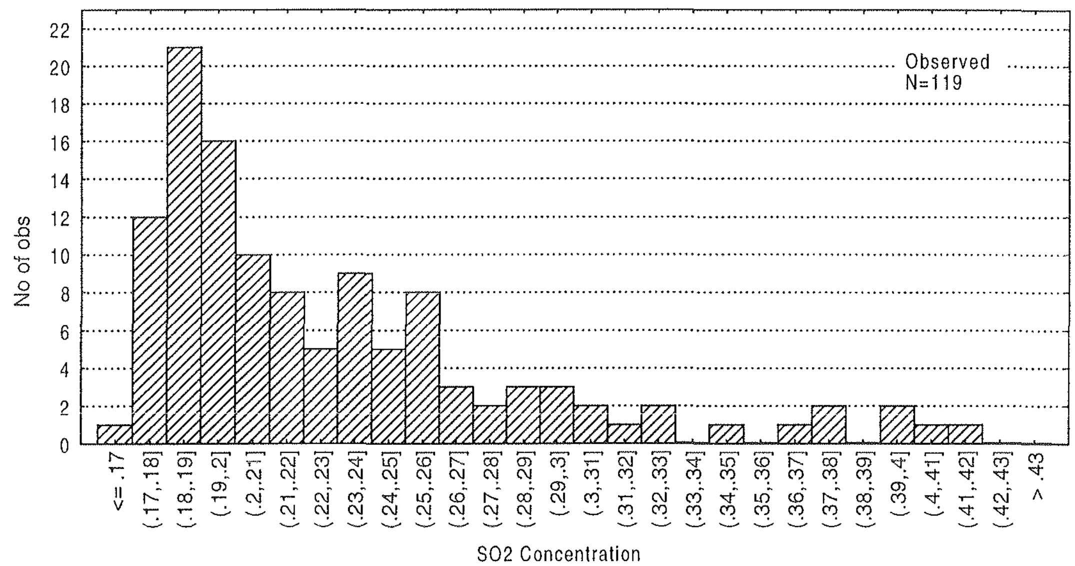


Figure 3.1 Summary of meteorological data used to evaluate the ISCST3 and ISC3BE models.

Table 3.7 Summary of ambient air quality observations used to evaluate the performance of the ISC3BE model.

Monitoring Site	Observed SO_2 Concentrations[a] (ppm)			N > 0.17 ppm[b]
	Maximum	5th Highest	10th Highest	(h)
Suncor				
Mannix (#2)	0.42	0.32	0.25	29 (17)
Lower Camp (#4)	0.32	0.20	0.14	8 (5)
Fina Airstrip (#5)	0.39	0.27	0.23	30 (18)
Poplar Creek (#9)	0.36	0.17	0.15	4 (2)
Athabasca Bridge (#10)	0.30	0.22	0.16	8 (5)
Syncrude				
AQS1 (Mine South)	0.40	0.25	0.17	11 (7)
AQS2 (Fort McMurray)	0.21	0.17	0.14	5 (3)
AQS3 (Mildred Lake)	0.41	0.21	0.19	12 (7)
AQS4 (Tailings North)	0.26	0.20	0.14	6 (4)
AQS5 (Tailings East)	0.18	0.11	0.07	1 (1)
AEP				
FMMU (Fort McMurray)	0.17	0.13	0.11	1 (1)
FRMU (Fort McKay)	0.25	0.17	0.13	4 (2)
AOSERP[c]				
Birch Mountain	0.08	0.05	n/a	0 (0)

(a) Based on values from November 1, 1993 to June 30, 1995 (20 months).
(b) The value in brackets are normalized for a 12 month period.
(c) Based on values from June 1977 to May 1978 (12 months).



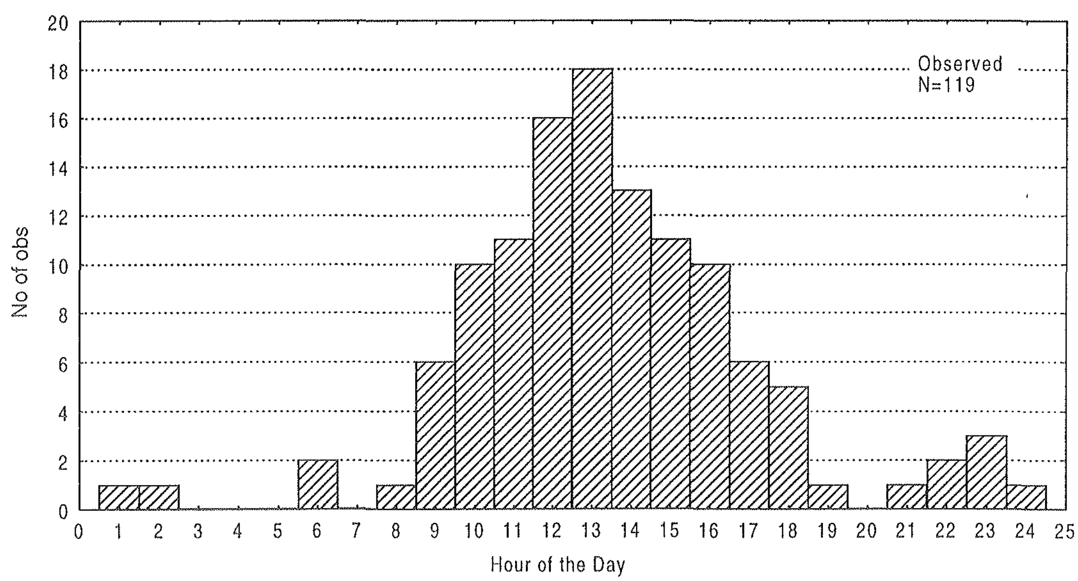


Figure 3.2 Observed composite frequency distribution of SO_2 concentrations for hourly events where the SO_2 concentration was greater than 0.17 ppm and the observed composition diurnal distribution of these same events.

For the purposes of this assessment, the following performance measures have been adopted:

- Comparison of extreme observed (O) with extreme predicted (P) at each location.
- Comparison of frequency distributions for predicted and observed values that exceed 0.17 ppm.
- Comparison of exceeding 0.17 ppm as a function of time of day.

These criteria were applied to predictions associated with the ISCST3 and ISC3BE models.

3.3 Model Evaluation

The comparison between the observations and predictions (using both ISCST3 and ISC3BE) are summarized in a series of tables and graphs as follows:

- Comparison of maximum observed and predicted SO_2 concentrations (Table 3.8 and Figure 3.3). The Pearson product-moment correlation coefficient (R^2) suggests a better degree of correlation between predicted and observed using the ISC3BE model.

  The comparison indicates that the average maximum ISCST3 prediction (0.31 ppm) corresponds well with the average maximum observed (0.28 ppm). The ISCST3 model predicts a relatively large value of 0.70 ppm at AQS2 (Fort McMurray) where the maximum observed is 0.21 ppm. The ISCST3 model also predicts many more exceedences (377) of 0.17 ppm than observed (119).

  The ISC3BE maximum predicted values are about 75% the maximum observed values. The maximum predicted values are very similar to the 5th highest observed values. While the number of exceedences of 0.17 ppm value (209) exceeds the observed value (119), it is much less than that predicted using the ISCST3 model.

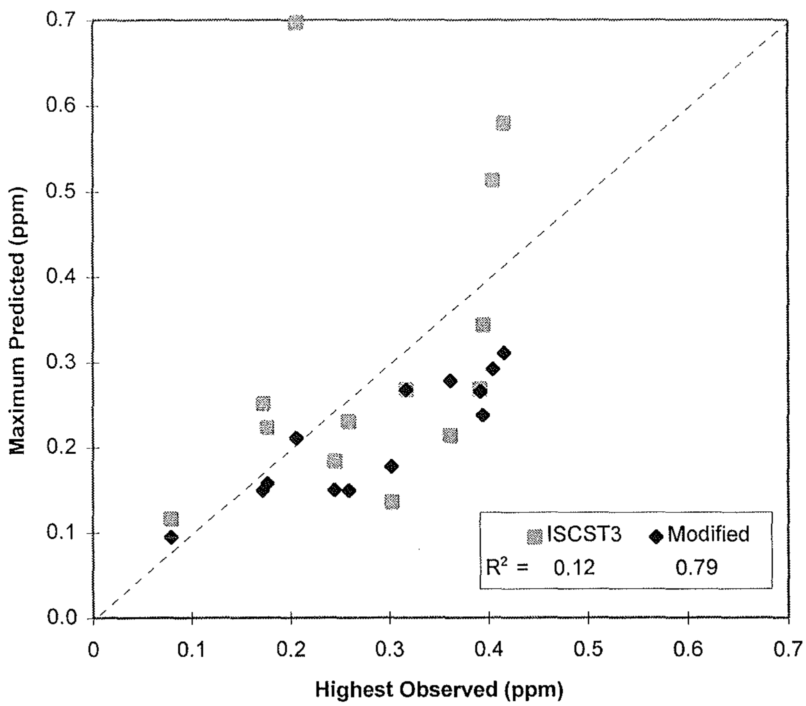
- Frequency distributions of observed and predicted values exceeding 0.17 ppm (Figures 3.4 and 3.5 for Mannix and Lower Camp meteorology, respectively). The use of both meteorological data sets indicates that the ISCST3 model tends to overpredict the occurrence of the higher concentrations. The ISC3BE model does not predict the higher values (greater than 0.3 ppm) that were observed.

- Diurnal distribution of observed and predicted values exceeding 0.17 ppm (Figures 3.6 and 3.7 for Mannix and Lower Camp meteorology, respectively). The use of both meteorological data sets indicates that the ISCST3 model does not predict the bias towards the daytime occurrence of SO_2 events. The modified ISC3BE model, however, shows the bias daytime basis that has been observed.

Table 3.8 Observed and predicted (using Mannix meteorology) SO_2 concentrations (ppm).

Monitoring Site	Observed[a]			Predicted			
	Maximum	5th Highest	N > 0.17[b]	ISCST3		ISC3BE	
				Maximum	N > 0.17[b]	Maximum	N > 0.17[b]
Mannix	0.42	0.32	29 (17)	0.58	197 (118)	0.31	75 (45)
Lower Camp	0.32	0.20	8 (5)	0.27	12 (7)	0.27	25 (15)
Fina	0.39	0.27	30 (18)	0.29	67 (40)	0.27	23 (14)
Poplar Creek	0.36	0.17	4 (2)	0.21	6 (4)	0.26	17 (10)
Athabasca	0.30	0.22	8 (5)	0.14	0 (0)	015	0 (0)
AQS1	0.40	0.25	11 (7)	0.34	11 (7)	0.24	12 (7)
AQS2	0.21	0.17	5 (3)	0.70	25 (15)	0.21	8 (5)
AQS3	0.41	0.21	12 (7)	0.51	37 (22)	0.29	47 (28)
AQS4	0.26	0.20	6 (4)	0.23	6 (4)	0.18	2 (1)
AQS5	0.18	0.11	1 (1)	0.22	11 (7)	0.16	0 (0)
Fort McKay	0.25	0.17	4 (2)	0.18	1 (1)	0.15	0 (0)
Fort McMurray	0.17	0.13	1 (1)	0.25	4 (2)	0.15	0 (0)
Birch Mountain[c]	0.08	0.06	0 (0)	0.12	0 (0)	0.10	0 (0)
Average	0.28	0.18	9 (5)	0.31	29 (17)	0.21	16 (10)
Total			119 (71)		377 (227)		209 (125)

(a) All observed are over the period November 1, 1993 to June 30, 1995 (20 months)
(b) The values in brackets are normalized for a 12 months period.
(c) From the period June 1977 to May 1978 (12 months).



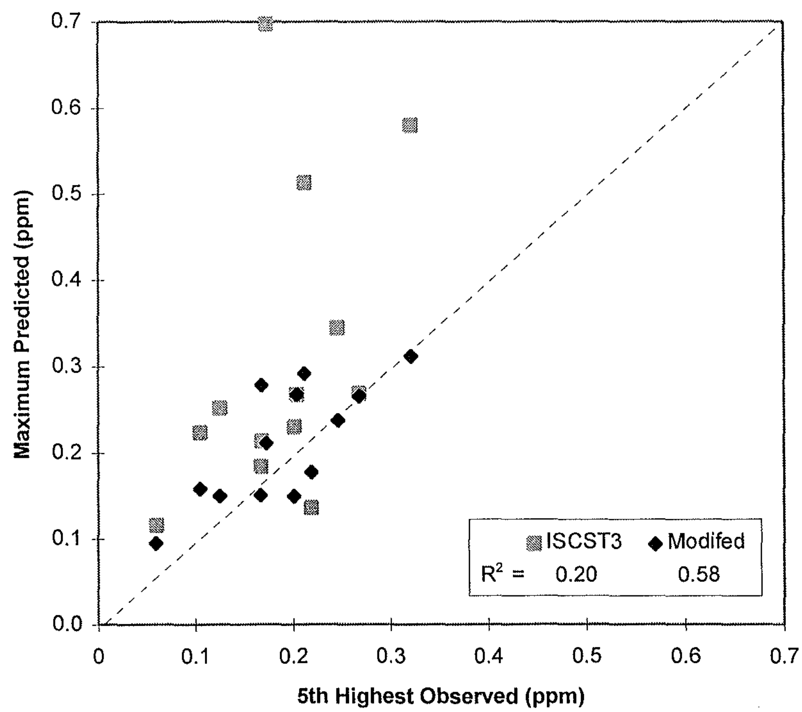


Figure 3.3 Comparison of maximum and predicted values at each site using the ISCST3 and ISC3BE models and Mannix meteorology.

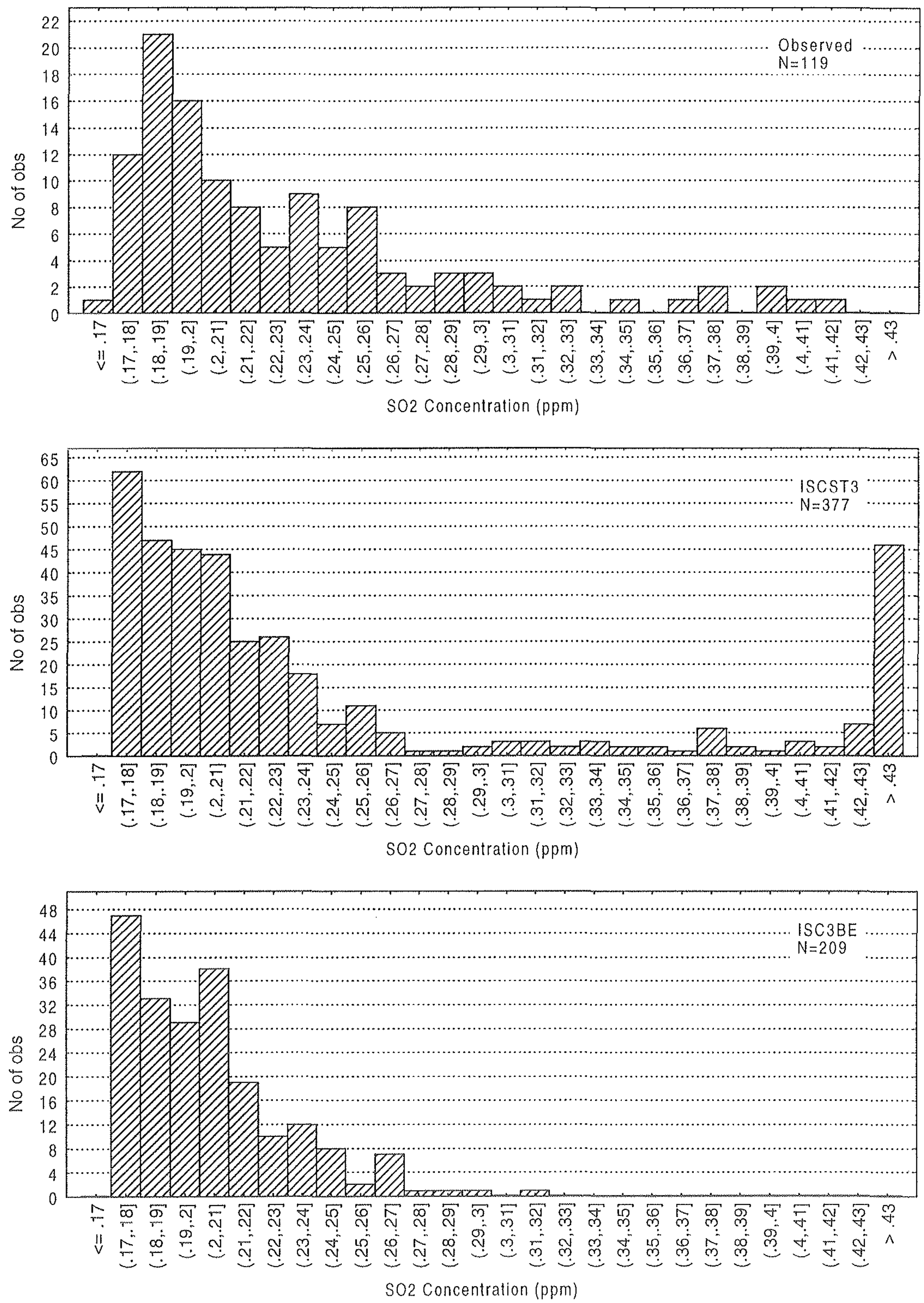


Figure 3.4 Exceedences when observed or predicted SO_2 concentrations are greater than 0.17 ppm using Mannix meteorology.

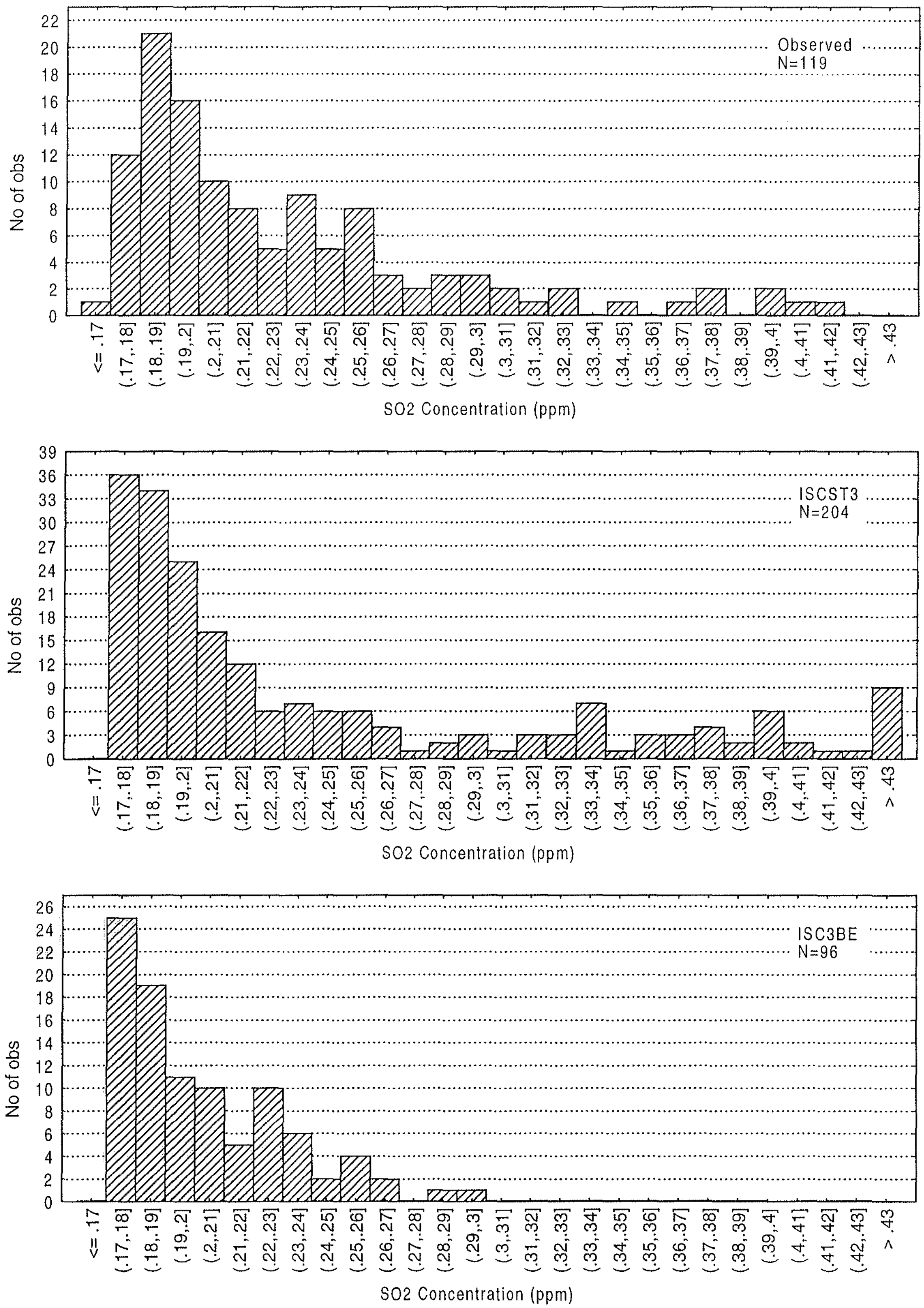


Figure 3.5 Exceedences when observed or predicted SO_2 concentrations are greater than 0.17 ppm using Lower Camp meteorology.

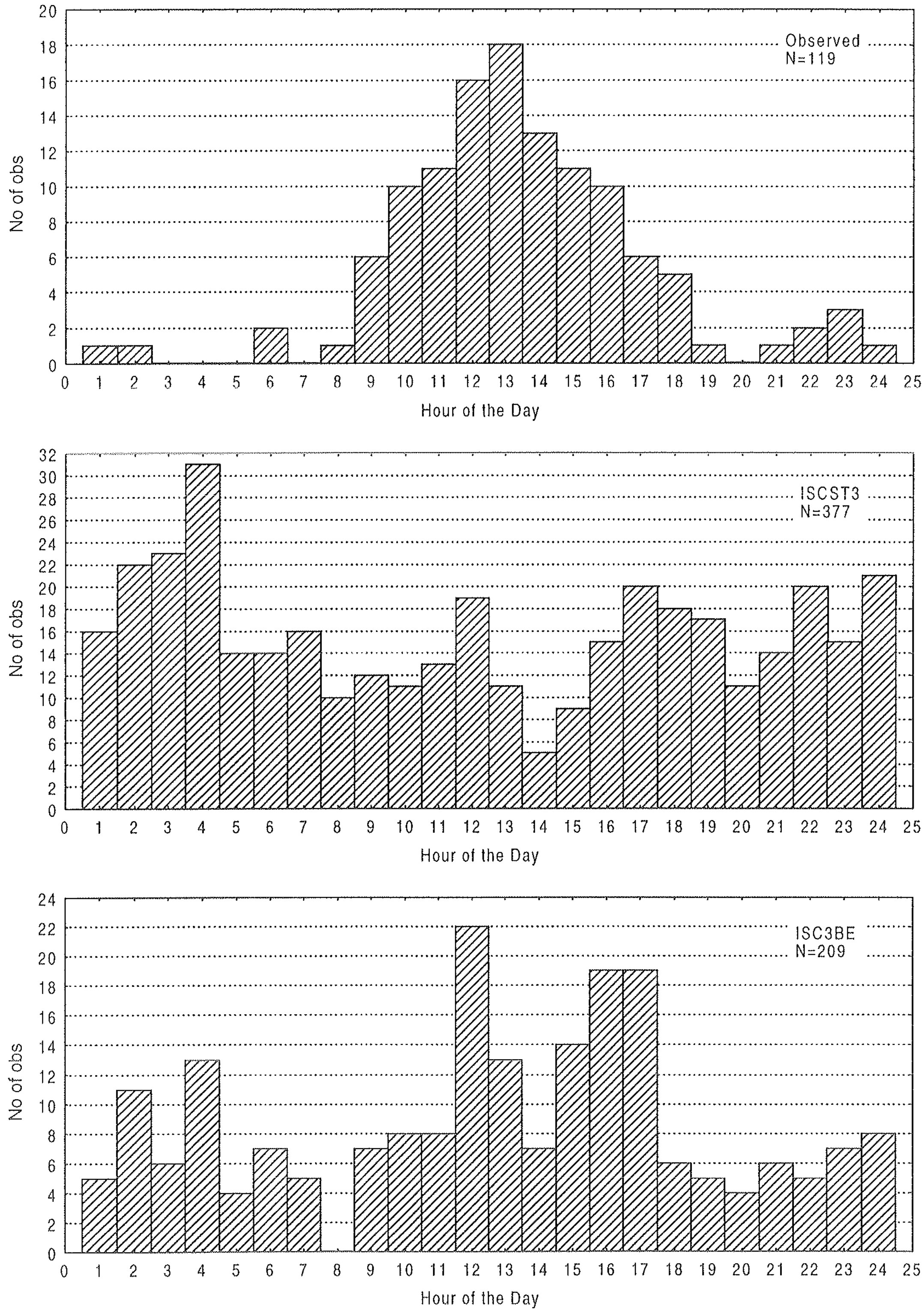


Figure 3.6 Comparison of diurnal distributions of observed and predicted hourly observations greater than 0.17 ppm (all stations, Mannix meteorology).

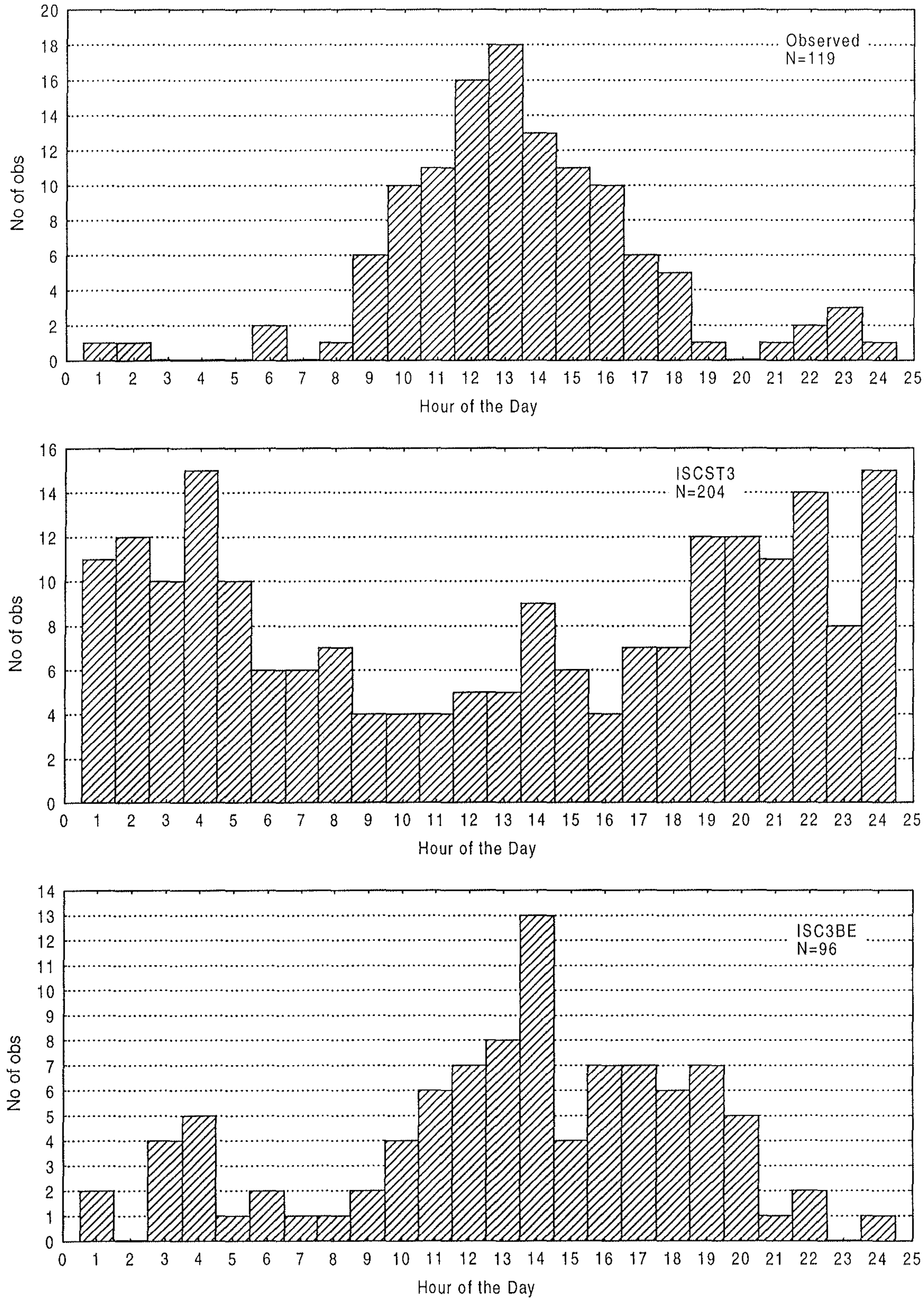


Figure 3.7 Comparison of diurnal distributions of observed and predicted hourly observations greater than 0.17 ppm (Lower Camp meteorology).

It should be noted the "models" evaluated in the tables and figures presented in this section not only include the computer code whose equations are selected to replicate reality but also include the parameterization of the source, the terrain, the meteorology and the receptor locations. For example, the selection of the 99th percentile SO_2 emission values could have been expected to produce maximum values comparable to those observed and to produce a greater frequency of exceedences. On this basis, the ISCST3 could be regarded as the "better" model. However, the bias for predicting nighttime exceedences is clearly an indication of the inadequacy of the model physics. On this basis, the ISC3BE model was judged to be superior to the ISCST3.

The Mannix meteorological data set is used for subsequent assessments since slightly larger predictions (maximum = 0.31 ppm) are associated with this set than with the Lower Camp set (maximum = 0.3 ppm). Similarly, the Mannix data predict 209 exceedences instead of the 96 values associated with the Lower Camp data. On this basis, the Mannix data set was selected as it is more conservative (that is the use of these data predicts larger values). The predictions based on the ISC3BE model and the Mannix meteorological data set produce a greater frequency of high values while the extreme maximum values are likely to be less than what can be observed. The user, however, should have reasonable assurance that this combination predicts the diurnal trends that were observed.

4.0 PREDICTED AMBIENT SO_2 CONCENTRATIONS

Ambient air quality changes associated with SO_2 emissions from industrial sources in the region are presented. Table 4.1 identifies the sources evaluated, the models used and the parameters predicted using the models. For the evaluation, the modelling results have been grouped as originating from either continuous or intermittent sources. The modelling also considers and reviews stacks on both an individual and combined operation basis.

4.1 Continuous Sources (Individual Operation)

Table 4.2 summarizes the stack and emission parameters associated with the continuous sources of SO_2 emissions. The Suncor incinerator parameters are provided for both before and after the commissioning of SuperClaus. The corresponding SO_2 emissions for all stacks are provided on an average basis as well as for all the respective approved values. The latter provide differing values for differing averaging periods.

4.1.1 *Hourly-Average SO_2 Concentrations*

The maximum one-hour average SO_2 concentrations were predicted using the SCREEN3 and ISC3BE models for the sources and SO_2 emission rates shown in Table 4.2. The SCREEN3 prediction assumes flat terrain and the AEP 55% adjustment factor was not applied. The ISC3BE model assumed elevated terrain and the Mannix based meteorological data.

Table 4.3 summarizes the maximum one-hour average SO_2 concentrations, the locations where these maxima occur and the associated meteorological conditions. A comparison of the values predicted using the two models is provided as a scatterplot in Figure 4.1. A comparison between the results predicted by both models indicates:

- The comparison between the maximum values predicted using both models shows good agreement. SCREEN3, however, predicts slightly larger maximum values (1055 $\mu g/m^3$ vs. 910 $\mu g/m^3$ for ISC3BE). Note that SCREEN3 assumes flat terrain, whereas ISC3BE incorporates the actual terrain.

- The maximum values predicted with the SCREEN 3 model are all associated with PG stability class A (daytime conditions) and the maximum values all occur between 0.8 and 1.4 km downwind of the respective sources.

- ISC3BE predicts maximum values associated with daytime conditions (PG stability class A and B) and the maximum occurs at distances of 1.1 km for the Suncor incinerator and 8.9 km for the Syncrude Main stack.

Table 4.1 Sources, models and predicted parameters for SO_2 emitting sources in the region.

SO_2 Sources	Hourly SO_2		Daily SO_2	Annual SO_2	
	SCREEN3	ISC3BE	ISC3BE	IS3BE	ADEPT3
Continuous Source					
Suncor					
Powerhouse	✓	✓	✓	✓	✓
Incinerator (before SuperClaus)	✓	✓	✓	✓	✓
Incinerator (after SuperClaus)	✓	✓	✓	✓	✓
Flaring	✓	×	×	×	×
Syncrude					
Main Stack	✓	✓	✓	✓	✓
SOLV-EX					
Bitumount (normal)	✓	✓	✓	✓	✓
Ruth Lake (normal)	✓	✓	✓	✓	✓
Intermittent Sources					
Suncor					
Flaring	✓	×	×	×	
Syncrude					
Diverter	✓	×	×	×	
Flaring	✓	×	×	×	
SOLV-EX					
Bitumount (abnormal)	✓	×	×	×	
Ruth Lake (abnormal)	✓	×	×	×	

✓ Model used.
× Model not used.

Table 4.2 SO_2 emissions associated with continuous sources in the region.

Source		Suncor Powerhouse	Suncor Incinerator (before SuperClaus)	Suncor Incinerator (after SuperClaus)	Syncrude Main	SOLV-EX Bitumount[a]	SOLV-EX Ruth Lake
Base elevation	(m AMSL)	259	259	259	304	284	326
Stack height	(m)	106.7	106.7	106.7	183	60	60
Stack diameter	(m)	5.79	1.80	1.80	7.90	1.35	1.50
Exit velocity	(m/s)	22.3	18.5	20.3	27.2	20.0	16.3
Exit temperature	(°C)	256	489	478	239	250	158
SO_2 emission							
Average	(t/d)	211	35	17	213	2.14[b]	1.44
Approved 90 day	(t/d)	-	-	-	260	-	-
Approved daily	(t/d)	259	51	-	292	-	-
Approved hourly	(t/h)	13.8	2.6	1.2	16.4	-	-
Approved abnormal	(t/h)	14.2	3.0	-	-	-	-

(a) The main stack servicing the incinerator and sulphur acid plant (Normal operation; Abnormal = 4.75 t/d).
(b) The main stack servicing the sulphur acid plant (Normal; Abnormal = 4.13 t/d).

Table 4.3 Maximum one-hour average SO_2 concentrations associated with continuous sources in the region.

Source / SO_2 Emission	SCREEN3				ISC3BE					
	SO_2 Concentration				SO_2 Concentration				Exeedences	
	SO_2 ($\mu g/m^3$)	PG Class	Wind Speed (m/s)	Distance (km)	SO_2 ($\mu g/m^3$)	PG Class	Wind Speed (m/s)	Location[a] (km / degrees)	N >[b] 450 $\mu g/m^3$	Location (km / degrees)
Continuous Suncor										
Powerhouse										
Average (211 t/d)	1237	A	2.5	1.2	1346	E	0.6	23.6 / 36	34	14.1 / 98
Daily (259 t/d)	1519	A	2.5	1.2	1652	E	0.6	23.6 / 36	45	15.1/ 98
Hourly (13.8 t/h)	1942	A	2.5	1.2	2173	E	0.6	23.6 / 36	57	19.4 / 102
Abnormal (14.2 t/h)	1998	A	2.5	1.2	2173	E	0.6	23.6 / 36	59	21.1 / 59
Incinerator (before SuperClaus)										
Average (35 t/d)	842	A	1.0	1.1	698	A	3.3	1.1 / 198	3	4.5 / 261
Daily (51 t/d)	1227	A	1.0	1.1	1017	A	3.3	1.1 / 198	25	2.2 / 202
Hourly (2.6 t/h)	1501	A	1.0	1.1	1244	A	3.3	1.1 / 198	97	2.2 / 207
Abnormal (3.0 t/h)	1732	A	1.0	1.1	1435	A	3.3	1.1 / 198	169	2.2 / 207
Incinerator (after SuperClaus)										
Average (17 t/d)	397	A	1.5	1.0	338	A	3.3	1.1 / 198	0	N/A
Hourly (1.2 t/h)	672	A	1.5	1.0	573	A	3.3	1.1 / 198	2[c]	10.2 / 101
Continuous Syncrude										
Main Stack										
Average (213 t/d)	662	A	3.0	1.4	322	B	5.7	8.9 / 6	0	N/A
90-day (260 t/d)	808	A	3.0	1.4	393	B	5.7	8.9 / 6	0	N/A
Daily (292 t/d)	908	A	3.0	1.4	441	B	5.7	8.9 / 6	0	N/A
Hourly (16.4 t/h)	1223	A	3.0	1.4	595	B	5.7	8.9 / 6	1[c]	64.0 / 321
SOLV-EX										
Bitumount (2.14 t/d)	120	A	1.0	0.8	69	E	1.4	40.3 / 353	0	N/A
Ruth Lake (1.44 t/d)	97.	A	1.0	0.8	151	E .	1.0	4.5 / 261	0	N/A
Average	1055	-	-	-	910	-	-	-	-	-

(a) Direction is indicated as the wind direction.
(b) Normalized for a 12 month period.
(c) Indicates that there are more than one occurrence (receptor) of the same maximum number of exceedences.

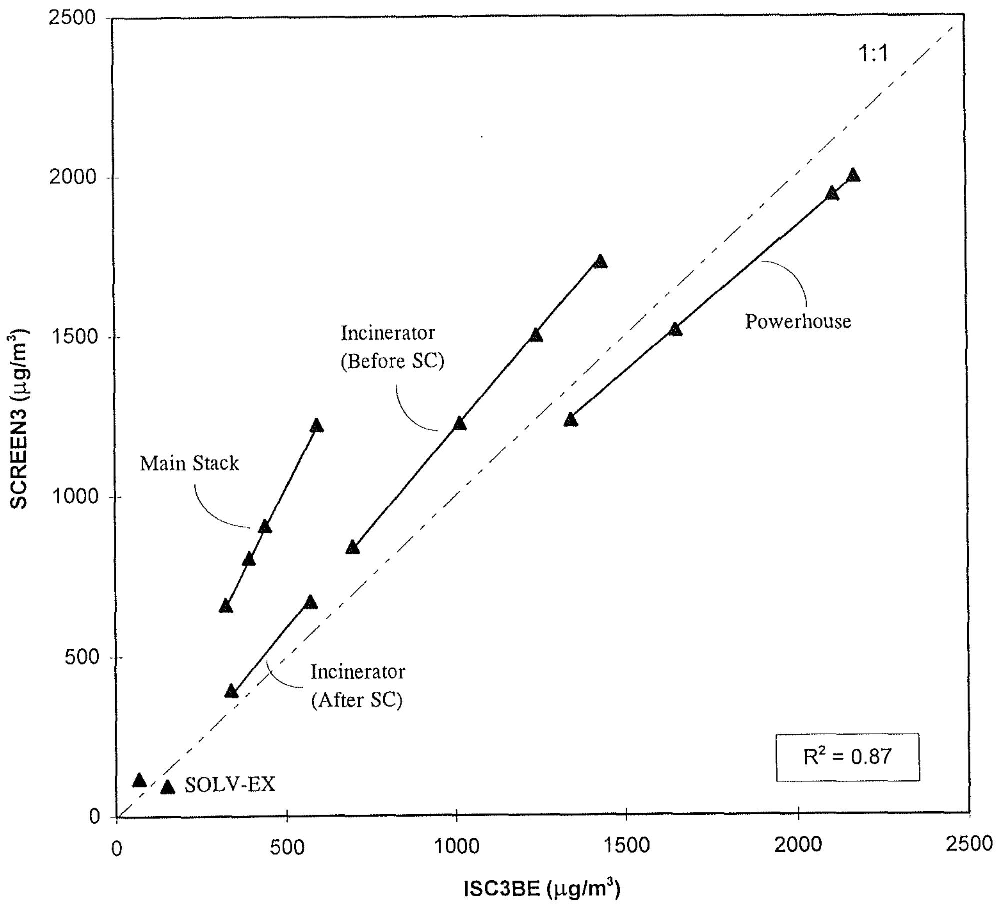


Figure 4.1 Comparison of maximum predicted values based on ISC3BE (full meteorology and complex terrain) and SCREEN3 (screening meteorology and flat terrain).

- ISC3BE also predicts maxima associated with nighttime conditions (PG stability class E). These maxima are typically predicted to occur at larger distances with elevated terrain (23.6 km downwind for the powerhouse stack; 40.3 km downwind for the SOLV-EX bitumen stack and 4.5 km downwind for the SOLV-EX Ruth Lake stack).

- The SCREEN3 model tends to predict maximum SO_2 concentrations from the Syncrude Main stack that are larger than the ISC3BE predictions by a factor of two.

The comparison does confirm that SCREEN3 could be used as a screening tool for all sources except the Syncrude Main stack when compared to the more rigourous ISC3BE application.

Based on the ISC3BE predictions, the following are noted:

- The maximum SO_2 concentrations associated with the powerhouse and incinerator (before SuperClaus) are predicted to exceed the 450 $\mu g/m^3$ guideline (0.17 ppm) for all emission cases.

- The maximum predicted SO_2 concentrations associated with the incinerator (after SuperClaus) and the Syncrude Main stack are less than the 450 $\mu g/m^3$ guideline except during abnormal conditions that could occur on an hour-by-hour basis.

- The maximum predicted concentration associated with the SOLV-EX operations are within the 450 $\mu g/m^3$ guideline.

For the three main sources of SO_2 emissions, the spatial concentration patterns expressed as the maximum one-hour average SO_2 concentration were prepared. These are presented in Figures 4.2, 4.3 and 4.4 for the Suncor Powerhouse, incinerator (after SuperClaus) and the Syncrude Main stack, respectively. The values presented in the figures are the maximum concentrations that could occur (even if it is only once during the 20 month simulation period) at any given location). The results indicate:

- For the powerhouse, values in excess of 450 $\mu g/m^3$ are predicted to occur over the elevated terrain areas of Thickwood Hills and Muskeg Mountain.

- The maximum SO_2 concentrations associated with the Suncor incinerator (after SuperClaus) and the Syncrude Main stack are well within the 450 $\mu g/m^3$ guideline.

The figures support the results in Table 4.3 and indicate the spatial distribution of maximum concentrations.

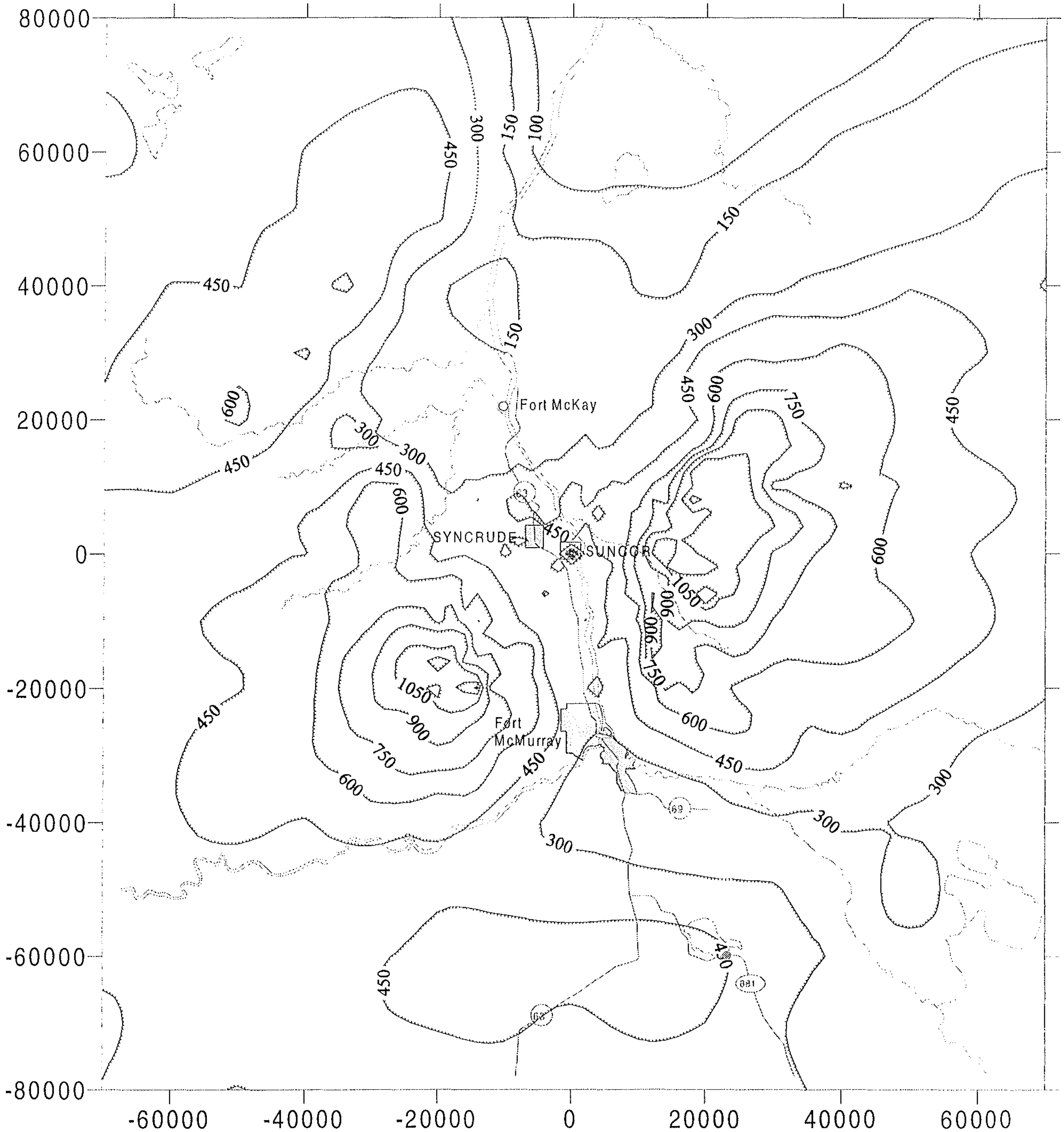


Figure 4.2 Maximum predicted one-hour average SO_2 concentration ($\mu g/m^3$) resulting from the operation of the **Suncor Powerhouse** (SO_2 emission = 211 t/d).

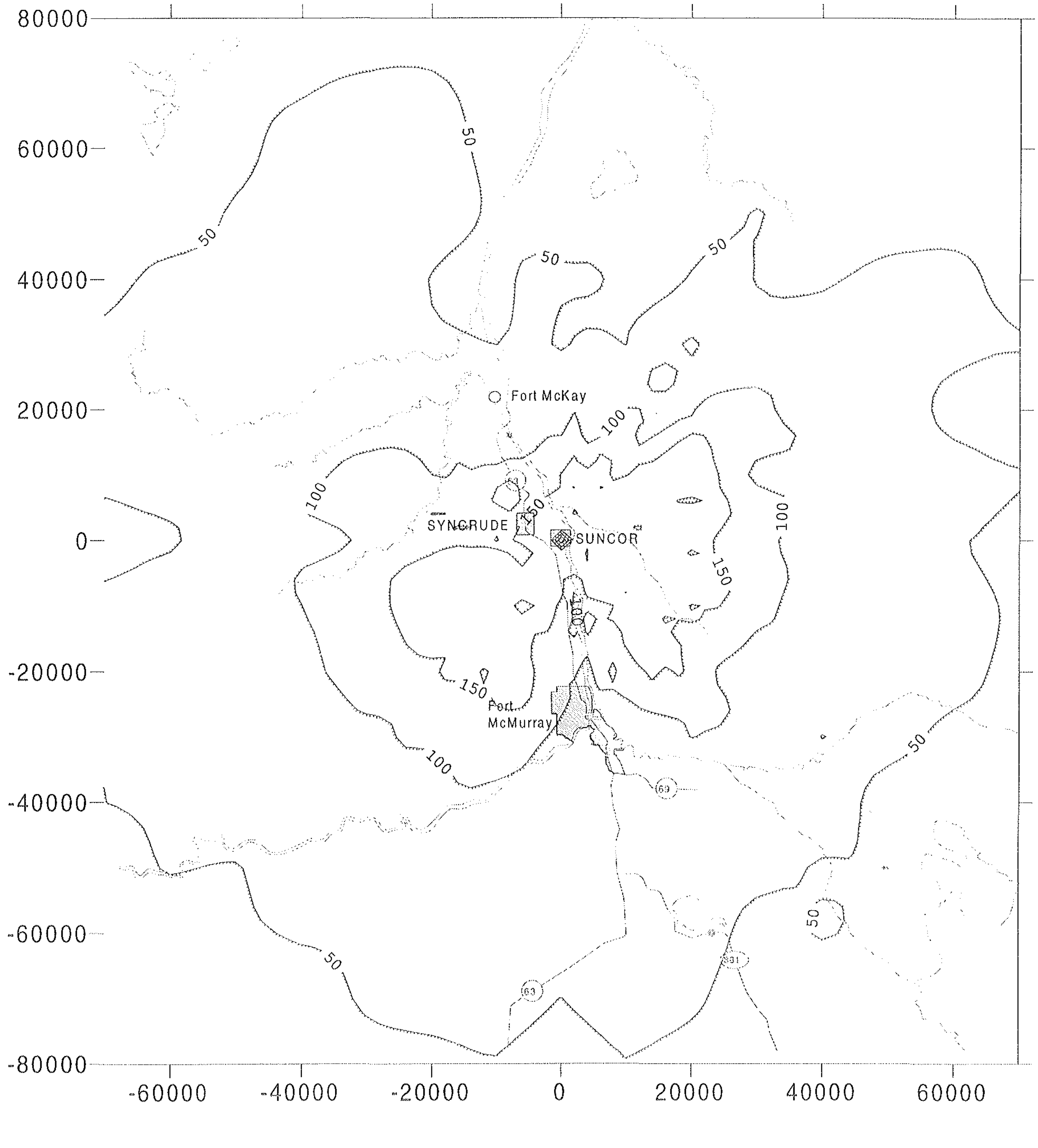


Figure 4.3 Maximum predicted one-hour average SO_2 concentration ($\mu g/m^3$) resulting from the operation of the **Suncor Incinerator (after SuperClaus)** (SO_2 emission = 17 t/d).

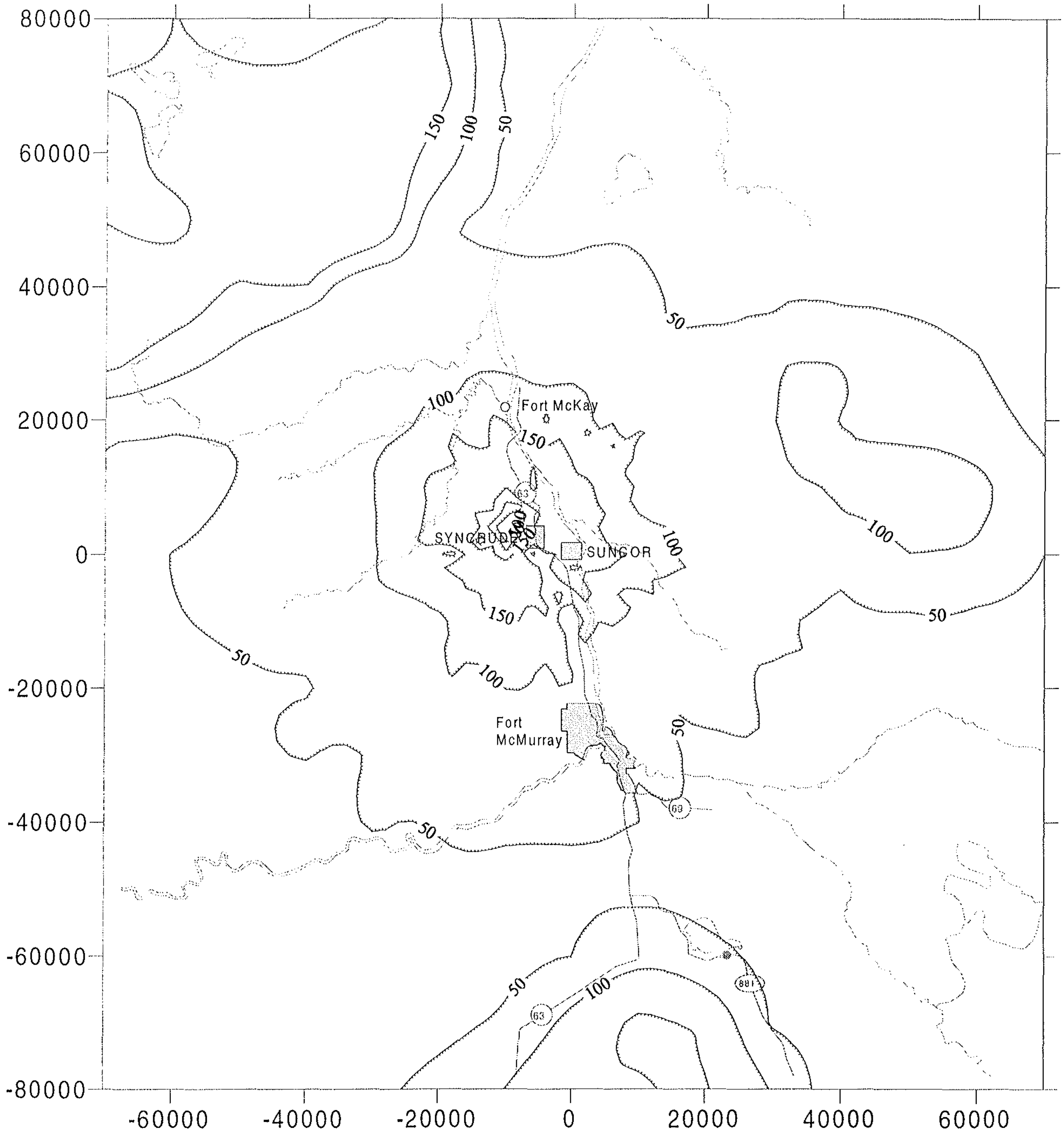


Figure 4.4 Maximum predicted one-hour average SO_2 concentrations (µg/m^3) resulting from the operation of the **Syncrude Main stack** (SO_2 emission = 213 t/d).

4.1.2 *Daily-Average SO_2 Concentrations*

The ISC3BE model was used to predict the maximum daily average SO_2 concentrations from the operation of the continuous sources on an individual basis. Table 4.4 summarizes the maximum 24-hour concentrations and the location where the maximum value occurs. Note that the predictions are only provided for the emission rates that correspond to daily emissions and do not include the extreme hourly rates that were shown in Tables 4.2 and 4.3. The maximum values are those associated with one full day (24 hours) over the 20 month period. Most of the maximum daily values are less than the guideline value of 150 $\mu g/m^3$ (0.06 ppm). Values that exceed the guideline are associated with the Suncor Powerhouse and incinerator (before SuperClaus) operations and the daily guideline for these cases is only exceeded 1 to 4 days per year.

Figures 4.5, 4.6 and 4.7 show the maximum predicted daily average SO_2 concentration patterns from the Suncor Powerhouse, the Suncor Incinerator and from the Syncrude Main stack, respectively. The results indicate:

- As with the hourly maxima, the maximum daily concentrations associated with the powerhouse stack are predicted to occur over the elevated Thickwood Hills and Muskeg Mountain terrain. The maximum daily values in these locations exceed the 150 $\mu g/m^3$ guideline.

- The maximum values associated with the Suncor incinerator (after SuperClaus) and the Syncrude Main stack are all less than the 150 $\mu g/m^3$ guideline.

4.1.3 *Annual-Average SO_2 Concentrations*

The ISC3BE and ADEPT2 models were used to predict the maximum annual average SO_2 concentrations from the operation of the continuous sources on an individual basis. Table 4.5 summarizes the maximum annual average SO_2 concentrations and the locations where these maxima occur. The results in the table indicate:

- The maximum values predicted by the two models are somewhat similar (within a factor of 2) for the Suncor sources. For the Syncrude Main stack, the ADEPT2 model predicts a maximum value four times that associated with the ISC3BE model.

- The ISC3BE maxima are generally predicted to occur closer to the source than those assumed with ADEPT2 (the exception being for SOLV-EX Bitumount).

- The maximum predicted values are all within the 30 $\mu g/m^3$ guideline.

Figures 4.8, 4.9 and 4.10 show the predicted annual average SO_2 concentrations from the operation of the Suncor Powerhouse, the Suncor Incinerator and the Syncrude Main stack,

Table 4.4 Maximum 24-hour average SO_2 concentrations associated with continuous sources of SO_2 emissions in the region.

Source / SO_2 Emission		ISC3BE					
		SO_2 Concentration			Exceedences		
		SO_2[(a)] ($\mu g/m^3$)	Location (km / degree)		N[(b)] > 150 $\mu g/m^3$	Location (km / degree)	
Suncor							
Powerhouse							
Average	(211 t/d)	251	25.6	231	1[(c)]	39.1	50
Daily	(259 t/d)	308	25.6	231	1[(c)]	19.9	1080
Incinerator (before SuperClaus)							
Average	(35 t/d)	231	2.2	207	1[(c)]	2.2	207
Daily	(51 t/d)	337	2.2	207	4[(c)]	2.2	202
Incinerator (after SuperClaus)							
Average	(17 t/d)	104	2.2	207	N/A	N/A	N/A
Syncrude							
Main Stack							
Average	(213 t/d)	40	23.9	237	N/A	N/A	
90 day	(260 t/d)	49	23.9	237	N/A	N/A	
Daily	(292 t/d)	55	23.9	237	N/A	N/A	
SOLV-EX							
Bitumount	(2.14 t/d)	13	40.3	353	N/A	N/A	
Ruth Lake	(1.44 t/d)	49	3.8	247	N/A	N/A	

(a) The air quality guideline for SO_2 is 150 $\mu g/m^3$ (0.06 ppm) as a 24-hour average.
(b) Normalized for a 12 month period.
(c) More than one location.

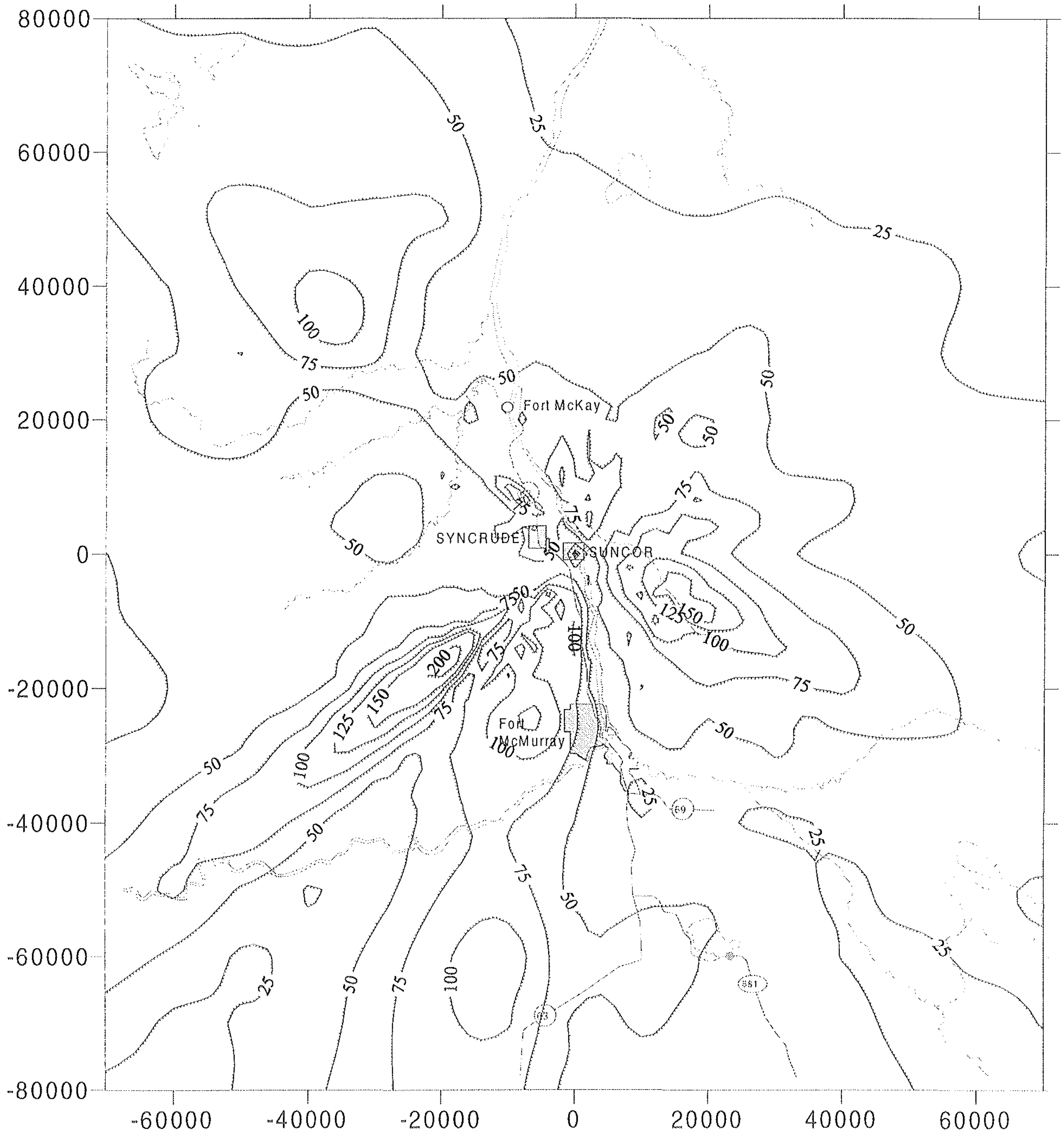


Figure 4.5 Maximum predicted daily average SO_2 concentration (μg/m^3) resulting from the operation of the **Suncor Powerhouse** (SO_2 emission = 211 t/d).

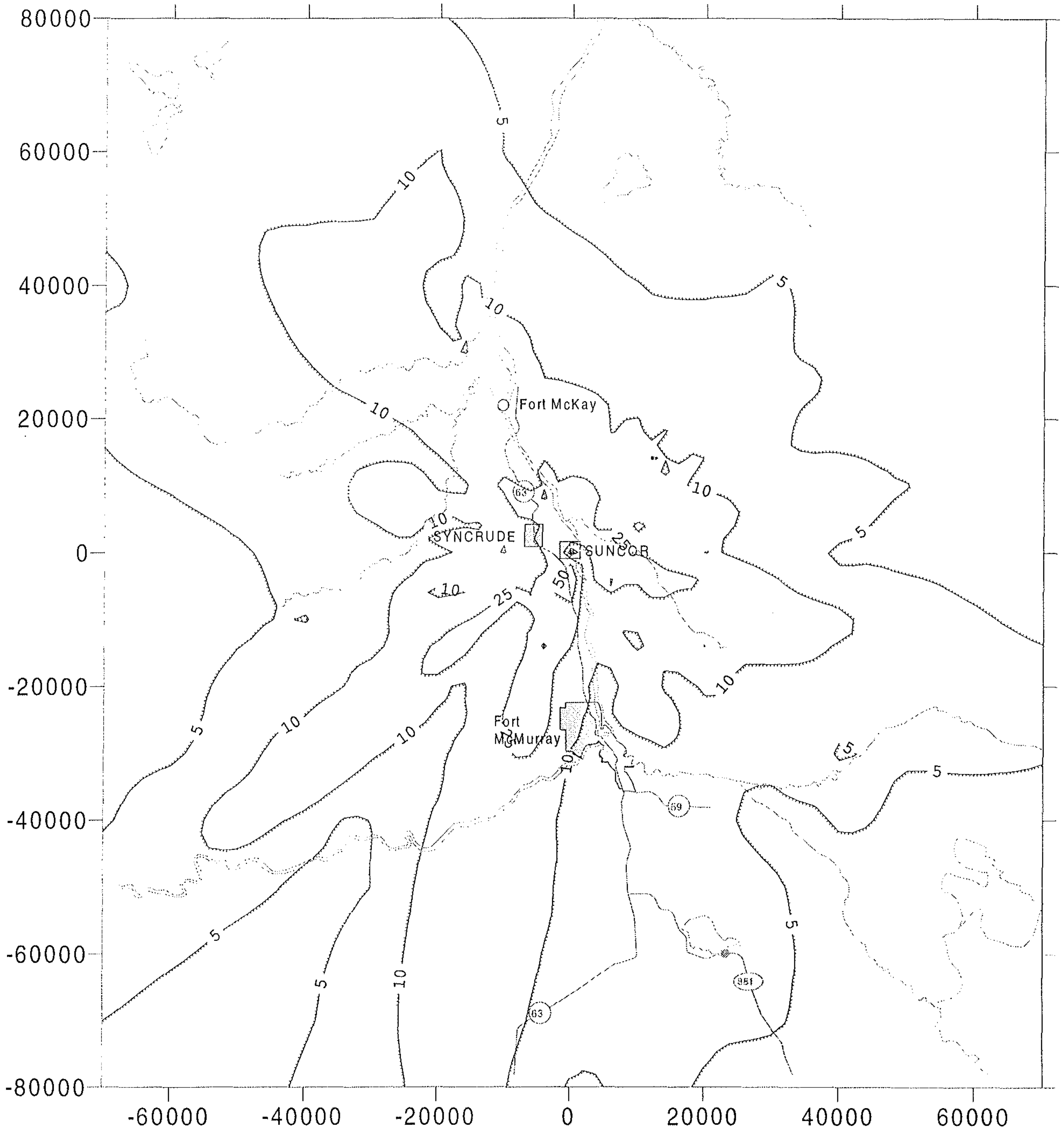


Figure 4.6 Maximum predicted daily average SO_2 concentrations ($\mu g/m^3$) resulting from the operation of the **Suncor Incinerator (after SuperClaus)** (SO_2 emission = 17 t/d).

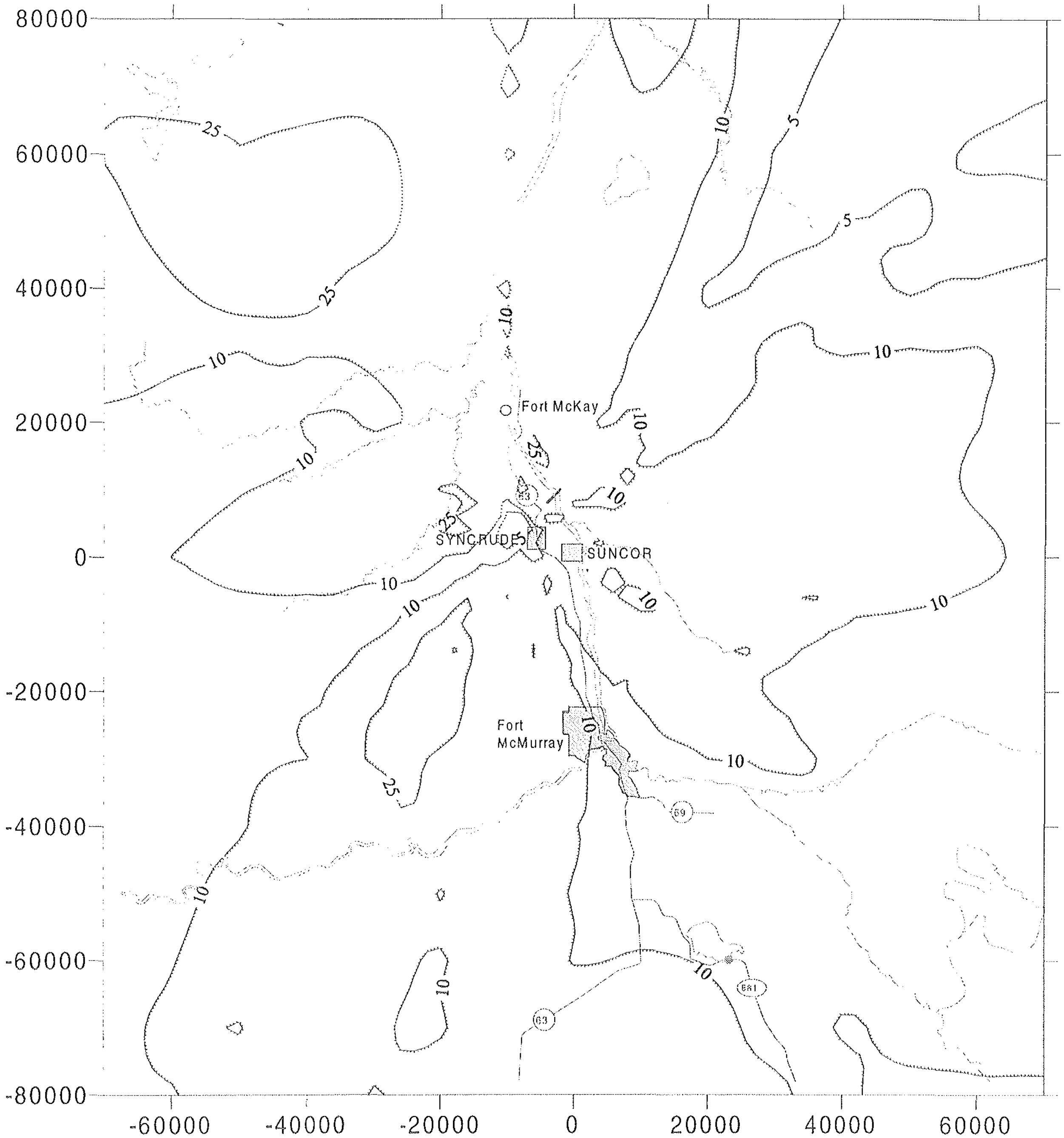


Figure 4.7 Maximum predicted daily average SO_2 concentrations ($\mu g/m^3$) resulting from the operation of the **Syncrude Main stack** (SO_2 emissions = 213 t/d).

Table 4.5 Maximum annual average SO_2 concentrations associated with continuous sources of SO_2 emissions in the region.

Source / SO_2 Emissions	ISC3BE		ADEPT2	
	SO_2 ($\mu g/m^3$)	Distance (km)	SO_2 ($\mu g/m^3$)	Distance (km)
Suncor				
Powerhouse (211 t/d)	9	7.1	11	13.9
Incinerator (35 t/d) (before SuperClaus)	12	2.2	7	4.8
Incinerator (17 t/d) (after SuperClaus)	5	2.2	3	9.2
Syncrude				
Main stack (213 t/d)	2	7.1	8	45.5
SOLV-EX				
Bitumount (2.14 t/d)	1	51.0	1	46.5
Ruth Lake (1.44 t/d)	5	4.0	0.5	5.9

The air quality guideline for SO_2 is 30 $\mu g/m^3$ (0.01 ppm) as an annual average.

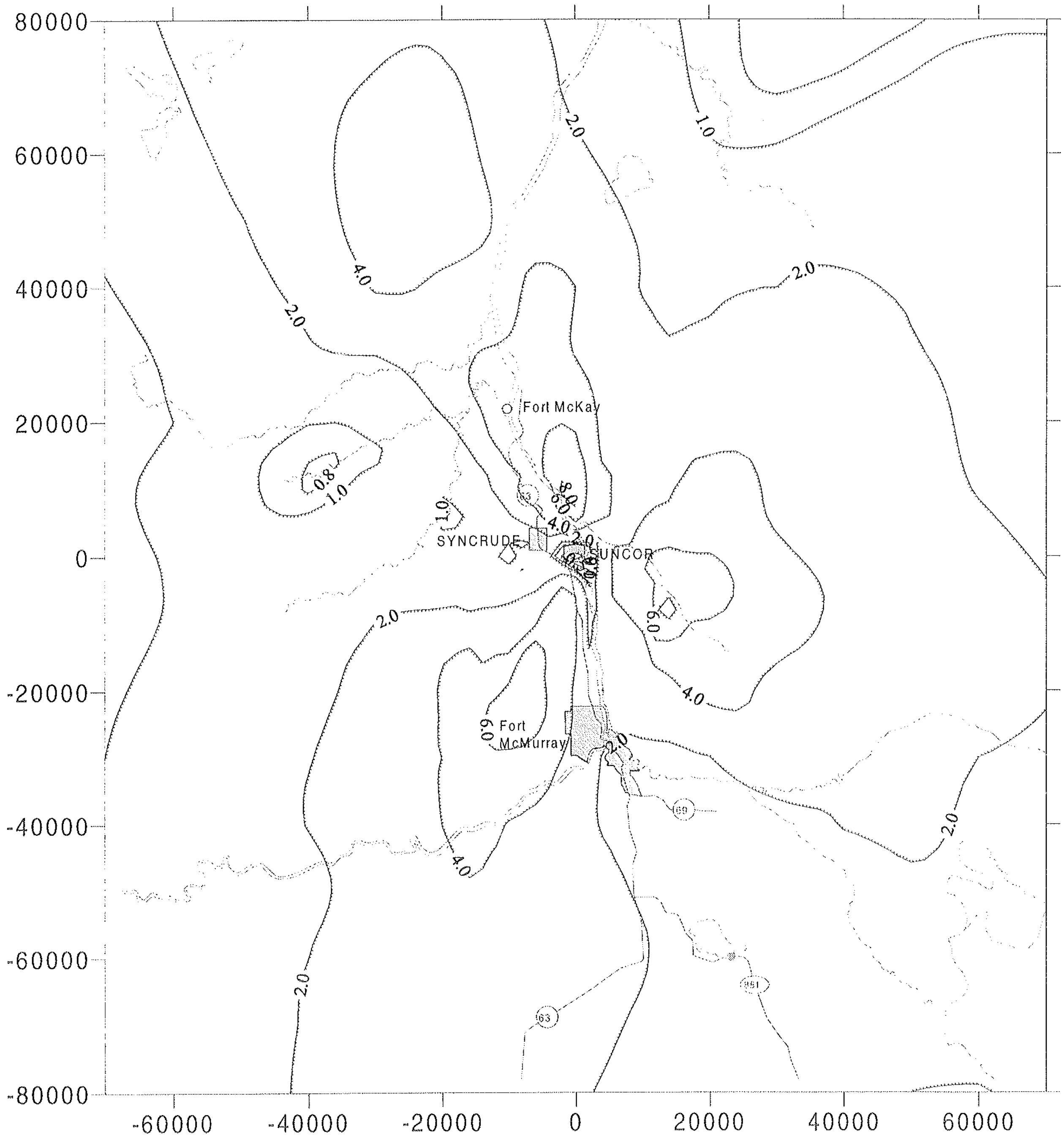


Figure 4.8 Predicted annual average SO_2 concentration ($\mu g/m^3$) resulting from the operation of the **Suncor Powerhouse** (SO_2 emissions = 211 t/d) (ISC3BE model).

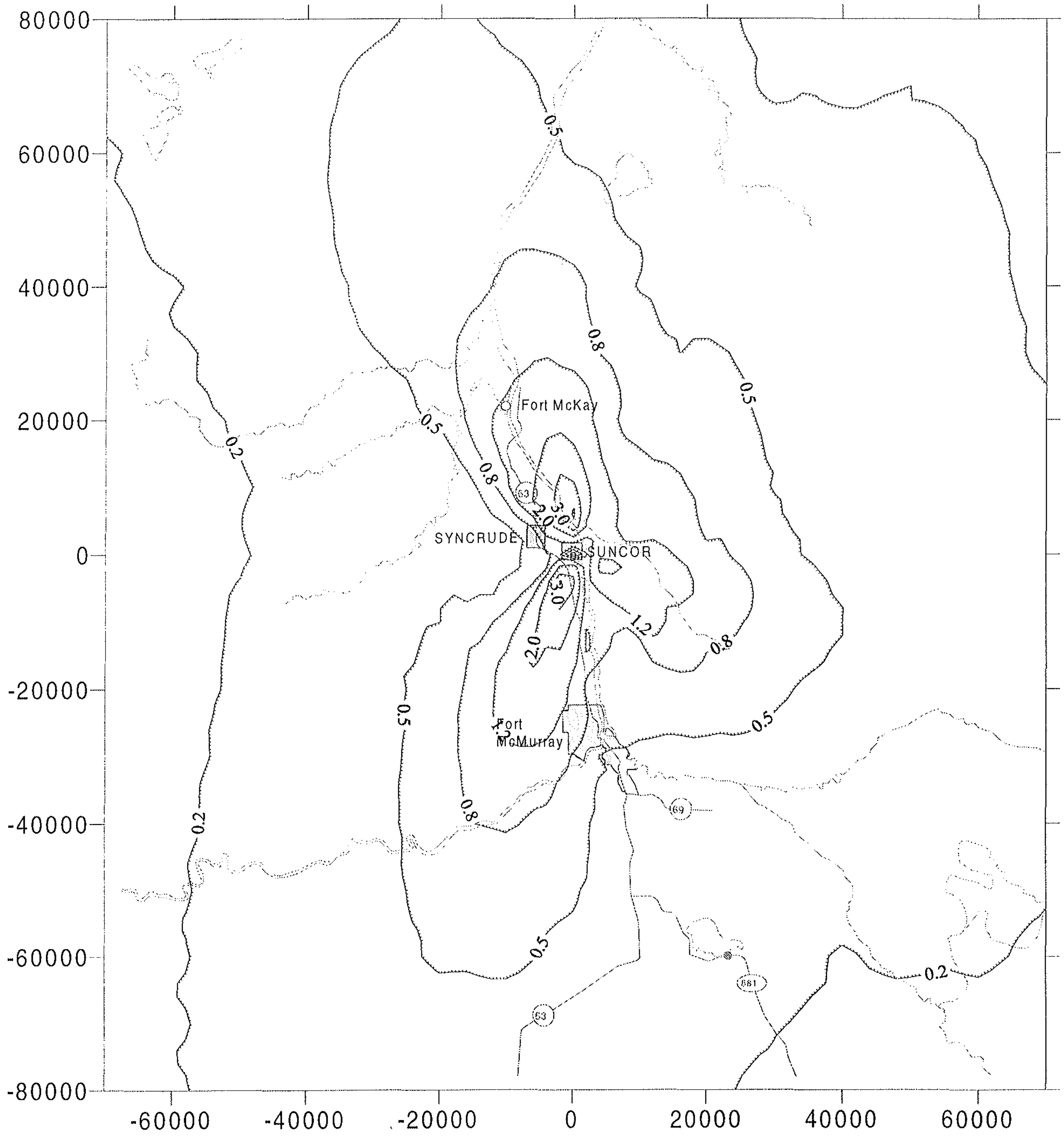


Figure 4.9 Predicted annual average SO_2 concentrations ($\mu g/m^3$) resulting from the operation of the **Suncor Incinerator (after SuperClaus)** (SO_2 emissions = 17 t/d) (ISC3BE model).

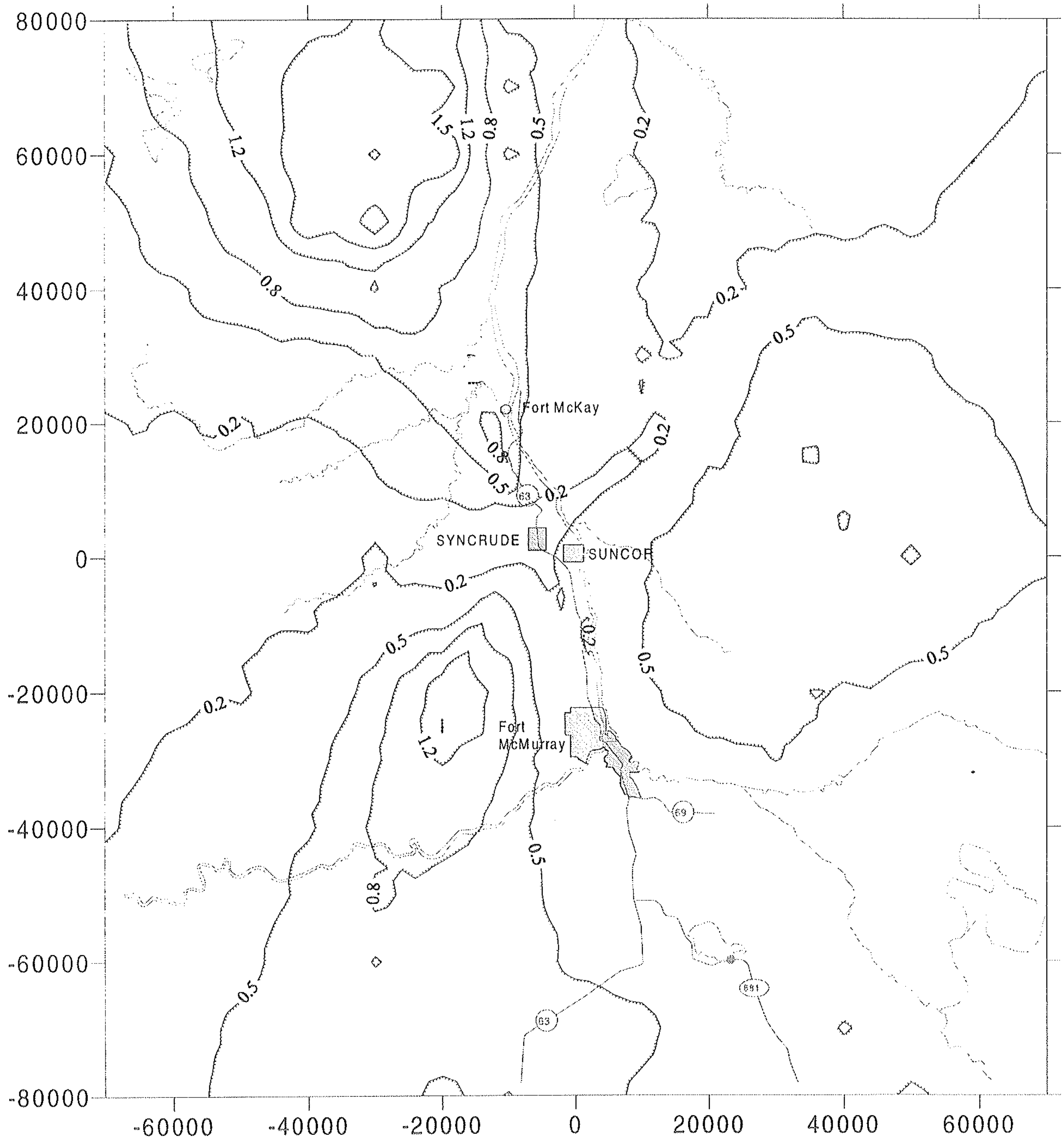


Figure 4.10 Predicted annual average SO_2 concentrations ($\mu g/m^3$) resulting from the operation of the **Syncrude Main stack** (SO_2 emissions = 213 t/d) (ISC3BE Model).

respectively. High annual average values are predicted to occur over Thickwood Hills and Muskeg Mountain for emissions from the Suncor Powerhouse and the Syncrude Main stack.

4.1.4 *Continuous Flaring*

While the operation of the previously identified sources (Suncor Powerhouse, Suncor Incinerator, Syncrude Main) are responsible for most of the SO_2 emissions in the region, there are other minor sources from these facilities. In particular, Suncor releases 2 to 3 t/cd of SO_2 on a continuous basis from the hydrocarbon flare. The continuous flaring disposes of gas streams from the 5C18, 7C28 and 10C23 units which contain H_2S. Gas streams from the 7C28 and 10C23 units are flared at a uniform rate over the course of the day, whereas gas from the 5C18 unit is flared during four one-half hour periods during the day (2 h/d).

For the purposes of completeness, the SCREEN3 model was used to estimate ambient SO_2 concentrations that could result from this continuous flaring. The following table summarizes the application of the SCREEN3 model to this flaring:

Unity **SO_2 Emission Rate** **Total Heat Release**	 **(cal/s)**	**Two Units** **0.8 t/d** **198,046**	**All Three** **0.75 t/h** **5,654,214**
SO_2 concentrations	(µg/m^3)	83	440
PG Classes		A	A
Wind speed	(m/s)	1.0	1.5
Distance	(km)	0.5	1.0

The heat release is the product of the total flow rate of the gas streams to the flare (m^3/d) and the heat content of these gas streams (MJ/m^3). The product is expressed in units of "cal/s" to be consistent with the input requirements of SCREEN3 for evaluating flare stacks. The results indicate higher SO_2 concentrations are associated with the shorter duration, higher SO_2 emission period.

4.2 Intermittent Sources (Individual Operations)

The facilities identified in Table 4.1 have intermittent SO_2 emissions that are associated with plant start-up, shut-down or upset (abnormal) activities. Intermittent SO_2 emissions result from flaring operations at both plants and diverter stack operations at Syncrude only. The emission parameters associated with flaring operations are summarized in Table 4.6 and those associated with diverter stack operators are summarized in Table 4.7. As the diverter stack is also a source of other sulphur compounds, these are also indicated in Table 4.7.

Table 4.6 Maximum one-hour average SO_2 concentrations associated with intermittent flaring at the Suncor and Syncrude facilities.

Source of SO_2 Emissions	SO_2 Emission (t/h)	Heat Release (cal/s)	SCREEN3 Predictions			
			SO_2 (µg/m^3)	PG Class	Wind Speed (m/s)	Distances (km)
Intermittent Suncor: (Stack Height: 99 m)						
5C10 (Coker Fractionation)	7.22	110,824,846	554	A	3.0	1.4
5C13/5C15 (Butane)	0.10	n/a	n/a	n/a	n/a	n/a
5C14 (Plant 5 HP sour gas)	1.00	6,162,657	557	A	1.5	1.0
7C3 (Plant 7 HP sour gas)	0.05	444,175	94	A	1.0	0.6
7C4 (Plant 7 LP sour gas)	0.93	5,364,372	544	A	1.0	1.1
7C6 (Plant 7 HP sour gas)	0.31	835,304	518	A	1.0	0.8
7C12 (Plant 7 HP sour gas)	0.12	686,696	202	A	1.0	0.7
7C13 (Plant 7 HP sour gas)	0.82	1,935,526	1111	A	1.0	0.8
7C15 (Plant 7 HP sour gas)	0.83	1,092,201	1333	A	1.0	0.8
7C24 (Plant 7 HP sour gas)	0.95	4,511,238	639	A	1.0	1.0
7C26 (Plant 7 HP sour gas)	1.24	1,984,920	1650	A	1.0	0.8
8C4 (Acid gas)	9.62	5,354,374	5633	A	1.0	111
Intermittent Syncrude: (Stack Height: 71.6 m)						
Cokers (Plant 8)	1.12	32,484,560	203	A	2.0	1.2
Amine Plants (Plant 11)	5.67	19,252,830	1517	A	2.0	1.1
Sulphur Recovery Plants (12)	1.30	11,289,590	506	A	1.5	1.1
Naphtha Hydrotreaters (13)	0.37	7,393,840	203	A	1.5	1.0
Gas-Oil Hydrotreaters (15)	0.66	18,282,670	178	A	2.0	1.1
Sour Water Plants (16)	0.37	3,017,060	373	A	1.0	0.9
Light Gas-Oil Hydrotreaters (18)	0.08	4,235,220	61	A	1.0	1.0
LC-Finer (Plant 22)	0.06	16,454,580	18	A	1.5	1.2

HP = high pressure
LP = low pressure

Table 4.7 Maximum one-hour average SO_2 and TRS concentrations associated with the Syncrude diverter stack[a].

Emission Case	Emission	Rate (t/sd)	SCREEN3 Predictions			
			Concentration (µg/m³)	PG Class	Wind Speed (m/s)	Distance (km)
Coker overhead only[b]	SO_2	6.6	47	A	2.0	1.2
	H_2S	11.7	83	A	2.0	1.2
	COS	14.4	102	A	2.0	1.2
	CS_2	0.26	2	A	2.0	1.2
Combined gas[c]	SO_2	1.93	13	A	2.0	1.3
	H_2S	3.1	21	A	2.0	1.3
	COS	4.9	33	A	2.0	1.3
	CS_2	0.10	1	A	2.0	1.3

(a) Stack height = 73.2 m
Stack diameter = 3.7 m

(b) Exit velocity = 26.5 m/s
Exit temperature = 600°C

(c) Exit velocity = 30.6 m/s
Exit temperature = 500°C

The SCREEN3 model was used to estimate maximum one-hour average SO_2 concentrations that could result from these sources and the results are also presented in Tables 4.6 and 4.7. Given the short duration of these emissions, only maximum hourly values were predicted. The results can be summarized as:

- Maximum predicted hourly values can range up to 5623 $\mu g/m^3$ (2.1 ppm) given the simultaneous occurrence of flaring and the worst case meteorological conditions for the case of flaring acid gas at Suncor (Unit 8C4).
- For other flaring cases, the maximum predicted hourly values range from 18 $\mu g/m^3$ (0.07 ppm) to 1650 $\mu g/m^3$ (0.62 ppm) given the simultaneous occurrence of flaring and the worst case meteorological conditions.
- Worst case meteorological conditions are day time summer periods under strong solar heating conditions (PG stability class A).
- Maximum values associated with flaring under these conditions occur between 630 to 1409 m from the respective flare stacks.

Although flaring is intermittent and of limited duration, flaring under certain meteorological conditions can result in relatively large short-term SO_2 concentrations.

For the Syncrude diverter stack the following are noted:

- Maximum predicted SO_2 and H_2S concentrations are 47 $\mu g/m^3$ (0.02 ppm) and 83 $\mu g/m^3$ (0.06 ppm), respectively.
- Maximum values are associated with daytime summer periods under strong solar radiation (PG stability class A) at the downwind distance of 1.2 to 1.3 km.

The resulting maximum H_2S concentrations exceed the odour threshold and therefore can be a source of odours.

4.3 Continuous Sources (Combined Operation)

The combined operation of the continuous SO_2 sources was evaluated for the two following emission cases:

SO_2 Emissions (t/d)	1994		1995	
Stack	**Average**	**Maximum**	**Average**	**Maximum**
Suncor Powerhouse	211	259	211	259
Suncor Incinerator	35	51	17	26
Syncrude Main	213	292	213	292

The difference between the 1994 and 1995 emission scenarios reflects the implementation of SuperClaus unit. The 1995 maximum daily SO_2 emission from the incinerator was selected as being one-half the value from the 1994 case.

Table 4.8 presents the maximum hourly average, daily average and annual average SO_2 concentrations for these emission scenarios. The corresponding hourly, daily and annual average concentration contour plots are shown in Figures 4.11, 4.12, 4.13 and 4.14, respectively. The figures only depict the concentrations that correspond to the average emission case.

The figures are similar to the previous figures shown for the Suncor Powerhouse confirming it as the most significant contributor to maximum concentrations that could occur in the region. The high values are predicted to occur over the elevated terms associated with Thickwood Hills to the southwest and with Muskeg Mountain to the east.

Figure 4.14 shows the frequency the 450 $\mu g/m^3$ guideline are exceeded for the 1995 average emission case. The ISC3BE model predicts SO_2 concentrations in excess of the 450 $\mu g/m^3$ guideline are exceeded for more than 20 hours per year over the elevated terrain associated with the Muskeg Mountain to the east of Suncor and Thickwood Hills to the southwest of Suncor and Syncrude.

4.4 Comparison with Ambient Air Quality Guidelines

The provincial and federal ambient air quality guidelines ($\mu g/m^3$) are summarized as:

Averaging Period	1 Hour	1 Day	Annual
Alberta	450	150	30
Federal Desirable	450	150	30
Federal Acceptable	900	300	60
Federal Tolerable	-	800	-

In comparing the model predictions presented in this section to the guidelines, the following are noted:

- **Suncor Powerhouse:** Maximum predicted concentrations are in the 1200 to 2200 $\mu g/m^3$ (0.45 to 0.83 ppm) range. This compares to maximum concentrations observed at Suncor's air quality monitoring stations that range from 0.31 to 0.60 ppm. These hourly values are clearly in excess of the provincial and federal guidelines. The 450 $\mu g/m^3$ guideline is predicted to be exceeded up to about 34 times per year (based on average emissions) (Table 4.2).

Table 4.8 Maximum predicted SO_2 concentrations resulting from the combined operation of the SO_2 emission sources in the region.

Emission Scenario	1994		1995	
SO_2 Emission	**Average**	**Maximum**	**Average**	**Maximum**
Hourly Average				
Maximum SO_2 ($\mu g/m^3$)	1492	1947	1279	1626
Location (km/deg)	18.8 / 66	18.8 / 66	23.6 / 216	23.6 / 216
N > 450 $\mu g/m^3$	43	67	37	49
Location (km/deg)	14.3 / 102	8.1 / 97	14.1 / 98	14.1 / 98
Daily Average				
Maximum SO_2 ($\mu g/m^3$)	280	359	246	311
Location (km/deg)	25.6 / 231	25.6 / 231	25.6 / 231	25.6 / 231
N > 150 $\mu g/m^3$	2	6	1	3
Location (km/deg)	2.2 / 207	7.1 / 352	14.1 / 98	16.8 / 107
Annual Average				
Maximum SO_2 ($\mu g/m^3$)	17	24	12	16
Location (km/deg)	7.1 / 352	7.1 / 352	7.1 / 352	7.1 / 352

Hourly Guideline 450 $\mu g/m^3$
Daily Guideline 150 $\mu g/m^3$
Annual Guideline 30 $\mu g/m^3$

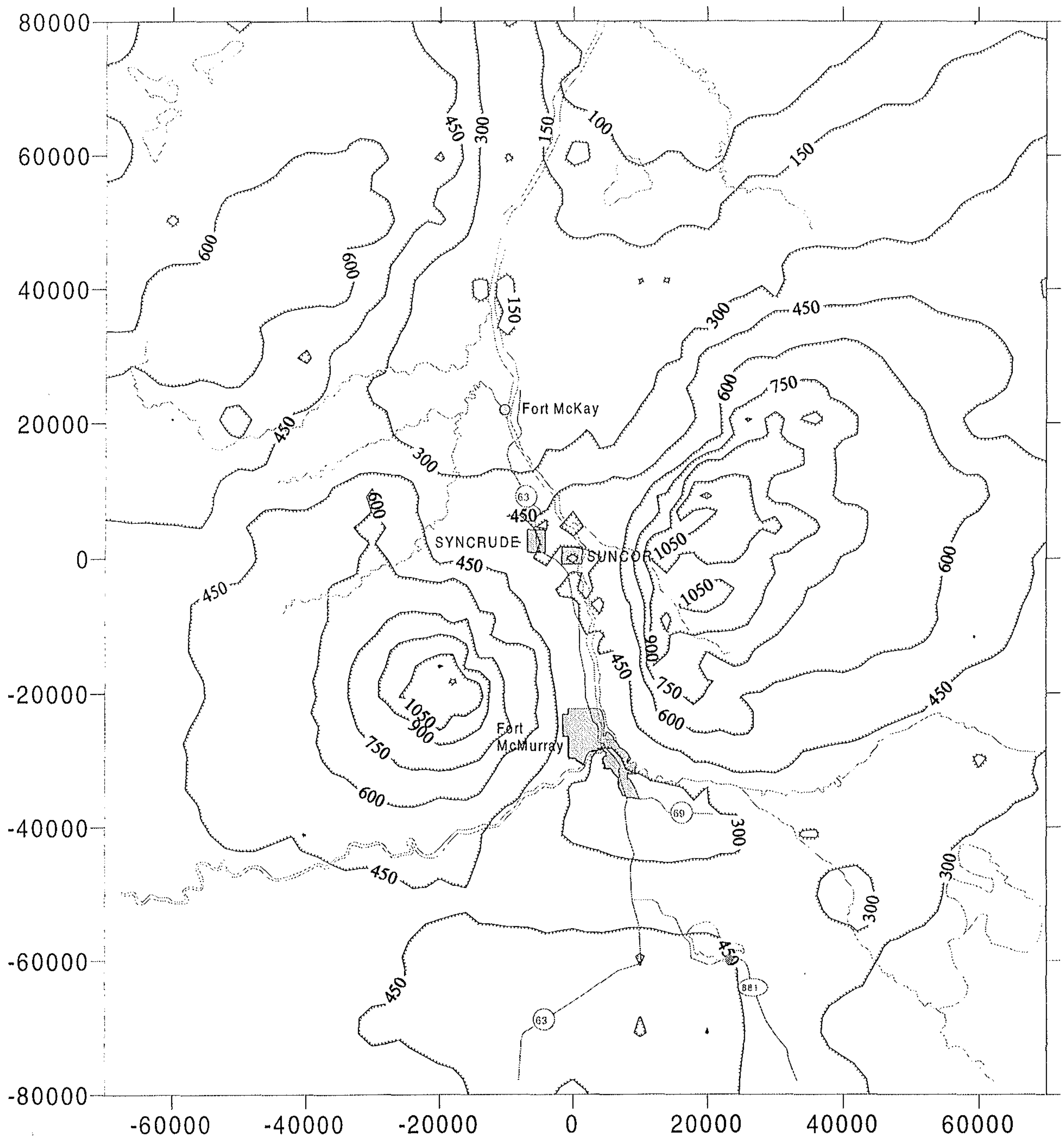


Figure 4.11 Maximum predicted hourly average SO_2 concentration ($\mu g/m^3$) resulting from the **combined operation** of the Suncor and Syncrude facilities (1995 average SO_2 emissions).

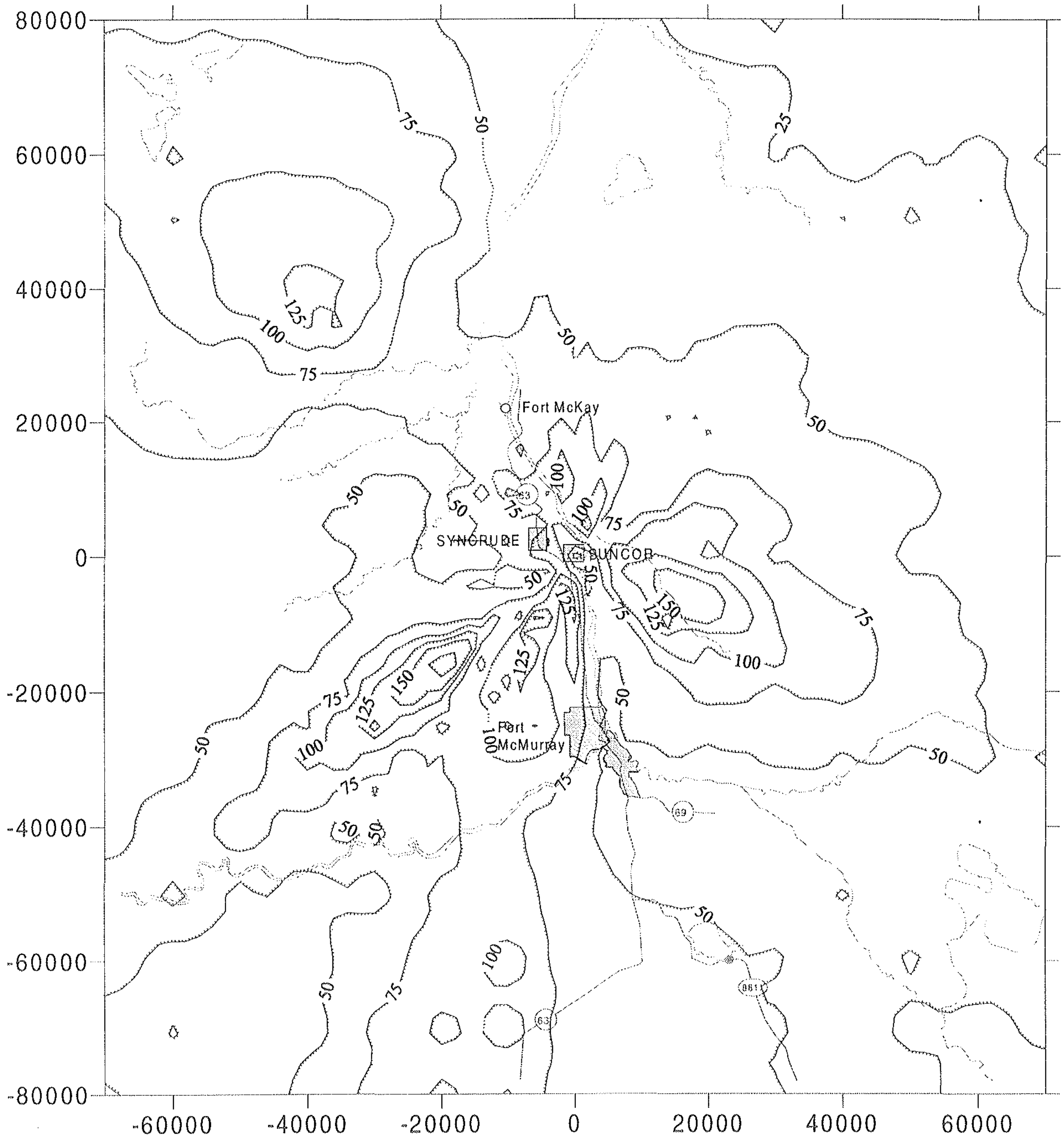


Figure 4.12 Maximum predicted daily average SO_2 concentration ($\mu g/m^3$) resulting from the **combined operation** of the Suncor and Syncrude facilities (1995 average SO_2 emissions).

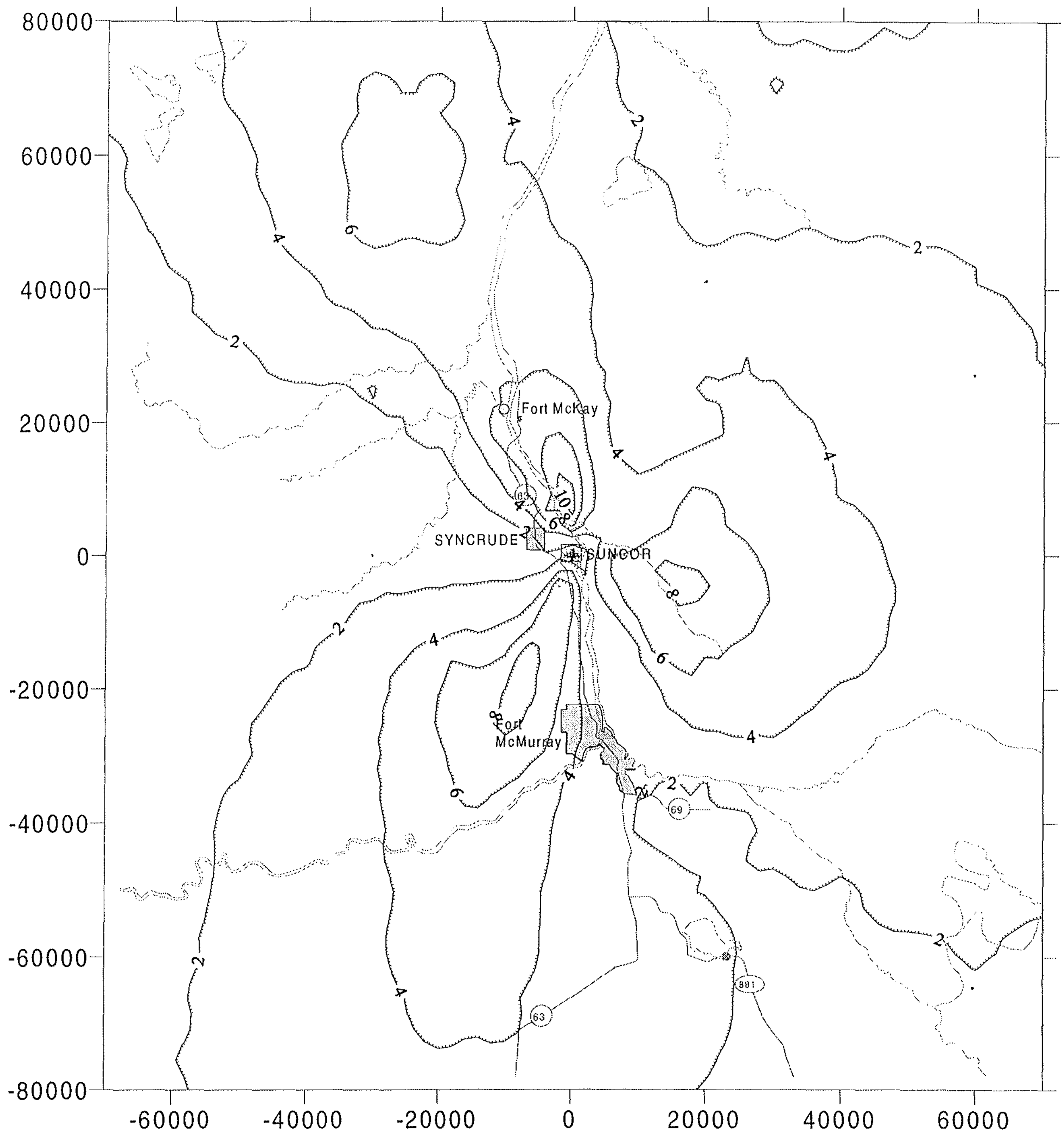


Figure 4.13 Predicted annual average SO_2 concentration ($\mu g/m^3$) resulting from the **combined operation** of the Suncor and Syncrude facilities (1995 average SO_2 emissions).

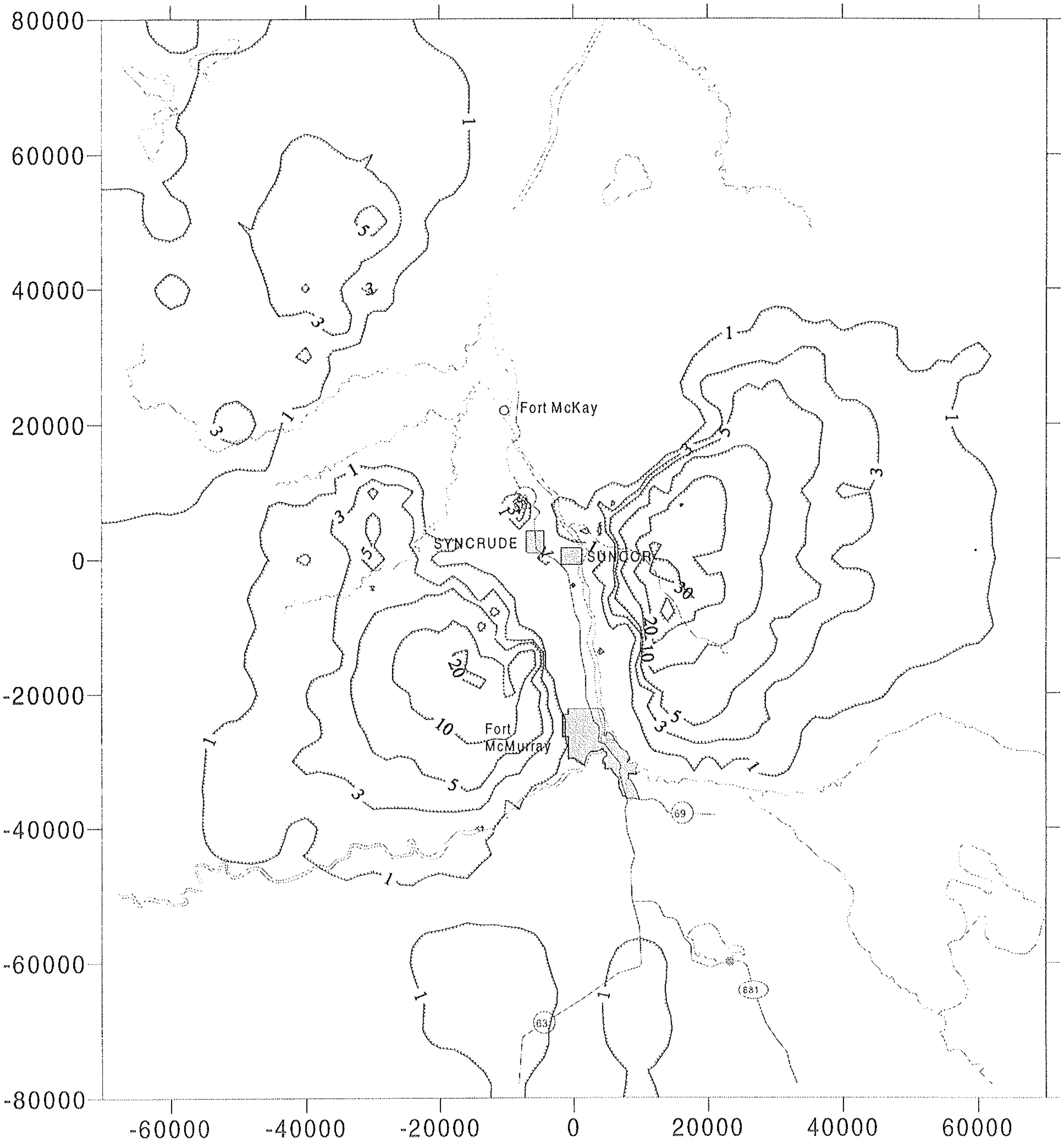


Figure 4.14 Predicted frequencies of exceeding the 450 $\mu g/m^3$ guideline (h/a) from the **combined operation** of the Suncor and Syncrude facilities (1995 average SO_2 emissions). Values have been normalized for a 12 month period.

- **Suncor Incinerator:** Maximum predicted concentrations before SuperClaus are in the 700 to 1700 $\mu g/m^3$ (0.26 to 0.64) range. With the implementation of SuperClaus, the corresponding maxima are in the 340 to 670 $\mu g/m^3$ (0.13 to 0.25 ppm) range. The values prior to SuperClaus are in excess of the provincial and federal hourly guidelines. The addition of SuperClaus reduces the maximum predicted values by a factor of two. These exceedences of the 450 $\mu g/m^3$ guideline per year are predicted prior to SuperClaus and no exceedences are predicted after the implementation of SuperClaus (based on average emissions). Under upset conditions, with the simultaneous occurrence of adverse meteorological conditions, exceedences may result from the post SuperClaus operation (Table 4.2).

- **Syncrude Main Stack:** Maximum predicted concentrations are in the 322 to 1223 $\mu g/m^3$ (0.12 to 0.46 ppm) range. The larger predicted values are associated with the SCREEN3 model and upset conditions. The ISCS3BE model predicts that one exceedence of the 450 $\mu g/m^3$ guideline could occur under upset conditions (Table 4.3).

- Relatively large SO_2 concentrations are predicted to occur on the elevated terrain to the east of Suncor (Muskeg Mountain) and to the southwest of Suncor (Thickwood Hills). These maximum values result from the Suncor Powerhouse stack and are in excess of the 900 $\mu g/m^3$ Federal air quality objectives (Figure 4.2). Similarly, relatively large daily average maxima are predicted to occur in the same areas due to the operation of the Powerhouse stack (Figure 4.5).

- Maximum daily SO_2 concentrations are predicted to exceed the 150 $\mu g/m^3$ guideline due to the operation of the Suncor Powerhouse and the Incinerator (before SuperClaus). The number of exceedences range from 1 to 4 days per year. The implementation of SuperClaus and the operation of Syncrude Main stack result in maximum predicted SO_2 concentrations in the 40 to 104 $\mu g/m^3$ range; these are less than the guideline values of 150 $\mu g/m^3$ (Table 4.4).

- Maximum annual average concentrations from the indirect operation of all continuous stacks are predicted to be less than the 30 $\mu g/m^3$ objectives (Table 4.5).

- Maximum hourly average concentrations resulting form the continuous flaring at the Suncor facilities are less than the 450 $\mu g/m^3$ guideline (Section 4.1.4).

- Intermittent flaring at the Suncor facilities can result in SO2 concentrations that exceed the 450 and 900 $\mu g/m^3$ guideline (Table 4.6).

- Intermittent flaring and at the Syncrude facilities can result in SO2 concentrations that exceed the 450 and 900 $\mu g/m^3$ guideline (Table 4.6).

- While the operation of the Syncrude diverter stack can result in SO_2 concentrations that are much less than the 450 $\mu g/m^3$ guideline, associated H_2S concentrations are in excess of the 14 $\mu g/m^3$ guideline (Table 4.7)

- The combined operation of the three major sources (Suncor Powerhouse, Suncor Incinerator (after SuperClaus) and Syncrude Main) is predicted to result in a maximum of 37 to 67 hourly exceedences of the 450 $\mu g/m^3$ and 1 to 6 daily exceedences of the 150 $\mu g/m^3$ guideline. The maximum predicted annual average concentrations for the combined operation is predicted to range from 12 to 24 $\mu g/m^3$ which is less than the 30 $\mu g/m^3$ annual guideline.

The predicted concentrations in these dispersion modelling estimates do not include background SO_2 values. The estimated winter and summer background levels are 3.8 and 1.0 $\mu g/m^3$, respectively. As these values are much less than those predicted for the area, not including them will not affect any conclusions drawn.

In summary, the largest SO_2 concentrations are associated with intermittent flaring which occurs on an intermittent basis and with the Suncor Powerhouse whose emissions are continuous.

5.0 PREDICTED DEPOSITION

The uptake of sulphur compounds by surface features provides another measure of air quality. This uptake that represents the removal of pollutants by vegetation, soil and water surfaces is often referred to as deposition. Deposition can involve the action of precipitation (**wet deposition**) through two processes:

- **Washout** occurs when rainfall intercepts a plume and gases and particulates in the plume are dissolved or adsorbed in the rain droplet.

- **Rainout** occurs when particles in the plume act as condensation nuclei on which rain droplets form.

Other deposition processes do not involve precipitation and are referred to as **dry deposition**. Dry deposition is the adsorption of gases and particulates directly to surfaces of vegetation, exposed soils and water bodies. In terms of potential acidification of terrestrial and/or aquatic systems, wet deposition delivers acidic compounds directly to the surface in short, intermittent rainfall events. In contrast, dry deposition relies on surface chemical or biological reactions to convert the deposited compounds to acidic species.

5.1 Method for Estimating Dry Deposition

The most common way to estimate dry deposition is through the use of the following relationship:

$$D_d = V_d \chi$$

where χ = ambient concentration at the surface ($\mu g/m^3$)
V_d = deposition velocity (m/s)
D_d = dry deposition ($\mu g/m^2/s$)

Alternatively, D_d can also be expressed in kg/ha/a through the use of the appropriate conversion factors. The estimation of dry deposition is therefore a two part exercise as follows:

- Provide estimates of the ambient concentrations above the canopy.

- Provide estimates of the deposition velocity in order to convert the concentration to a deposition flux.

For large particles, the deposition velocity is analogous to a settling velocity. For small particles and gases, the deposition velocity incorporates three components:

- An atmospheric turbulence component that provides a measure of turbulence required to ensure the pollutant is brought in contact with the surface feature.

- A boundary-layer component that looks at the transfer of pollutants across surface boundary layers (~ a few mm).

- An adsorption component that characterizes the reactivity of the surface once the component is brought in contact with the surface.

The deposition velocities will therefore be dependent on meteorological conditions, receptor conditions and pollutant. The deposition velocity concept while simple in application, incorporates complex physical, chemical and biological interactions. Deposition velocities can be based on empirical measurements or on theoretical understandings. The values reported on the literature can cover two orders of magnitude.

5.1.1 *SO_2 Deposition Velocity*

Deposition velocities have to account for different meteorological conditions, seasonal variations and differing receptor types. The following tables present deposition velocities that have been used for estimating deposition of SO_2:

- Table 5.1 summarizes the deposition velocities for different stability classes and season for a coniferous forest canopy. These are the internal values used by ADEPT2. As the deposition velocity depends on wind speed, the values shown are the ranges that correspond to a given stability class. Dry deposition for precipitation periods are large since the surface is assumed to be a perfect adsorber of SO_2.

- Table 5.2 summarizes the deposition velocities for an ungrazed forest canopy. These values were used by the RELMAP model in its application to Alberta (Cheng and Angle 1993).

- Table 5.3 summarizes the deposition velocities for a forest canopy. These values were selected using similar approaches to those in Table 5.1 except conservative assumptions were made to produce slightly larger values.

Tables 5.1, 5.2 and 5.3 also show the default values specified by Alberta Environment (1988) prior to the approach used in Table 5.1. The Alberta Environment 1988 approach also provided a single default value of 0.8 cm/s for all conditions. This compares to the single default value of 0.7 cm/s used by Peake and Davidson (1990) for their assessment of deposition in Alberta.

In general, the largest deposition velocities are associated with daytime and spring/summer conditions. The smaller values are associated with nighttime and winter values. The deposition velocities vary by a factor of two or more which would affect the estimation of dry deposition by a similar factor.

Table 5.1 SO_2 deposition velocities (cm/s) used by the ADEPT2 model for coniferous forest canopies.

Dry Periods

Stability Class	Spring	Summer	Fall	Winter	AEP (1988)
A	0.55 to 0.66	0.25 to 0.27	0.12 to 0.13	0.19 to 0.20	2.0
B	0.36 to 0.41	0.22 to 0.23	0.12 to 0.13	0.19 to 0.20	1.6
C	0.33 to 0.41	0.21 to 0.23	0.12	0.18 to 0.20	1.4
D	0.23 to 0.25	0.21 to 0.25	0.10 to 0.11	0.19 to 0.20	0.8
E	0.09 to 0.10	0.05 to 0.11	0.09 to 0.11	0.16 to 0.20	0.4
F	0.08 to 0.10	0.09 to 0.11	0.10 to 0.11	0.14 to 0.20	0.2

Comments: Largest values are associated with stability class A spring conditions (> 0.5 m/s). Nighttime values (E and F) are in the 0.05 to 0.20 cm/s range. Daytime values (A, B and C) are in the 0.12 to 0.66 cm/s range. Winter values are near constant at about 0.19 cm/s.

Precipitation Periods

Stability Class	All Seasons	AEP (1988)
A	3.1 to 38.5	2.0
B	2.6 to 32.2	1.6
C	1.6 to 20.7	1.4
D	3.3 to 16.5	0.8
E	0.9 to 11.5	0.4
F	0.4 to 5.5	0.2

Comments: The same values are used for all seasons since canopy resistance is assumed to be zero when wet and hence a "perfect" adsorber of SO_2.

Table 5.2 SO_2 deposition velocities (cm/s) used by the RELMAP model for ungrazed forest and woodlands.

Stability Class	Spring	Summer	Fall	Winter	AEP (1988)
A	0.85	0.85	0.65	0.40	2.0
B	0.85	0.85	0.65	0.40	1.6
C	0.85	0.85	0.65	0.40	1.4
D	0.35	0.35	0.25	0.15	0.8
E	0.05	0.05	0.05	0.05	0.4
F	0.07	0.07	0.07	0.07	0.2

Comments: Largest values associated with stability classes A, B and C spring and summer conditions (0.85 cm/s). Nighttime values (E and F) are 0.05 to 0.07 cm/s. Daytime values (A, B and C) are in the 0.40 to 0.85 cm/s range.

Table 5.3 SO_2 deposition velocities (cm/s) used for forested regions in Alberta (Concord Scientific 1989).

Stability Class	Spring	Summer	Fall	Winter	AEP (1988)
A	1.0	1.5	1.0	0.2	2.0
B	0.5	0.7	0.5	0.2	1.6
C	0.3	0.4	0.3	0.2	1.4
D	0.3	0.3	0.3	0.2	0.8
E	0.2	0.2	0.2	0.2	0.4
F	0.2	0.2	0.2	0.2	0.2

Comments: Largest values associated with summer stability class A (1.5 cm/s). Daytime values (A, B and C) are in the 0.3 to 1.5 cm/s range. Nighttime values (E and F) are 0.2 cm/s.

5.1.2 *SO_4^{-2} Deposition Velocity*

The dry deposition velocity for SO_4^{-2} (sulphate) is much smaller than that for SO_2. Table 5.4 summarizes the values used in the ADEPT2 and RELMAP models. These values compare to those used by Peake and Davidson (1990) of 0.1 cm/s for fine (less than 2.5 μm) sulphate particulates and 2 cm/s for course (greater than 2.5 μm) sulphate particulates. The split between fine and coarse particulates are about 80% (fine) and 20% (coarse).

Again, there is a range in the SO_4^{-2} deposition velocities. However, near the source, the affect of varying dry deposition is not expected to have a significant effect on overall deposition as most of the sulphate is in the SO_2 form.

5.2 Method for Estimating Wet Deposition

The ADEPT2 model estimates wet removal using the reversible scavenging approach that addresses only washout. The approach for SO_2 is as follows:

$$D_w = W \cdot I \cdot \chi$$

where:
- χ = ambient SO_2 concentrations ($\mu g/m^3$)
- I = precipitation intensity (m/s)
- W = scavenging coefficient
- D_w = wet deposition ($\mu g/m^2/s$)

Again, D_w is usually expressed in units of kg/ha/a. Since scavenging by snow is negligible, wet deposition during the winter is assumed to be zero.

For SO_4^{-2} the approach is:

$$D_w = \Lambda\,(H)\,\chi$$

where:
- Λ = scavenging ratio (s^{-1})
- H = depth of layer in which pollutants are mixed (m)
- χ = ambient SO_4^{-2} concentrations

The deposition approach used by ADEPT2 was not varied.

Table 5.4 SO_4^{-2} deposition velocities (cm/s) used by the ADEPT2 and RELMAP models for coniferous forest canopies.

Stability Class	ADEPT2	RELMAP			
		Spring	**Summer**	**Fall**	**Winter**
A	0.53 to 1.0	0.40	0.50	0.40	0.25
B	0.27 to 1.0	0.40	0.50	0.40	0.25
C	0.11 to 1.0	0.40	0.50	0.40	0.25
D	0.08 to 0.41	0.40	0.50	0.40	0.25
E	0.03 to 0.34	0.35	0.45	0.35	0.20
F	0.02 to 0.22	0.07	0.07	0.07	0.07

5.3 Dry Deposition Predictions

The ADEPT2 model was used to predict total dry deposition (SO_2 and SO_4^{-2}) for the following emission scenarios:

Source	SO_2 Emissions (t/d)
Suncor Powerhouse	211
Suncor Incinerator	17
Syncrude Main	213
Combined	211 + 17+ 213

Three sets of deposition velocities were used for the initial sensitivity evaluation:

	SO_2 dry	SO_2 wet	SO_4 dry
ADEPT2	Table 5.1	Table 5.1	Table 5.4 (A)
RELMAP	Table 5.2	None	Table 5.4 (R)
Concord	Table 5.3	None	Table 5.4 (A)

The following table summarizes the maximum predicted dry deposition associated with the use of the three deposition velocities. The use of the larger RELMAP and Concord deposition values results in dry deposition values that are 1.5 to 1.8 times those associated with the internal ADEPT2 values.

Source	ADEPT2	RELMAP	Concord
Powerhouse	8.5	13.6	13.2
Incinerator	2.7	5.1	4.0
Main Stack	3.6	6.6	5.5
Combined	10.4	18.3	16.7

Figures 5.1, 5.2 and 5.3 show the dry deposition contour patterns for the powerhouse, the incinerator and the main stacks, respectively. The figures show the values based on the RELMAP deposition velocities. The patterns based on using the ADEPT2 deposition velocities are similar but differ in magnitude. The largest dry deposition results from the operation of the powerhouse stack.

Figure 5.4 shows the maximum dry deposition based on the combined operation of the three main stacks. The maximum value of 18.3 kg SO_4^{-2}/ha/a is predicted to occur about 20 km to the north-northwest of the Suncor Powerhouse stack. Note that the combined maximum is less than the sum of the three individual maxima since these latter values occur at different locations and are therefore not additive.

5.4 Wet Deposition Predictions

The ADEPT2 model was used to predict wet sulphate equivalent deposition for the same emission scenarios. The maximum predicted wet deposition values (expressed as kg SO_4^{-2}/ha/a) are:

Source		Wet Deposition
Powerhouse	(211 t/d)	8.2
Incinerator	(17 t/d)	4.3
Main Stack	(213 t/d)	3.2
Combined	(211 + 17 + 213 t/d)	10.0

These maximum values are about 50 to 80% of the maximum values associated with dry depositions.

Figures 5.5, 5.6, 5.7 and 5.8 show the wet deposition contour patterns for the Suncor Powerhouse, Suncor Incinerator, Syncrude Main stack and combined operations, respectively. The largest wet deposition results from the operation of the powerhouse stack. The maximum value associated with the combined operation of 10.0 kg SO_4^{-2}/ha/a is predicted to occur about 20 km to the south-southeast of the Suncor Powerhouse.

The predicted wet sulphate deposition for Fort McMurray is between 3.0 and 4.0 kg SO_4^{-2}/ha/a. This value does not include a background value. The observed Fort McMurray values range from 3.0 to 5.2 kg SO_4^{-2}/ha/a with an average of 4.9 kg SO_4^{-2}/ha/a. The observed values would include the contributions from the plants as well as a background value. The average background value based on Cree Lake data is 1.7 kg SO_4^{-2}/ha/a. One would expect the background (1.7) plus the plant contribution (3.0 to 4.0) to equal the observed (4.9). In fact, the sum equals 4.7 to 5.7 which indicates reasonable agreement with the observations.

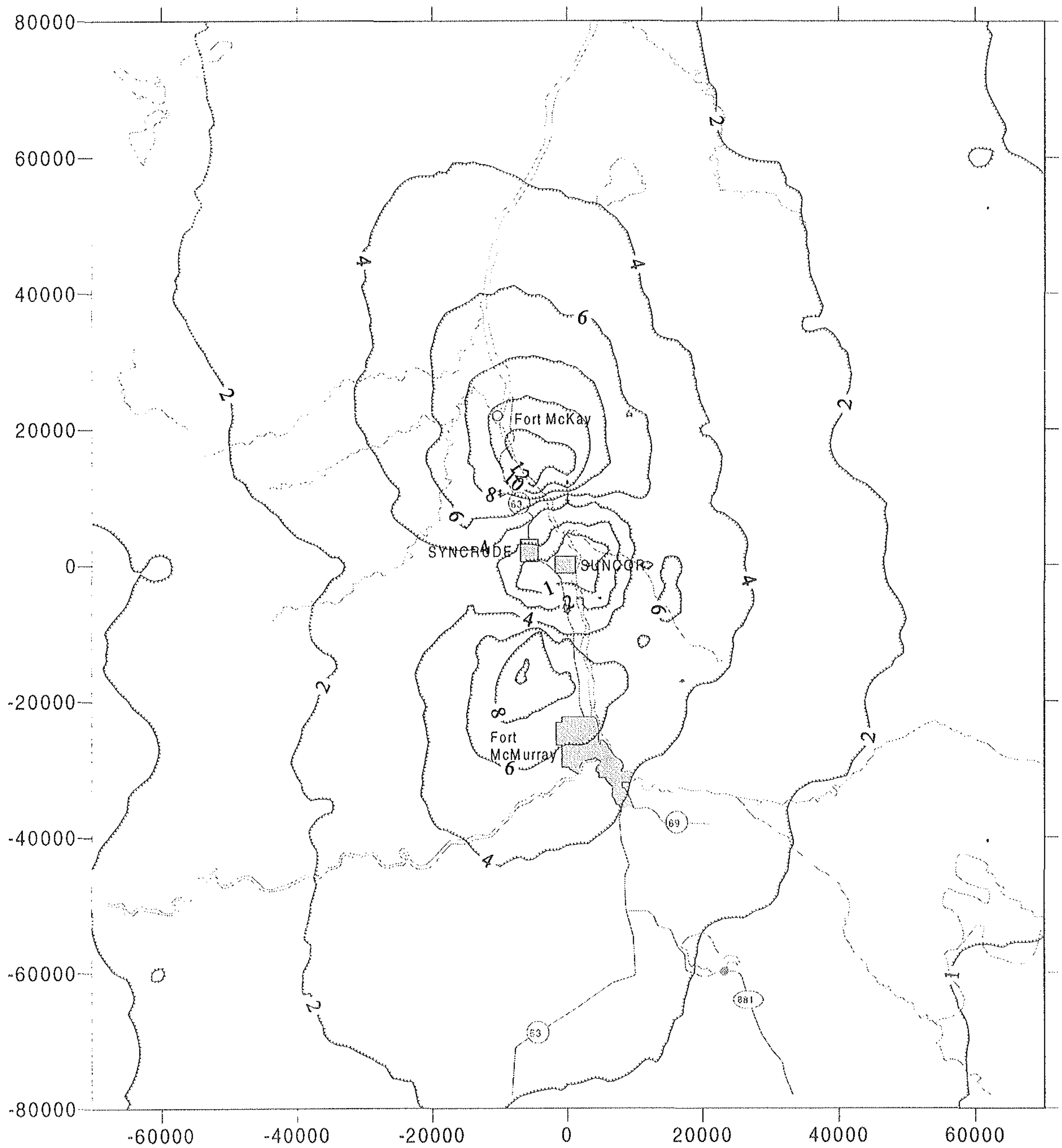


Figure 5.1 Predicted dry deposition (kg SO_4^{-2}/ha/a) from the operation of the **Suncor Powerhouse stack** (211 t/d) (RELMAP deposition velocities).

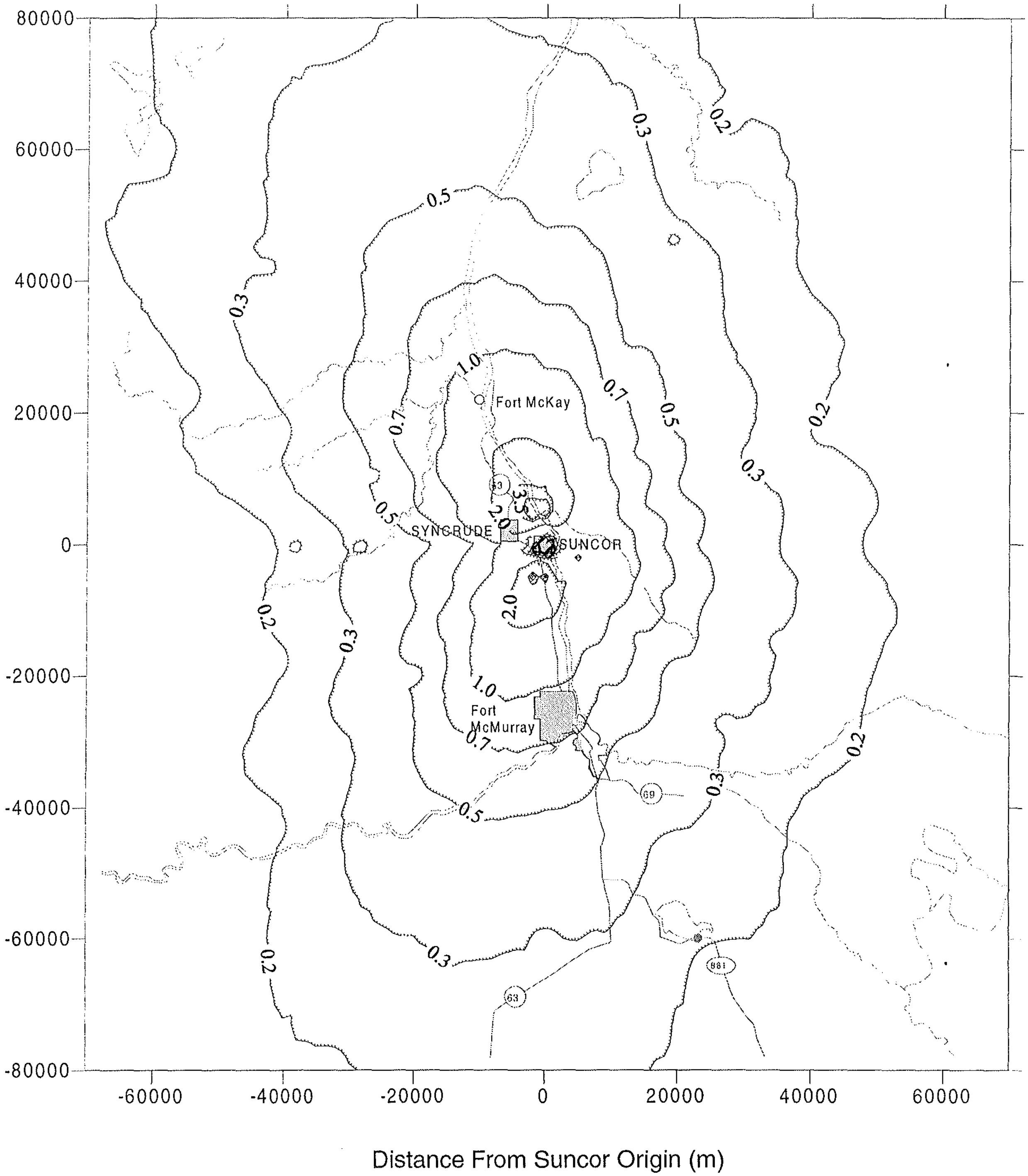


Figure 5.2 Predicted dry deposition (kg SO_4^{-2}/ha/a) from the operation of the **Suncor Incinerator stack** (17 t/d) (RELMAP deposition velocities).

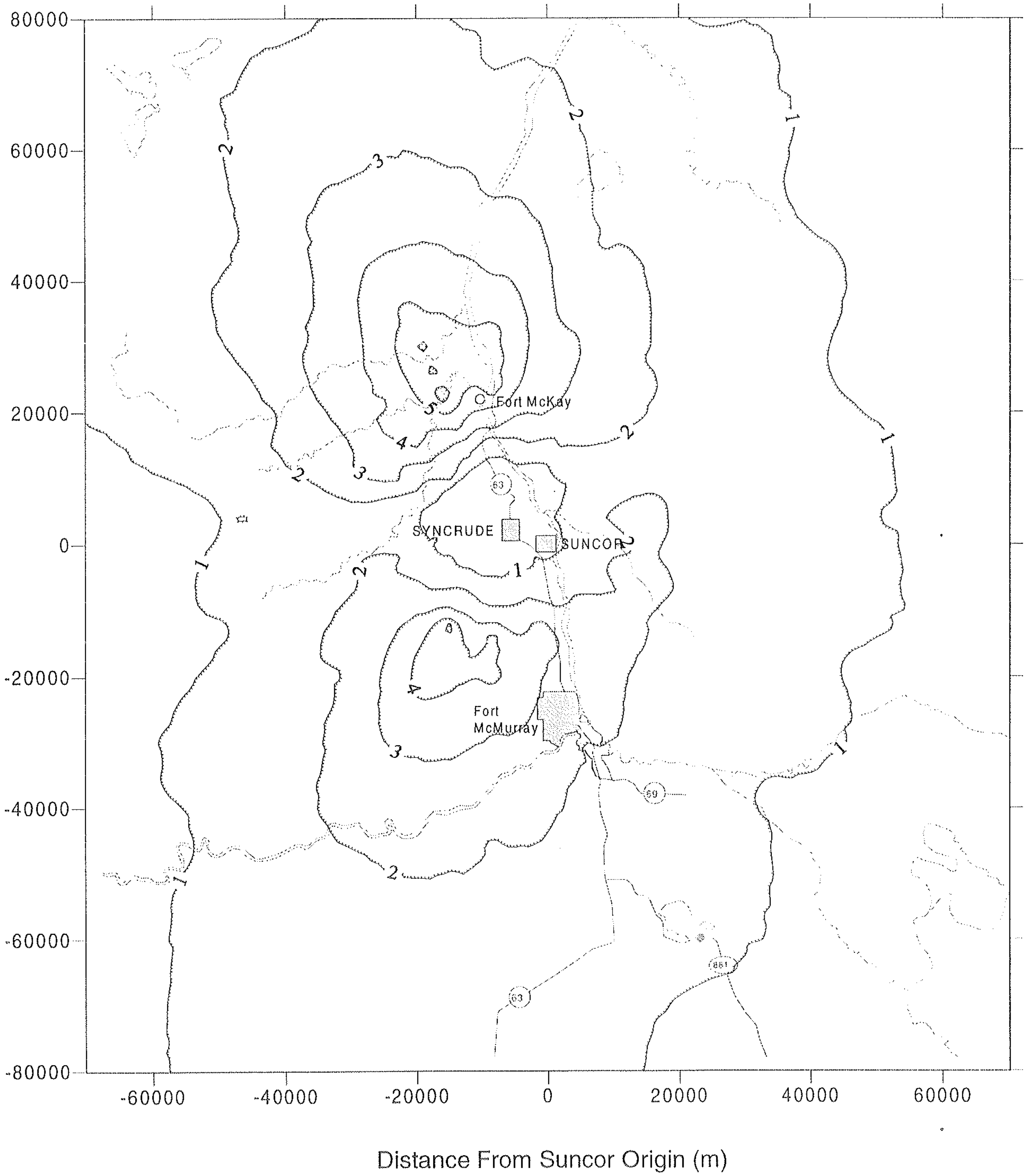


Figure 5.3 Predicted dry deposition (kg SO_4^{-2}/ha/a) from the operation of the **Syncrude Main stack** (213 t/d) (RELMAP deposition velocities).

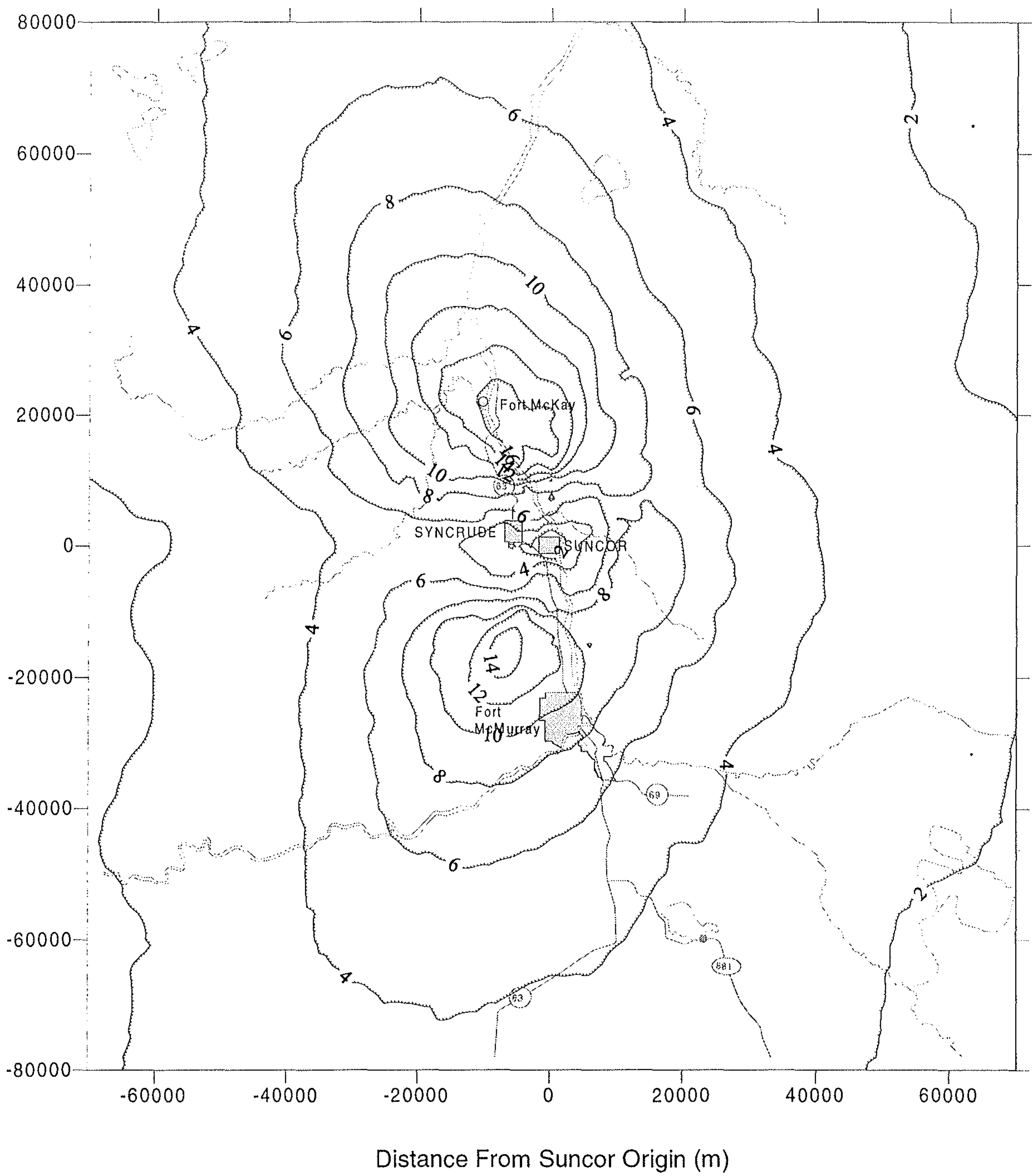


Figure 5.4 Predicted dry deposition (kg SO_4^{-2}/ha/a) from the **combined operation** of the main stacks in the region (RELMAP deposition velocities).

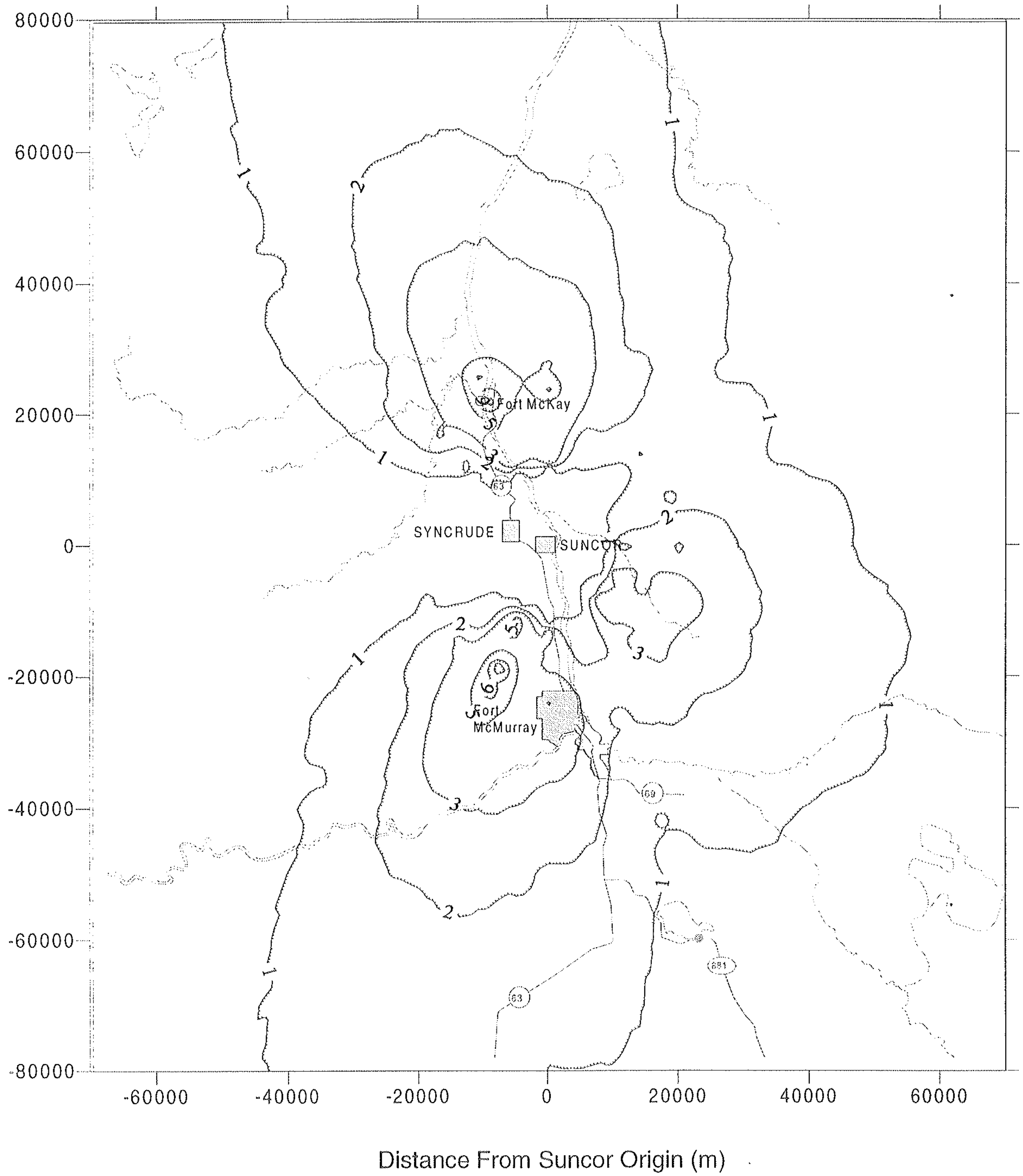


Figure 5.5 Predicted wet deposition (kg SO_4^{-2}/ha/a) from the operation of the **Suncor Powerhouse stack** (211 t/d).

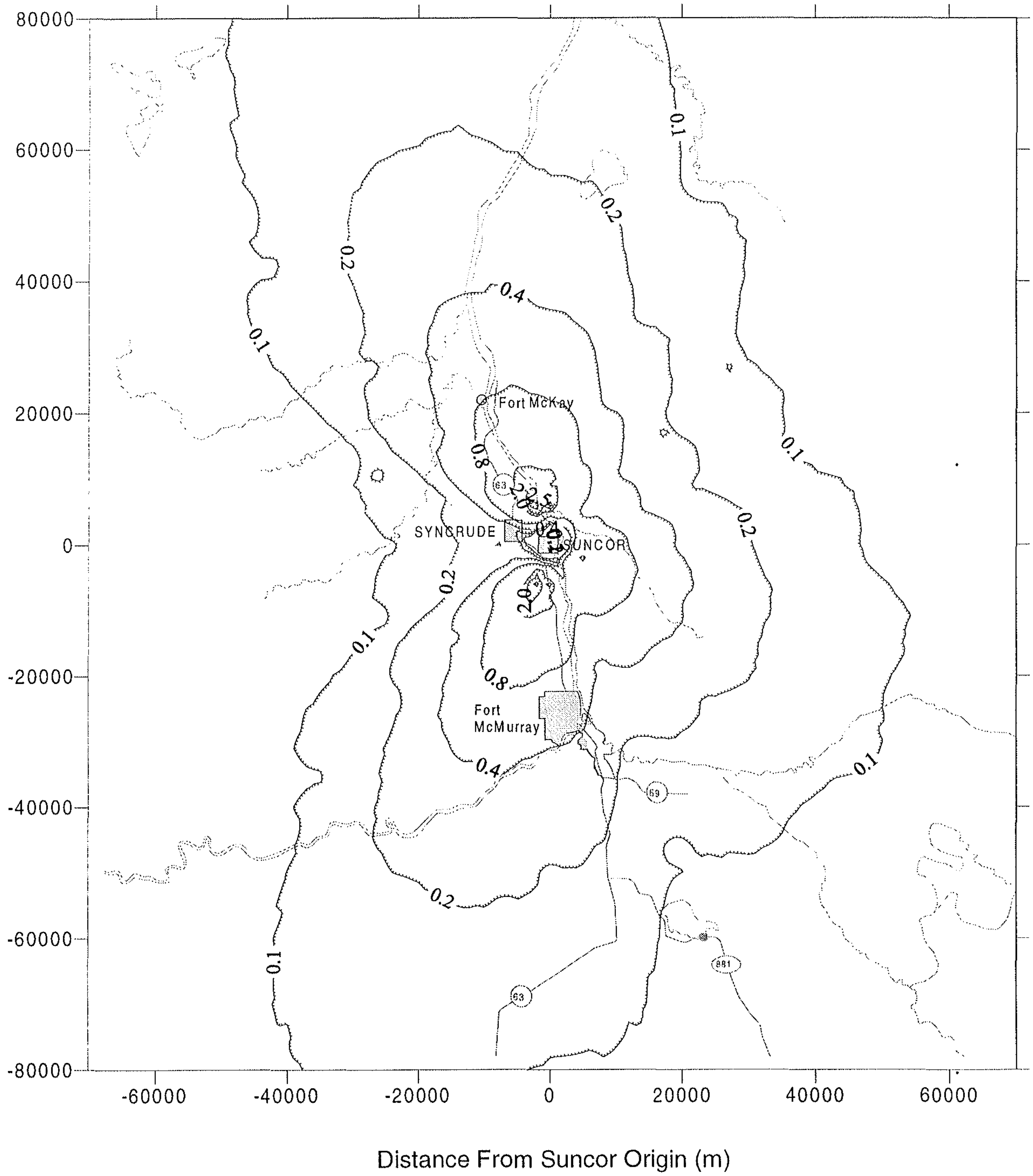


Figure 5.6 Predicted wet deposition (kg SO_4^{-2}/ha/a) from the operation of the **Suncor Incinerator stack** (17 t/d).

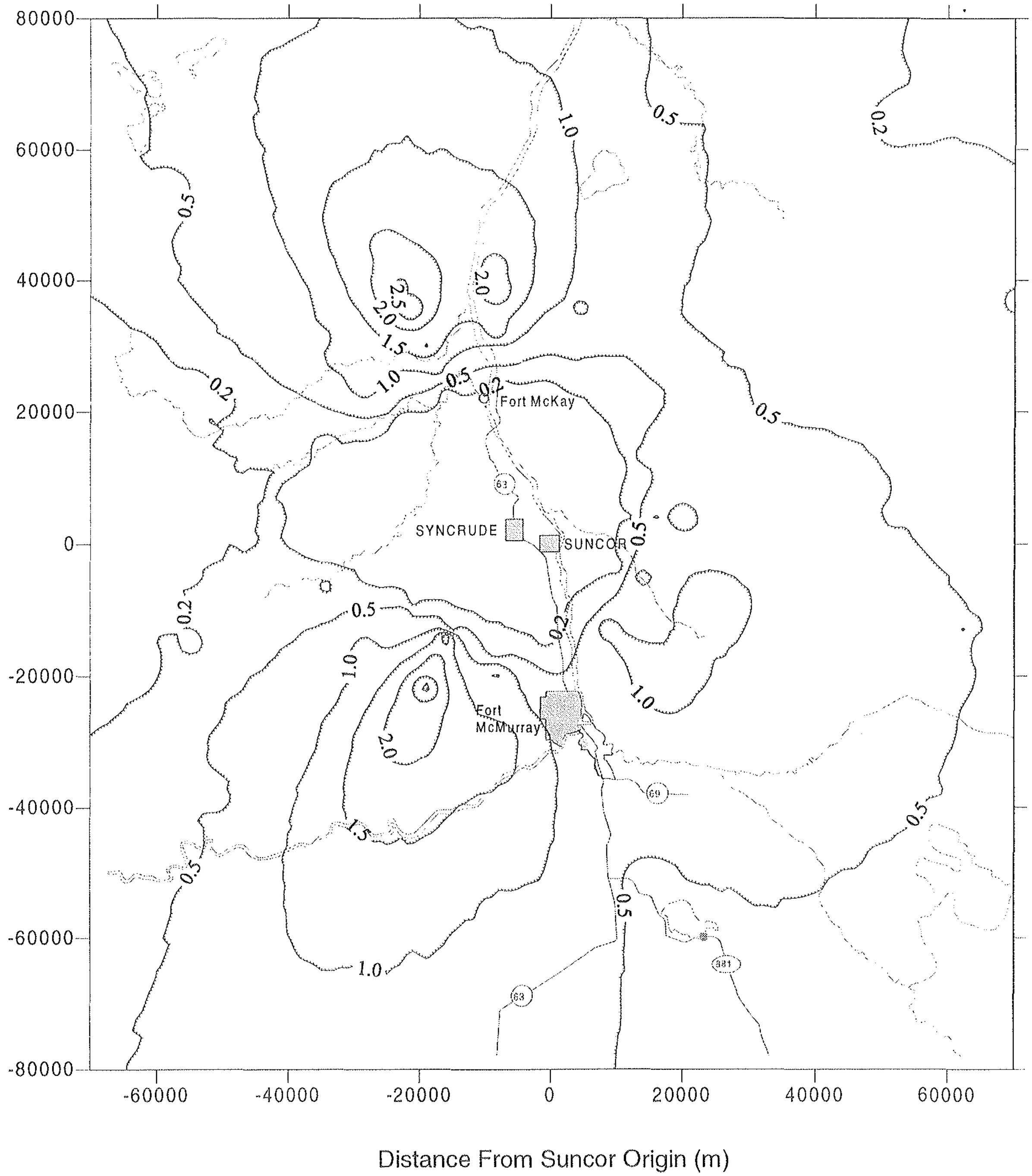


Figure 5.7 Predicted wet deposition (kg SO_4^{-2}/ha/a) from the operation of the **Syncrude Main stack** (213 t/d).

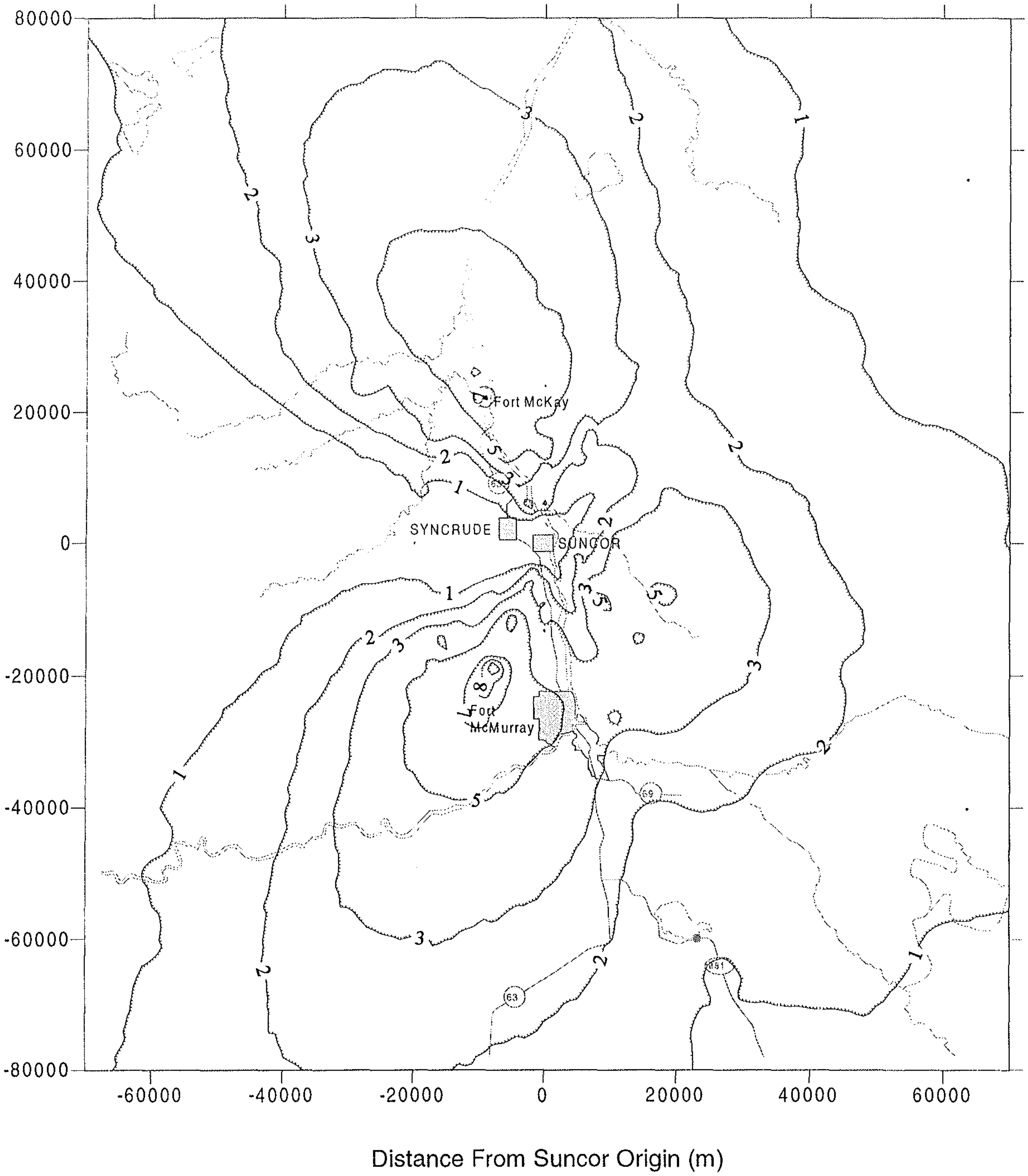


Figure 5.8 Predicted wet deposition (kg SO_4^{-2}/ha/a) from the **combined operation** of the main stacks in the region.

5.5 Combined Total Deposition

The ADEPT2 model was used to predict the total (wet plus dry) deposition (expressed as kg SO_4^{-2}/ha/a) from the same emission sources:

Source		Total Deposition
Powerhouse	(211 t/d)	19.2
Incinerator	(17 t/d)	9.4
Main Stack	(213 t/d)	8.2
Combined	(211 + 17 + 213 t/d)	25.5

These values are based on the use of the RELMAP dry deposition velocities.

Figure 5.9 shows the total deposition contour pattern for the combined operation. The maximum value of 25.5 kg SO_4^{-2}/ha/a is predicted to occur about 26 km to the north-northwest of the powerhouse stack. High values are also predicted to occur about 20 km to the south-southwest of the powerhouse stack.

5.6 Effective Acidity

The estimation of an effective acidity (EA) accounts for other compounds in precipitation that can either enhance or neutralize acidification. For soil systems one recommended approach for calculating effective acidity is through the relationship:

$$EA_{total} = EA_{wet} + EA_{dry}$$

where:

$$EA_{wet} = [H^+] + 1.15\ [NH_4^+] - 0.7\ [NH_4]$$
$$EA_{dry} = [SO_4^{-2}] + [SO_2] + 1.15\ [NH_4^+] - 0.7\ [NO_3]$$

This relationship was provided in Report 2. In the application of this relationship, the following was used:

$$EA_{total} = \text{Background}\ (EA_{wet} + EA_{dry}) + \text{Combined}\ (EA_{wet} + EA_{dry})$$

The background wet and dry values based on Cree Lake observations are 0.05 and 0.08 kmol H^+ equivalent/ha/a, respectively (Report 2). For the purposes of conservatism, the plant contribution, that is, Combined (EA_{wet} + EA_{dry}) can be estimated from combined (wet + dry) sulphate deposition divided by a factor of 48. On this basis, the maximum estimated EA in the region is:

$$\begin{aligned} EA_{total}\ (\text{maximum}) &= 0.05 + 0.08 + (25.5/48) \\ &= 0.13 + 0.53 \\ &= 0.66\ \text{kmol}\ H^+\ \text{equivalent/ha/a.} \end{aligned}$$

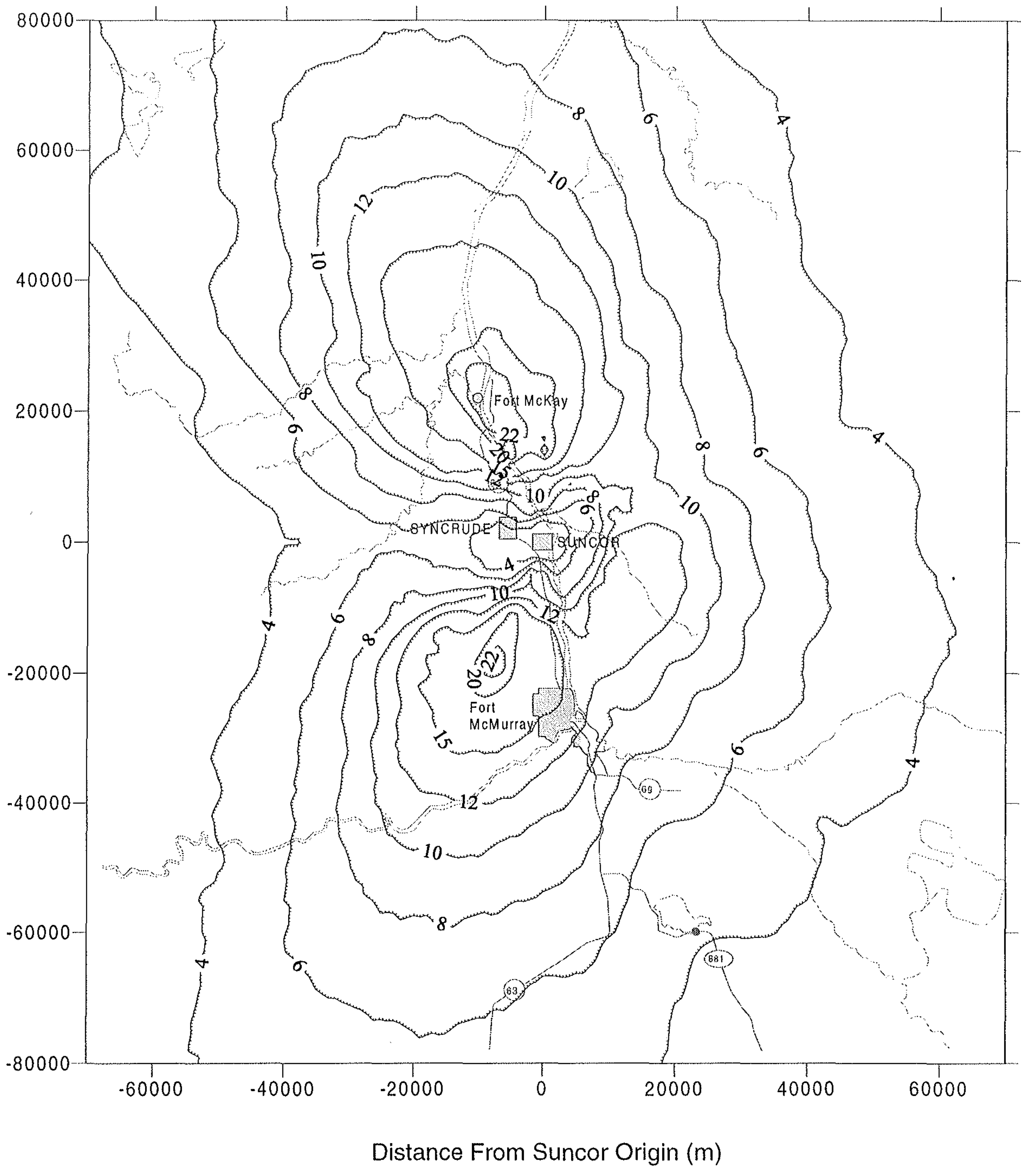


Figure 5.9 Total (wet + dry) sulphate deposition (kg SO_4^{-2}/ha/a) from the **combined operation** of the main stacks in the region.

This approach assume that each mole of SO_2 or SO_4^{-2} that is deposited is converted to two hydrogen ions (H^+). This maximum EA values occur 26 km to the north-northwest of the Suncor site and 20 km to the south-southeast of the Suncor plant site.

Figure 5.10 shows the EA contour pattern based on the combined operation. The contour plants in Figure 5.10 depict the preliminary deposition limits proposed by Alberta Environment (1990). Specifically, the following are shown:

Sensitivity Class	**Range ($kmol\ H^+/ha/a$)**
Low	0.7 to 1.0
Medium	0.3 to 0.4
High	0.1 to 0.3

The following table identifies the areas where each of the sensitivity class criteria are exceeded:

Criteria ($kmol\ H^+/ha/a$)	**Area (km^2)**	**Area (% of Total)**
1.0	0	0
0.7	0	0
0.4	1926	9
0.3	6033	27
0.1	22 400	100

For the purpose of comparing, the total area depicted in the figure is 22 400 km^2. The percentage values in the above table are based on this value.

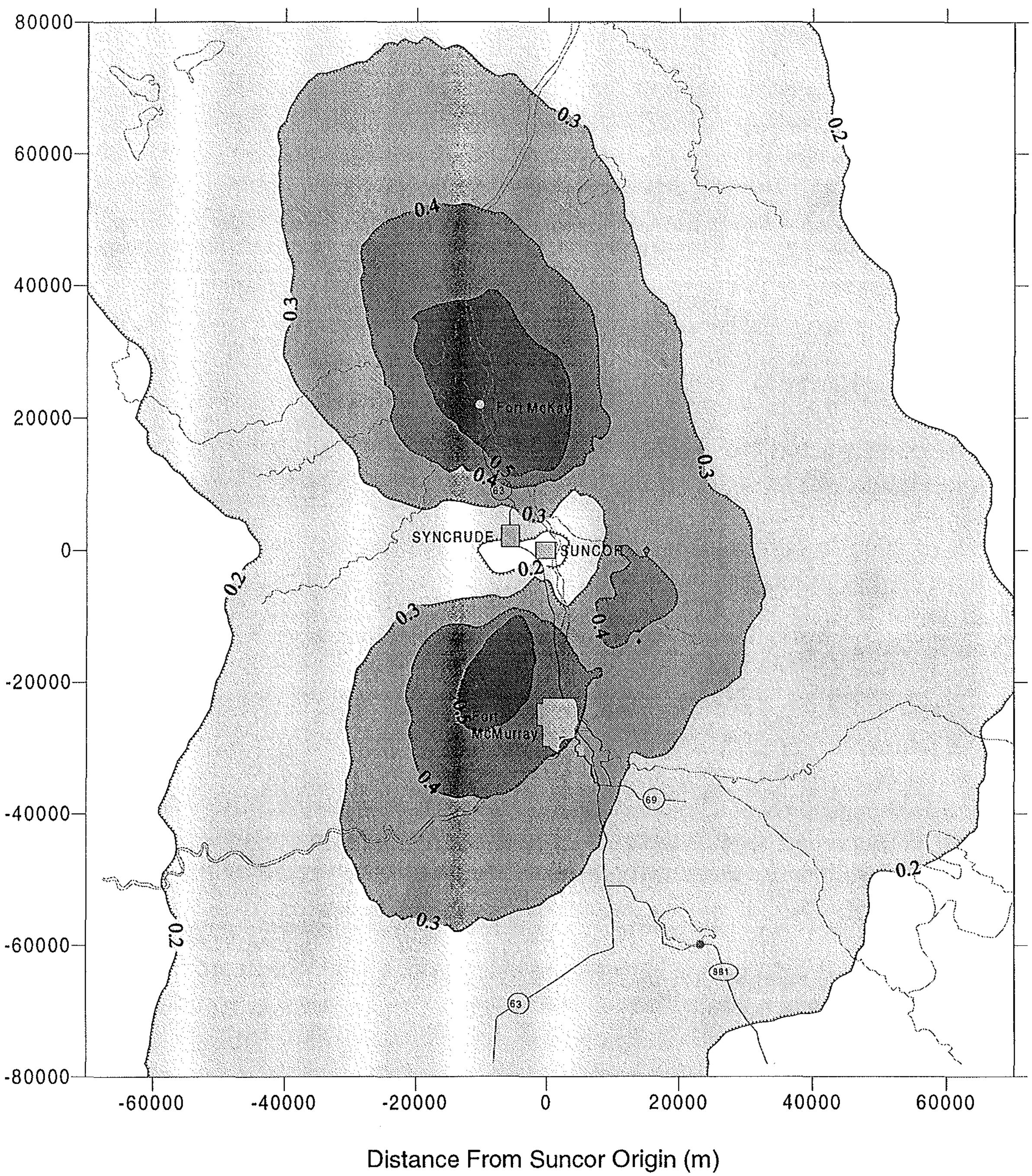


Figure 5.10 Estimated Effective Acidity (EA) (kmol H^+/ha/a) from the **combined operation** of the main stacks in the region.

5.7 Comparison with Other Studies

The Alberta Research Council has estimated annual concentrations and depositions across Alberta using the Regional Lagrangian Acid Deposition model (RELAD) (Cheng 1994). The RELAD model appears to be reasonable for regional scale predictions; however, the model is not capable of resolving the fine scale concentration or deposition patterns in the vicinity of local sources.

Table 5.5 provides a comparison of the SO_2 emissions used by the RELAD and the ADEPT2 models and the corresponding deposition and concentration predictions. While the corresponding SO_2 emissions differ, they are not likely sufficient to explain the differences in the predicted deposition. The wet deposition values predicted by both models are nearly identical. In essence, the RELAD model predicts a maximum dry deposition value that is nearly twice that predicted by ADEPT2. The likely reason for the difference is the differing predicted annual average concentrations.

5.8 Comparison with Preliminary Guidelines

The results presented in this assessment can be compared to preliminary limits. The EA values shown in Figure 5.10 indicate that the maximum predicted EA value (0.66 kmol H^+/ha/a) is less than the preliminary limits associated with low sensitivity ecosystems (0.7 to 1.0 kmol H^+/ha/a). An area of 2000 to 6000 km^2 is characterized by predicted EA values that correspond to the preliminary limits of medium sensitivity limits (0.3 to 0.4 kmol H^+/ha/a). The background value of 0.13 kmol H^+/ha/a is within the preliminary range for high sensitivity ecosystems (0.1 to 0.3 kmol H^+/ha/a).

5.9 Comments

The predicted deposition of sulphur compounds and the associated Effective Acidity (EA) values presented in this report are not comparable to those presented in previous assessments (i.e., the Syncrude Air Quality Assessment undertaken in 1992) because different methods were used. Specifically:

- Larger dry deposition velocities to be consistent with those used by Cheng and Angle (1993) were adopted.

- The Effective Acidity can be calculated in numerous ways (see Section 3.2.3, Baseline Report 2). The method used differs in the manner other compounds (both wet and dry) are incorporated.

Table 5.5 Comparison between ADEPT2 and RELAD predictions of deposition in the Fort McMurray and surrounding region.

	ADEPT2	RELAD
SO_2 emissions (t/d)		
Powerhouse	211	154
Incinerator	17	28
Main Stack	213	226
Total	441	408
Deposition (kg SO_4^{-2}/ha/a)		
Dry	18.3	34.2
Wet	10.0	9.9
Combined	25.5	44.4
SO_2 Concentration ($\mu g/m^3$)	12.9	34.7

The first change will result in predicted dry depositions that are larger than those in the previous assessment, typically by a factor of 1.5 to 1.8 (Section 5.3 of this report). The second change will also result in a larger dry deposition than the previous assessment by a factor of 1.2 to 2.0, depending on the chemistry of the region (Table 3.3, Background Report 2). Assuming these factors are somewhat multiplicative, the predictions of EA provided in this assessment are expected to be 2 to 3 times that presented in the previous Syncrude assessment.

Until a methodology for predicting EA is selected by the technical and regulatory community, it is difficult to interpret the model predictions in terms of environmental effects. For this reason, the presented deposition and EA contours presented in the figures should be regarded as providing an indication of relative spatial distributions and relative changes associated with differing emission sources.

6.0 PREDICTED AMBIENT NO_x CONCENTRATIONS

As indicated in Background Report 1, there are numerous NO_x emissions associated with the Suncor, Syncrude and other sources in the region. This section estimates ambient NO_x concentrations associated with these sources. The SCREEN3 model is used to examine each source on an individual basis. This model provides an efficient means of ranking individual sources in terms of their contribution to the overall ambient NO_x concentration and provides an indication of where maximum concentrations could occur.

6.1 Maximum Hourly Average NO_x Concentrations

Table 6.1 provides a summary of the maximum predicted NO_x concentrations for each of the continuous Suncor sources. The results indicate:

- The largest maximum NO_x concentration is associated with the operation of the powerhouse stack (99 $\mu g/m^3$).
- The individual contribution from the other sources range from 2.6 to 15.1 $\mu g/m^3$.
- All maximum values are associated with daytime conditions (PG stability class A) and are predicted to occur between 0.4 and 1.3 km from the individual stacks.
- The sum of all the NO_x maxima is 251 $\mu g/m^3$. This sum, although not physically realistic due to temporal and spatial variations, indicates that the maximum NO_x values are less than the 400 $\mu g/m^3$ guideline for NO_2.

Table 6.2 provides a summary of the maximum predicted NO_x concentrations associated with each of the continuous Syncrude sources. The results indicate:

- The largest NO_x concentration is associated with the operation of the main stack (43 $\mu g/m^3$) and the 9-3F-1 reformer stack (42 $\mu g/m^3$). Both maxima are predicted to occur 1.4 and 1.0 km downwind of each respective source.
- The next largest concentrations are associated with the Bitumount tank heaters (28 and 35 $\mu g/m^3$) and the associated maximum are predicted to occur within 115 to 150 m downwind of each source.
- The remainder of the maximum predicted NO_x concentrations are predicted to range from 4 to 25 $\mu g/m^3$ and these maxima are predicted to occur between 0.3 and 1.1 km downwind of each source.
- The sum of all the NO_x maxima is 596 $\mu g/m^3$. The sum of all maxima, excluding the bitumen tank heaters and the reformer furnaces (which are associated with high wind speeds), is 250 $\mu g/m^3$. This latter value is less than the 400 $\mu g/m^3$ guideline for NO_2.

Table 6.1 Maximum hourly average NO_x concentrations associated with Suncor's combustion sources.

Source	Unit No.	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (°C)	NO_x (t/d)	NO_x ($\mu g/m^3$)	Wind Speed (m/s)	PG Stability Class	Distance (km)
Powerhouse Stack		106.70	5.79	22.30	256	16.90	99.09	2.5	A	1.2
Incinerator Stack		106.70	1.80	18.50	489	0.11	2.64	1.0	A	1.1
Diluent Heater	5F-1A	48.50	1.83	13.71	454	0.27	9.516	1.0	A	1.0
	5F-1B	48.50	1.83	13.71	454	0.27	9.516	1.0	A	1.0
Coker Feeder	5F-2	41.10	2.18	14.94	454	0.42	10.37	1.5	A	0.9
	5F-3	41.10	2.18	14.94	454	0.42	10.37	1.5	A	0.9
	5F-4	41.10	2.18	14.94	454	0.42	10.37	1.5	A	0.9
Diluent Heater	5F-5	50.29	1.88	12.71	454	0.27	9.835	1.0	A	0.9
Coker Feeder	5F-6	41.10	2.50	11.61	454	0.43	10.52	1.5	A	0.9
Reformer	6F-2A	48.77	2.13	11.06	288	0.39	15.17	1.0	A	0.9
	6F-2B	48.77	2.13	11.06	288	0.39	15.17	1.0	A	0.9
	6F-2C	48.77	2.13	11.06	288	0.39	15.17	1.0	A	0.9
Hydrogen	6F-5	33.53	1.37	5.87	426	0.05	4.071	3.0	A	0.4
Naphtha	7F-1	40.80	1.26	9.18	454	0.06	4.283	1.0	A	0.8
Deprop	7F-2	45.40	1.49	8.76	454	0.08	5.44	1.0	A	0.8
Kerosene	7F-10	41.10	1.26	9.80	454	0.06	4.482	1.0	A	0.8
	7F-11	45.40	1.49	8.27	415	0.08	5.447	1.0	A	0.8
Gas Oil Heater	7F-20A	40.80	1.26	6.12	454	0.04	3.236	2.0	A	0.5
	7F-20B	40.80	1.26	6.12	454	0.04	3.236	2.0	A	0.5
	7F-20C	40.80	1.26	6.12	454	0.04	3.236	2.0	A	0.5

Table 6.2 Maximum hourly average NO_x concentrations associated with Syncrude's combustion sources.

Source	Unit No.	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (°C)	NO_x (t/d)	NO_x ($\mu g/m^3$)	Wind Speed (m/s)	PG Stability Class	Distance (km)
Main Stack	8-F4	182.9	7.93	23.60	234	12.17	43	3.0	A	1.4
Gas Turbine	31 GTG 201	34	2.4	46.36	490	1.65	17	2.0	A	1.1
	31 GTG 202	34	2.4	46.36	490	1.65	17	2.0	A	1.1
Bitumen Heater	7-1F-1A	51.8	3.2	7.09	283	0.61	17	1.0	A	1.0
	7-1F-1B	51.8	3.2	7.75	283	0.61	16	1.0	A	1.0
	7-2F-1A	53.2	3.05	8.53	283	0.61	116	1.0	A	1.0
	7-2F-1B	53.2	3.05	8.53	283	0.61	16	1.0	A	1.0
Super Heater	8-1F-6A	39.6	2.12	5.16	343	0.11	8	1.0	A	0.8
	8-1F-6B	44.7	1.08	6.10	343	0.03	4	1.0	A	0.5
	8-2F-6A	39.6	2.12	5.16	343	0.11	8	1.0	A	0.8
	8-2F-6B	44.7	1.08	6.10	343	0.03	4	1.0	A	0.5
Reformer Furnace	9-1F-1	23.47	4.11	11.57	267	1.55	25	20.0	D	1.1
	9-2F-1	23.47	4.11	11.57	267	1.55	25	20.0	D	1.1
	9-3F-1	22.9	3.66	14.34	160	1.91	42	20.0	D	1.0
Hydrogen Heater	15-1F-1	41.76	1.72	6.29	153	0.13	11	1.0	A	0.6
	15-2F-1	41.76	1.72	6.29	153	0.13	11	1.0	A	0.6
	18F-1	42.67	1.82	4.31	160	0.10	9	1.5	A	0.5
	22-1F-2	45.72	1.67	7.15	296	0.11	7	1.0	A	0.8

Table 6.2 Concluded.

Source	Unit No.	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (°C)	NO_x (t/d)	NO_x (μg/m^3)	Wind Speed (m/s)	PG Stability Class	Distance (km)
Fractionator Reboiler	15-1F-2	45.72	1.94	5.34	380	0.09	11	1.0	A	0.6
	15-2F-2	45.72	1.94	5.34	380	0.09	11	1.0	A	0.6
	18F-2	42.67	1.82	4.31	160	0.10	9	1.5	A	0.5
	22-1F-3	45.72	1.06	6.14	312	0.04	4	1.0	A	0.5
Sulfreen Furnace	12-0F-101	15.39	0.46	37.2	343	0.04	9	8.0	C	0.3
Bitumen Feed	22-1F-1	45.72	1.67	3.70	475	0.05	4	1.0	A	0.7
Diluent Reboiler	14F-1	30.48	1.07	9.10	345	0.07	7	3.0	A	0.3
Bitumen North	21F-7	6.1	0.3	29.00	566	0.03	35	10.0	C	0.1
	21F-8	6.1	0.3	29.00	566	0.03	35	10.0	C	0.1
	21F-9	6.1	0.3	29.00	566	0.03	35	10.0	C	0.1
	21F-10	6.1	0.3	29.00	566	0.03	35	10.0	C	0.1
Bitumen East	21F-50	7.6	0.3	29.00	566	0.03	28	8.0	C	0.1
	21F-51	7.6	0.3	29.00	566	0.03	28	8.0	C	0.1
	21F52	7.6	0.3	29.00	566	0.03	28	8.0	C	0.1
	21F53	7.6	0.3	29.00	566	0.03	28	8.0	C	0.1

The maximum values presented in Tables 6.1 and 6.2 do not incorporate building downwash effects. The effects of building downwash (where applicable) increase ambient concentrations nearer the source (i.e., within and downwind of the building wake). On this basis, the values presented in the tables (for the shorter stacks) are likely to be underestimated.

The values presented in the tables are for NO_x and not NO_2. The assumption of 100% conversion of NO to NO_2 results in the NO_x values in Tables 6.1 and 6.2 being treated as NO_2. This assumption will result in an overestimation. The air quality observations in Report 2 indicated that for high NO_x values, the NO_2 is typically 20% of the total NO_x. If one assumes that all NO_x is in the form of NO_2, the values presented in the table are conservative (i.e., overestimate the values).

A more rigorous assessment of NO_2 concentrations resulting from the combined operation of Syncrude sources was undertaken by Concord Environmental (1992b). These results indicated a maximum predicted NO_x concentration of 1.15 ppm (2190 $\mu g/m^3$) as a one-hour average was predicted to occur on-site. On the basis of the empirical 20% factor, the maximum NO_2 concentration on-site is about 440 $\mu g/m^3$ which is slightly over the 400 $\mu g/m^3$ environmental guideline. These predictions were based on the ISCST2 model; the maximum predicted NO_x value associated with the Alberta Environment model SEEC was 0.08 ppm (152 $\mu g/m^3$). This value was predicted to occur 3 km to the east of the plant.

6.2 Maximum Daily Average NO_x Concentrations

The SCREEN3 model can only predict maximum hourly average concentrations. Corresponding daily average values can be inferred from the hourly predictions using an empirical conversion factor. The SCREEN3 model documentation indicates maximum 24-hour average concentrations are generally about 0.4 ± 0.2 times the maximum one-hour average concentration (U.S. EPA 1992). In contrast, AEP assumes a factor of 0.25 to convert hourly values to 24-hour values (Alberta Environmental Protection 1994). For dispersion amid irregular terrain, the U.S. EPA CTSCREEN model approach assumes the 24-hour average values are 0.15 the maximum one-hour values (Perry *et al.* 1990). The SO_2 predictions (Table 4.8) which were undertaken more rigorously support the use of a 0.2 conversion factor.

For conservative reasons, the 0.6 conversion factor was applied to the hourly predictions. For example, the application of 0.6 to the 250 $\mu g/m^3$ concentration mentioned in the previous section results in a corresponding 24-hour value of 150 $\mu g/m^3$. A 0.25 factor results in a 24-hour value of 63 $\mu g/m^3$. For the purposes of comparison, the 24-hour guideline is 200 $\mu g/m^3$.

6.3 Maximum Annual Average NO_x Concentrations

The SCREEN approach recommends an empirical conversion factor of 0.08 ± 0.02 to estimate annual concentrations from the one-hour maximum. The regional SO_2 predictions in Table 4.8

maximum annual average concentrations. The U.S. EPA CTSCREEN model approach assumes a conversion factor of 0.03 for annual estimates (Perry *et al.* 1990).

The application of the more conservative 0.01 factor to the hourly value of 250 $\mu g/m^3$ results in a corresponding annual value of about 25 $\mu g/m^3$. This compares to the annual objective of 60 $\mu g/m^3$.

6.4 Comparison with Ambient Air Quality Guidelines

The provincial and federal air quality guidelines ($\mu g/m^3$) for NO_2 are summarized as:

Averaging Period	Hour	Day	Annual
Alberta	400	200	60
Federal Desirable	-	-	60
Federal Acceptable	400	200	100
Federal Tolerable	1000	400	-

In comparing the model predictions in this section to these guidelines, the following are noted:

- Maximum predicted hourly average NO_2 concentrations are expected to be within the corresponding guidelines of 400 $\mu g/m^3$ for NO_2.
- Maximum daily average NO_2 concentrations are expected to be within the corresponding guidelines of 200 $\mu g/m^3$ for NO_2.
- Maximum annual average NO_2 concentrations are expected to be within the corresponding guidelines of 60 $\mu g/m^3$ for NO_2.

In summary, screening and previous modelling have indicated that the maximum NO_x concentrations will tend to occur within 1 km of the respective plant sites and specifically are likely to be confined to the plant site. The off-site NO_2 concentrations are likely to be well below the guideline values. This conclusion is somewhat confirmed with the air quality data collected by Syncrude (Report 2). It should be noted, however, that the ambient data for NO_x are somewhat limited.

7.0 PREDICTED AMBIENT CO CONCENTRATIONS

The major continuous sources of CO emissions in the region are the Syncrude main stack (47.2 t/d); the Suncor Powerhouse stack (14.1 t/d); and the secondary Syncrude and Suncor combustion sources (2.6 and 5.5 t/d, respectively). The major intermittent source of CO emissions is the Syncrude diverter stack (360 t/d when diverting takes place). As with the evaluation of NO_x emissions, the SCREEN3 model was used to estimate ambient CO concentrations for each source on an individual basis.

7.1 Maximum Hourly Average CO Concentrations

Table 7.1 provides a summary of the maximum predicted CO concentrations for each of the Suncor sources. The results indicate:

- The maximum CO concentrations for the individual operation of each source range from 1 to 132 $\mu g/m^3$ as one-hour averages.

Table 7.2 provides a summary of the maximum predicted CO concentrations associated with each of continuous Syncrude sources. The results indicate:

- The maximum CO concentrations from the individual operation of each continuous source range from 1 to 165 $\mu g/m^3$ as one-hour averages.

- During abnormal conditions, gas streams containing large amounts of CO can be vented into the atmosphere from either one of Syncrude's diverter stacks. The maximum ground-level CO concentration during a diverter stack incident is predicted to be 2564 $\mu g/m^3$ as a one-hour average.

The maximum results presented in Tables 7.1 and 7.2 do not incorporate building downwash effects. The effects of building downwash (where applicable) can increase ambient concentrations nearer the source (i.e., within and downwind of the building wake). The values presented in the tables for the shorter stacks are therefore likely to be underestimated.

Table 7.1 Maximum hourly average CO concentrations associated with Suncor's combustion sources.

Source	Unit No.	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (°C)	CO (t/d)	CO ($\mu g/m^3$)	Wind Speed (m/s)	PG Stability Class	Distance (km)
Powerhouse Stack		106.70	5.79	22.30	256	14.1	83	2.5	A	1.2
Incinerator Stack		106.70	1.80	18.50	489	5.5	132	1.0	A	1.1
Diluent Heater	5F-1A	48.50	1.83	13.71	454	0.05	2	1.0	A	1.0
	5F-1B	48.50	1.83	13.71	454	0.05	2	1.0	A	1.0
Coker Feeder	5F-2	41.10	2.18	14.94	454	0.08	2	1.5	A	0.9
	5F-3	41.10	2.18	14.94	454	0.08	2	1.5	A	0.9
	5F-4	41.10	2.18	14.94	454	0.08	2	1.5	A	0.9
Diluent Heater	5F-5	50.29	1.88	12.71	454	0.05	2	1.0	A	0.9
Coker Feeder	5F-6	41.10	2.50	11.61	454	0.09	2	1.5	A	0.9
Reformer	6F-2A	48.77	2.13	11.06	288	0.08	3	1.0	A	0.9
	6F-2B	48.77	2.13	11.06	288	0.08	3	1.0	A	0.9
	6F-2C	48.77	2.13	11.06	288	0.08	3	1.0	A	0.9
Hydrogen	6F-5	33.53	1.37	5.87	426	0	0	3.0	A	0.4
Naphtha	7F-1	40.80	1.26	9.18	454	0.01	1	1.0	A	0.8
Deprop	7F-2	45.40	1.49	8.76	454	0.02	1	1.0	A	0.8
Kerosene	7F-10	41.10	1.26	9.80	454	0.02	1	1.0	A	0.8
	7F-11	45.40	1.49	8.27	415	0.02	1	1.0	A	0.8
Gas Oil Heater	7F-20A	40.80	1.26	6.12	454	0.01	1	2.0	A	0.5
	7F-20B	40.80	1.26	6.12	454	0.01	1	2.0	A	0.5
	7F-20C	40.80	1.26	6.12	454	0.01	1	2.0	A	0.5

Table 7.2 Maximum hourly average CO concentrations associated with Syncrude's combustion sources.

Source	Unit No.	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (°C)	CO (t/d)	CO (μg/m^3)	Wind Speed (m/s)	PG Stability Class	Distance (km)
Main Stack	8-F4	182.9	7.93	23.60	234	47.2	165	3.0	A	1.4
Gas Turbine	31 GTG 201	34	2.4	46.36	490	0.4	4	2.0	A	1.1
	31 GTG 202	34	2.4	46.36	490	0.4	4	2.0	A	1.1
Bitumen Heater	7-1F-1A	51.8	3.2	7.09	283	0.12	3	1.0	A	1.0
	7-1F-1B	51.8	3.2	7.75	283	0.12	3	1.0	A	1.0
	7-2F-1A	53.2	3.05	8.53	283	0.12	3	1.0	A	1.0
	7-2F-1B	53.2	3.05	8.53	283	0.12	3	1.0	A	1.0
Super Heater	8-1F-6A	39.6	2.12	5.16	343	0.03	2	1.0	A	0.8
	8-1F-6B	44.7	1.08	6.10	343	0.01	1	1.0	A	0.5
	8-2F-6A	39.6	2.12	5.16	343	0.03	2	1.0	A	0.8
	8-2F-6B	44.7	1.08	6.10	343	0.01	1	1.0	A	0.5
Reformer Furnace	9-1F-1	23.47	4.11	11.57	267	0.31	5	20.0	D	1.1
	9-2F-1	23.47	4.11	11.57	267	0.31	5	20.0	D	1.1
	9-3F-1	22.9	3.66	14.34	160	0.38	8	20.0	D	1.0
Hydrogen Heater	15-1F-1	41.76	1.72	6.29	153	0.03	2	1.0	A	0.6
	15-2F-1	41.76	1.72	6.29	153	0.03	2	1.0	A	0.6
	18F-1	42.67	1.82	4.31	160	0.02	2	1.5	A	0.5
	22-1F-2	45.72	1.67	7.15	296	0.03	2	1.0	A	0.8

Table 7.2 Concluded.

Source	Unit No.	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (°C)	CO (t/d)	CO ($\mu g/m^3$)	Wind Speed (m/s)	PG Stability Class	Distance (km)
Fractionator Reboiler	15-1F-2	45.72	1.94	5.34	380	0.02	1	1.0	A	0.7
	15-2F-2	45.72	1.94	5.34	380	0.02	1	1.0	A	0.7
	18F-2	42.67	1.82	4.31	160	0.02	2	1.5	A	0.5
	22-1F-3	45.72	1.06	6.14	312	0.01	1	1.0	A	0.5
Sulfreen Furnace	12-0F-101	15.3924	0.4572	37.2	343	0.03	2	8.0	C	0.3
Bitumen Feed	22-1F-1	45.72	1.67	3.70	475	0.01	2	1.0	A	0.7
Diluent Reboiler	14F-1	30.48	1.07	9.10	345	--	1	3.0	A	0.3
Bitumen North	21F-7	6.1	0.3	29.00	566	--	--	10.0	C	0.1
	21F-8	6.1	0.3	29.00	566	--	--	10.0	C	0.1
	21F-9	6.1	0.3	29.00	566	--	--	10.0	C	0.1
	21F-10	6.1	0.3	29.00	566	--	--	10.0	C	0.1
Bitumen East	21F-50	7.6	0.3	29.00	566	--	--	8.0	C	0.1
	21F-51	7.6	0.3	29.00	566	--	--	8.0	C	0.1
	21F52	7.6	0.3	29.00	566	--	--	8.0	C	0.1
	21F53	7.6	0.3	29.00	566	--	--	8.0	C	0.1
Diverter Stack[a]		73.2	3.7	26.5	600	360.7	2564	2.0	A	1.2

[a] Diverting Coker Overhead operating intermittently.

7.2 Comparison with Ambient Air Quality Guidelines

The provincial and federal air quality guidelines ($\mu g/m^3$) for CO are summarized as follows:

Agency Period	**1-hour**	**8-hour**
Alberta	15000	6000
Federal Desirable	15000	6000
Federal Acceptable	35000	15000
Federal Tolerable	-	20000

A comparison of the guidelines with the values presented in Tables 7.1 and 7.2 indicates that maximum predicted CO concentrations are much less than the air quality guidelines.

8.0 PREDICTED AMBIENT PARTICULATE CONCENTRATIONS

The Suncor Powerhouse and Syncrude Main stacks are the main continuous sources of particulate emissions resulting from combustion operations. As indicated in Report 1 (Source Characterization), the following particulate emissions result from the operation of these stacks:

- Suncor Powerhouse 6.3 t/d (based on 1994)
- Syncrude Main 7.8 t/d (based on 1995)

The ISC3BE model was used to estimate ambient particulate concentrations and deposition of particulates resulting from the individual and combined operation of these stacks.

To estimate deposition (dry and wet), the ISC3BE model requires additional source parameters that characterize the particulates and information regarding precipitation. These parameters are identified in Table 8.1. In the absence of recent particle size information, all particulates were assumed to be 10 µm in diameter and of unity density. The scavenging coefficients provided in the ISCST3 manual were used. The ambient concentrations and depositions of specific metals based on the analysis conducted for each stack were also calculated.

8.1 Predicted Concentrations and Depositions

Table 8.2 summarizes the maximum ambient particulate concentrations, dry deposition, wet deposition and total deposition predicted by the model. The locations where these maxima occur are also provided in the table.

Figures 8.1, 8.2 and 8.3 show the annual average ambient particulate concentrations for the Suncor powerhouse stack, the Syncrude main stack and for both stacks, respectively. Figure 8.4 shows the maximum total deposition from the combined operation of both stacks. The following comments are noted with respect to the information presented in these tables and figures:

- Maximum daily average particulate concentrations range from 1.6 (Syncrude) to 7.5 (Suncor) $\mu g/m^3$. These are predicted to occur 26 (Suncor) and 57 (Syncrude) km downwind of the sources.

- Maximum annual average particulate concentrations range from 0.1 (Syncrude) to 0.3 (Suncor) $\mu g/m^3$. These are predicted to occur 7 (Suncor) and 58 (Syncrude) km downwind of the sources.

- Maximum annual dry deposition of particulates ranges from 0.8 (Syncrude) to 3.1 (Suncor) kg/ha/a. The respective maximums occur at the same locations as those from the annual average concentrations.

Table 8.1 Assumptions used to estimate deposition associated with the Suncor Powerhouse and Syncrude Main stacks.

Data	**Source**
Meteorological Data	Meteorological data based on Mannix 75 m level as discussed in Report 2 (Meteorological Data). Precipitation data are from AES Mildred Lake site.
Particulate Emissions	Suncor Powerhouse 6.3 t/d Syncrude Main stack 7.8 t/d
Particulate Characteristics	Diameter = 10 μm Density = 1 g/cm^3
Wet Deposition	Scavenging Coefficient Liquid = 6.6×10^{-4} $(s \cdot mm/h)^{-1}$ Ice = 2.2×10^{-4} $(s \cdot mm/h)^{-1}$

Table 8.2 Summary of particulate concentrations and deposition associated with the Suncor Powerhouse and Syncrude Main stack.

Stack	**Suncor Powerhouse**	**Syncrude Main**	**Combined**
Particulate Emissions (t/d)	**6.3**	**7.3**	**6.3 + 7.3**
Daily concentration			
Maximum ($\mu g/m^3$)	7.5	1.6	7.5
Location (km/degree)	25.6 / 231	56.6 / 315	25.6 / 231
Annual concentration			
Maximum ($\mu g/m^3$)	0.26	0.1	0.3
Location (km/degree)	7.1 / 352	58.3 / 329	7.1 / 352
Annual dry deposition[(a)]			
Maximum (kg/ha/a)	3.1	0.8	3.1
Location (km/degree)	7.1 / 352	58.3 / 329	7.1 / 352
Annual wet deposition[(a)(b)]			
Maximum (kg/ha/a)	105	105	106
Location (km/degree)	0.2 / 180	9.3 / 296	0.2 / 180
Total deposition[(a)(b)]			
Maximum (kg/ha/a)	105	105	106
Location (km/degree)	0.2 / 180	9.3 / 296	0.2 / 180

(a) Adjusted for a 12 month period; model simulation period is 20 months.

(b) Maximum value ~ 200 m from the stack; higher values are predicted to occur nearer the stack.

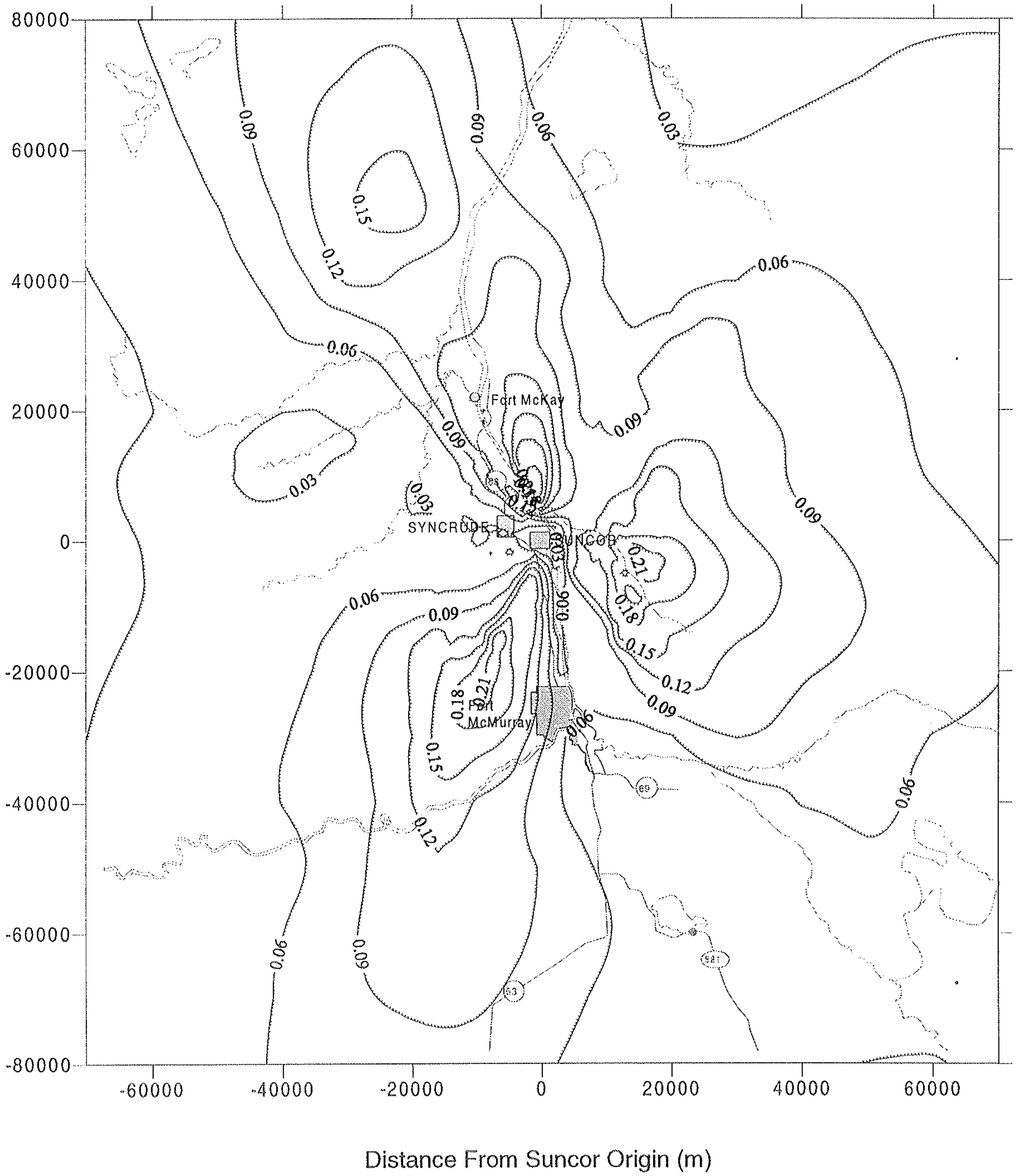


Figure 8.1 Annual average particulate concentration ($\mu g/m^3$) resulting from the operation of the **Suncor Powerhouse stack** (Particulate = 6.3 t/d).

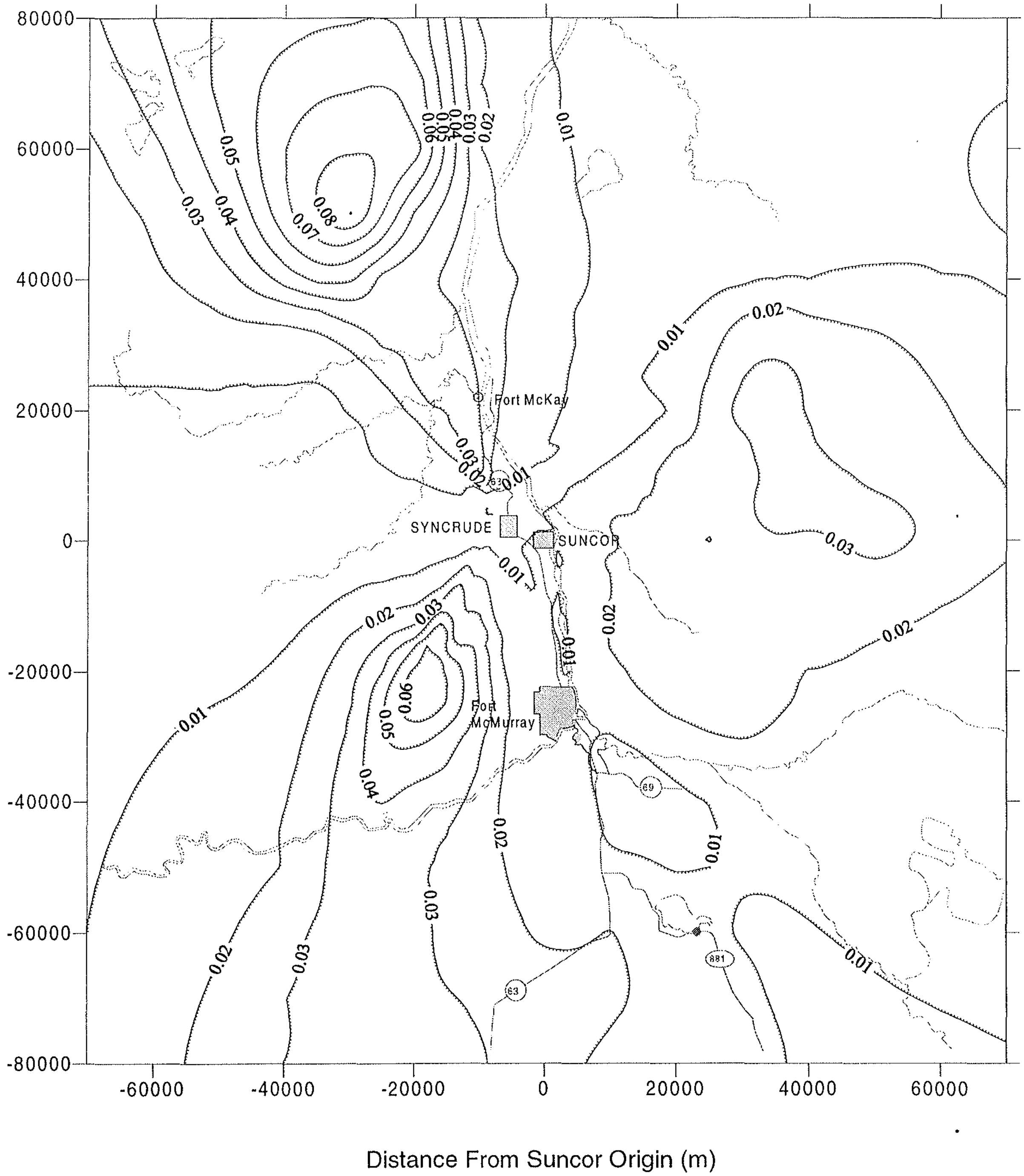


Figure 8.2 Annual average particulate concentrations (μg/m^3) resulting from the operation of the **Syncrude Main stack** (Particulate = 7.8 t/d).

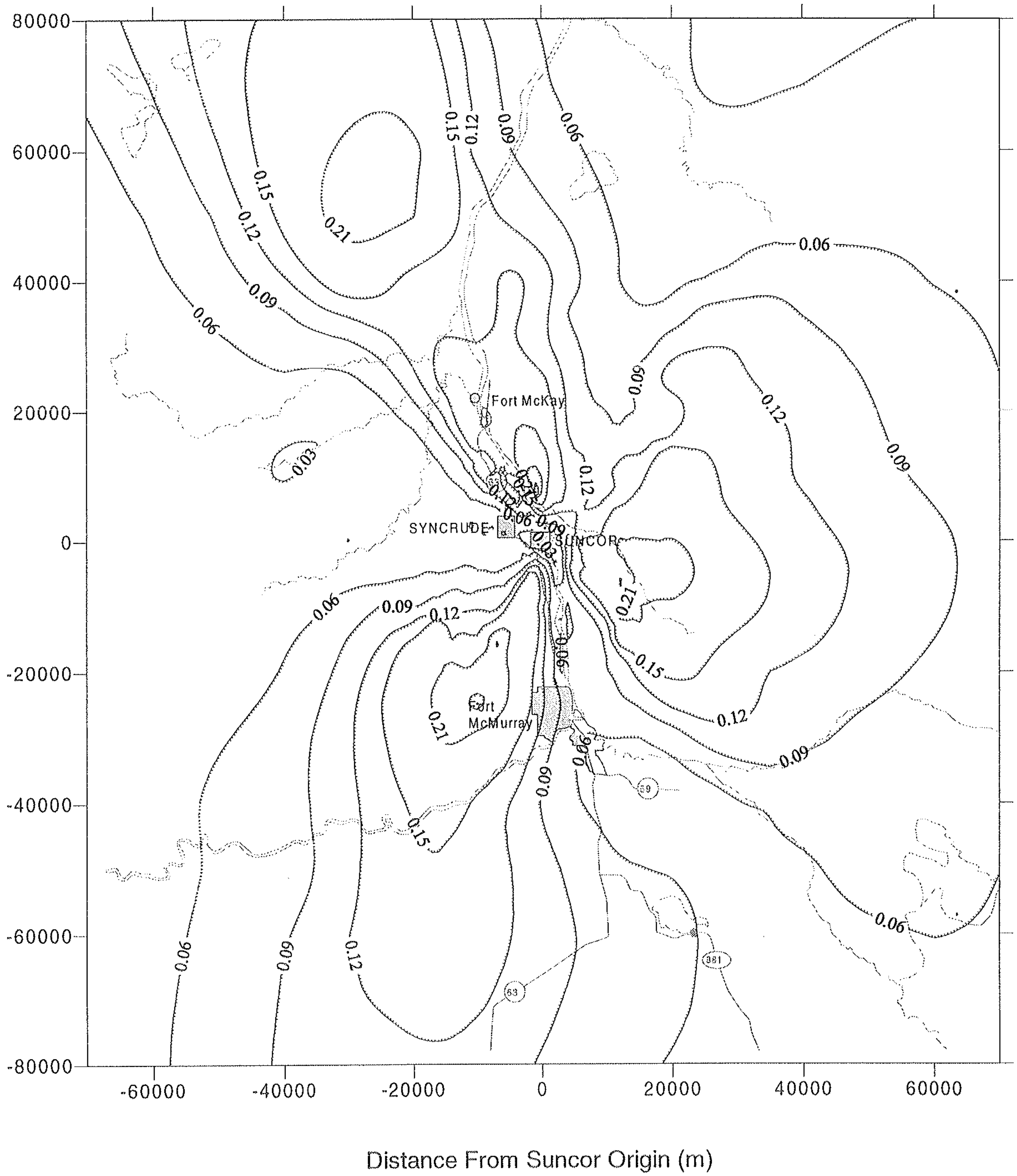


Figure 8.3 Annual average particulate concentrations ($\mu g/m^3$) resulting from the **combined operation** of the Suncor Powerhouse and Syncrude Main stacks (6.3 + 7.8 t/d).

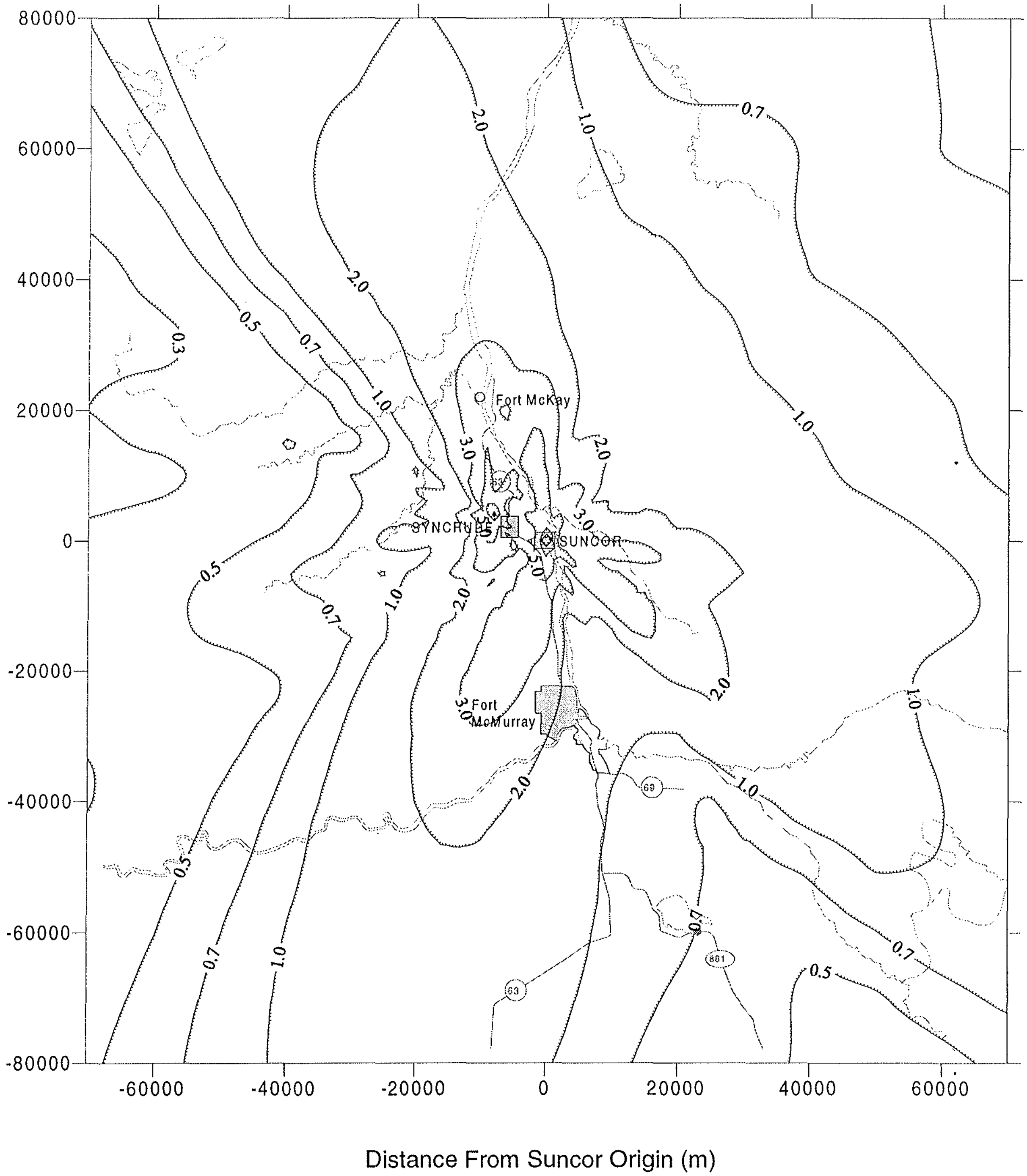


Figure 8.4 Total (dry + wet) particulate deposition (kg/ha/a) resulting from the **combined operation** of the Suncor Powerhouse and Syncrude Main stacks (6.3 + 7.8 t/d).

- Maximum wet depositions occur at the locations of each respective stack. The values shown in the table are about 200 m from the stack to represent adjacent deposition values. The values of the stack are about 200 kg/ha/a.

- The total deposition values given in the table are controlled by the wet deposition values.

Total suspended particulate (TSP) concentration and particulate deposition values resulting from the combined operation of both stacks were calculated for Fort McMurray and Fort McKay:

		Fort McMurray	**Fort McKay**
Maximum daily concentration	($\mu g/m^3$)	2.4	1.7
Annual concentration	($\mu g/m^3$)	0.13	0.17
Annual dry deposition	(kg/ha/a)	1.2	1.9
Annual wet deposition	(kg/ha/a)	1.1	2.3
Total deposition	(kg/ha/a)	2.0	4.2

These maximum values are much less than those shown in Table 8.2, showing the effect of decreasing concentrations and depositions with increasing distances from the sources..

For the purposes of comparison, the annual average (geometric mean) TSP values observed at AQS2 (Fort McMurray) and AQS4 (Tailings North) are in the 9.4 to 14.9 $\mu g/m^3$ range at AQS2 and in the 10.5 to 19.0 $\mu g/m^3$ at AQS4. These values were observed during 1991 to 1994 (Background Report 2 - Ambient Air Quality Observations). The maximum daily average values observed at these two locations for the period range from 34 to 273 $\mu g/m^3$. The latter value was associated with a truck that was left running during a routine calibration visit. As the predicted values associated with the Suncor Powerhouse and Syncrude Main stacks are much less than those observed, one can conclude that these two sources are not the main contributor to the ambient particulate concentrations observed in the region.

8.2 Concentrations and Deposition of Metals

Analyses of particulates from the Suncor Powerhouse and Syncrude Main stacks indicated metallic element content. The ambient concentrations and deposition for each metallic element can be estimated on the basis of proportionality. For example, the maximum annual average particulate concentration of 0.26 $\mu g/m^3$ was associated with the Suncor Powerhouse and this value was based on a particulate emission rate of 6.3 t/d (6300 kg/d). For iron, the associated emission and maximum concentration are 283 kg/d and 0.012 $\mu g/m^3$.

Tables 8.3 and 8.4 provide summaries of the maximum daily and annual concentrations; and maximum dry and wet depositions associated with the Suncor Powerhouse and Syncrude main stack, respectively. The maximum dry deposition values occur at the locations indicated in Table 8.2. The wet deposition values occur at the respective plant sites (~ 200 m downwind).

8..3 Comparison with Ambient Air Quality Guidelines

The provincial and federal air quality guidelines ($\mu g/m^3$) for particulates are summarized as:

Averaging Period	1 hour	1 day	Annual
Alberta	-	100	60
Federal Desirable	-	-	60
Federal Acceptable	-	120	70
Federal Tolerable	-	400	-

These guidelines refer to total suspended particulate (TSP) that effectively includes particles as large as 30 to 50 μm in diameter. Particulate matter less than 10 μm in diameter (PM_{10}) can be correlated with human health responses. While Canada has not adopted a PM_{10} guideline, the U.S. EPA and the state of California have. The province of British Columbia has accepted the California value as an interim objective based on the recommendation of Vedal (1993). These guidelines are ($\mu g/m^3$):

Averaging Period	1 hour	1 day	Annual
U.S. EPA	-	150	50
Primary	-	150	50
Secondary	-	150	-
California	-	50	-
British Columbia	-	50	-

Table 8.3 Maximum predicted concentrations and depositions of metallic elements from the operation of the **Suncor Powerhouse stack**.

Element	**Emission Rate (kg/d)**	**Concentration (μg/m³)**		**Deposition (kg/ha/a)**	
		Daily	**Annual**	**Dry**	**Wet**
Total Particulates	6300	7.5	0.26	3.1	105
Iron (Fe)	283	0.34	0.012	0.14	4.7
Zinc (Zn)	157	0.19	0.006	0.08	2.6
Aluminum (Al)	151	0.18	0.006	0.07	2.5
Magnesium (Mg)	117	0.14	0.005	0.06	1.9
Vanadium (V)	79	0.094	0.003	0.04	1.3
Sodium (Na)	70	0.083	0.003	0.03	1.2
Nickel (Ni)	18	0.021	0.0007	0.0089	0.3
Titanium (Ti)	17	0.020	0.0007	0.0084	0.3
Boron (B)	4.3	0.005	0.0002	0.0021	0.07
Silver (Ag)	4.0	0.005	0.0002	0.0020	0.07
Manganese (Mn)	4.0	0.005	0.0002	0.0020	0.07
Molybdenum (Mo)	3.8	0.005	0.0002	0.0019	0.06
Lead (Pb)	1.4	0.002	0.00006	0.0007	0.02
Strontium (Sr)	0.94	0.001	0.00004	0.0005	0.02
Copper (Cu)	0.89	0.001	0.00004	0.0004	0.01
Chromium (Cr)	0.83	0.001	0.00003	0.0004	0.01
Lithium (Li)	0.45	0.0005	0.00002	0.0002	0.01
Cobalt (Co)	0.4	0.0005	0.00002	0.0002	0.007
Arsenic (As)	0.31	0.0004	0.00001	0.0002	0.005
Cadmium (Cd)	0.08	0.0001	0.000003	0.00004	0.001
Selenium (Se)	0.04	0.00005	0.000002	0.00002	0.001
Mercury (Hg)	0.03	0.00004	0.000001	0.00001	0.0005

Table 8.4 Maximum predicted concentrations and deposition of metallic elements from the operation of the **Syncrude Main stack**.

Element	Emission Rate (kg/d)	Concentration ($\mu g/m^3$)		Deposition (kg/ha/a)	
		Daily	Annual	Dry	Wet
Total Particulates	7800	1.583	0.091	0.800	105.300
Iron (Fe)	69.6	0.014	0.001	0.007	0.940
Aluminum (Al)	25.3	0.0051	0.0003	0.003	0.342
Silicon (Si)	24.2	0.0049	0.0003	0.002	0.327
Calcium (Ca)	19.3	0.0039	0.0002	0.002	0.261
Sodium (Na)	10.8	0.0022	0.0001	0.001	0.146
Vanadium (V)	7.2	0.0015	0.0001	0.001	0.097
Magnesium (Mg)	6.7	0.0014	0.0001	0.001	0.090
Phosphorous (P)	2.2	0.0004	0.00003	0.0002	0.030
Nickel (Ni)	2.1	0.0004	0.00002	0.0002	0.028
Zinc (Zn)	1.0	0.0002	0.00001	0.0001	0.014
Lead (Pb)	0.08	0.00002	0.000001	0.000009	0.001
Chromium (Cr)	0.77	0.0002	0.000009	0.00008	0.010
Copper (Cu)	0.39	0.0001	0.000005	0.00004	0.005
Cadmium (Cd)	0.35	0.0001	0.000004	0.00004	0.005
Barium (Ba)	0.34	0.0001	0.000004	0.00003	0.005
Selenium (Se)	0.25	0.00005	0.000003	0.00003	0.003
Molybdenum (Mo)	0.23	0.00005	0.000003	0.00002	0.003
Cobalt (Co)	0.15	0.00003	0.000002	0.00002	0.002
Zirconium (Zr)	0.13	0.00003	0.000002	0.00001	0.002
Tin (Sn)	0.05	0.00001	0.0000006	0.000005	0.001
Arsenic (As)	0.05	0.00001	0.0000006	0.000005	0.001
Mercury (Hg)	0.01	0.000002	0.0000001	0.000001	0.000
Silver (Ag)	0.005	0.000001	0.00000006	0.0000005	0.000
Beryllium (Be)	0.001	0.0000002	0.00000001	0.0000001	0.000

The California and B.C. PM_{10} guidelines are more stringent than the U.S. EPA primary and secondary values.

The predicted maximum values given in Table 8.2 are much less than the TSP or PM_{10} guidelines. While these sources are the largest sources associated with the oil sands combustion sources, they are not the only sources of particulate emissions. Other sources include other industrial operations (i.e., beehive burners), residential wood combustion, fugitive road dust and natural windborne dusts and pollens.

Alberta does not have guidelines for ambient metal concentrations. For this reason, the predicted values in Tables 8.3 and 8.4 were compared to the Ontario ambient air quality criteria (AAQC) (Ontario Ministry of the Environment and Energy 1994). The comparison in Table 8.5 shows the Ontario AAQC and the ratio of the predicted values in Tables 8.3 and 8.4 to the AAQC. If the ratio is less than unity (1), then the predicted value is less than the AAQC; if the ratio is greater than unity, then the value exceeds the AAQC. The results indicate that the maximum predicted values associated with either the Suncor or Syncrude particulate emissions are several orders of magnitude less than the corresponding Ontario AAQC.

Table 8.5 Comparison of maximum predicted ambient metal concentrations to Ontario air quality standards.

	AAQC Daily ($\mu g/m^3$)	**Suncor Ratio ($\mu g/m^3$)[a]**	**Syncrude Ratio ($\mu g/m^3$)[a]**
Vanadium (V)	2.0	0.047	0.00075
Nickel (Ni)	2.0	0.0105	0.0002
Zinc (Zn)	120.0	0.00158	0.000002
Lead (Pb)	0.0	0.03	0.0003
Chromium (Cr)	1.5	0.00067	0.00013
Copper (Cu)	50.0	0.00002	0.000002
Cadmium (Cd)	2.0	0.00005	0.00005
Barium (Ba)	10.0	-	0.00001
Selenium (Se)	10.0	0.000005	0.000005
Molybdenum (Mo)	120.0	0.00004	0.0000004
Cobalt (Co)	0.1	0.005	0.0003
Tin (Sn)	10.0	-	0.000001
Arsenic (As)	0.3	0.0013	0.00003
Mercury (Hg)	2.0	0.00002	0.000001
Silver (Ag)	1.0	0.005	0.000001
Beryllium (Be)	0.0	-	0.00002

[a] Ratio less than unity indicates predicted values are less than AAQC.

9.0 PREDICTED AMBIENT HYDROCARBON CONCENTRATIONS

Total hydrocarbon (THC) emissions are comprised of both methane (C_1 or CH_4) and non-methane components. The latter are often referred to as volatile organic compounds (VOCs). THC and VOC emissions result from a number of sources identified in Table 9.1. At both the Suncor and Syncrude oil sands operations, the main sources are the evaporation of hydrocarbons from the surfaces of tailings ponds.

9.1 Model Approach

For the purposes of assessment, a simple box model was used to estimate THC and VOC hydrocarbon emissions from the two plants. Specifically, the concentration changes in the community of Fort McMurray and Fort McKay were estimated based on Suncor and Syncrude emissions. The box model is based on the following relationship:

$$\chi = \frac{Q}{AU}$$

when Q is the emission rate (t/d) that is assumed to be uniformly mixed and passing through a vertical plane of cross-sectional area A (m^2) with a mean wind speed of U (m/s). The cross-sectional area can be defined by looking at the terrain cross-sections at Fort McMurray and Fort McKay. Based on winds measured at the Lower Camp stack, the 25, 50 (median) and 75 percentile wind speeds are 1.0, 2.5 and 3.5 m/s, respectively.

9.2 Fort McKay Predictions

Figure 9.1 shows a series of cross-sectional terrain profiles in the vicinity of Fort McKay. Two valley trapping situations were considered. The first situation considered the width of the valley defined by the 275 m terrain contour. There profiles were considered, one through the community and two 500 m upvalley and downvalley of the community. The river is located at an elevation of 232. The valley width is about 2.5 km and the depth about 43 m at these locations. The second situation considered the width of the valley defined by the 310 terrain contours. The width of the valley is about 12 km and the depth about 78 m for this second situation. The following table shows the cross-sectional areas for the valley situation described by these elevations:

Area (m^2)

	275 m	**310 m**
- 500 m	54 000	329 000
0 m	52 000	349 000
+ 500 m	48 000	340 000
Average	51 000	339 000

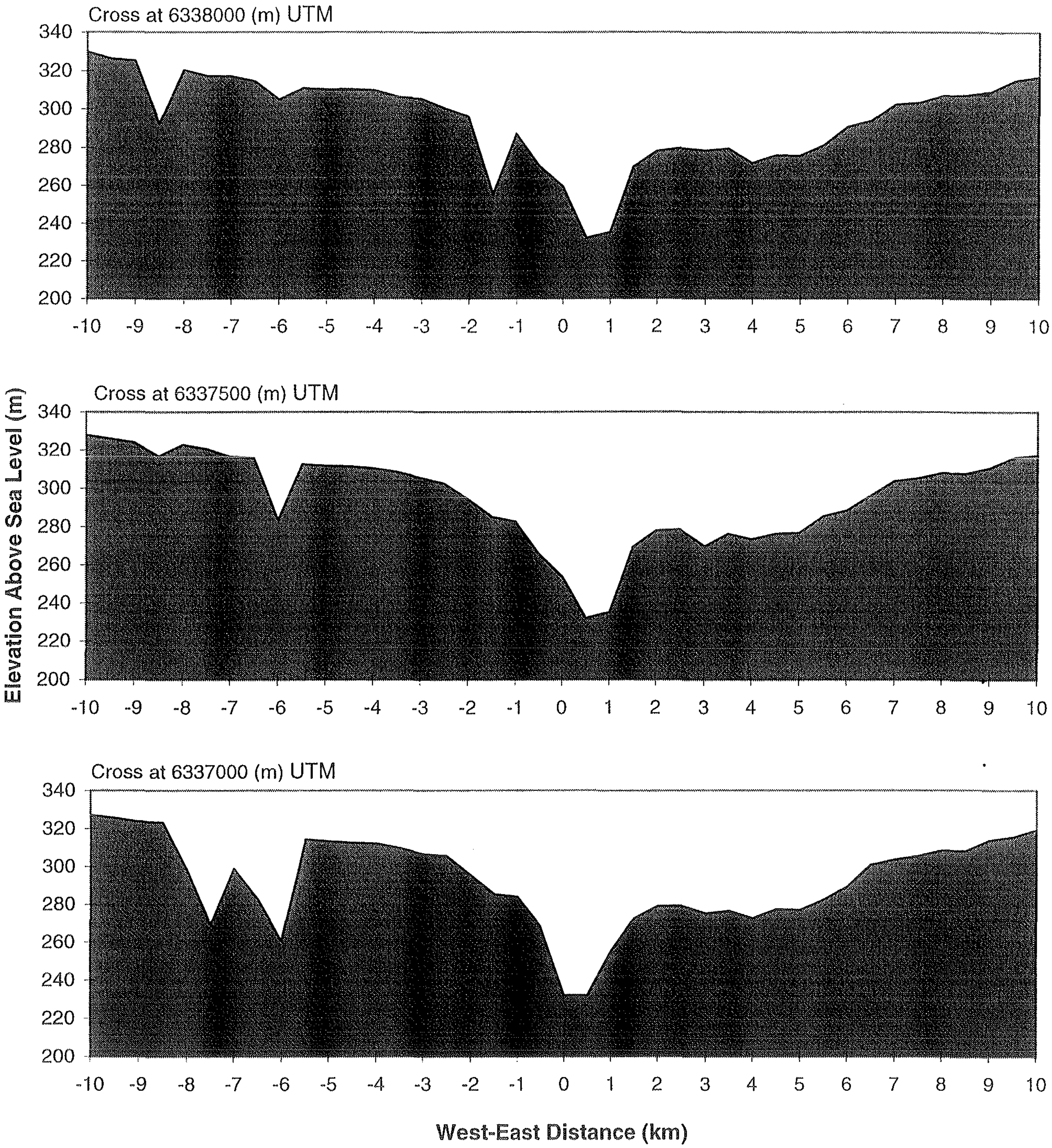


Figure 9.1 Terrain cross-sections in the vicinity of Fort McKay. The individual cross-sections are separated by 500 m.

Table 9.1 Predicted ambient hydrocarbon concentrations[a] (ppm) in **Fort McKay** from emissions associated with the Suncor and Syncrude operations.

Source	Wind Speed (m/s)	280 m[b]	310 m[c]
Suncor	1	12.1	1.8
(35.2 t/cd)	2.5	4.8	0.7
	3.5	3.5	0.5
Syncrude	1.0	5.9	0.9
(17.2 t/cd)	2.5	2.3	0.3
	3.5	1.7	0.3
Combined	1.0	18.0	2.7
(52.4 t/cd)	2.5	7.2	1.1
	3.5	5.1	0.8

[a] Expressed as methane (C_1) equivalent.
[b] Depth = 43 m.
[c] Depth = 78 m.

The results in Table 9.1 indicate that under a poor dispersion case (trapping depth = 43 m; wind speed = 1 m/s) relatively high HC concentration values could be observed in Fort McMurray based on Suncor emissions (12.1 ppm). Given the elevation of the Syncrude plant site, it is unlikely that the poor dispersion case defined by a 43 m trapping depth is reasonable. Based on the 78 m depth, the maximum concentrations for the combined emissions are about 2.7 ppm. The simplistic box model therefore supports the observations of relatively high HC concentrations downwind of the plant. The highest concentrations are likely due to the limited mixing of the Suncor emissions in the valley.

9.3 Fort McMurray Predictions

Figure 9.2 shows a series of cross-sectional terrain profiles in the vicinity of Fort McMurray. As with Fort McKay, two valley trapping situations were considered. The first assumes valley width defined by the 290 m terrain contour. The valley widths and depths defined by this contour are in the 2 to 3 km and 45 to 50 m ranges, respectively. The second situation considers the valley width defined by the 330 m terrain contour. The valley widths and depths for this contour are in the 4 to 4.5 km and the 85 to 90 m ranges, respectively. The following table shows the cross-sectional areas for the valley situations described by the three elevations:

Area (m^2)

	290 m	330 m
Athabasca	105 000	231 000
	48 000	186 000
	67 000	191 000
Average	73 000	203 000

The results in Table 9.2 indicate that under a poor dispersion case (trapping depth = 45 to 50 m, wind speed = 1 m/s) relatively high hydrocarbon concentrations could also occur in Fort McMurray (4.5 to 8.4 ppm). Because of the position of Syncrude relative to the valley, it is unlikely that their fugitive HC emissions could be trapped within a layer 45 to 50 m in depth.

9.4 Summary

Under poor dispersion conditions, the box model approach predicts hydrocarbon concentrations of around 8 to 12 ppm in Fort McMurray and Fort McKay, respectively. Maximum observed values at these two locations are 8.6 and 4.1 ppm at Fort McMurray and Fort McKay, respectively. At valley locations, closer to the sources (i.e., Athabasca Bridge and Poplar Creek), the maximum observed values have ranged from 7 to 50 ppm. The observed background values are typically in the 1.5 to 2.0 ppm range.

Table 9.2 Predicted ambient hydrocarbon concentrations[a] (ppm) in **Fort McMurray** from emissions associated with the Suncor and Syncrude operations.

Source	**Wind Speed (m/s)**	**290 m[b]**	**330 m[c]**
Suncor	1	8.4	3.0
(35.5 t/cd)	2.5	3.4	1.2
	3.5	2.4	0.9
Syncrude	1.0	4.1	1.5
(17.2 t/cd)	2.5	1.6	0.6
	3.5	1.2	0.4
Combined	1.0	12.5	4.5
(52.4 t/cd)	2.5	5.0	1.8
	3.5	3.6	1.3

(a) Expressed as methane (C_1) equivalent.
(b) Depth = 45 to 50 m.
(c) Depth = 85 to 90 m.

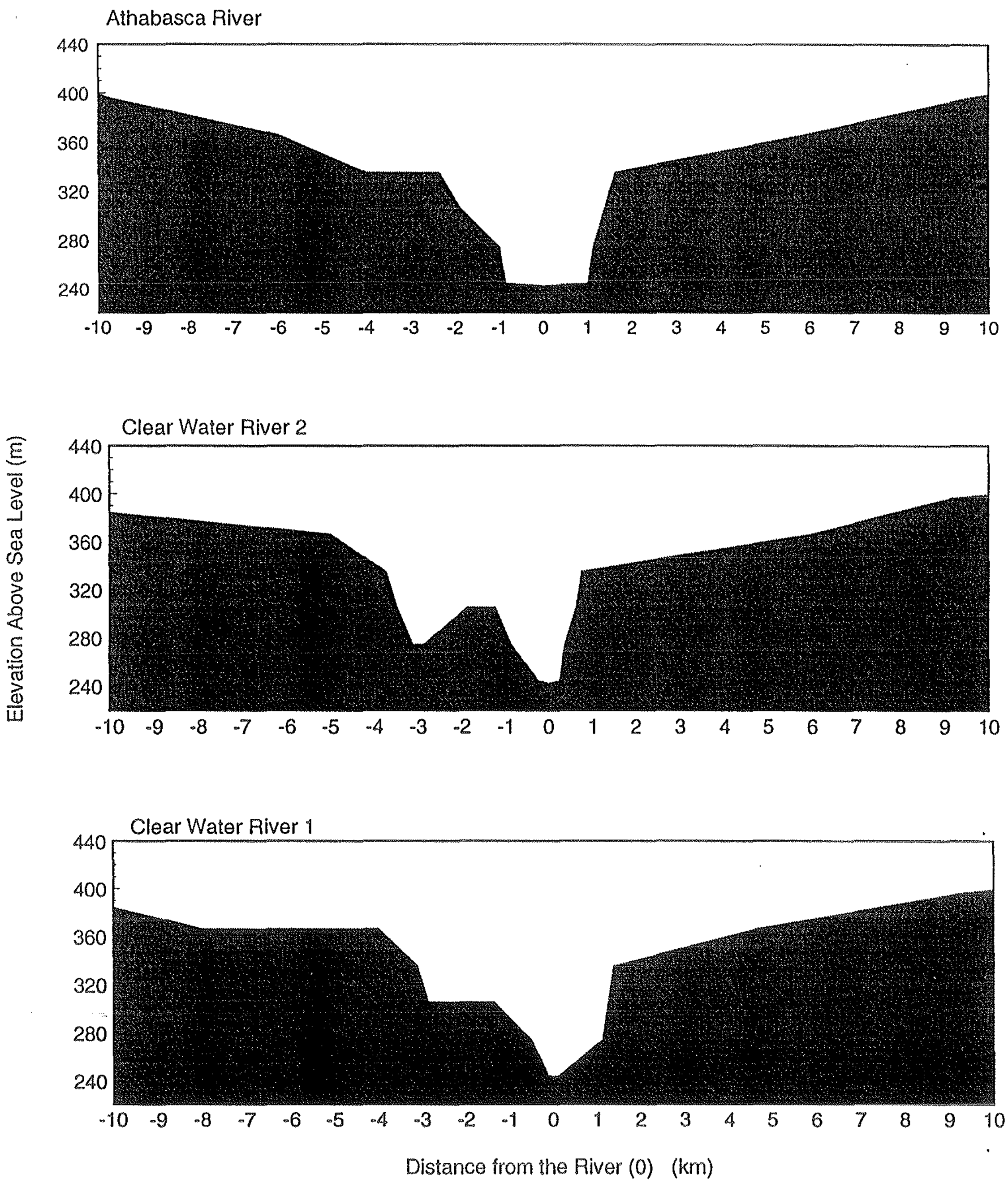


Figure 9.2 Terrain cross-sections in the vicinity of Fort McMurray.

The box model is likely to overestimate ambient concentrations for longer travel times because of mixing of valley air with outside air. The model predictions presented in this section may underestimate since uniform emission rates are used. The high concentration values that have been observed are likely associated with an abnormal emission scenario.

The model predictions are not compared to ambient air quality guidelines since Alberta does not have specific guidelines for hydrocarbons.

10.0 SUMMARY AND COMMENTS

10.1 Model Approach and Limitations

Air quality simulation models provide a scientific means of relating industrial emissions to changes in ambient air quality. This modelling can complement ambient monitoring in terms of providing an understanding of air quality changes. As such, modelling forms an important component of an air quality assessment.

Four models were applied to the emission sources in the region:

- **SCREEN3**. This U.S. EPA model was used as a general model to evaluate the effect of emissions from stacks on ambient air quality.

- **ISC3BE**. This is a modified version of the U.S. EPA model ISCST3 which was used to evaluate ambient SO_2 concentrations resulting from the regional sources. The model was modified to ensure that the predicted trends were similar to the observed trends.

- **ADEPT2**. This AEP model was used to evaluate annual SO_2 concentration and the deposition of sulphur compounds from the major sources. A modified version of the model using the dry deposition velocities specified by the Alberta Research Council was used.

- **Box model**. A simple box model was used to evaluate hydrocarbon concentrations that could occur in Fort McMurray or Fort McKay from fugitive oil sands emissions.

Where applicable, model predictions were compared to air quality guidelines.

Dispersion models employ simplifying assumptions in order to describe the random processes associated with atmospheric motions and turbulence. These simplifying processes will limit the ability of a model to replicate individual events. A model's predictive capability and strength lies in the ability to predict an average for a given meteorological condition.

Other factors that limit the ability of a model to predict values that match observations are limitations in the input data and information used by the model. Specifically, models require source data and meteorological information. Additionally, ambient air quality data are required to evaluate the performance of the model. For example, the following limitations are noted:

- The model does not account for hour-by-hour variations in the source strength and exit characterization.

- There are limitations on the characterization of the secondary combustion sources, and flaring events.

- The meteorological data do not fully reflect the more westerly flows that may be associated with Syncrude main stack.

- The ambient air quality data are from a limited number of sites and do not measure small concentration values.

Notwithstanding these limitations, the data used by the models and for the model evaluation did undergo a review in the baseline reports and they were deemed to be sufficient for this modelling application. Specifically, the model predictions show familiar agreement with observations (Table 3.8, Figure 3.3).

10.2 Model Predictions

The results of the model predictions are summarized in each of the respective sections, and the main findings are presented in this summary.

10.2.1 *SO_2 Concentrations*

- **Suncor Powerhouse:** Maximum predicted concentrations are in the 1200 to 2200 µg/m^3 (0.45 to 0.83 ppm) range. These predictions compare to maximum concentrations observed at Suncor's air quality monitoring stations that range from 0.31 to 0.60 ppm. These hourly values are in excess of the provincial and federal guidelines. The 450 µg/m^3 guideline is predicted to be exceeded up to about 34 times per year (based on average emissions (Table 4.3)).

  Relatively large SO_2 concentrations are predicted to occur on the elevated terrain to the east of Suncor (Muskeg Mountain) and to the southwest of Suncor (Thickwood Hills). These maximum values result from the Suncor Powerhouse stack and are in excess of the 900 µg/m^3 Federal air quality objectives (Figure 4.3). Similarly, relatively large daily average maxima are predicted to occur in the same area due to the operation of the Powerhouse stack (Figure 4.5).

  Intermittent flaring at the Suncor and Syncrude operations can result in SO_2 concentrations that exceed the 450 and 900 µg/m^3 guidelines (Table 4.6), given the simultaneous occurrence of flaring and the worst case meteorological conditions.

- **Suncor Incinerator:** Maximum predicted concentrations before SuperClaus are in the 700 to 1700 µg/m^3 (0.26 to 0.64 ppm) range. With the implementation of SuperClaus, the corresponding maxima are in the 340 to 670 µg/m^3 (0.13 to 0.25 ppm) range. The maximum predicted values prior to SuperClaus were in excess of the provincial and federal hourly guidelines. The addition of SuperClaus reduces the maximum predicted values by a factor of two. Three exceedences of the 450 µg/m^3 guideline per year were predicted prior to SuperClaus, and no exceedences are predicted after the implementation of SuperClaus (based on average emissions). Under upset conditions, with the simultaneous occurrence of adverse meteorological conditions, exceedences may result from the post SuperClaus operation (Table 4.3).

- **Syncrude Main Stack:** Maximum predicted concentrations are in the 322 to 1233 $\mu g/m^3$ (0.12 to 0.46 ppm) range. The larger predicted values are associated with the SCREEN3 model and upset conditions. The ISCS3BE model predicts that one exceedence of the 450 $\mu g/m^3$ guideline could occur under upset conditions (Table 4.3).

The combined operation of the three major sources (Suncor Powerhouse, Suncor Incinerator (after SuperClaus) and Syncrude Main) is predicted to result in a maximum of 37 to 67 hourly exceedences of the 450 $\mu g/m^3$ guideline and 1 to 6 daily exceedences of the 150 $\mu g/m^3$ guideline. The maximum predicted annual average concentrations for the combined operation are predicted to range from 12 to 24 $\mu g/m^3$ which is less than the 30 $\mu g/m^3$ annual guideline.

In summary, the largest SO_2 concentrations are associated with intermittent flaring, which occurs on an intermittent basis, and with the Suncor Powerhouse whose emissions are continuous.

10.2.2 *Deposition*

The deposition calculations were undertaken to provide a measure of the uptake of sulphur compounds by vegetation canopies. The uptake is comprised of dry and wet deposition processes.

Dry deposition is proportional to a deposition velocity that accounts for atmospheric turbulence to ensure the pollutant is brought into contact with the surface feature, the transfer of pollutants across a surface boundary layer and the reactivity of the surface. These factors can change with surface type (i.e., vegetation canopy types), season and time of day. Three sets of deposition velocities were evaluated: defaulted ADEPT2, Alberta Research Council RELMAP and Concord Scientific. The predicted depositions were similar for the RELMAP and Concord deposition velocities, and the use of both of these sets predicted rates that were almost double those predicted using the ADEPT2 model values. For the purposes of being conservative (i.e., over-predicting), the RELMAP values were used.

The following table summarizes the maximum total (wet + dry) deposition values (expressed as kg SO_4^{-2}/ha/a) predicted to result from the combined operation of the three main SO_2 emitting sources:

Source		Total Deposition
Suncor Powerhouse	(211 t/d)	19.2
Suncor Incinerator	(17 t/d)	9.4
Syncrude Main Stack	(212 t/h)	8.2
Combined		25.5

Based on model predictions, dry deposition is responsible for about two-thirds the total deposition, and the Suncor Powerhouse stack is the main contributor. Maximum values are predicted to occur about 26 km to the north-northwest and 20 km to the south-southwest of the Suncor Powerhouse. The locations result from the frequent winds that tend to align with the valley axis.

The model prediction of sulphate equivalent depositions was related to an effective acidity (EA) using background measurements from Cree Lake. These were compared to preliminary deposition limits specified by Alberta Environmental Protection. The maximum estimated EA (0.66 kmol H^+/ha/a) is less than the range specified for low sensitivity soils (0.7 to 1.0 kmol H^+/ha/a). Approximately 900 km^2 to the north, southwest and south of the plants were associated with EA values that exceed the upper range (0.4 kmol H^+/ha/a) of that specified for medium sensitivity soils. Approximately 6000 km^2 in the same relative directions were associated with EA values that exceed the upper range (0.3 kmol H^+/ha/a) of that specified for high sensitivity soils (Figure 5.10).

As the methodology for calculating EA and the guidelines have not been finalized, the magnitudes of EA values should only be used on a relative and not an absolute basis.

10.2.3 *NO_x Concentrations*

The SCREEN3 model was used to estimate maximum NO_x concentrations from each of the Suncor and Syncrude combustion sources. The results indicate that the associated NO_2 concentrations should be within the hourly, daily and annual guidelines for NO_2. This is somewhat confirmed by air quality data collected by Syncrude.

10.2.4 *CO Concentrations*

The SCREEN3 model was also used to estimate maximum CO concentrations. The largest CO concentrations from the main continuous stacks, are in the 83 to 165 $\mu g/m^3$ range (Tables 7.1 and 7.2). The intermittent use of the Syncrude diverter stack results in a maximum predicted CO concentration of 2560 $\mu g/m^3$. These maxima are all within the air quality guideline of 15 000 $\mu g/m^3$.

10.2.5 *Particulate Concentrations*

Ambient concentrations and depositions associated with particulate emissions from the Suncor Powerhouse and Syncrude main stacks were calculated as daily and annual averages. The following was found:

- Maximum daily average particulate concentrations are in the 2 to 8 $\mu g/m^3$ range. These values are well within total suspended particulate (TSP) and PM_{10} daily guideline values (100 and 50 $\mu g/m^3$, respectively).

- Maximum annual average particulate concentrations are in the 0.1 to 0.3 $\mu g/m^3$ range. These are well within the TSP annual guideline (60 $\mu g/m^3$).

- Maximum dry deposition of particulates ranges from 0.8 to 3.1 kg/ha/a. Maximum wet deposition values (in excess of 100 kg/ha/a) are predicted at the source and decrease rapidly with increasing distance from the source.

While the sources modelled are the largest combustion sources of particulates associated with oil sands developments, the relatively low predictions, when compared to some of the observations, suggest other significant contributors to ambient particulate concentrations observed in the region. These include other industrial operations (i.e., conical burners), residential wood combustion, fugitive road dust and natural airborne dusts and pollens.

The particulate emissions from the Suncor Powerhouse and Syncrude main stack are comprised of metallic compounds. The maximum concentrations associated with these emissions were compared to Ontario Ambient Air Quality Criteria (AAQC) as equivalent guidelines or criteria do not exist for Alberta. The comparison indicated that the maximum predicted levels are several orders of magnitude less than the Ontario criteria.

10.2.6 *Hydrocarbon Concentrations*

A simple box model was used to predict ambient hydrocarbon concentrations in Fort McMurray and Fort McKay that could occur for fugitive emissions. The box model approach assumes these emissions are transported up and down the Athabasca River Valley and the sides of the box are defined by the valley walls and the top is defined by two selected levels. The results indicate that the likely source of high ambient HC concentrations that have occurred upvalley and downvalley are due to emissions from Suncor.

10.3 Conclusions

Predictions from the dispersion model complement the conclusions associated with the review of the ambient air quality monitoring data (Background Report 2). Both the modelling and monitoring indicate that the operation of the Suncor and Syncrude facilities has resulted in changes to the quality of the air downwind. Specifically, relatively high SO_2 concentrations have been observed and the model predictions indicate the Suncor powerhouse as the main contributor to these values. The models also indicate that intermittent flaring associated with each plant can also result in relatively large SO_2 concentrations.

The modelling confirms that ambient concentrations of NO_x, CO and PM_{10} associated with combustion sources within both plants should be within the respective guideline values. The modelling also provides annual average concentration and deposition estimates that can be used to help select locations for future receptor monitoring programs.

Finally, the modelling assessment provides a tool by which air quality changes associated with future operations can be assessed. The effect of new sources and changes to existing sources can be evaluated and compared to the baseline information (~ 1994/95) presented in this report.

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APPENDICES

APPENDIX A FILE DOCUMENTATION

An important part of any project where a large amount of data are handled is file management. The purpose of this appendix is to identify the computer files associated with the modelling assessment conducted in this report. These files and their associated formats can be categorized as such:

- Model input and output files.
- Post-processed data and graphics files.
- Report text files.

The first two categories, together referred to as model related files, are summarized in Table A.1, while Table A.2 lists the files in the third category.

The data, text and graphics files were all prepared using commercial MS-DOS or WINDOWS (Microsoft Corporation) based software.

All files generated for the modelling assessment purposes in this report are identified with the "report output" files, i.e., figures and tables, and grouped by the model type which they are associated with. The following two tables provide brief information on the model versions that are adopted in this report and a file type classification, respectively.

Model	Base Model	Modification
ADEPT2	V2.2 (84215)	With anemometer height and deposition velocity options
ISCST3	V95250	
ISC3BE	V95250	With adjusted plume rise, terrain and plume spreads
SCREEN3	V95250	No modification

File Type	Description
*.DAT	Input data file in standard ASCII format.
*.EXC	Three-column ASCII data file from ISCST3 model run for exceedences analysis.
*.GRD	Surfer grid file.
*.MET	Meteorological data file in ASCII format.
*.OUT	Output data file in standard ASCII format.
*.PRE	Lotus Freelance graphics file.
*.SRF	Surfer graphics file.
*.STA	Statistica database file.
*.STG	Statistica graphics file.
*.XLS	Excel spreadsheet or chart file.
*.XYZ	Three-column ASCII data file from secondary processing of ISCST output file for concentration or deposition contouring.

Table A.1 Model related files.

Report Output	Models Selected	Model Input File (*.DAT)	Model Output File (*.OUT)	Secondary Output File	Summary Data File
Figure 3.1				SUNMETRV.STA	MERVFIGS.PRE
Figure 3.2	Observed				ALLSITEO.STA
Table 3.8 Figure 3.3	ISCST3	SUN2M, SUN4M, SUN5M, SUN9M, SUN10M, SYN1M, SYN2M, SYN3M, SYN4M, SYN5M, FTMKM, FTMCM, BMSM	SUN2M, SUN4M, SUN5M, SUN9M, SUN10M, SYN1M, SYN2M, SYN3M, SYN4M, SYN5M, FTMKM, FTMCM, BMSM		PTIMEALL.STA
	ISC3BE	SUN2M, SUN4M, SUN5M, SUN9M, SUN10M, SYN1M, SYN2M, SYN3M, SYN4M, SYN5M, FTMKM, FTMCM, BMSM	SUN2M, SUN4M, SUN5M, SUN9M, SUN10M, SYN1M, SYN2M, SYN3M, SYN4M, SYN5M, FTMKM, FTMCM, BMSM		TIMEBEMA.STA
Figure 3.4 Figure 3.6	Observed				ALLSITEO.STA
	ISCST3	SUN2M, SUN4M, SUN5M, SUN9M, SUN10M, SYN1M, SYN2M, SYN3M, SYN4M, SYN5M, FTMKM, FTMCM, BMSM	SUN2M, SUN4M, SUN5M, SUN9M, SUN10M, SYN1M, SYN2M, SYN3M, SYN4M, SYN5M, FTMKM, FTMCM, BMSM		12SITEMA.STA
	ISC3BE	SUN2M, SUN4M, SUN5M, SUN9M, SUN10M, SYN1M, SYN2M, SYN3M, SYN4M, SYN5M, FTMKM, FTMCM, BMSM	SUN2M, SUN4M, SUN5M, SUN9M, SUN10M, SYN1M, SYN2M, SYN3M, SYN4M, SYN5M, FTMKM, FTMCM, BMSM		12SITEMA.STA
	Observed				ALLSITEO.STA

Table A.1 Continued.

Report Output	Models Selected	Model Input File (*.DAT)	Model Output File (*.OUT)	Secondary Output File	Summary Data File
Figure 3.5 Figure 3.7	ISCST3	SUN2L, SUN4L, SUN5L, SUN9L, SUN10L, SYN1L, SYN2L, SYN3L, SYN4L, SYN5L, FTMKL, FTMCL, BMSL	SUN2L, SUN4L, SUN5L, SUN9L, SUN10L, SYN1L, SYN2L, SYN3L, SYN4L, SYN5L, FTMKL, FTMCL, BMSL		12SITELC.STA
	ISC3BE	SUN2L, SUN4L, SUN5L, SUN9L, SUN10L, SYN1L, SYN2L, SYN3L, SYN4L, SYN5L, FTMKL, FTMCL, BMSL	SUN2L, SUN4L, SUN5L, SUN9L, SUN10L, SYN1L, SYN2L, SYN3L, SYN4L, SYN5L, FTMKL, FTMCL, BMSL		12SITELC.STA
Table 4.3 Figure 4.1	SCREEN3	BITUMEN, INASAVG, INASHR, INBSANB, INBSAVG, INBSDAY, INBSHR, MS90D, MSAVG, MSDAY, MSHR, PHABN, PHAVG, PHDAY, PHHR, RUTHLAKE	BITUMEN, INASAVG, INASHR, INBSANB, INBSAVG, INBSDAY, INBSHR, MS90D, MSAVG, MSDAY, MSHR, PHABN, PHAVG, PHDAY, PHHR, RUTHLAKE		SO2_1SRC.XLS
	ISC3BE	BITUMEN, INASAVG, INASHR, INBSANB, INBSAVG, INBSDAY, INBSHR, MS90D, MSAVG, MSDAY, MSHR, PHABN, PHAVG, PHDAY, PHHR, RUTHLAKE	BITUMEN, INASAVG, INASHR, INBSANB, INBSAVG, INBSDAY, INBSHR, MS90D, MSAVG, MSDAY, MSHR, PHABN, PHAVG, PHDAY, PHHR, RUTHLAKE		SO2_1SRC.XLS

Table A.1 Continued.

Report Output	Models Selected	Model Input File (*.DAT)	Model Output File (*.OUT)	Secondary Output File	Summary Data File
Figure 4.2	ISC3BE	PHAVG	PHAVG	PHAVGH.XYZ	PHAVGH.GRD
Figure 4.3	ISC3BE	INASAVG	INASAVG	INASAVGH.XYZ	INASAVGH.GRD
Figure 4.4	ISC3BE	MSAVG	MSAVG	MSAVGH.XYZ	MSAVGH.GRD
Table 4.4	ISC3BE	PHAVG, PHDAY, INBSAVG, INBSDAY, INASAVG, MSAVG, MS90D, MSDAY, BITUMEN, RUTHLAKE	PHAVG, PHDAY, INBSAVG, INBSDAY, INASAVG, MSAVG, MS90D, MSDAY, BITUMEN, RUTHLAKE	(*.EXC): PHAVGD, PHDAYD, INBSAVGD, INBSDAYD, INASAVGD, MSAVGD, MS90DD, MSDAYD, BITUMEND, RUTHLKD	
Figure 4.5	ISC3BE	PHAVG	PHAVG	PHAVGD.XYZ	PHAVGD.GRD
Figure 4.6	ISC3BE	INASAVG	INASAVG	INASAVGD.XYZ	INASAVGD.GRD
Figure 4.7	ISC3BE	MSAVG	MSAVG	MSAVGD.XYZ	MSAVGD.GRD
Table 4.5	ISC3BE	PHAVG, INBSAVG, INASAVG, MSAVG, BITUMEN, RUTHLAKE	PHAVG, INBSAVG, INASAVG, MSAVG, BITUMEN, RUTHLAKE		
	ADEPT2	PHAVG, INBSAVG, INASAVG, MSAVG, BITUMEN, RUTHLAKE	PHAVG, INBSAVG, INASAVG, MSAVG, BITUMEN, RUTHLAKE		
Figure 4.8	ISC3BE	PHAVG	PHAVG	PHAVGA.XYZ	PHAVGA.GRD
Figure 4.9	ISC3BE	INASAVG	INASAVG	INASAVGA.XYZ	INASAVGA.GRD
Figure 4.10	ISC3BE	MSAVG	MSAVG	MSAVGA.XYZ	MSAVGA.GRD

Table A.1 Continued.

Report Output	Models Selected	Model Input File (*.DAT)	Model Output File (*.OUT)	Secondary Output File	Summary Data File
Table 4.6	SCREEN3	5C10, 5C14, 7C12, 7C13, 7C15, 7C24, 7C26, 7C3, 7C4, 7C6, 8C4, AMINE, COKERS, GASOIL, LCFINER, LIGHT, NAPHTHA, SOUR, SULPHUR	5C10, 5C14, 7C12, 7C13, 7C15, 7C24, 7C26, 7C3, 7C4, 7C6, 8C4, AMINE, COKERS, GASOIL, LCFINER, LIGHT, NAPHTHA, SOUR, SULPHUR		SO2FLARE.XLS
Table 4.7	SCREEN3	COKERCOS, COKERCS2, COKERH2S, COKERSO2, COMBCOS, COMBCS2, COMBH2S, COMBSO2	COKERCOS, COKERCS2, COKERH2S, COKERSO2, COMBCOS, COMBCS2, COMBH2S, COMBSO2		
Table 4.8	ISC3BE	CASEA, CASEB, CASEC, CASED	CASEA, CASEB, CASEC, CASED	(*.EXC): CASEAD, CASEBD, CASECD, CASEDD, CASEAH, CASEBH, CASECH, CASEDH	
Figure 4.11	ISC3BE	CASEC	CASEC	CASECH.XYZ	CASECHPL.GRD
Figure 4.12	ISC3BE	CASEC	CASEC	CASECD.XYZ	CASECDPL.GRD
Figure 4.13	ISC3BE	CASEC	CASEC	CASECA.XYZ	CASECAPL.GRD
Figure 4.14	ISC3BE	CASEC	CASEC	CASECH.EXC	CASECHEX.GRD
Figure 5.1	ADEPT2	SUNSYN	SUNSYN	PHNOZERO.OUT	PHDRYSO4.GRD
Figure 5.2	ADEPT2	SUNSYN	SUNSYN	INNOZERO.OUT	INDRYSO4.GRD
Figure 5.3	ADEPT2	SUNSYN	SUNSYN	MSNOZERO.OUT	MSDRYSO4.GRD
Figure 5.4	ADEPT2	SUNSYN	SUNSYN	PHNOZERO.OUT, INNOZERO.OUT, MSNOZERO.OUT	ALDRYSO4.GRD
Figure 5.5	ADEPT2	SUNSYN	SUNSYN	PHNOZERO.OUT	PHWETSO4.GRD
Figure 5.6	ADEPT2	SUNSYN	SUNSYN	INNOZERO.OUT	INWETSO4.GRD

Table A.1 Continued.

Report Output	Models Selected	Model Input File (*.DAT)	Model Output File (*.OUT)	Secondary Output File	Summary Data File
Figure 5.7	ADEPT2	SUNSYN	SUNSYN	MSNOZERO.OUT	MSWETSO4.GRD
Figure 5.8	ADEPT2	SUNSYN	SUNSYN	PHNOZERO.OUT, INNOZERO.OUT, MSNOZERO.OUT	ALWETSO4.GRD
Figure 5.9	ADEPT2	SUNSYN	SUNSYN	PHNOZERO.OUT, INNOZERO.OUT, MSNOZERO.OUT	ALTOTSO4.GRD
Figure 5.10	ADEPT2	SUNSYN	SUNSYN	PHNOZERO.OUT, INNOZERO.OUT, MSNOZERO.OUT	ALLEA.GRD
Table 6.1	SCREEN3	5F_1AB, 5F_234, 5F_5, 5F_6, 6F_2ABC, 6F_5, 7F_1, 7F_10, 7F_11, 7F_2, 7F_20ABC	5F_1AB, 5F_234, 5F_5, 5F_6, 6F_2ABC, 6F_5, 7F_1, 7F_10, 7F_11, 7F_2, 7F_20ABC		NOXEMISS.XLS
Table 6.2	SCREEN3	8_F4, 31GTG20X, 7_1F_1A, 7_1F_1B, 7_2F_1AB, 8_12F_6A, 8_12F_6B, 9_12F_1, 9_3F_1, 15_12F_1, 18F_1, 18F_2, 22_1F_1, 22_1F_2, 22_1F_3, 15_12F_2, 18F_2, 120F101, 14F_1, 21F_7890, 21F_5123	8_F4, 31GTG20X, 7_1F_1A, 7_1F_1B, 7_2F_1AB, 8_12F_6A, 8_12F_6B, 9_12F_1, 9_3F_1, 15_12F_1, 18F_1, 18F_2, 22_1F_1, 22_1F_2, 22_1F_3, 15_12F_2, 18F_2, 120F101, 14F_1, 21F_7890, 21F_5123		NOXEMISS.XLS
Table 7.1	SCREEN3	5F_1AB, 5F_234, 5F_5, 5F_6, 6F_2ABC, 6F_5, 7F_1, 7F_10, 7F_11, 7F_2, 7F_20ABC	5F_1AB, 5F_234, 5F_5, 5F_6, 6F_2ABC, 6F_5, 7F_1, 7F_10, 7F_11, 7F_2, 7F_20ABC		

Table A.1 Continued.

Report Output	Models Selected	Model Input File (*.DAT)	Model Output File (*.OUT)	Secondary Output File	Summary Data File
Table 7.2	SCREEN3	8_F4, 31GTG20X, 7_1F_1A, 7_1F_1B, 7_2F_1AB, 8_12F_6A, 8_12F_6B, 9_12F_1, 9_3F_1, 15_12F_1, 18F_1, 18F_2, 22_1F_1, 22_1F_2, 22_1F_3, 15_12F_2, 18F_2, 120F101, 14F_1, 21F_7890, 21F_5123, DIVERTER	8_F4, 31GTG20X, 7_1F_1A, 7_1F_1B, 7_2F_1AB, 8_12F_6A, 8_12F_6B, 9_12F_1, 9_3F_1, 15_12F_1, 18F_1, 18F_2, 22_1F_1, 22_1F_2, 22_1F_3, 15_12F_2, 18F_2, 120F101, 14F_1, 21F_7890, 21F_5123, DIVERTER		
Table 8.2	ISC3BE	95CBCON, 95CBDEP, 95MSCON, 95MSDEP, 95PHCON, 95PHDEP	95CBCON, 95CBDEP, 95MSCON, 95MSDEP, 95PHCON, 95PHDEP		
Figure 8.1	ISC3BE	95PHCON	95PHCON	PH95ANCN.XYZ	PH95ANCN.GRD
Figure 8.2	ISC3BE	95MSCON	95MSCON	MS95ANCN.XYZ	MS95ANCN.GRD
Figure 8.3	ISC3BE	95CBCON	95CBCON	CB95ANCN.XYZ	CB95ANCN.GRD
Figure 8.4	ISC3BE	95CBDEP	95CBDEP	CB95TDEP.XYZ	CB95TDEP.GRD
Table 8.3	ISC3BE	95PHCON, 95PHDEP	95PHCON, 95PHDEP		TBL8384.XLS
Table 8.4	ISC3BE	95MSCON, 95MSDEP	95MSCON, 95MSDEP		TBL8384.XLS
Table 8.5	Based on Ontario AAQC and Table 8.3, 8.4 results				METALS.XLS
Table 9.1	Box Model[(a)]	Based on Figure 9.1			
Table 9.2	Box Model	Based on Figure 9.2			

Table A.1 Concluded.

Report Output	Models Selected	Model Input File (*.DAT)	Model Output File (*.OUT)	Secondary Output File	Summary Data File
Figure 9.1	GETACTTR. EXE[b]	FTMK0.INP, FTMK5.INP, FTMK_5.INP & DEM (*.GRD) files	FTMK0.XYZ, FTMK5.XYZ, FTMK_5.XYZ		FTMKCROS.XLS
Figure 9.2	Based on Fort McMurray ATM map				FTMCCROS.XLS

[a] A simplified model used to calculate concentration based on emission rate and area.

[b] A program designed to extract terrain data from the Surfer gridded DEM files and produce a regional matrix of X, Y, Z data for further terrain profile analysis.

Table A.2 Report text files.

Section	File Name	File Size	Date	Time
1	sec-1.doc	46080	April 17, 1996	7:40:32 a.m.
2	sec-2.doc	64000	April 17, 1996	9:11:46 a.m.
3	sec-3.doc	775680	April 17, 1996	7:43:42 a.m.
4	sec-4.doc	1595904	April 17, 1996	11:16:28 a.m.
5	sec-5.doc	1127936	April 17, 1996	1:24:30 p.m.
6	sec-6.doc	59904	April 17, 1996	8:08:48 a.m.
7	sec-7.doc	45056	April 17, 1996	8:10:38 a.m.
8	sec-8.doc	664576	April 17, 1996	1:37:36 p.m.
9	sec-9.doc	52736	April 17, 1996	1:30:02 p.m.
10	sec-10.doc	40960	April 17, 1996	9:36:32
11	sec-11.doc	50688	April 17, 1996	11:41:48
Appendix A	app-a.doc	35328	April 17, 1996	11:55:14