Saskatchewan Air Quality Modelling Guideline

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PREFACE

The “Saskatchewan Air Quality Modelling Guideline” is developed to ensure consistency in carrying out air dispersion modelling for regulatory applications in the Province of Saskatchewan. The guidance document will be reviewed periodically to ensure that up to date information and models are available for predicting air quality in Saskatchewan.

The guideline document was drafted by Lakes Environmental and reviewed by the Saskatchewan Ministry of Environment (the ministry), and air modeling experts from across Canada. Based on comments received, the document was finalized by the ministry with the assistance of SENES Consultants. As a result, this document is the first official guideline being released for conducting air dispersion modeling in Saskatchewan.

In support of this guideline and to facilitate dispersion modelling in the province, the ministry has developed Regional Meteorological Data Sets for five air dispersion modelling zones (Appendix A). The regional meteorological files can be downloaded from the ministry website. The ministry has also prepared a summary of air contaminant background concentrations for each of these five air dispersion modelling zones (Appendix B). These ambient background concentrations are to be added to the modelled concentrations. In addition, a Modelling Report Checklist is available (Appendix C) to ensure the air quality analysis report is complete.

Any comments, questions, or suggestions regarding the content of this document may be directed to imran.maqsood@gov.sk.ca.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

A guidance document is essential for consistency in conducting air quality modelling in the Province of Saskatchewan so that all approvals, environmental impact assessments and environmental protection plans, as examples, are treated equitably. Guidance also promotes efficient use of resources by providing a common starting point for setting up the modelling protocol. No guidance document can define the modelling needed for all possible situations; there will always be some circumstances where different approaches from those in this document are more appropriate.

The Saskatchewan Ministry of the Environment (the ministry) has recognized the need to develop its regulatory air quality modelling guideline to have a more representative analysis that make use of Screening, Refined and Specialized air dispersion models. The ministry has designated two approved Screening models – AERSCREEN and SCREEN3 – and an approved refined model – AERMOD. AERMOD is based on current science (Cimorelli *et al*., 2005; U.S. EPA, 2004(a); Paine *et al*., 2003; U.S. EPA, 2003; Cimorelli *et al*., 2002), which better represents the effects of atmospheric conditions, land use, terrain, and other factors on resulting concentrations when compared to older models such as ISCST3. This improved capability requires additional knowledge and input data, which additional guidance is required. The ministry acknowledges that there will be situations where specialized air dispersion models such as CALPUFF, CALQ3HCR and others may be applicable. The use of specialized models requires consultation with the ministry and their use is not discussed, except in within this document.

This document provides guidance for short range (less than 50 km) modelling for regulatory applications. Short range (or “near field”) modelling can be accomplished with validated and recommended steady-state plume models. Long-range transport modelling and photochemical modelling require more complex models such as CMAQ, and are not addressed in this guideline.

Modelling is most often required for the development of approvals, environmental impact assessments or environmental protection plans for source construction or expansion. Modelling is also conducted for the selection of air monitoring sites and for the development of appropriate air monitoring programs. Modelling may also be used by the ministry to respond to the public or to design plans for air quality management in the province.

The guideline is directed to modellers, environmental protection plan developers, approval or permit writers, permittees, regulators, and consultants involved in any aspect of modelling or permit or environmental protection plan development. This guideline does not constitute rulemaking by the ministry and may not be relied upon to create a right or benefit, substantive or procedural, enforceable by law or in equity, by any person.

Decisions that must be addressed in the proper modelling assessment include the choice of:

- An appropriate model for the specific situation;
- The sources of emissions and the development of appropriate facility source emission rates;
- The inclusion of existing air quality in the air zone; and,
- The determination of compliance criteria to apply.

The guideline provides for indepth details on these decision choices to assist in determining regulatory compliance.

Approved air dispersion models range in complexity depending on the needs of the modeller or the regulator. The model approach is summarized as:

- Screening models – AERSCREEN and SCREEN3;
- Refined models – AERMOD multi-source air dispersion model using fully prepared Regional meteorological data sets or site specific meteorology; and,
- Specialized models – models such as CALPUFF or CALQ3HC, which are used infrequently for specific circumstances.

In general, when developing facility and exhaust emission rates, the emission rates and emissions scenarios should be developed based on the appropriate averaging times relative to the standards or criteria for the contaminants being assessed. Additional details on the development of emissions scenarios are discussed in Section 4.0 of this document. The development of the emissions scenarios is also often dictated by the choice of model.

When conducting modelling, ambient background concentrations must be considered in the analysis to assess the impact of a facility. Section 10.1 of this document details how the ambient concentrations are to be incorporated.

The Saskatchewan air quality regulatory requirements are mandated through:

- The *Clean Air Act*, Chapter C-12.1 of the Statutes of Saskatchewan, 1986-87-88 (effective November 1, 1989) as amended by the Statutes of Saskatchewan, 1989-90, c.30 and 31; 1992, c.22; 1995, c.A-12.1; 2000, c.50; 2002, c.C-11.1; and 2003, c.29;
- The Clean Air Regulations, C-12.1 Reg;
- The *Environmental Management and Protection Act*, 2010; and,
- The Saskatchewan Environmental Code.

These regulations require compliance with air quality standards for a limited subset of contaminants including particulate matter, sulphur containing compounds, nitrogen oxides, ozone, and carbon monoxide. However, all contaminants from the facility must be modelled and compared against criteria that can be found through the following sources, in order of preferences.

- Canadian Council of Ministers of the Environment (CCME) or Environment Canada;
- Alberta Ministry of Environment and Water;
- Ontario Ministry of the Environment; and,
- Texas Commission on Environmental Quality.

During the development of this document, efforts were made to maintain consistency with modelling procedures and recommended approaches used in both Alberta (Alberta Environment, 2009) and British Columbia (British Columbia Ministry of the Environment, 2008). This was done in support of the New West Partnership agreement (the Partnership) between the Provinces of British Columbia, Alberta and Saskatchewan. According to Schedule 1 of the Partnership, the parties shall cooperate to minimize differences in standards or regulations adopted or maintained to achieve legitimate objectives.

The information presented in this document represents the ministry's guidance at the time of publication. Any deviation from this guidance should be justified and clearly documented. When in doubt, pre-consultation with the ministry is recommended to discuss variations in air dispersion modelling methodologies. The ministry supports innovation and is open to new or improved modelling methodologies proposed by the modeller.

2.0 OVERALL MODELLING APPROACH

The ministry recommends an air dispersion modelling approach appropriate to the facility complexity using the models identified by the United States Environmental Protection Agency (U.S. EPA). The latest version of each of these models, available on the U.S. EPA website, is required to be used. Note that the version number is the date of its release. For example, AERMOD version 11353 was released in 2011 on the 353rd day (Julian date) (19th December).

This approach should focus toward the required level of effort according to site requirements. In general, a greater level of detail and modelling knowledge is required as the complexity of the facility or emission sources increases. Consequently, an approach based on increasing complexity and level of effort is recommended and outlined as follows:

Screening Modelling is performed using either the U.S. EPA SCREEN3 or U.S. EPA AERSCREEN model, which produce estimates of worst case 1-hour concentrations for a single source without the need for meteorological data. If an air quality study meets appropriate standards using this screening level analysis, there is no need for additional modelling. The screening level analysis is appropriate for simple facilities with a limited number of exhausts and contaminants; or, for more complex facilities, which want to justify that a minor source is negligible without having to do detailed model assessments. Only very simple facilities are likely to find the screening level analysis useful as the iterations required for multiple exhausts and contaminants at the screening level can be just as complex, yet provide less detail than with refined modelling.

Refined Modelling involves the use of the more sophisticated U.S. EPA AERMOD model and the use of regional meteorological data sets made available by the ministry. If an air quality study passes appropriate standards and/or guidelines using conservative modelling assumptions (i.e. assuming all processes are emitting at maximum emission rate simultaneously and continuously), there is no need for additional modelling. However, refined modelling lends itself to emissions scenario refinements such as including operating hours, variable emission rates, number of exceedances, and locations and frequencies of maximum concentrations. The ministry should be contacted to discuss further options, such as the use or the preparation of localized meteorological data.

Specialized Modelling consists of the use of models that are specialized to specific situations or tasks. The CALPUFF model handles complex terrain and land-water interfaces and has some limited chemical transformation algorithms. CALPUFF is also the model of choice in areas where there is a large frequency of very low wind speeds. Road and rail traffic infrastructure projects may be modelled with a transportation model such as CALQ3HCR. Pre-consultation with the ministry must be undertaken prior to the facility conducting specialized modelling.

A key advantage to the use of the refined or specialized air dispersion models is the ability to compare to effects-based standards with appropriate averaging times. Refined and some specialized models allow the input of variable emission rates, where appropriate, for assessing concentrations over longer averaging times. With screening models, assessment of a facility is typically limited to the maximum 1-hour emissions and corresponding concentrations.

In addition to the choice of a particular model, the emissions estimation scenarios considered may be made to be more representative. The most conservative approach is to assume that all operations are occurring simultaneously releasing the maximum contaminant emissions from all sources for all hours. Using this approach provides for a high level of conservatism, particularly with intermittent processes. However, it is not always possible to demonstrate compliance with such a conservative approach and a facility may wish to provide for more realistic scenarios using refinements such as the consideration of operating hours and production variations. The emissions scenario approach is discussed in greater detail in Section 4.0.

Figure 2-1 presents a flow diagram for air dispersion modelling in Saskatchewan, illustrating how a facility may start with screening, refined or specialized models to demonstrate compliance.

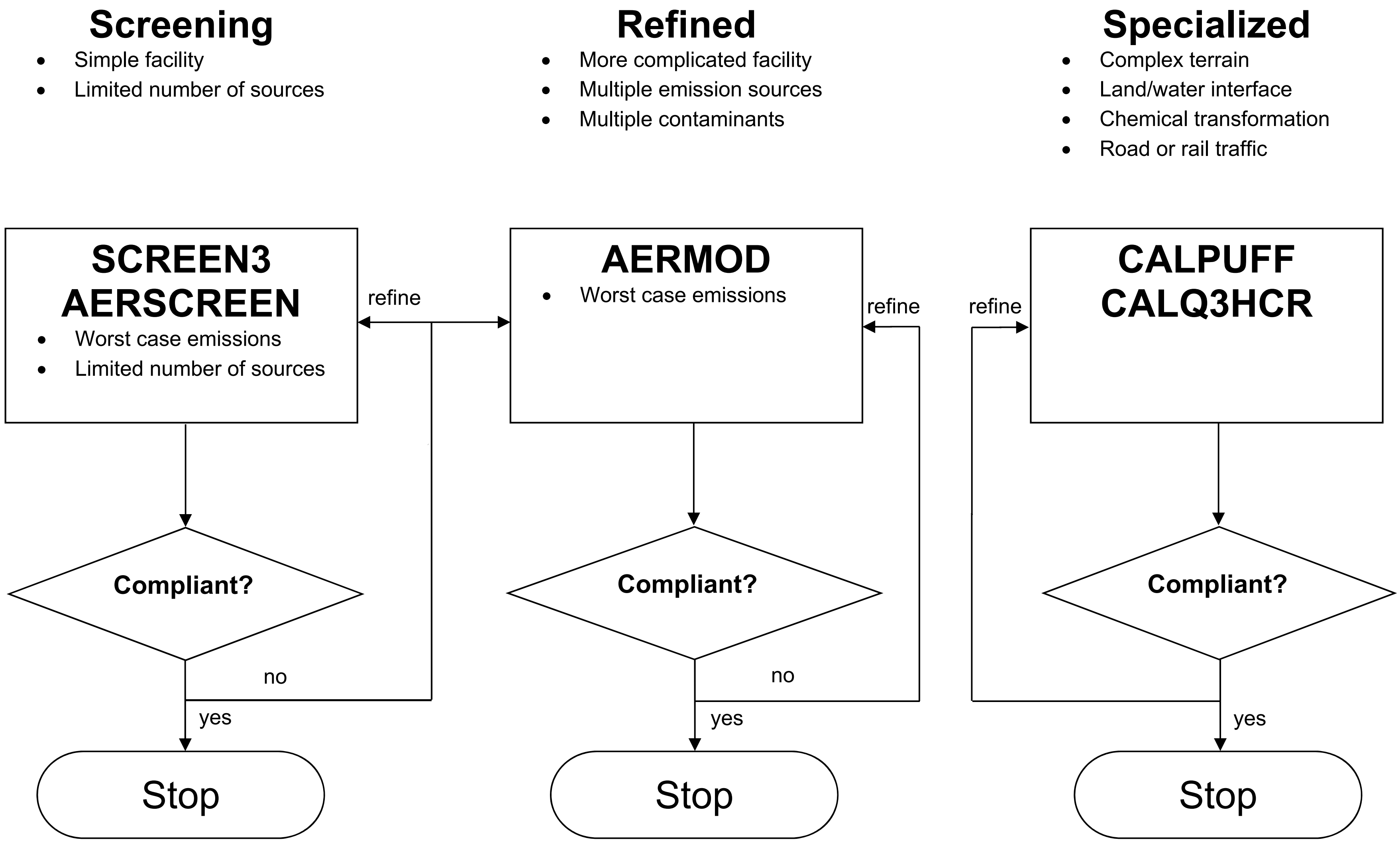

Figure 2-1 – Air Dispersion Modelling Flow Diagram

3.0 APPLICATION OF MODELS

3.1 Model Overview

Air dispersion modelling is the mathematical estimation of contaminant concentrations from emissions sources within a study area. Several factors impact the fate and transport of contaminants in the atmosphere including meteorological conditions, site configuration, emission release characteristics, and surrounding terrain. The modelled contaminant concentrations can then be compared to applicable standards to determine potential impacts.

All modelling and reports are to use SI (metric) units for all parameters.

3.2 Approved Models

Approved models are standard models that are to be used for air quality studies in Saskatchewan. Specialized models may be used if conditions warrant their use. Single source screening analysis may be performed with either the U.S. EPA SCREEN3 model, or the U.S. EPA AERSCREEN model with screening meteorology. Refined multi-source, near-field analysis shall be performed using the approved U.S EPA AERMOD model. A brief overview of each of these models can be found below. Refer the respective model user's guides (U.S. EPA, 2010; U.S. EPA, 2004(a); U.S. EPA, 1995(b)) for more details, including specific lists of input data required by each model. For appropriate model selection, review the section that outlines:

- AERSCREEN;
- SCREEN3; and,
- AERMOD.

3.2.1 AERSCREEN Overview

AERSCREEN is a single source screening model based on AERMOD. The model produces estimates of "worst-case", one-hour concentrations for a single source, without the need for hourly meteorological data, and also includes conversion factors to estimate "worst-case" 3-hour, 8-hour, 24-hour, and annual concentrations (U.S. EPA, 2010).

AERSCREEN is intended to produce concentration estimates that are equal to or greater than the estimates produced by AERMOD with a fully developed set of meteorological and terrain data, but the degree of conservatism will vary depending on the application.

For many facilities, the amount of set up and data required to complete the AERSCREEN assessment is such that typically there is not significantly more effort required to conduct a full AERMOD assessment.

3.2.2 SCREEN3 Overview

SCREEN3 is a single source screening model based on Industrial Source Complex model (ISC). It was developed to provide an easy-to-use method of obtaining screening level contaminant concentration estimates which tend to be conservative in comparison to more refined estimates. These estimates are based on the document "Screening Procedures for Estimating the Air Quality Impact of Stationary Sources" (U.S. EPA, 1992).

The SCREEN3, version 3.0 of the SCREEN model, can perform all of the single source short-term calculations including:

- Estimating maximum ground-level concentrations and the distance to the maximum concentration;
- Incorporating the effects of simple (i.e., not PRIME) building downwash on the maximum concentrations for both the near wake and far wake regions;
- Estimating concentrations in the cavity recirculation zone;
- Estimating concentrations due to inversion break-up and shoreline fumigation; and,

- Determining plume rise for flare releases.

SCREEN3 (U.S. EPA, 1995(b)) can also:

- Incorporate the effects of simple elevated terrain (i.e., terrain not above stack top) on maximum concentrations;
- Estimate 24-hour average concentrations due to plume impaction in complex terrain (i.e., terrain above stack top) using the VALLEY model 24-hour screening procedure;
- Model simple area sources using a numerical integration approach;
- Calculate the maximum concentration at any number of user-specified distances in flat or elevated simple terrain;
- Examine a full range of meteorological conditions, including all stability classes and wind speeds to find maximum impacts;
- Include the effects of buoyancy-induced dispersion (BID); and,
- Explicitly calculate the effects of multiple reflections of the plume off the elevated inversion and off the ground when calculating concentrations under limited mixing conditions.

3.2.3 AERMOD Overview

The AERMIC (American Meteorological Society/EPA Regulatory Model Improvement Committee) Regulatory Model, AERMOD, (Cimorelli *et al*., 2005; U.S. EPA, 2004(a); Paine *et al*., 2003; Cimorelli *et al*., 2002) was specially designed to support the U.S. EPA's regulatory modelling programs. AERMOD is the next-generation multi-source air dispersion model that incorporates concepts such as planetary boundary layer theory and advanced methods for handling complex terrain. AERMOD was developed to replace the Industrial Source Complex Model-Short Term (ISCST3) as U.S. EPA's approved model for most small scale regulatory applications. (U.S. EPA, 1995(c); U.S. EPA, 1995(e)). The latest versions of AERMOD also incorporate the Plume Rise Model Enhancements (PRIME) building downwash algorithms which provide a more realistic handling of downwash effects than previous approaches.

The PRIME algorithm was designed to incorporate two fundamental features associated with building downwash (Schulman *et al*., 2000):

- Enhanced plume dispersion coefficients due to the turbulent wake; and,
- Reduced plume rise caused by a combination of the descending streamlines in the lee of the building and the increased entrainment in the wake.

AERMOD contains basically the same options as the old ISCST3 model with a few exceptions which are described below:

- AERMOD requires two types of meteorological data files; a file containing surface scalar parameters and a file containing vertical profiles. These two files are produced by the U.S. EPA AERMET meteorological pre-processor program (U.S. EPA, 2004(b); and,
- For applications involving elevated terrain, the user must also input a hill height scale along with the receptor elevation. The U.S. EPA AERMAP terrain pre-processing program (U.S. EPA, 2004(c)) can be used to generate hill height scales as well as terrain elevations for all receptor locations.

AERMOD will be used for most air dispersion modelling assessments in Saskatchewan.

3.3 Specialized Models

Occasionally situations are encountered where the approved model is not the most appropriate one to use. The use of a specialized model may be approved by the ministry on a case-by-case basis. This justification should clearly state the reasons why the approved models are not appropriate. For example, along the shoreline of a large lake with local sea/lake breeze, very rugged terrain (with mountain/valley winds), high frequency of very light winds and boundary layer effects are not accounted for by AERMOD. It may be more appropriate to use CALPUFF, depending on the exact situation.

The following list contains some specialized models that may be considered for use by the ministry in special situations.

- CALPUFF; and,
- CAL3QHCR.

CALPUFF

CALPUFF is a Lagrangian puff model that is a more sophisticated model than AERMOD. However, to utilize the advantages, it is necessary to have more detailed inputs related to local meteorology and land use. The CALMET meteorological model uses detailed meteorological data, terrain and land use information to develop 3D meteorological data files which are used by the CALPUFF model.

CALPUFF should only be used with well refined meteorology and not with single point or screening level meteorology files as the benefits of the model are lost when using simple meteorology.

CALQ3HCR

The CALQ3HC model is a Gaussian plume model that can simulate the dispersion of vehicular tailpipe emissions along roadways. It includes the line source algorithms from the CALINE3 model and incorporates an algorithm for estimating vehicular queue lengths and enhanced dispersion due to the increased mixing resulting from vehicle turbulence. The model uses the same meteorological files as ISC with the limitation that it can run a maximum of one year of meteorological data in a single model run.

Refer to the respective user's guides for more detailed information about each model, and specific data input requirements.

3.4 Summary of Model Capabilities

Each air dispersion models has different capabilities. Table 3-1 summarizes the capabilities of the screening and refined approved models as well as some of the common specialized models. The table shows that except for small simple facilities, the refined model, AERMOD, will likely be the model of choice for most users. The specialized model, CALPUFF, has some unique capabilities that include the use of 3-dimensional meteorological data that may have an advantage when there is complex terrain and or large bodies of water in the modelling domain. CAL3QHCR is a specialized traffic model that may be used to simulate roads or railways. CAL3QHCR accepts a large number of links and receptors and uses hourly meteorological data. Contact the ministry to discuss the capabilities of any of these (or other) models.

Table 3-1 – Summary of Model Capabilities

			Terrain (above stack base)	Hourly Meteorological Data	3 Dimensional Meteorological Data	Multiple Sources	Point, Area, Volume Sources	Line Sources	Flares	Horizontal and Capped Stacks	Variable Emission Rate	Chemical Transformation	Building Downwash	Plume Visibility and Fog	Stagnation Conditions	Deposition (Gases / Particles)	Acid Deposition(Nitrate/Sulphate)	Shoreline Effects	Regional Air Zone Modelling	Long Range Transport (>50 km)	Roadway Emissions
Approved	Screening	SCREEN3	√				√		√				√								
		AERSCREEN	√				√		√				√								
	Refined	AERMOD	√	√		√	√	√3	√4	√	√		√			√					
Requires Approval	Specialized	CALPUFF	√	√	√	√	√	√1,3	√4		√	√5	√	√	√	√	√2	√	√	√	
		CAL3QHCR		√		√		√													√

1 buoyant line source only
2 deposition of particles only
3 line sources may be simulated using a series of elongated area sources or a series of volume sources
4 necessary to develop pseudo point source parameters external to model
5 for distances >50 km

4.0 EMISSION SCENARIOS TO BE CONSIDERED

As part of the modelling assessment, emission rates for the sources and contaminants at the facility must be determined. The estimation of emission rates from processes and facilities is not part of the scope of this guideline; however the following resources may be useful:

- NPRI Toolbox – Located on the Environment Canada web site (www.ec.gc.ca). It is a compilation of information related to the generation of NPRI submission information. There is some general information on emission factors and emission estimation techniques. There are useful equations, conversion factors and example emission calculations;
- AP-42 – The Technology Transfer Network of the U.S. Environmental Protection Agency maintains a web based clearinghouse for emission factors. An emission factor relates the quantity of a contaminant released to the atmosphere with an activity level. Emission factors are available for many different processes, operations and equipment types both with and without emission controls (http://www.epa.gov); and,
- Ontario Ministry of the Environment (OMOE) ESDM Procedure Document – Located on the OMOE Web site (www.ene.gov.on.ca). This document contains information on the use of emission factors, engineering estimates and other methods of estimating emission rates as information on methods of assessing negligibility of sources or contaminants.

Emission rates should be consistent with the averaging time of the criterion for the contaminant being assessed. For example, if the standard has a 24-hour averaging time, the emissions per day may be averaged evenly over 24 hours. If the plant operates for a limited number of hours per day (i.e., 8:00h to 18:00h), the emissions from that time period may be evenly spread over the 24 hours or, if using a refined model, the emissions may be spread over the operating hours and switched on and off in the model.

When conducting an air dispersion modelling assessment, there are several different emissions scenarios that may be considered;

- Maximum emissions scenario;
- Refined emissions scenario;
- Startups and shutdowns; and,
- Malfunctions and emergency scenarios.

4.1 Maximum Emissions Scenario

A maximum emissions scenario typically assumes that all equipment is operating concurrently at maximum capacity. It is typically a good first approach at determining compliance and is applicable to standards with shorter averaging times such as one-hour. It can lead to over-prediction of 24-hour and annual average modelled concentrations, particularly if the facility does not operate 24 hours per day or has processes that operate intermittently.

The maximum emissions scenario may be used as a screening approach as it allows a facility to determine contaminants of interest based on their compliance status. Using a maximum emissions scenario for assessment provides for the greatest flexibility at the facility as no limits to production hours or equipment capacity are required if compliance is predicted using this approach.

In some cases, the maximum emissions scenario can lead to non-realistic predictions and modelled non-compliance, due to the conservatism of the approach. When this occurs, the facility can refine emissions to reflect a more typical emissions scenario. Prior to refining an emissions scenario, the facility may also want to detail the frequency and location of potential exceedances to determine whether refinement may be a suitable approach or whether it may be more beneficial to move to abatement. If the exceedances are localized and only occur a few times, refinement could provide a more realistic assessment. However, refinement is unlikely to be as beneficial for facilities that operate continuously with little variation in emissions.

4.2 Refined Emissions Scenario

A refined emissions scenario considers a more realistic model simulation of a facility's operations than a maximum emission scenario. This typically requires more data and increasingly complex model inputs. A refined emissions scenario can include the consideration of:

- Hours of operation;
- Variable emission rates;
- Intermittent emission sources; and,
- Site specific meteorology (if necessary).

AERMOD offers several variable emission options. Factors are entered that are a multiplier of the emission rate specified for a source. The variable emission options are described below with the (KEYWORD) in parentheses:

- By Season (SEASON) – vary by four seasons:
    - Winter - December, January, February;
    - Spring – March, April, May;
    - Summer – June, July, August; and,
    - Fall – September, October, November.
- By Month (MONTH) – vary month by month;
- By Hour-of-Day (HRODY) – vary hour by hour over 24 hours (every day the same);
- By Wind Speed (WSPEED) – vary emissions by 6 wind speed categories (1.54 m/s, 3.09 m/s, 5.14 m/s, 8.23 m/s, 10,8 m/s and >10.8 m/s);
- By Season / Hour (SEASHR) – vary hour by hour for each of the four seasons;
- By Season / Hour / Day (SHRDOW) – vary hour by hour for Monday-Friday, Saturday and Sunday;
- By Season / Hour / Seven Days (SHRDOW7) – vary hour by hour for each day of the week, Monday, Tuesday, Wednesday, etc. for each of the four seasons;
- By Month / Hour / Day (MHRDOW) – vary hour by hour for Monday-Friday, Saturday and Sunday for each month January, February, March etc.;
- By Month / Hour / Seven Days (MHRDOW7) – vary hour by hour for each day of the week Monday, Tuesday, Wednesday, etc. for each month January, February, March etc.;
- By Hour / Seven days (HRDOW7) - vary hour by hour for each day of the week, Monday, Tuesday, Wednesday, etc.; and,
- By Hour / Day (HRDOW) - vary hour by hour for Monday-Friday, Saturday and Sunday.

Further information on the use of these options can be found in the AERMOD User's Guide (U.S. EPA 2004(a)).

The use of the variable emission options listed above makes the assumption that only the emission rate is changing and other source parameters (temperature, velocity) do not change. This is usually a reasonable assumption. These options may be applied to individual sources or a group of sources. For a source that is non-continuous, a factor of 0 is entered for the periods when the source is not operating or is inactive.

Facilities may choose to consider hours of operation in their modelling by using one or more of the variable emission options described above. In this manner emissions may be applied to only those hours in which the facility is emitting. For example, if a facility only operates during the daytime, this can prevent an artificial prediction of potential non-compliance that may occur during night time hours when dispersion is generally poorer.

If one of the variable emission options does not accurately describe the pattern of emissions at a facility, it is possible to construct an external emission file that allows for an hour-by-hour variable emission rate, temperature and velocity for each hour in the modelling period. For example, this would allow a facility to model exactly how it operated over a period of a year to demonstrate compliance. Consult the AERMOD manual for construction of this type of file.

The AERMOD model allows for sources that have emissions that vary by wind speed (e.g., wind erosion from coal piles and rock piles and emissions due to material handling (drops)) and can be accomplished by using the variable emissions feature. This can be important as using a fixed emission rate can lead to over or under estimates of emissions and resulting concentrations as wind speed changes. Emission factors are entered that are multipliers of the emission rate specified for each source, which establishes the correlation between emissions and wind speed categories. The model will then vary the emissions based on the wind conditions in the meteorological data. The AERMOD default values of wind speed for the 6 wind speed categories can also be adjusted.

4.3 Startups and Shutdowns

Plant startups and shutdowns can occur periodically due to maintenance or designated vacation periods. These processes impact emissions over the related time periods. As an example, process upsets or problems with the air pollution control system can impact emissions. As result, over short periods of time, upset emissions are often expected to be greater than normal source emissions (U.S. EPA, 1998).

Startups and shutdowns are typically addressed only on a case-by-case basis as requested by the ministry. However, if a facility has a startup and shutdown on a frequent basis – every few days or more frequently – it should be considered as part of “normal” operations. If a facility only has a startup a few times a year, it is likely that startups and shutdowns do not need to be considered. If startups and shutdowns do not increase emission rates they do not require any special assessment.

4.4 Malfunctions and Emergency Scenarios

Potential malfunctions such as equipment failures, spills, and emergency scenarios are not typically required for assessment by the ministry during the permitting process. However, for large emitters, such as a refinery or a large chemical plant, the emissions during malfunctions and emergency scenarios may be very significant and some assessment of their impact should be made.

A typical approach to account for the greater emissions due to a malfunction or emergency is the application of an upset factor. The value of the upset factor used must be well documented and supported by literature references or site specific emissions or process data.

The ministry may request that a facility assess impacts of a malfunction or emergency after an event of this type has occurred.

5.0 MODEL INPUT - EMISSION SOURCE CHARACTERISTICS

5.1 Comparison of Screening and Refined Model Requirements

This section gives general information on model input requirements. For detailed model input information, refer to the respective model user's guides.

Screening model requirements are the least intensive but produce the most conservative results. The SCREEN3 and AERSCREEN models have straight-forward input requirements which are further described in Sections 5.1.1 and 5.1.2, respectively. Refined air dispersion modelling using the AERMOD model supports multiple sources and hourly meteorological data which require more detailed model inputs as described in Section 5.1.3.

Table 5-1 presents a comparison of screening and refined model input requirements.

Table 5-1 – Screening and Refined Model Input Requirements

Input Parameter	**Screening SCREEN3, AERSCREEN**	**Refined AERMOD**
Sources	Single source	Multiple sources
Emission Rate	Fixed rate	Fixed rate plus varying by season, day of week, hour of day etc.
Site Parameters	Only building source dimensions required	Location of all sources and building must be entered using UTM coordinates – property line may also be entered to exclude receptors within the site
Building Downwash	One building	All onsite buildings using PRIME algorithm
Receptors	1 dimensional grid with automatic spacing or choose specific distance from source	2 dimensional grid with many spacing options as well as discrete receptors
Terrain	May enter a height for each of the chosen receptor distances from the source	Can import terrain data that is assigned to each receptor in the modelling domain
Meteorological Data	None required or simple inputs	Usually use 5 years of hourly data that must be pre-processed with AERMET – The ministry has prepared 11 fully processed AERMOD ready Regional Meteorological Data Sets for use
Land Use	Urban / rural	AERMET can be used to process variable land use by sector – land use is characterized by albedo, surface roughness and Bowen ratio
Time Averaging	Calculates maximum 1 hour average concentration at each specified receptor – conversion to other averaging times must be achieved using time averaging factors	Calculates maximum 1 hour average concentration as well as 2, 3, 4, 6, 8, 12 and 24-hour, month, and annual averaging times
Graphical Output	Can plot the maximum 1 hour average concentrations with distance by importing into a spreadsheet	Text output 1^{st} 2^{nd}, 3^{rd}, up to 999^{th} highest tables for each averaging time chosen – can generate a graphical format output file that can be imported into a plotting program to generate isopleths.

5.1.1 SCREEN3 Model Requirements

The SCREEN3 model (U.S. EPA, 1995(b)) is a screening model that was developed to provide an easy-to-use method of obtaining contaminant concentration estimates. To perform a modelling study using SCREEN3, data for the following input requirements must be supplied:

- *Source Type* (Point, Flare, Area or Volume);
- *Physical Source and Emissions Characteristics*. For example, a point source requires:
    - Emission Rate;
    - Stack Height;
    - Stack Inside Diameter;
    - Stack Gas Exit Velocity;
    - Stack Gas Exit Temperature;
    - Ambient Air Temperature; and,
    - Receptor Height Above Ground.
- *Meteorology:* SCREEN3 can consider all conditions or a specific stability class and wind speed can be provided. No external meteorological data is required;
- *Building Downwash:* If this option is used then building dimensions (height, length and width) must be specified;
- *Terrain:* SCREEN3 supports flat, elevated and complex terrain. If elevated or complex terrain is used, distance and terrain heights must be provided; and,
- *Fumigation:* SCREEN3 supports shoreline fumigation. If used, distance to shoreline must be provided.

The input requirements are minimal to perform a screening analysis using SCREEN3. This model is normally used as an initial screening tool to assess single sources of emissions. SCREEN3 can be applied to multi-source facilities by conservatively summing the maximum concentrations for the individual emissions sources. However, for facilities with more than a few sources, the use of the approved refined model AERMOD is recommended.

5.1.2 AERSCREEN Model Requirements

AERSCREEN is the next generation screening-level air quality model that is being developed jointly by U.S. EPA and State modellers with contractor support (U.S. EPA, 2010). The AERSCREEN model, which is based on AERMOD, interfaces with a program called MAKEMET, which generates a meteorological matrix, as well as with AERMAP and BPIPPRM to automate the processing of terrain and building information. The model then interfaces with the AERMOD model utilizing the SCREEN option to perform the modelling runs.

The AERSCREEN program is currently limited to modelling a single point, capped stack, horizontal stack, rectangular area, circular area, flare, or volume source.

Inputs or options to AERSCREEN (U.S. EPA, 2010) are:

- Source parameters for point, rectangular area, circular area, volume, capped stack, horizontal stack or flare sources;
- Building downwash information for point, capped stack, horizontal stack, and flare sources;
- Terrain heights for sources and receptors via AERMAP;
- Minimum and maximum temperatures for MAKEMET;
- Minimum wind speed and anemometer height for MAKEMET;
- Surface characteristics for input to MAKEMET by the following methods:
    - user-defined single values for albedo, Bowen ratio, and surface roughness (no temporal or spatial variation in surface characteristics);
    - AERMET seasonal tables; and,
    - Values listed in an external file, either an AERSURFACE output file or surface characteristics listed in an AERMET stage 3 input file.

- Probe distance (maximum downwind distance) of receptors.

Other inputs or options used by AERSCREEN (U.S. EPA, 2010) are:

- Units of inputs (metric or imperial);
- Urban/rural source classification, and urban population if urban source;
- Fence line distance for ambient air receptors; and,
- Use of flagpole receptors and a defined flagpole height.

The AERSCREEN program also performs error checks on AERSCREEN inputs, AERMOD output and/or AERMAP output. It calculates the maximum concentration by distance and has a search routine to find the overall worst case scenario (maximum concentration).

Due to the limitation of handling only a single source, the amount of effort required to generate screening meteorology with MAKEMET and the fact that the ministry has prepared fully processed AERMOD-ready Regional Meteorological Data Sets, it is expected that most people will use AERMOD over AERSCREEN.

5.1.3 AERMOD Model Requirements

AERMOD is a refined model that is approved for most near-field modelling applications. The supported refined models have many input options, which are described throughout this document as well as in respective technical documents (U.S. EPA, 2004(a); U.S. EPA, 1997; U.S. EPA, 1995(c); U.S. EPA, 1995(e)).

A general overview of the process typically used for performing an air dispersion modelling assessment is presented in Figure 5-1. The figure is not meant to be exhaustive in all data elements, but rather provides a picture of the major steps involved in an assessment.

The AERMOD modelling system is comprised of four primary components as illustrated in Figure 5-1:

- AERMET – Meteorological data pre-processor;
- AERMAP – Digital terrain pre-processor;
- BPIP-PRIME – Building downwash processor; and,
- AERMOD – Air dispersion model.

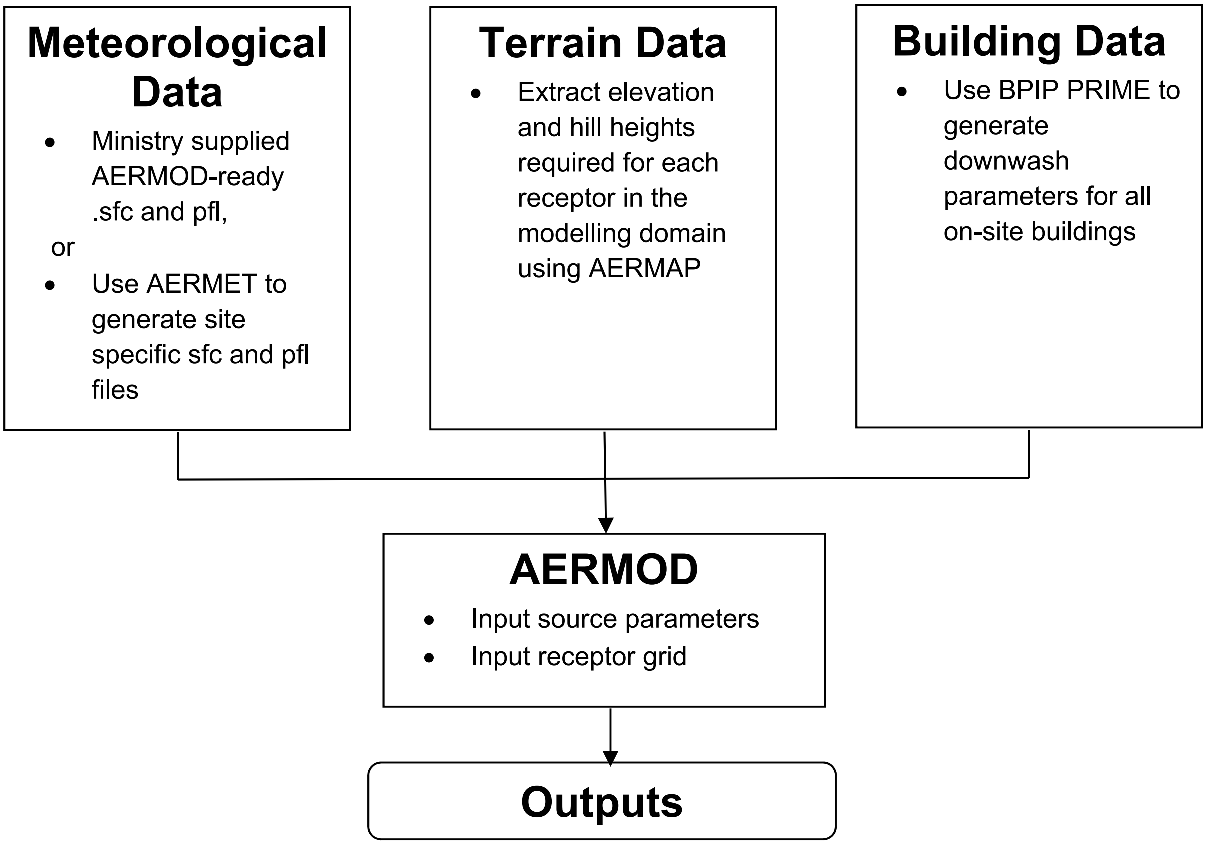

Figure 5-1 – AERMOD Air Dispersion Modelling System

The general steps for the use of AERMOD are outlined below:

- Obtain applicable AERMOD-ready Regional Meteorological Data Set (.sfc and .pfl) from the ministry web site or use AERMET to create site specific .sfc and .pfl meteorological data;
- Input parameters for all significant on-site buildings into BPIP-PRIME to determine building downwash parameters;
- Complete source and receptor information in AERMOD;
- Obtain digital terrain elevation data, if terrain is being considered and run AERMAP;
- Run AERMOD; and,
- Analyze results.

5.2 Use of Regulatory Default Options and Non-Default Options

All of the approved models were developed for use by the United States Environmental Protection Agency (U.S. EPA). In most cases, the "regulatory default" option should be selected to ensure that switches and settings in the model meet U.S. EPA requirements. There will be some situations in Saskatchewan where selected "non-default" options should be used, as discussed below.

AERSCREEN and SCREEN3

The approved screening models, AERSCREEN and SCREEN3 do not have a "regulatory default" option.

AERMOD

The "Regulatory Default" options in AERMOD include:

- Output Type:
    - Concentration;
    - Dry deposition;
    - Wet deposition;
    - Total deposition.
- Depletion Options:
    - Dry depletion;
    - Disable dry depletion;
    - Wet depletion;
    - Disable wet depletion.

In Saskatchewan, the depletion options are not typically used. However, they may be applied on a case by case basis with prior approval by the ministry.

There are several "Non-Default" options that are available, which may be of interest to modellers in Saskatchewan:

- No stack-tip downwash;
    - This would likely be done when representing certain types of fugitive sources with POINT sources (i.e., when emissions are represented by a stack but do not typically behave as stack emissions).
- Conversion of NO_x to NO_2 via Ozone Limiting Method(OLM) or Plume Volume Molar Ratio Method (PVMRM); and,
- Capped and horizontal stack releases.

Except for the use of the capped and horizontal stack release option, it is recommended that the use of any non-regulatory options be discussed with the ministry before submission of a modelling report.

5.3 Coordinate Systems

AERSCREEN and SCREEN3

The screening models do not use a coordinate system as only single sources are considered at a time. The model inputs are based on the dimensions of the emission source or building. The maximum concentrations are output as distance(s) from the centre of the emission source.

AERMOD

Since AERMOD is capable of modelling multiple emission sources and buildings it is necessary to enter all of the information in a consistent coordinate system. AERMOD uses hour-by-hour meteorology that is aligned to the north and requires the coordinates of the sources and buildings to be aligned in the same manner. The most common coordinate system used is the Universal Transverse Mercator (UTM) system. UTM coordinates consist of a Northing and an Easting, both in metres, and a zone. Saskatchewan is located in longitudinal Zones 11, 12 and 13 and latitudinal zones U and V. The most common datum is NAD83 (North American datum of 1983) while some older drawings may be in NAD27 (North American datum of 1927). AERMOD outputs the model-predicted concentrations at specified receptor locations, which can be defined as a gridded network of receptors and/or individual points within the coordinate system being used. Care must be taken that all geographical data including source and building locations, property boundaries and terrain data are in the same coordinate system.

5.4 Averaging Times

The averaging times selected for an assessment should correspond to the averaging times of the standards for the contaminants being assessed. The time averaging capabilities of each of the models differ, as outlined below.

AERSCREEN and SCREEN3

The approved screening models calculate maximum one-hour average concentrations. The AERSCREEN program includes averaging time factors to convert the maximum 1-hour predictions to worst-case, 3-hour, 8-hour, 24-hour and annual averages. See Section 11.0 for more information on conversion factors at different averaging times.

AERMOD

AERMOD can produce maximum concentrations for a range of averaging times - 1, 3, 4, 6, 8, 12 and 24-hours, month and annual averages - eliminating the need for conversion factors within these averaging times. This allows modelled results to be compared directly to effects-based standards. There is still a need for conversion factors if the results must be expressed in averaging times less than one hour.

5.5 Defining Sources

The SCREEN3, AERSCREEN and AERMOD models support a variety of source types that can be used to characterize most emissions within a study area. The following sections outline the primary source types and their input requirements for both screening and refined models. Detailed descriptions on the input fields for these models can be found for SCREEN3 (U.S. EPA, 1992), AERSCREEN (U.S. EPA, 2010) and for AERMOD (Cimorelli *et al*., 2005; U.S. EPA, 2004) in their respective users guides.

As shown in Table 3-1, different models have different capabilities in terms of the type of sources that are supported.

5.5.1 Point Sources

Point sources are typically used when modelling releases from sources such as stacks and isolated vents. This includes horizontal sources and capped stacks.

Table 5-2 summarizes the data required to use for a point source in each of the approved models.

Table 5-2 – Point Source Model Input Requirements

Required Point Source Parameters	SCREEN3	AERSCREEN	AERMOD
Source ID			✓
X Coordinate			✓
Y Coordinate			✓
Base Elevation (m)			✓
Emission rate (g/s)	✓	✓	✓
Stack Diameter (m)	✓	✓	✓
Stack Height (m)	✓	✓	✓
Exit Velocity (m/s)	✓	✓	✓
Stack Temperature (K)	✓	✓	✓

5.5.2 *Area Sources*

Area sources are typically used to model low level or ground level releases where the emissions occur over an area (e.g., landfills, storage piles, slag dumps, and lagoons). SCREEN3 allows definition of a rectangular area source with no rotational angle. The AERSCREEN and AERMOD models accept rectangular areas that may also have a rotation angle specified relative to a north-south orientation, as well as circular area sources. AERMOD also allows the use of a polygon area source.

It should be noted that the maximum U.S. EPA recommended length/width aspect ratio for area sources is 10 to 1. If this is exceeded, U.S. EPA recommends that the area be divided to achieve a 10 to 1 aspect ratio (or less) for all sub-areas.

The area source input requirements for each of the approved models are shown in Table 5-3.

Table 5-3 – Area Source Model Input Requirements

Required Area Source Parameters	SCREEN 3	AERSCREEN	AERMOD
Rectangular Area Source	✓	✓	✓
Rotated Rectangular Area Source		✓	✓
Circular Area Source		✓	✓
Polygon Area Source			✓
Source ID			✓
X Coordinate			✓
Y Coordinate			✓
Base Elevation (m)			✓
Emission rate (g/m²/s)	✓	✓ 1	✓
Release Height (m)	✓	✓	✓
Length of Source (m)	✓	✓	✓
Width of Source (m)	✓	✓	✓
Radius (m) (for circular sources)		✓	✓
Rotation Angle Relative to North (°)		✓	✓
Initial Vertical Dimension (sigma y) (m)		✓	✓

Note: 1 Area source emission rate in AERSCREEN is in g/s or lb/hour, not emission rate per unit area as entered in AERMOD input files. AERSCREEN (U.S. EPA, 2010) internally calculates the emission rate per unit area to input into AERMOD

There are no restrictions in AERMOD on the location of receptors relative to area sources. Receptors may be placed within the area and at the edge of an area. AERMOD will integrate over the portion of the area that is upwind of the receptor. The numerical integration is not performed for portions of the area that are closer than 1.0 meter upwind of the receptor. Therefore, caution should be used when placing receptors within or adjacent to areas that are less than a few meters wide.

5.5.3 *Volume Sources*

Volume sources are used to model releases from a variety of industrial sources, such as building roof monitors, fugitive leaks from an industrial facility, multiple vents, and conveyor belts.

Table 5-4 summarizes the data required to use a volume source in each of the approved models.

Table 5-4 – Volume Source Model Input Requirements

Required Volume Source Parameters	SCREEN 3	AERSCREEN	AERMOD
Source ID			✓
X Coordinate			✓
Y Coordinate			✓
Base Elevation (m)			✓
Emission rate (g/s)	✓	✓	✓
Release Height (m)	✓	✓	✓
Length of Side (m)	✓	✓	✓
Initial Vertical Dimension (σ_{yo}) (m)	✓	✓	✓
Initial Lateral Dimension (σ_{zo}) (m)	✓	✓	✓

Table 5-5 presents the calculation method for determining values for the initial lateral dimension (σ_{yo}) and initial vertical dimension (σ_{zo}) for volume sources.

Table 5-5 – Estimating Initial Lateral and Vertical Dimensions for Volume and Line Sources

Dimension	Type of Source	Procedure for Obtaining Initial Dimension
Initial Lateral Dimension (σ_{yo})	**Single Volume Source**	σ_{yo} = (side length) / 4.3
	Line Source Represented by Adjacent Volume Sources	σ_{yo} = (side length) / 2.15
	Line Source Represented by Separated Volume Sources	σ_{yo} = (center to center distance) / 2.15
Initial Vertical Dimension (σ_{zo})	**Surface-Based Source** (h_e ~ 0)	σ_{zo} = (vertical dimension of source) / 2.15
	Elevated Source (h_e > 0) on or Adjacent to a Building	σ_{zo} = (building height) / 2.15
	Elevated Source (h_e > 0) not on or Adjacent to a Building	σ_{zo} = (vertical dimension of source) / 4.3

5.5.4 Line Sources

Examples of line sources are roadways and rail lines. None of the approved models - SCREEN3, AERSCREEN or AERMOD have a dedicated line source type to represent sources of this nature. However, AERMOD can simulate emissions from line sources through a series of volume or area sources.

For consideration of emissions of traffic related contaminants from roadways, a traffic air dispersion model such as CAL3QHCR may need to be considered.

5.5.5 Flare Sources

Flare sources are used as control devices for a variety of sources. SCREEN3 and AERSCREEN support flares directly through their flare source type. However, AERMOD does not have a specific source type option for flare sources. Instead, flares are modelled as point sources using a series of manual calculations to determine pseudo-stack parameters to appropriately represent the source characteristics of the flare stack. SCREEN3 and AERSCREEN use a similar approach and similar calculations except that these are completed internally by the models.

The inputs required to model a flare using SCREEN3 or AERSCREEN are described below.

SCREEN3

The required inputs for a Flare are:

- **Emission Rate [g/s]:** The emission rate of the contaminant in grams per second (g/s).
- **Flare Stack Height [m]:** The stack height above ground.
- **Total Heat Release Rate [cal/s]:** The heat release rate in calories per second (cal/s) for the flare.
- **Receptor Height above Ground [m]:** This shall be used to model impacts at "flagpole" receptors. A flagpole receptor is defined as any receptor which is located above ground level, e.g., to represent the roof or balcony of a building. The default value is assumed to be 0.0 m (i.e., ground-level receptors).

Note 1: SCREEN3 model calculates plume rise for flares based on an effective buoyancy flux parameter. An ambient temperature of 293 K is assumed in this calculation and therefore no ambient temperature is entered by the user. It is assumed that 55% of the total heat is lost due to radiation. Plume rise is calculated from the top of the flame, assuming that the flame is bent 45 degrees from the vertical. SCREEN3 calculates and prints out the effective release height for the flare.

Note 2: For Flare releases, SCREEN3 model assumes a stack gas exit velocity (V_s) of 20 m/s, an effective stack gas exit temperature (T_s) of 1,273 K, and calculates an effective stack diameter based on the heat release rate.

AERSCREEN

Flare source inputs are:

- **Emission Rate** [g/s or lb/hr]
- **Stack Height** [m or ft]
- **Total Heat Release Rate** [cal/sec]
- **Radiative Heat Loss Fraction** [%]

Note: The heat loss fraction can be user selected or the SCREEN3 default value of 55% used. AERSCREEN will process the flare in AERMOD as a POINT source type. For the exit velocity and exit temperature, AERSCREEN defaults these values to 20 m/s and 1,273 K, respectively as done in SCREEN3.

The calculation methodology for determining the appropriate stack pseudo-parameters and the detailed approach for modelling flares using AERMOD is described in Sections 5.6.3 and 11.1, respectively.

5.6 Special Considerations

During some air quality studies, modellers may encounter certain source configurations that require special attention. Some examples include horizontal sources or emissions from storage tanks. The following sections outline modelling techniques on how to account for the special characteristics of such scenarios.

5.6.1 Multiple Stacks

When the plumes from multiple closely-spaced stacks or flues merge, the plume rise can be enhanced. Briggs (1974) has proposed equations to account for this and should be referenced for further details. Most models do not explicitly account for enhanced plume rise from this case, resulting in conservative overestimates of the resulting concentrations. However, in the case of a single stack with multiple flues, or multiple stacks very close together (less than approximately one stack diameter apart), the multiple plumes may be treated as a single plume by developing stack pseudo-parameters to represent a single plume. To do this, a pseudo stack diameter is used in the calculations, such that the total volume flow rate of the stack gases is correctly represented. This method may not be correct if the flues have very different velocities and/or temperatures. In most instances it will likely be sufficient to conservatively model the emissions as multiple separate/individual sources. Should a proponent wish to model multiple flues as a single source, pre-consultation should be completed with the ministry to approve the proposed approach.

5.6.2 Horizontal Sources and Capped Sources

Both horizontal flues and capped vertical flues (rain caps) have little or no initial vertical velocity. Plume rise calculations in most air dispersion models take into account both rise due to vertical momentum of the plume as it leaves the stack and the buoyancy of the plume.

With horizontal and capped sources it is necessary to modify the source input parameters to minimize the effects of momentum while leaving the buoyant plume rise calculations unchanged. Since version 06341 of AERMOD there have been source type options for modelling horizontal (POINTHOR) and capped sources (POINTCAP). With these options, the vertical momentum is suppressed while buoyancy of the plume is conserved. The user specifies the actual stack parameters of release height, exit temperature, exit velocity and stack diameter and the AERMOD model performs the necessary adjustments internally to account for plume rise and stack tip downwash.

For models that do not have built-in functions for capped or horizontal sources, the revised source parameters must be determined external to the model. The suggested methodology is similar to that in the U.S. EPA Model Clearinghouse Memo 93-II-09 (U.S. EPA, 1993) and in Tikvart (1993):

- While maintaining volumetric flow, reduce velocity to 0.1 m/s or a velocity based on limiting the exit diameter to 5 times the actual diameter up to a maximum of 5 meters; and,
- If the source is a vertical stack with a rain cap, account for the frequent stack tip downwash by reducing the stack height input to the model by three times the actual stack diameter: H'=H–3D ensuring that the stack tip never goes below the elevation of the roof.

5.6.3 Modelling Flares

Flare sources can be modelled similar to point sources, except that there are buoyancy flux reductions associated with radiative heat losses and a need to account for the flame length in estimating plume release height (U.S. EPA, 1992). As mentioned previously, flares are modelled in SCREEN3, AERSCREEN and AERMOD by using POINT sources, and applying a series of stack pseudo-parameters (i.e., stack diameter, height and exit velocity). These parameters are used in lieu of the actual parameters, since the actual flame length and rising gases behave in the same manner as a much taller stack, and the combusted gases rapidly expand to form a much wider plume than the actual diameter of the flare. The equations shown below are used internally by the SCREEN3 and AERSCREEN models to calculate the effective diameter and the effective stack height from the input information.

$$D = 9.88 \times 10^{-4} \times \sqrt{H_r \times (1 - F_r)}$$

$$H_{sl} = H_s + 4.56 \times 10^{-3} \times {H_r}^{0.478}$$

Where:

D = effective stack diameter (m)
H_r = heat release rate (cal/s)
F_r = fraction of radiative heat loss
H_{sl} = effective flare height (m)
H_s = stack height above ground (m)

The heat loss fraction can be user selected in AERSCREEN, or the SCREEN3 default value of 55% can be used. For the exit velocity and exit temperature, AERSCREEN defaults these values to 20 m/s and 1,273 K, respectively, as done in SCREEN3.

The approach used in the AERMOD model is similar to that used by AERSCREEN, but the pseudo parameters are calculated manually and entered into the AERMOD input file. Input requirements are similar to those for a POINT source, except that the release height must be calculated as an effective release height and stack parameters need to be estimated by matching the radiative loss reduced buoyancy flux. The ERCB spreadsheet described in Section 11.1 of this report should be used to calculate the required stack pseudo-parameters.

The net heat release rate is calculated using the gas flow rate to the flare, the composition of the gas, net heating value of each component, and the fractional heat loss through radiation. The exit velocity and resulting stack diameter are calculated assuming that both buoyancy and momentum flux are conserved. This results in more realistic exit velocities and pseudo-diameters than previous methods, which incorporated only conservation of buoyancy flux.

The ERCB spreadsheet also calculates a stack gas exit temperature based on the excess air combustion of the user specified fuel gas composition, rather than an assumed temperature of 1,273 K as is used in SCREEN3. Further details on the input and output parameters are described in Section 11.1.

5.6.4 Liquid Storage Tanks

Storage tanks are generally of two types - fixed roof tanks and floating roof tanks. In the case of fixed roof tanks, most of the contaminant emissions occur from a vent, with some additional contribution from hatches and other fittings. In the case of floating roof tanks, most of the contaminant emissions occur through the seals between the roof and the wall, and between the deck and the wall, with some additional emissions from fittings such as ports and hatches.

Approaches for modelling impacts from emissions from various types of storage tanks are described below.

Fixed roof tanks

Model fixed roof tanks as a point source representing the vent, which is usually in the centre of the tank, and representing the tank itself as a building for downwash calculations.

Floating roof tanks

Model floating roof tanks as a circle of eight (or more) point sources, representing the tank itself as a building for downwash calculations. Distribute the total emissions equally among the circle of point sources. Alternately, the tanks may be represented as volume sources. Emissions will not be downwashed using this approach; but instead, are considered to be emitted from the entire volume.

All tanks

There is virtually no plume rise from tanks. Therefore, the stack parameters for the stack gas exit velocity and stack diameter shall be set to near zero for the stacks representing the emissions. In addition, stack temperature shall be set equal to the ambient temperature. This is done in AERMOD by entering a value of 0.0 K for the stack gas temperature.

If a tank is being modelled as a building with point sources used to represent the vents or emission points, it is very important for the diameter to be at or near zero. With low exit velocities and larger diameters, stack tip downwash will be calculated. Since downwash effects are already being calculated as building downwash, the additional stack tip downwash calculations is not required, as it artificially "double counts" the effect in this situation. Since the effect of stack tip downwash is to lower plume height by a maximum of three stack diameters, use of a very small stack diameter in these cases effectively eliminates the stack tip downwash.

AERMOD also allows stack tip downwash to be turned “off” in the Control options, but this turns it off for all stacks, which may not be appropriate. Therefore, this option must be used with caution. The recommended stack parameters are summarized in Table 5-6.

Table 5-6 – Stack Parameter Values for Modelling Tanks

Velocity	Diameter	Temperature
Near zero i.e., 0.001 m/s	Near zero i.e., 0.001 m	Ambient – 0.0 K sets AERMOD to use ambient temperature

It should be noted that there may be some cases when these suggested parameters may not be appropriate. For example, if the tank contents are heated, the temperature may be adjusted to a constant value that is based on the temperature of the tank contents. Provide clear documentation when making changes to the ministry suggested methods.

5.7 Building Downwash

Buildings and other structures located near short stacks can have a substantial effect on plume transport and dispersion and on the resulting ground-level concentrations that are observed. When the airflow meets a building (or other obstruction), it is forced up and over the building. On the lee side of the building, the flow separates, leaving a closed circulation containing lower wind speeds. Further downwind, the air flows downward again. In addition, there is more shear resulting in more turbulence. This is the turbulent wake zone (see Figure 5-2).

If a plume gets caught in this cavity, very high concentrations can result. If the plume escapes the cavity, but remains in the turbulent wake, it may be carried downward and dispersed more rapidly by the turbulence. This can result in either higher or lower concentrations than would occur without the building, depending on whether the reduced height or increased turbulent diffusion has the greater effect.

The height to which the turbulent wake has a significant effect on the plume is generally considered to be about the building height plus 1.5 times the lesser of the building height or width. This results in a height of 2.5 building heights for cubic or squat buildings, and less for tall, slender buildings. Since it is considered good engineering practice to build stacks taller than adjacent buildings by this amount, this height came to be called “good engineering practice” (GEP) stack height.

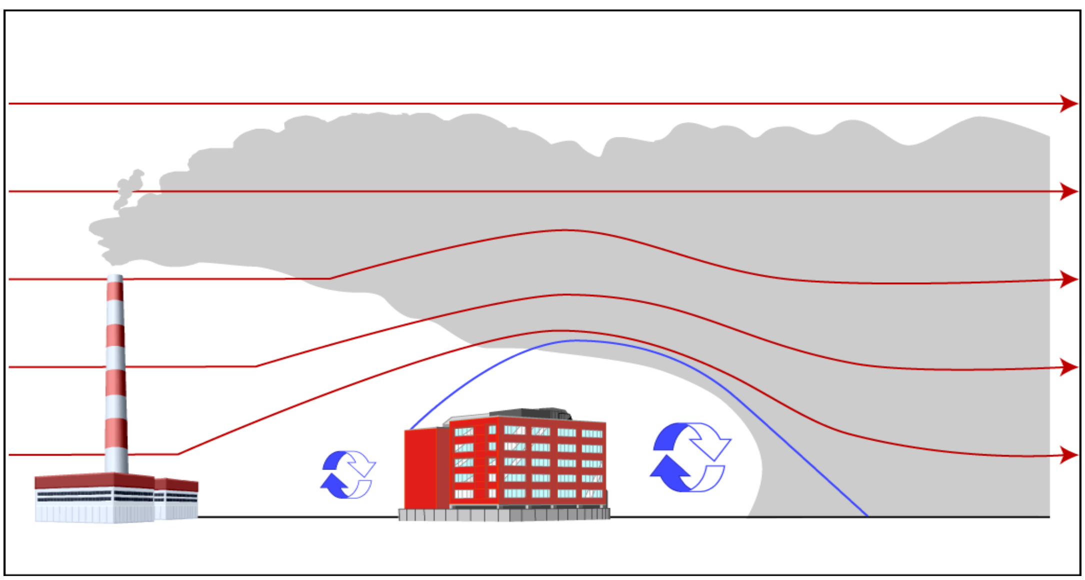

Figure 5-2 – Building Downwash

Building downwash for point sources that are within the Area of Influence of a building should be considered. A building is considered sufficiently close to a stack to cause wake effects when the distance between the stack and the nearest part of the building is less than or equal to five (5) times the lesser of the building height or the projected width of the building (width of the building “seen” by the wind blowing in a particular direction).

5.7.1 Defining Buildings

The approved screening and refined models all allow for the consideration of building downwash. SCREEN3 and AERSCREEN consider the effects of a single building while AERMOD can consider the effects of complicated sites consisting of up to hundreds of buildings.

SCREEN3

SCREEN3 requires the building height, minimum horizontal building dimension and the maximum horizontal building dimension of the single building.

Building wake effects are included for all calculations made by the model. Cavity calculations are made for two building orientations, first with the minimum horizontal building dimension along wind, and second with the maximum horizontal dimension along wind.

AERSCREEN

Parameters needed by AERSCREEN (U.S. EPA, 2010) for input into the U.S. EPA Building Profile Input Program – Plume Rise Model Enhancements (BPIP-PRIME) are:

- Building height;
- Maximum building horizontal dimension;
- Minimum building horizontal dimension;
- Degrees from north of maximum building horizontal dimension;
- Angle from north of stack location relative to building centre; and,
- Distance between stack and building centre.

An example building/stack configuration is shown in Figure 5-3 (U.S. EPA, 2010).

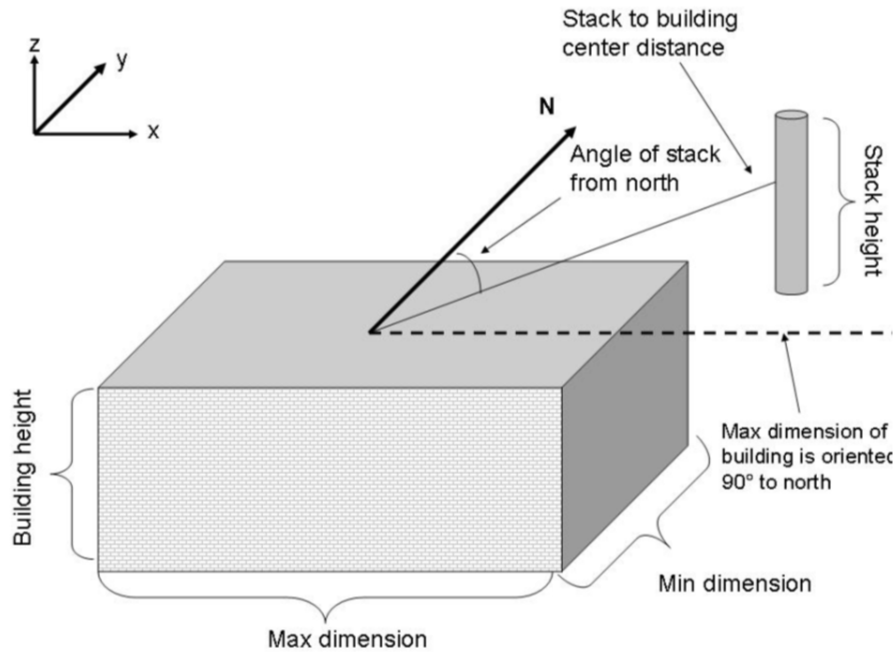

Figure 5-3 – AERSCREEN Building Downwash

AERMOD

AERMOD allows for the capability to consider downwash effects from multiple buildings using BPIP-PRIME. A building need not be rectangular and may have many vertices (corners) and different tiers. The following information is required to perform building downwash analysis within BPIP:

- X and Y location and height for all stacks;
- X and Y location for all building corners;
- Height for all buildings (meters). For building with more than one height or roofline, identify each height (tier); and,
- Base elevations for all stacks and buildings.

The BPIP User's Guide (U.S. EPA, 1995 (d)) provides details on how to input building and stack data to the program.

The BPIP model is divided into two parts.

- **Part One:** Based on the GEP technical support document, (U.S. EPA, 1985) this part is designed to determine whether or not a stack is subject to wake effects from a structure or structures. Values are calculated for GEP stack height and GEP related building heights (BH) and projected building widths (PBW). Indication is given to which stacks are being affected by which structure wake effects.

- **Part Two:** Calculates building downwash BH and PBW values based on references by Tikvart (Tikvart, 1988; Tikvart, 1989) and Lee (1993). These can be different from those calculated in Part One. The calculations are performed only if a stack is being influenced by structure wake effects.

In addition to the standard variables reported in the output, BPIP-PRIME adds the following:

- **BUILDLEN:** Projected length of the building along the flow.

- **XBADJ:** Along-flow distance from the stack to the center of the upwind face of the projected building.
- **YBADJ:** Across-flow distance from the stack to the center of the upwind face of the projected building.

The results from BPIP-PRIME can then be incorporated into the modelling studies for consideration of downwash effects. For a more detailed technical description of the U.S. EPA BPIP-PRIME model and how it relates to the PRIME algorithm see the *Addendum to ISC3 User's Guide* (U.S. EPA, 1997).

While BPIP-PRIME supports the use of tiers on a building, if there are several tiers on a single building it is often preferable to enter each tier as a separate building.

6.0 MODEL INPUT - GEOGRAPHICAL INFORMATION

6.1 Comparison of Screening and Refined Model requirements

Geographical information requirements range from “basic” for screening analysis to “advanced” for refined modelling. SCREEN3 and AERSCREEN make use of geographical information only for terrain data for complex or elevated terrain where it requires simply distance from source and height in a straight-line. The AERMOD model makes use of complete three-dimensional geographic data with support for digital elevation model files and real-world spatial characterization of all model objects.

6.2 Coordinate System

The AERMOD model’s terrain pre-processor, AERMAP, requires digital terrain in Universal Transverse Mercator (UTM) coordinates. The UTM system uses meters as is its basic unit of measurement and allows for more clear definition of specific locations than latitude / longitude. The modeller shall ensure that all model objects (sources, buildings, receptors) are defined in the same horizontal datum. Defining some objects based on a NAD27 (North American datum of 1927) while defining others within a NAD83 (North American datum of 1983) can lead to significant errors in relative locations.

6.3 Terrain Processing

6.3.1 Terrain Concerns in Short Range Modelling

For situations where the terrain around the facility is not relatively flat or gently rolling, AERMAP may be used to assign elevations to the receptors and to generate hill heights. Terrain elevations, relative to the facility base elevation, can have a large impact on the air dispersion and deposition modelling results and therefore on the estimates of potential risk to human health and the environment.

The following section describes the primary types of terrain. The consideration of a terrain type is dependent on the study area, and the definitions below should be considered when determining the characteristics of the terrain for your modelling analysis.

6.3.2 Simple Elevated, Complex and Flat Terrain

The terrain around a modelled facility can be defined as simple elevated or complex. In complex terrain, there are terrain elevations within 50 km of the stack that are above the height of the stack under study. Simple elevated terrain is defined as terrain that is above the base elevation of the stack but below the top of the stack. AERMOD does not require the modeller to determine whether terrain in the region being modelled is complex or simple elevated. The degree of terrain and its effects are automatically determined using the terrain data provided.

The AERMOD “flat terrain” option, which AERMOD internally sets all receptor heights to zero, is valid in gently rolling areas as it allows the plume to follow the terrain. While there may be some savings of work and time by running AERMOD in “flat terrain mode”, the ministry recommends that terrain information is always incorporated into AERMOD by using AERMAP.

6.3.3 Obtaining Terrain Data for Saskatchewan

Terrain data that are input into AERMOD should be provided in electronic form when making submissions to the ministry. Digital elevation terrain data are available for the Province of Saskatchewan from a variety of sources in several different formats.

Canadian terrain data may be downloaded from GeoBase Canada. GeoBase is a federal, provincial and territorial government initiative that is overseen by the Canadian Council on Geomatics (CCOG). The data is available at no cost and with unrestricted use. However, it is necessary to register as a user before you can download data.

The data is available at 1:250,000 and 1:50,000 resolutions. Each tile consists of gridded data of 1201 points in the east-west direction by 1201 points in the north-south direction. The 1:250,000 terrain data has a horizontal resolution of approximately 45 m in the east-west direction by 92 m in the north-south direction. The 1:50,000 terrain data has a horizontal resolution of approximately 13.5 m in the east-west direction by 23 m in the north-south direction. The use of the 1:50,000 terrain data is recommended for improved accuracy. No manipulation of the downloaded data is required. Once the data is downloaded and processed by AERMAP, the elevations assigned to the receptors should be compared to another source of data, such as Google Earth, to ensure that the pattern of data looks reasonable. A graphic showing terrain elevations used would be helpful for the reviewer to see that data was correctly processed. There are free DEM viewing programs that may be used to prepare such graphics.

AERMAP will accept data in at least the following formats:

- USGS DEM;
- NED/SRTM GEOTIFF;
- SRTM3/SRTM1;
- GTOP30/SSRTM30;
- XYZ file;
- AutoCAD DXF;
- UK DTM; and,
- UK NTF.

In the majority of the cases the GeoBase Canada DEM files should be sufficient for air dispersion modelling use. However, in some cases site specific information may be best represented by facility generated or other data. The ministry should be contacted before using such data to determine suitability and compatibility.

6.4 Land Use Characterization

Characterization of representative land use data in the vicinity of a site is necessary to determine the appropriate surface characteristics, which govern how plumes are dispersed as they move away from a source. This data is used for AERMOD and AERSCREEN but not required for SCREEN3. Surface characteristics such as roughness, albedo and Bowen Ratio are used by AERMET in the development of the surface meteorological data (.sfc files). The surface characteristics can be determined manually using the approach described in Section 3.1 of the AERMOD Implementation Guide (U.S. EPA, 2008(a)) or using the U.S. EPA AERSURFACE program (if the required data are available in the appropriate format) (U.S. EPA 2008(b)). The MAKEMET module of AERSCREEN also uses surface characteristics it its generation of screening meteorology.

The Saskatchewan Regional Meteorological Data Sets have been prepared using data from the GlobCover Land Cover v2 (2008) database, based on the most common uniform land uses observed in each Region, and have been categorized as such (i.e., Central Urban, Central Agricultural). However, wind sector dependent surface characteristics will have to be determined on a site specific basis when using alternate meteorological data files, such as the partially processed AERMET Stage 3 input files, which are available upon request from the ministry. Section 7.2.2 provides additional guidance on manually determining surface characteristics for use with the partially processed AERMET Stage 3 input files.

7.0 MODEL INPUT - METEOROLOGICAL INFORMATION

7.1 Comparison of Screening and Refined Model Requirements

Meteorological data are essential for air dispersion modelling as they describe the primary environment through which the contaminants being studied migrate. Similar to other data requirements, screening model requirements are less demanding than refined models.

SCREEN3 uses internally generated meteorological conditions to calculate the maximum concentrations. SCREEN3 provides 3 methods of defining meteorological conditions:

- **Full Meteorology:** SCREEN3 will examine all six stability classes (five for urban sources) and their associated wind speeds. SCREEN3 examines a range of stability classes and wind speeds to identify the "worst case" meteorological conditions, i.e., the combination of wind speed and stability that results in the maximum ground level concentrations.
- **Single Stability Class:** The modeller can select the stability class to be used (A through F). SCREEN3 will then examine a range of wind speeds for that stability class only.
- **Single Stability Class and Wind Speed:** The modeller can select the stability class and input the 10-meter wind speed to be used. SCREEN3 will examine only that particular stability class and wind speed.

AERSCREEN requires more inputs compared to SCREEN3. The more detailed inputs are used by AERSCREEN to generate a set of screening meteorological data that is dependent on the surface characteristics around the modelled site. AERSCREEN provides three options for generating the screening meteorology:

- One option allows for user-specified surface characteristics – albedo, Bowen ratio, and surface roughness (no temporal or spatial variation).
- The second option is to use seasonally varying surface characteristics for generic land use classifications based on Tables 4-1, 4-2, and 4-3 of the AERMET User's Guide.
- The third option is to use surface characteristics listed in an external file such as an AERSURFACE output file or AERMET Stage 3 input file.

AERMOD uses hour-by-hour meteorological data that must be processed through AERMET into a form that AERMOD can use as input. AERMET requires at least one surface meteorological station and one upper air station. Surface characteristics of albedo, surface roughness and Bowen ratio may be input on a sector-by-sector basis. The selection and preparation of appropriate input files is time consuming and requires skill in handling these types of inputs. To aid modellers in Saskatchewan, the ministry has developed a series of fully processed AERMOD ready Regional Meteorological Data Sets which are described in the following section.

7.2 Meteorological Data for the Province of Saskatchewan

7.2.1 Saskatchewan Regional Meteorological Data Sets

The ministry prepared a series of fully processed AERMOD ready screening meteorological data sets that will be referred to as "Regional Meteorological Data Sets" for air dispersion modellers to use. The purpose of these data sets is to make modelling more consistent and reproducible across the province. It is anticipated that the vast majority of the AERMOD modelling undertaken in Saskatchewan will be completed using one of these Regional Meteorological Data Sets. Modellers pick the fully processed AERMOD ready data file that best represents the meteorology for the location of their site. The Regional Meteorological Data Sets contain 5 years of hourly meteorological data (~43,800 hours) representing the years 2003 to 2007.

The use of the Regional Meteorological Data Sets will promote the use of AERMOD and all of its advantages (multiple sources, building downwash, more source types) over the screening models, SCREEN3 and AERSCREEN.

The ministry delineated the province into five zones for the purpose of air dispersion modelling (Figure 7-1). Regional Meteorological Data Sets for the period of 2003-2007 were generated for each of the five zones for use with AERMOD. The fully processed AERMOD ready Regional Meteorological Data Sets have been manipulated to include the extra parameters required for the determination of wet deposition. The Regional Meteorological Data Sets are complete with missing parameters interpolated from previous and subsequent hours. In some cases, where blocks of data were unavailable an alternate surface station was used to fill in the required values.

Table 7-1 summarizes the names of all of the fully processed screening data files and the partially processed AERMET Stage 3 input files (Section 7.2.1 and 7.2.2) for each of the five Air Dispersion Modelling Zones and all of the applicable Surface Classes. The names of the surface and upper air stations on which the files are based are also included in the Table for reference.

Details on how the Regional Meteorological Data Sets were prepared are available in Appendix A.

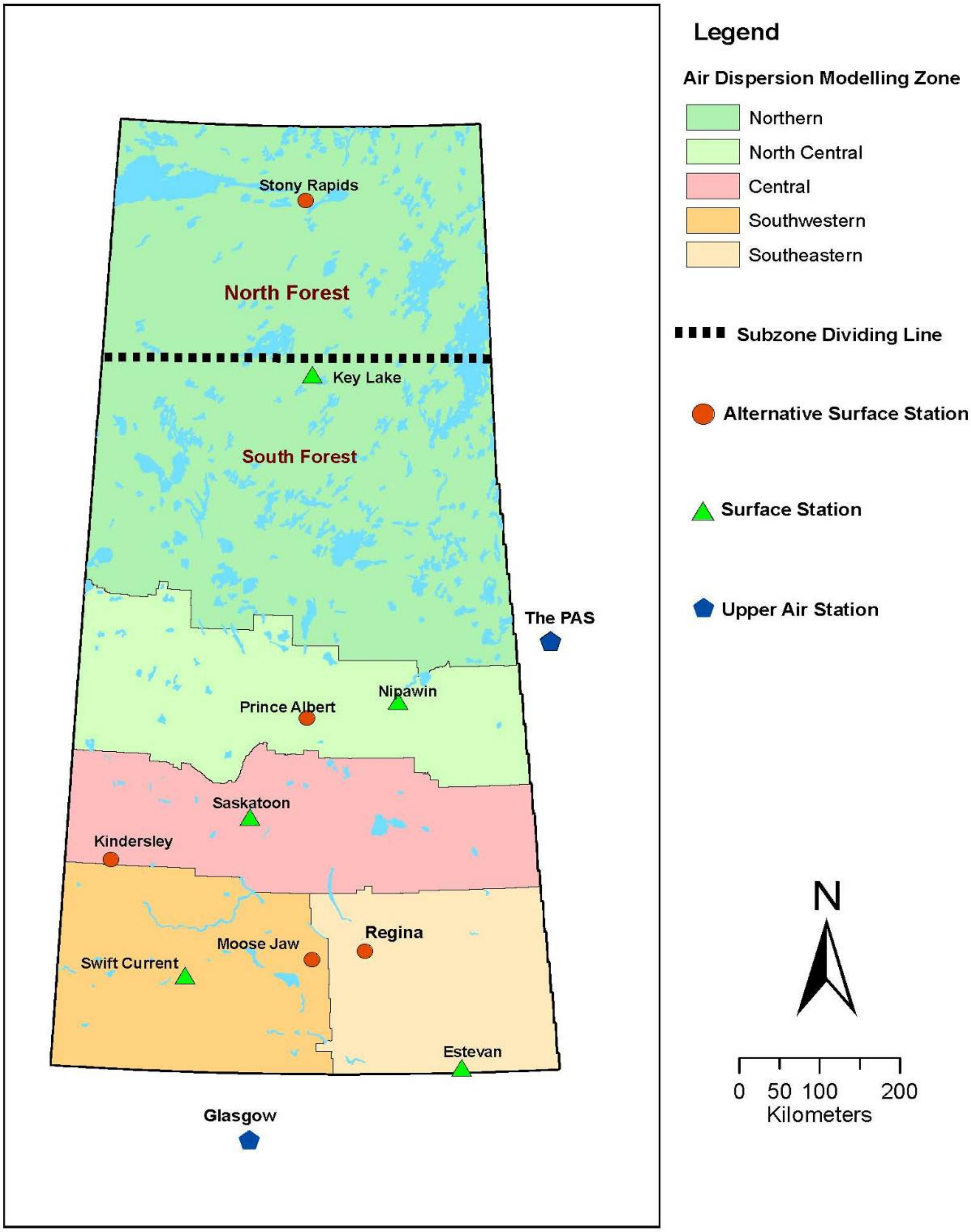

Figure 7-1 – Saskatchewan Air Dispersion Modelling Zones

Note: The dividing latitude between the North Forest and South Forest sub-zones is 57.25º N.

Table 7-1 – Screening AERMOD Meteorological Data Files

Air Dispersion Modelling Zone	Surface Class	Fully Processed Screening Data Files (surface/profile)	Partially Processed AERMET Stage 3 Input Files	Surface/ Upper Air Station
Northern	North Forest	NORFORN0307WD.sfc NORFORN0307WD.pfl	NORSTG0307. met	Key Lake The Pas
	South Forest	NORFORS0307WD.sfc NORFORS0307WD.pfl		
North Central	Forest	NCEFOR0307WD.sfc NCEFOR0307WD.pfl	NCESTG0307.met	Nipawin The Pas
	Agricultural	NCEAGR0307WD.sfc NCEAGR0307WD.pfl		
	Urban	NCEURB0307WD.sfc NCEURB0307WD.pfl		
Central	Agricultural	CENAGR0307WD.sfc CENAGR0307WD.pfl	CENSTG0307.met	Saskatoon Glasgow
	Urban	CENURB0307WD.sfc CENURB0307WD.pfl		
Southwestern	Agricultural	SOWAGR0307WD.sfc SOWAGR0307WD.pfl	SOWSTG0307.met	Swift Current Glasgow
	Urban	SOWURB0307WD.sfc SOWURB0307WD.pfl		
Southeastern	Agricultural	SOEAGR0307WD.sfc SOEAGR0307WD.pfl	SOESTG0307.met	Estevan Glasgow
	Urban	SOEURB0307WD.sfc SOEURB0307WD.pfl		

7.2.2 Alternate Meteorological Data Sets

The Regional Meteorological Data Sets are very useful for assessing the compliance of a facility. By using 5 years of data, every combination of wind speed, wind direction and stability that can occur in the area near the facility is likely to be included. However, there may be rare occasions when it is desirable to use an alternate meteorological data set.

The Regional Meteorological Data Sets were prepared assuming that the surface characteristics around the facility are relatively uniform. If the facility to be modelled has surface characteristics that do not match any of the available fully processed AERMOD ready meteorological data files, such as being in a forested area in the Central Air Dispersion Modelling Zone, then the fully processed Regional Meteorological Data sets may not be appropriate. Also, when the surface characteristics are non-uniform around a facility, such as having forested area to the north, crops to the east and south and water to the west, the fully processed Regional Meteorological Data sets may not be appropriate. In these cases, the use of the partially processed AERMET Stage 3 input files is recommended. Their use is described below.

If the facility is located in a geographical area where the meteorology does not match the meteorology in the Regional Meteorological Data Sets, other meteorological data may be used, such as on-site data or computational derived data using meso-scale weather models. Other sources of meteorological data are discussed below.

Unique geographical features, such as the facility being on the shore of a large body of water or in a valley, may mean that AERMOD and the Regional Meteorological Data Sets cannot represent the meteorological conditions at the facility. For these rare situations, it may be necessary to use a specialized model such as CALPUFF with representative meteorology.

AERMET Stage 3 Input File Processing

If the site is located in an Air Dispersion Modelling Zone, but the surface characteristics near the site do not match any of the fully processed Regional Meteorological Data Sets, it is possible to use a partially processed AERMET Stage 3 input file and complete the last stage of processing. For example, if the site was located in a heavily forested area in the Southeastern Air Dispersion Modelling Zone, it can be seen that in Table 7-1 fully processed meteorological data files are available for agricultural and urban land uses only. It is necessary for the modeller to create the AERMET Stage 3 input file that contains sector by sector values for albedo, surface roughness and Bowen ratio. Consultation with the ministry is encouraged to ensure methodology for determining the necessary parameters is acceptable. It should be noted that the partially processed AERMET Stage 3 input files listed in Table 7-1 do not include the precipitation data required for wet deposition.

The modeller should follow guidance from the AERSURFACE and AERMET manuals in preparing the necessary surface characteristic parameters. The following recommendations are quoted from the AERSURFACE Manual (U.S. EPA, 2008):

1. The determination of the surface roughness length should be based on an inverse distance weighted geometric mean for a default upwind distance of 1 kilometre relative to the measurement site. Surface roughness length may be varied by sector to account for variations in land cover near the measurement site; however, the sector widths should be no smaller than 30 degrees.
2. The determination of the Bowen ratio should be based on a simple unweighted geometric mean (i.e., no direction or distance dependency) for a representative domain, with a default domain defined by a 10 km by 10 km region centered on the measurement site.
3. The determination of the albedo should be based on a simple unweighted arithmetic mean (i.e., no direction or distance dependency) for the same representative domain as defined for Bowen ratio, with a default domain defined by a 10 km by 10 km region centered on the measurement site.

The AERMET Stage 3 input files will be available, upon request, from the ministry. Proponents are requested to submit methodology for the determination of suitable land surface characteristics for approval by the ministry when making a request.

Other Surface Meteorological Data

If the modelling study is being undertaken to assess impact at specific receptors or to match modelled and monitored data, the choice of the surface meteorological data becomes more important. Use of any alternate source of meteorological data requires prior approval from the ministry, which will review the source of the proposed data set and the methodology to be used for its processing/handling. With more representative meteorology, a minimum of one year of meteorological data is required as opposed to the five years contained in the Regional Meteorological Data Sets.

The choices for more representative surface data are:

- Use of existing Environment Canada or similar monitoring station;
- Use of on-site data from a meteorological tower; or
- Use of numerically generated meteorological data.

The parameters required by AERMET that are collected at a surface meteorological station are:

- Wind speed;
- Wind direction;
- Temperature;
- Relative humidity;
- Cloud cover; and,

- Ceiling height.

Airport stations generally collect all of these parameters although smaller airports may collect some data during the daylight hours only. Typically, on-site stations collect only temperature, wind speed and direction. To use on-site data it is necessary to blend in cloud cover and ceiling height from the nearest airport.

Any stations that are proposed to be used as a source of meteorological data for air dispersion modelling must be representative, have minimal missing data, have been QA/QC'd for accuracy including calibration, and have been correctly sited (away from buildings and trees that mask certain wind directions).

Numerical computation of meteorological data using sophisticated meso-scale weather models can be used to generate very accurate site specific meteorology that can be manipulated into a form that may be used as input into AERMET.

For any of these options, consultation with the ministry is required to approve the proposed methodology.

8.0 MODEL INPUT - RECEPTOR LOCATIONS

The AERMOD air dispersion model computes results-based on user-specified spatial points. Modellers commonly refer to these points as receptors. The term is somewhat ambiguous as receptor can also refer to a specific entity of concern, such as a school or endangered wildlife habitat, a usage common in risk analysis. For the purpose of this discussion, unless specified otherwise, receptor refers to a location where model computations are output. Receptors are to include locations along the property boundary and beyond but not within the facility property.

Receptor selection is critical to capturing the maximum point of impact and proper placement can be achieved through several approaches. The following sections outline the various types of receptor grids.

8.1 Multi-Tier Cartesian Grid

The ministry requires the use of a multi-tier Cartesian grid with pre-defined grid spacing as defined below. The advantage of this approach is that it gives the user a specific starting point with set criteria for the design of the receptor network and minimizes the number of receptors which directly effects model run times.

- 20-m receptor spacing in the general area of maximum impact and the property boundary;
- 50-m receptor spacing within 0.5 km from the source and over steep terrain;
- 250-m receptor spacing within 2 km from the source of interest;
- 500-m receptor spacing within 5 km from the sources of interest; and,
- 1,000-m receptor spacing beyond 5 km.

Figure 8-1 is an example of a nested grid with increased density of grid points near the site. For short stacks or those facilities with significant fugitive or ground based sources, the maximum concentration will occur at the property line. The plume has had little time to spread and may be quite narrow. The close spacing of the receptors in this area is necessary to capture the maximum concentration as the modelled concentration will change rapidly with distance from the source and from centreline of the plume. Figure 8-1 also shows that the receptors within the plant boundary have been removed.

For the cases where a facility has a tall stack that is clear of building downwash, the maximum ground level concentration will occur at some distance from the facility. The maximum concentration from a tall stack will be significantly lower than if the same mass of emissions was emitted from a shorter stack or as a fugitive source as the emissions from the tall stack are spreading in the horizontal and vertical directions as the plume moves away from the stack. The resulting ground level concentrations from a tall source generally change more slowly with distance and a more diffuse grid will still adequately capture the maximum concentration. Additional receptors may be added to this minimum grid setup as one of the other types of grids explained in the following sections.

The grid should extend far enough away from the facility to ensure that the maximum concentration is captured (concentrations start to drop before the edge of the modelling domain). In the case of very tall stacks a distance of 10 km or greater may be necessary.

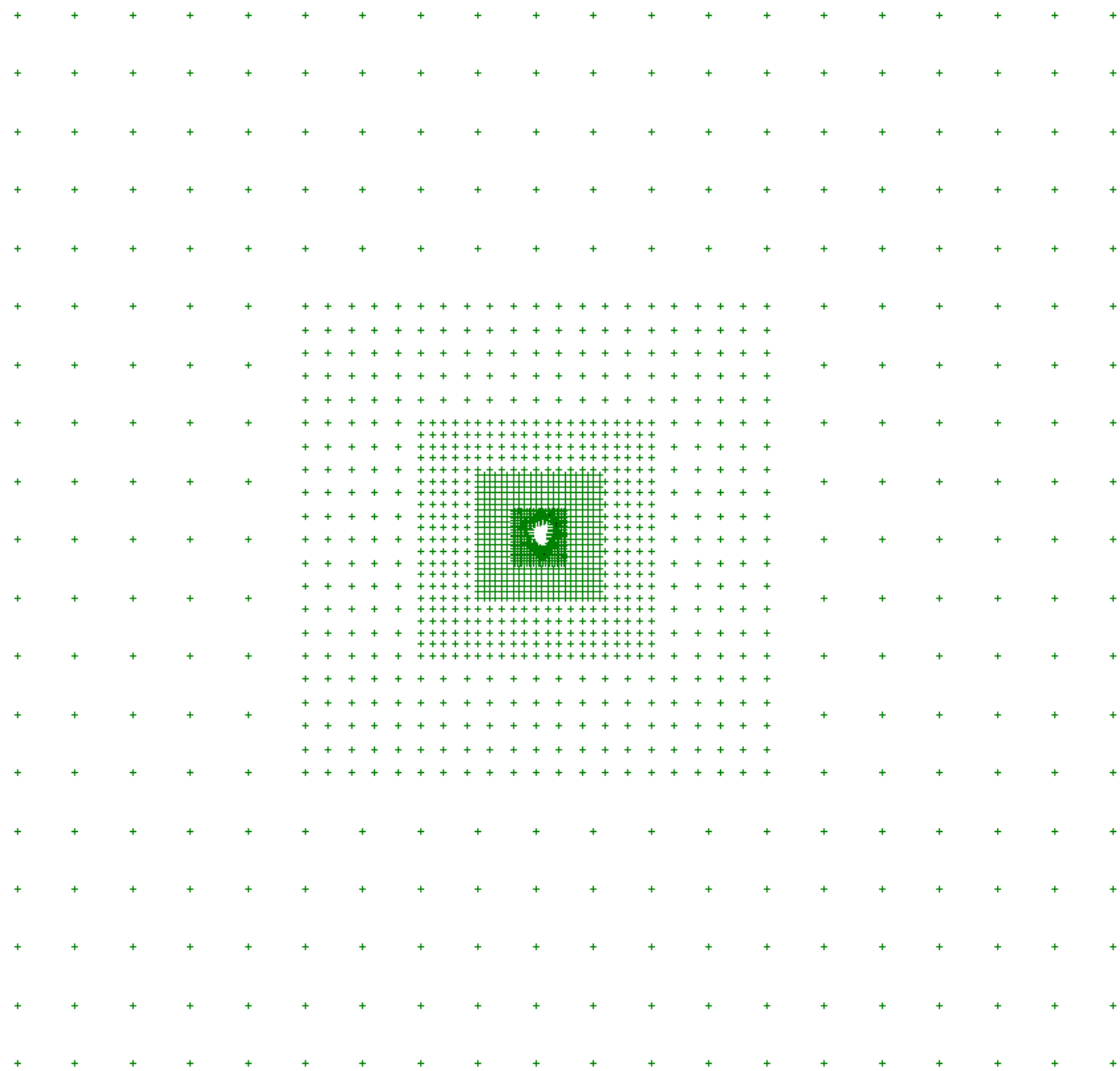

Figure 8-1 – Example of a Nested Grid

Predefined receptor placement criteria are not optimized for all modelling conditions. For this reason, the ministry may require or pre-approve deviations to these standard grid spacings.

8.2 Cartesian Receptor Grids

Cartesian receptor grids are receptor networks that are defined by an origin with receptor points evenly (uniform) spaced receptor points in x and y directions. It may be necessary or desirable to place an additional Cartesian receptor grid in an area where there are sensitive receptors or in cases where the maximum concentration occurs at some distance from the facility, to provide details in that area. Figure 8-2 illustrates a sample uniform Cartesian receptor grid below.

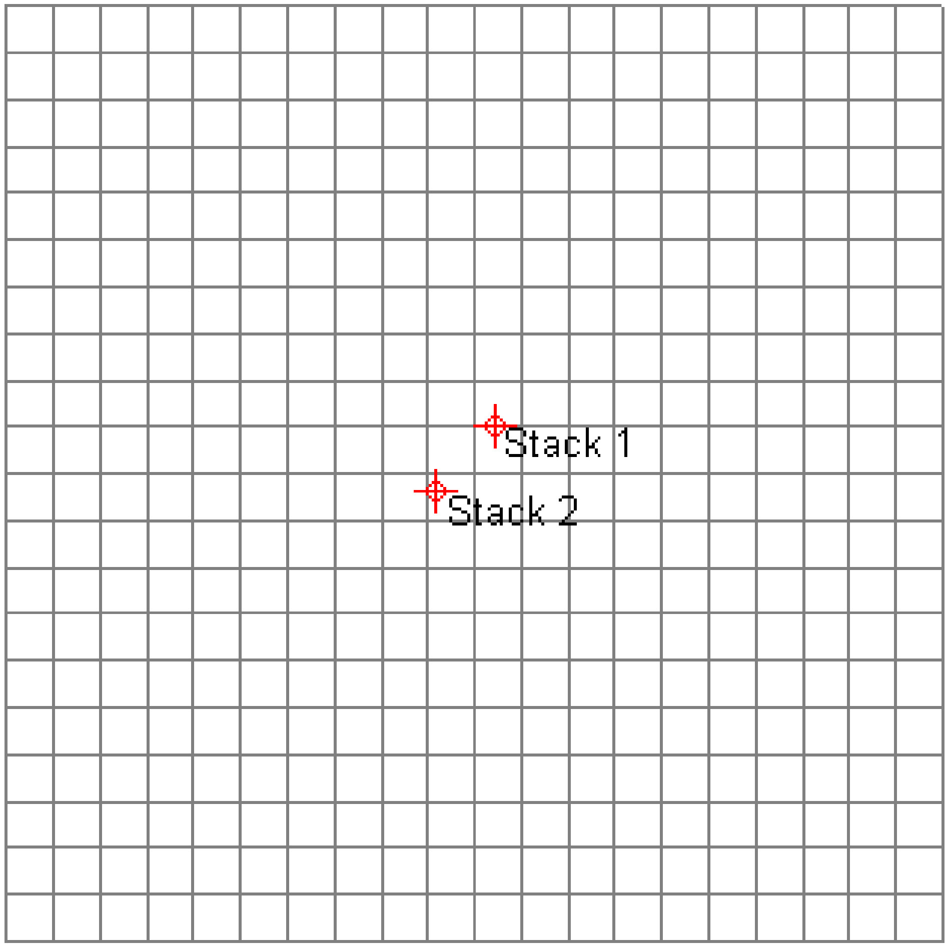

Figure 8-2 – Example of a Cartesian Grid

8.3 Polar Receptor Grids

AERMOD also supports the use of polar receptor grids. Polar receptor grids are designed primarily for single source studies; however, the receptor spacing becomes too large too quickly in many studies as the distance increases from the source. This can be seen in Figure 8-3 below.

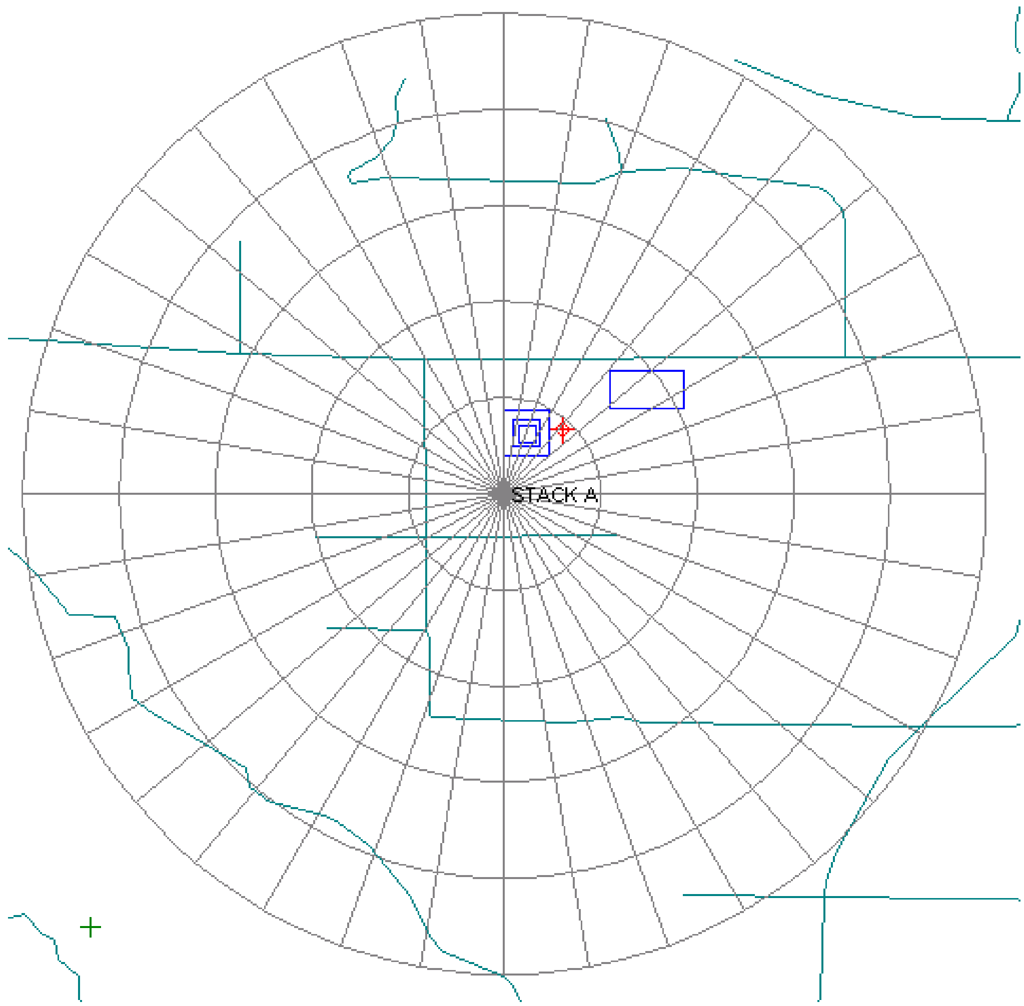

Figure 8-3 – Example of a Polar Grid

In general, the ministry does not permit the use of polar receptors for determining compliance. However, there are some modelling situations for which their use may be justified and these must be approved by the ministry on a case-by-case review.

8.4 Fenceline Receptors

The ambient air quality objectives apply to areas where there is public access (i.e., outside of the plant boundary). The plant boundary is typically defined as the facility fenceline or the perimeter of the area disturbed by the operation of the facility. If a facility is located within a larger related facility boundary, the plant boundary is assumed, for modelling purposes, to be the plant boundary of the encompassing facility. Receptors within the plant boundary should be removed. The ministry requires that receptors be placed along the fenceline at no more than 20 meter intervals. Figure 8-4 is an example of the receptors along the fenceline of the property and shows that receptors within the plant boundary were removed.

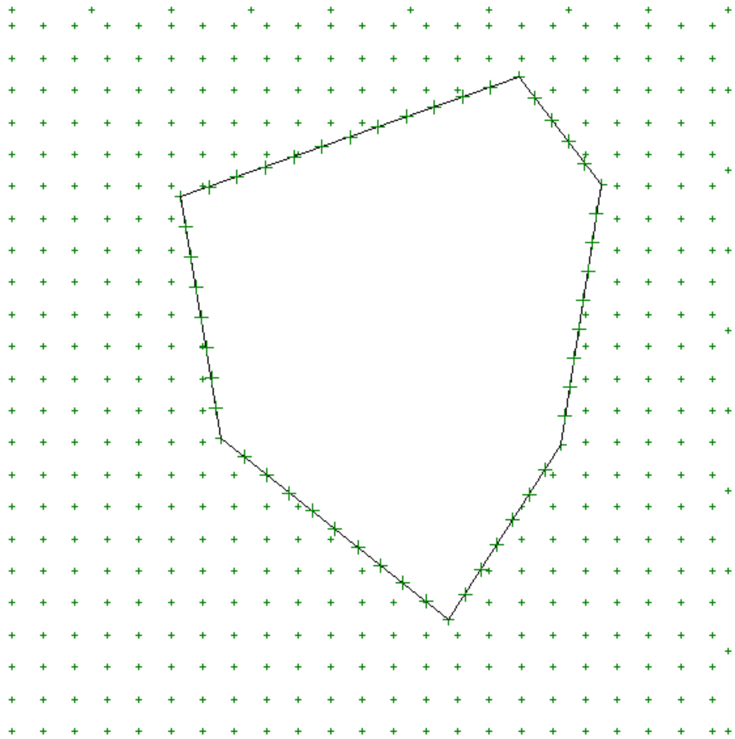

Figure 8-4 – Example of Fenceline Receptors

8.5 Roadways and Railroads Bisecting the Property

In some cases, a facility property will be bisected by a roadway or railroad. For modelling purposes, the ministry allows the property to be considered a single property. Fenceline receptors are required to be added around the perimeter of the joined properties. Receptors are to be excluded from within the perimeter of the joined properties.

8.6 Discrete Receptors

Receptor grids do not always cover precise locations that may be of interest in modelling projects. Specific locations of concern can be modelled by placing single receptors at desired locations. This enables the modeller to achieve data on specific points for which accurate data is especially critical. In particular, for elevated receptors the maximum concentrations can be larger than that found at ground level.

Common locations of concern can include, among others, the following:

- Residential zones;
- Schools;
- Apartment buildings;
- Day care centers;
- Air intakes on nearby buildings;
- Hospitals;
- Parks;
- Sensitive species; and,
- Protected species habitat.

Depending on the project resolution and location type, these can be characterized by a single discrete receptor or a series of discrete receptors.

8.7 Receptor Elevations

AERMOD makes use of receptor elevation information for simple elevated or complex terrain studies. Note that receptor elevation data is commonly obtained from digital terrain data in a variety of formats. The AERMOD model obtains receptor elevation and hill height values through the use of AERMAP, its terrain pre-processor.

9.0 MODEL INPUT – OUTPUT OPTIONS

Dispersion models typically have various options that can be selected to specify how the results are output to the user. This includes options to specify results for certain sources or groups of sources, the time over which the results are averaged, and the specific receptor locations where the results are required.

9.1 Averaging Times

Models have differing capabilities in terms of the time over which the results of the dispersion calculations are averaged. However, it is important to note that when specifying the averaging times for the resulting contaminant concentrations, these should be consistent with the averaging time of the criterion for the contaminant being assessed. For example, if the criterion is based on a 24-hour average, the resulting concentrations at the specified receptor locations should also be averaged over 24 hours.

The screening models (SCREEN3 and AERSCREEN) only provide results on an hourly average basis, whereas AERMOD and other advanced models can calculate concentrations at various different averaging times including one-hour, eight-hour, 24-hour, monthly, annual and over specified times. In addition, multiple averaging times can be specified in a single run.

If using SCREEN3 or AERSCREEN when comparing to 24-hour or annual criteria, the maximum 1-hour concentrations produced by the model must be converted to a maximum 24-hour or annual average concentrations. This is done using conversion factors as described below. It should be noted that these conversions must be done externally when using the SCREEN3 model, but they are completed internally when using AERSCREEN.

9.1.1 Conversion Factors at Different Averaging Times

The use of conversion factors is a useful way to estimate concentrations for other averaging times. This allows screening models to be used to estimate concentrations for longer averaging times, such as 24-hours or annual. When using the SCREEN3 or AERSCREEN model, the following ratios should be used to convert 1-hour maxima to longer term averages:

Averaging Time	SCREEN3 Multiplying Factor (Ratio)	AERSCREEN Multiplying Factor (Ratio)
3 hours	0.9	1.0
8 hours	0.7	0.9
24-hours	0.4	0.6
Annual	0.08	0.1

Conversion factors may also be used to convert 1-hour peak concentrations from refined models (e.g., AERMOD) to compare with standards for shorter averaging times such as a ½ hour standard or a 10 minute odour-based standard. The ministry recommends the following power law equation to convert concentrations from one hour to the desired minutes:

$$C_p = C_m \left(\frac{T_m}{T_p} \right)^p$$

Where

C_p = Peak concentration, expressed on the new averaging time [μg/m^3]
C_m = Mean concentration on one hour averaging time [μg/m^3]
T_m = Averaging time for 1 hour [60 minutes]
T_p = New averaging time [minutes]
p = Decay value = 0.28 [non-dimensional]

Experimental data has shown that the value of *p* used in the power law equation varied over a large range, with dependencies based on source type, distance, land characteristics, stability class and other factors. It is recommended using a decay factor of $p = 0.28$ is used, which gives conservative results when converting from a longer time averaging time to a shorter one.

9.2 Maximum Predicted Concentrations

Screening models output the highest predicted concentrations at the point of the maximum prediction or at specified distances downwind from a source. The refined models (i.e., AERMOD) output data files of results at specified receptor locations. The most common model results are the maximum predicted concentrations at each receptor location. These are typically used in comparisons against appropriate standards and criteria, as they represent the highest concentrations that could occur at any location in the modelling domain. These can be output in different ways, depending on the needs of the user.

9.2.1 Tabular Results

The model predictions from AERMOD can be generated in tabular format using the RECTABLE and MAXTABLE keywords in the output. The RECTABLE keyword provides the highest, second-highest and third-highest values by receptor. The MAXTABLE keyword provides a table of the overall highest concentrations, regardless if these occur at the same receptor in multiple instances (i.e., on different days). For both of these keywords, the user has additional flexibility to specify for which averaging times the outputs are selected. For the MAXTABLE keyword, the user can also specify the number of overall maximum values (i.e., top 100) to summarize for each averaging time selected.

9.2.2 Plot Files

The PLOTFILE keyword in AERMOD is used to generate a file that contains the maximum value at each receptor included in the model inputs, for the specified averaging time. These files are most used to generate contour plots of the high values, for graphical presentation (i.e., plots of 1-hour maximum NO_2 concentrations in the model domain). Plot files can also be imported into a spreadsheet program to easily identify the overall predicted maximum value in the model domain.

Plot files can also be generated to present the maxima for individual source groups, which are discussed later in Section 9.5.

9.3 Post files

Refined models, such as AERMOD, have the option of using post files (POSTFILE keyword) to output the model predictions for every hour in the meteorological data set at every receptor specified in the model inputs. These files are very useful for showing the time varying trends in the model predictions at specific receptors. However, because they include all of the model results, post files can be extremely large. It is recommended that post files be used at selected receptor locations, or over short durations, such as individual specific days. Post files can be specified to provide the hourly concentrations for all hours in the five year meteorological period at a specific sensitive receptor, or to provide the hourly concentrations on a specific day at all receptors.

9.4 Threshold Violation Files

Threshold violation files (MAXIFILE keyword) can be specified in AERMOD to keep an account of exceedances of a user-specified concentration threshold. The date of the occurrence and the model predicted concentration are stored in the MAXIFILE for each occurrence. These files are useful for assessing the frequency of exceedances at specific receptor locations, and are required for running the EVENT model in AERMOD. The EVENT model is used to complete source contribution assessments of these exceedances. However, it should be noted that this option can produce large files if the runs have a large number of receptors and there are a significant number of exceedances of the threshold.

9.5 Source Grouping

When using the AERMOD model, analysis of individual groups of sources may be performed by using the SRCGROUP option. The AERMOD model automatically places the cumulative results from all sources into a group called ALL. AERMOD also allows sources to be placed into groups as specified by the user. Source groups enable modelling results that can be generated for specific groups of one or more sources. One example may be to assign each source to a separate source group to determine the different extent of effects from each individual source. This approach provides the *maximum* value for each source group, which may occur during different hours or days. As a result, this approach should not be used to attempt to assess the contribution of individual sources, unless the model is run for a specific hour or day in the meteorological data.

For regulatory purposes, the ministry requires the use of the source group "ALL" in AERMOD, which considers all the sources at the same time.

10.0 MODEL RESULTS

10.1 Ambient Background Concentration

The ministry requires inclusion of ambient background concentrations of an air contaminant to predicted values to obtain total concentrations before a comparison to the applicable ambient air quality standard is made.

“Background concentration” is the portion of the ambient concentration due to both natural and anthropogenic sources, which are other than the source(s) being evaluated. Often background includes two components:

- Regional background, consisting of natural sources, distant anthropogenic sources and other minor sources; and,
- Local background consisting of significant nearby sources (other than the source being evaluated), if applicable.

If a facility is not located near any other significant source of contaminant emissions then local background need not be considered.

10.1.1 Regional Background Concentrations

Regional background concentrations can be obtained from air quality measurements made in isolated rural areas. Air quality monitors that are located in areas not affected by local sources may be designated as “background monitors” and used to provide regional background data for modelling of sources in the region.

The ministry has a series of air quality monitoring stations that may be used as representative regional background concentrations. Data collected from these stations has been processed to give a series of percentiles of measured concentrations (Appendix B).

Air quality data collected in the vicinity of the proposed source or at a representative site may be used as background values. The following method should be used to determine a background concentration:

- At least one year of monitoring data is necessary, as there are usually significant seasonal differences in ambient concentrations. This can be due to atmospheric differences or because of the seasonal nature of some operations.
- All monitoring data should be subjected to validation and quality control to ensure its accuracy.
- For one-hour and 24-hour predicted averaging times, the value selected for background depends on the purposes of the modelling assessment, as follows:
  - For screening modelling, the 99^{th} percentile value from the cumulative frequency distribution of the background monitoring data should be used.
  - For refined modelling, the 90^{th} percentile value from the cumulative frequency distribution of the background monitoring data should be used.
- For the annual predicted averaging time, use the 50^{th} percentile from the cumulative frequency distribution of the background monitoring data.

The ministry should be contacted if planning to use data other than ministry data for regional background use (Appendix B).

10.1.2 Local Background Concentrations

In most cases, the use of the conservative regional background concentrations contained in Appendix B will be sufficient to describe current ambient conditions. However, in areas where there are other significant sources of the contaminants emitted by the facility being modelled, these sources need to be taken into account when determining the regional plus a local background concentration. If there is an air quality monitoring station that is very close to the facility being modelled, the data could be used to represent the regional plus local background. While information on the other local sources could be entered into the air dispersion model, there is no practical way to determine the source parameters and emission rates.

10.1.3 AERMOD and Background Concentrations

AERMOD has the capability to accept an external hour-by-hour time varying background concentration file. The use of this option with matching years of meteorological data would result in modelling results that represent reality as much as possible. Pre-consultation with the ministry is required before using such data.

10.2 Comparing Modelling Results to Standards

The Saskatchewan Ambient Air Quality Standards includes standards for one-hour, eight-hour, 24-hour and annual averaging times. The maximum modelled concentrations can be due to rare and unusual meteorological conditions. It is optionally allowed to eliminate these outliers when assessing compliance.

To determine compliance using screening models, the maximum modelled concentration must be added to the background concentration. The combined concentration must be compared to the applicable standard or guideline, as there is no way to obtain any output other than the maximum concentrations at each receptor.

For refined models, it is possible to eliminate these outliers by specifying the X^{th} highest concentrations (in addition to the maximum) to be output for each receptor location. The following compliance points may be used as shown below:

- 1-hour average – use the 9^{th} highest concentration;
- 8-hour average – use the 5^{th} highest concentration; and,
- 24-hour average – use the 2^{nd} highest concentration.

For all time averaging times greater than 24 hours, no modelled concentrations may be eliminated.

In the version of AERMOD that was current at the time this document was prepared (ver. 11353), choosing the ANNUAL time averaging option actually outputs the average over the length of the meteorological data used (typically five years). Ideally, the model should be run five times (once for each year of meteorological data) and the highest annual average chosen for comparison to the annual standard. However, the ministry will accept the model five-year average for determining compliance as exceedance of an annual standard is nearly always accompanied by exceedance of shorter time averaging standards.

11.0 MODELLING SPECIAL TOPICS

11.1 Approach to Modelling Flares

This section borrows from the Alberta Environment and Water's "*Emergency / Process Upset Flaring Management: Modelling Guidance*" (Alberta Environment, 2003). The purpose of this section is to outline a methodology for dispersion modelling that should be used to determine appropriate flaring air dispersion modelling for the Province of Saskatchewan. Flaring may be necessary for venting excess gases during oil and gas exploration and in the event of upset conditions in facilities, when large volumes of gas cannot be piped or stored. Modelling flare stacks is difficult since parameters, such as duration, gas composition and flow rates, will vary depending on the nature of the emergency or upset flaring event.

The shortest averaging time that most models predict for is one-hour, while emergencies or flaring events could be much shorter in duration. , These emergency or upset flaring events are typically intermittent (Alberta Environment, 2003).

11.1.1 Source Parameters

As mentioned previously, SCREEN3 and AERSCREEN contain a FLARE source type, which calculates stack pseudo-parameters from user inputs. However, SCREEN3 utilizes a conservatively high value of 55% for radiative heat loss when calculating ground level concentrations. Alberta Environment and Water recommends that a radiative heat loss of 25% be used in the calculation of the flare stack pseudo-parameters (Alberta Environment, 2003), which, is also recommended for use in Saskatchewan. This can be incorporated into assessments of flares using SCREEN3 by selecting the point source option and manually specifying the stack pseudo-parameters by following the calculation methodology described earlier. Conversely, AERSCREEN allows the user to enter the radiative heat loss fraction or select the SCREEN3 default value of 0.55.

The AERMOD model does not have the capability to model flares directly. Therefore, the pseudo stack parameters (e.g. height, diameter) must be calculated manually (i.e., external to the model) to compensate for the flame height, and initial dispersion from the flame. While these parameters can be calculated in a number of different ways, the ministry recommends consistency with the approach used in Alberta. Alberta Environment and Water prefers the use of the Alberta EUB method. The Alberta Energy Resources Conservation Board (ERCB) has also developed a spreadsheet which calculates the pseudo-parameters using their approach. This spreadsheet can be found at http://www.ercb.ca.

The **Flaring Input** parameter tab in the spreadsheet is used to specify the required inputs which are as follows:

1. Flare stack tip height;
2. Flare diameter;
3. Total volume of gas flared [10^3 m^3];
4. Maximum and average flow rate [10^3 m^3/d];
5. Number of days of flaring;
6. Lift gas added (if any);
7. Fuel gas to raw gas ratio;
8. Composition of raw and fuel gas; and,
9. % of H_2S.

The ERCB flaring spreadsheet provides the following outputs on the **Dispersion Modelling** tab:

1. Effective stack height;
2. Pseudo-stack diameter;
3. Pseudo-stack exit velocity; and,
4. Pseudo-stack exit temperature.

The pseudo parameters calculated by the ERCB spreadsheet account for stack tip downwash. Therefore, the modeller must disable this option when using either AERMOD or CALPUFF.

In addition, the flare design and performance should meet the requirements of the Saskatchewan Ministry of Energy and Resources when needed using:

- Saskatchewan Upstream Flaring and Incineration Specifications, S-20;
- Saskatchewan Upstream Petroleum Industry Associated Gas Conservation Standards, Directive S-10.

The documents S-10 and S-20 are available at http://www.er.gov.sk.ca/.

11.1.2 Adjustment of Predictions to Shorter-Averaging Times

If the flaring time is more than one-hour, the flare will be modelled as a continuous source and the model predictions are directly compared with the air quality standards. If the flare duration is less than one-hour, the predicted ground level concentrations must be first converted to one-hour equivalent and then compared with the standards.

There are numerous methods to convert a one-hour predicted concentration. A synopsis of the different methods is presented with an example assuming a ten-minute release. Sakiyama (1984) shows further examples than displayed in the Alberta Guidance.

1. Assume that the total release occurs over ten-minutes. The substance rate can be divided by 6, and modelled for the entire hour, and the resulting prediction can be directly compared with a one-hour standard.
2. Model the release as though the gas is released over the entire hour. Assume that the resulting concentration is what would actually occur over a ten-minute interval, for the rest of the hour, the observed concentration would be zero (Once the flare release stops). The resulting prediction from the model can be divided by 6 to obtain the actual 1-hour observed concentration.

*Concentration (1hr) = Concentration (Predicted) * duration (seconds) / 3600s*

Example:

Emission Rate of 50g/s, over 10 min (600 sec) at 100% Processing Capacity. Maximum Predicted Concentration of 5000 μg/m^3 from model output:

5000 μg/m^3 * 600 / 3600 = 833 μg/m^3 is the hourly predicted concentration.

11.2 Nitrogen Oxides to Nitrogen Dioxide Conversion

The most common source of atmospheric nitrogen oxides (NO_x) is the combustion of a fuel. The nitrogen in the air is oxidized when exposed to the high temperatures of combustion. Anthropogenic sources of nitrogen oxides emit predominantly in the form of nitric oxide (NO), with some nitrogen dioxide (NO_2). NO_2 can be seen as the brown haze above or plume downwind of cities and is the form of nitrogen oxides that has potential health effects. NO converts to NO_2 over time in a series of complex atmospheric reactions. The Saskatchewan Ambient Air Quality Standard is based on NO_2. The recommended methods for estimating the concentration of NO_2 in the plume described below are presented in the order of the most conservative first. If the modeller wants to use an alternate method that is not listed, such as Janssen Method, contact the ministry before doing so.

11.2.1 Total Conversion Method

This is the most conservative screening approach in which 100% of the nitrogen oxides are assumed to be instantly converted to NO_2. If this assumption shows that the maximum modelled concentration is below the applicable Saskatchewan Ambient Air Quality Standards, no further modelling is required.

The following methods allow for refinement if the total conversion method is too conservative.

11.2.2 Ambient Ratio Method (ARM)

The Ambient Ratio Method (ARM), another conservative methodology, involves the use of an empirical NO_2/NO_x ratio based on representative annual ambient ratio of NO_2/NO_x that is used to estimate NO_2 concentrations. A ratio different from the ministry default ratio of 0.7 may be used if the modeller can show that it is based upon sound local data.

11.2.3 Ozone Limiting Method (OLM)

The ozone limiting method (OLM) involves an initial comparison of the estimated maximum NO_x concentration and the ambient ozone concentration to determine which is the limiting factor to NO_2 formation. If the ozone concentration is greater than 90% of the NO_x concentration, total conversion to NO_2 is assumed. If the concentration of NO_x is greater than the ozone concentration, then the formation of NO_2 is limited by the ambient ozone concentrations.

The following equations are used in the OLM to calculate NO_2 levels based on modelled NO_x concentrations:

If $[O_3] > 0.9*[NO_x]$ then $[NO_2] = [NO_x]$
otherwise $[NO_2] = [O_3] + 0.1*[NO_x]$

Note that the above equation requires the concentrations used to be in ppm.

According to the above equations, if the ozone concentration is greater than 90% of the predicted NO_x concentrations, all the NO_x is assumed to be converted to NO_2. The OLM is based on the assumption that approximately 10% of the NO_x emissions are generated as NO_2. The majority of NO_x emissions are typically in the form of NO, which reacts with ambient levels of ozone to form additional NO_2.

AERMOD allows the ozone level to be entered as a fixed annual concentration or has a built-in series of time varying emission options that are similar to the options for variable emissions (season, month, day of week, etc.) Alternatively, AERMOD can also accept a file of hourly ozone data.

If no on-site ozone data is available, the ozone data presented in Table 11-1 should be used.

Table 11-1 – Ministry Recommended Ozone Levels

Averaging Time	Urban		Rural	
	(ppm)	(µg/m^3)	(ppm)	(µg/m^3)
1-hour average	0.050	98	0.055	108
24-hour average	0.035	69	0.040	79
Annual average	0.025	49	0.030	59

Note: Converted from ppm to µg/m^3 using standard conditions of 25ºC and 1 atm

The OLM is conservative as it does not address the fact that in the atmosphere the ambient ozone is entrained only at the edges of the plume, and is not immediately mixed to the centre of the plume as assumed by the model.

11.2.4 Plume Volume Molar Ratio Method (PVMRM)

The Plume Volume Molar Ratio Method (PVMRM) (MACTEC, 2004; U.S. EPA Addendum, AERMOD) option is incorporated into AERMOD. The PVMRM determines the conversion rate for NO_x to NO_2, based on a calculation of NO_x moles emitted into the plume and on the number of moles of ozone contained within the volume of the plume between the source and the receptor. This method is still conservative in the close field in that it mixes the ozone into the plume and increases conversion of NO to NO_2.

This method may be used with a fixed annual ozone concentration, variable ozone concentrations or an external hourly ozone data file. On-site ozone data is preferred. If no on-site ozone measurements are available, regional recommended ozone values should be used as shown in Table 11-1.

11.3 Odour Modelling

Odour emissions may be modelled using any of the approved air dispersion models. A model typically uses mass emission rates entered in grams per second (g/s). The resultant concentrations output by the model are in micrograms per cubic metre ($\mu g/m^3$), as the models inherently have a factor of 1,000,000 built in to the code (gram to microgram).

Odour concentrations are typically expressed in odour units per cubic metre (OU/m^3). To enter into the model, multiply the OU/m^3 in the exhaust by the volumetric flow in cubic metres per second (m^3/s) to obtain emission rates in OU/s.

For the screening models, multiply the calculated emission rate in OU/s by 1,000,000, so that the results are in OU/m^3 for comparison to criteria. AERMOD has an option to change the emission output factor to one, so that emissions do not need to be multiplied by 1,000,000.

As odours are detected by humans and are a nuisance odour modelling should be assessed at locations where human activities regularly occur, such as:

- residences;
- health care facilities;
- senior citizen's residences or long-term care facilities;
- child care facilities;
- camping grounds;
- schools;
- community centres;
- day care centres;
- recreational centres and sports facilities;
- outdoor public recreational areas; or,
- other locations as specified by the ministry.

The ministry has developed a set of DRAFT ambient odour criteria to be used for dispersion modelling assessment in Saskatchewan. These are presented in Table 11-2 below, and are based on a 1-hour averaging time, and vary depending on the land use surrounding the facility. In addition, compliance is based on achieving the criteria at a minimum of 99.5% of the time. These draft criteria are subject to change based on validation work that is currently being done.

Table 11-2 – Recommended Ambient Odour Criteria for Odour Dispersion Modeling in Saskatchewan

Odour criteria (emission measured by olfactometers)	Averaging Time	Annual Frequency	Land Use
1 OU/m^3	1 hour*	99.5%	Urban residential zones
2 OU/m^3			Urban commercial zones or mixed residential and commercial zones
4 OU/m^3			Industrial or restricted business zones and rural zones with mixed utilisation
6 OU/m^3			Industrial or agricultural zones with predominantly agricultural utilisation

*Not applicable for source emission measurement, for which point odour sample(s) or the geometric mean of multiple representative samples taken during the interested modeling time should be used to as the source odour concentration and the resultant source emission rate should be used in the dispersion modeling.

11.4 Fugitive Emissions

Fugitive emissions from paved and unpaved roads, parking lots, storage piles, etc. may or may not be significant contributors to particulate emissions from a facility. These types of emissions should be included in modelling assessments if the emissions are significant or if they contain metals or other hazardous constituents. Ambient concentration standards for metals are typical much lower than for particulate matter.

For sources that involve wind erosion, the use of wind speed dependent emission rate factors is highly recommended.

11.5 Acid Deposition

The modeling of acid deposition cannot be undertaken with a screening or refined model and requires the use of a specialized model such as CALPUFF. The simpler models cannot speciate the various forms of nitrogen and sulphur as they move through the atmosphere. Also acid deposition tends to be more regional modelling and the long-range transport capability of models like CALUFF is required. Details of such modelling are outside the scope of this document.

To ensure that a facility does not result in acid deposition issues, proponents are required to undertake regional acid deposition modelling if:

- the proponent's combined emissions of SO_2, NO_x, and NH_3 are greater than 0.175 t/d of H+ equivalent, where:

  total H+ equivalent (t/d) =2*(SO_2 t/d)/(64)+1*(NO_x t/d)/(46)+1*(NH_3 t/d)/(17)

- or the emissions from the facility are >5% of the baseline emissions in the region.

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13.0 GLOSSARY OF TERMS

AERMAP: The terrain preprocessor for AERMOD. AERMAP allows the use of digital terrain data in AERMOD.

AERMET: The meteorological preprocessor for AERMOD.

AERMIC: The joint work committee between the American Meteorological Society (AMS) and the U.S. Environmental Protection Agency (U.S. EPA), which developed the AERMOD model.

AERMOD: The Saskatchewan Ministry of Environment recommended air dispersion model.

AERSCREEN: A Screening model based on AERMOD.

Air Emissions: Releases from a source of contaminants into the air.

Albedo: Portion of the incoming solar radiation reflected and scattered back to space, which is an input data to AERMET.

Ambient Air: The portion of the atmosphere outside the pollution plume in the study.

AMS: American Meteorological Society.

Bowen Ratio: The ratio of sensible heat to latent heat transport from the ground to the atmosphere, which is generally calculated from the ratio of the vertical gradients of vapour pressure and temperature.

CALPUFF: An advanced, non-steady-state puff dispersion model for assessing long range transport of contaminants

CAL3QHCR: A refined version Carbon Monoxide (CO) model with queuing, hot spot calculations and a traffic model to calculate delays and queues that occur at signalized intersections.

Calm: In the Province of Saskatchewan (the province), CALM is defined as the weather condition where the wind speed is below 1 m/s.

Complex Terrain: Terrain exceeding the height of the stack being modelled.

DEM: Digital terrain files containing elevations across the province.

Dispersion Model: A group of related mathematical algorithms used to estimate (model) the dispersion of contaminants in the atmosphere due to advection by the mean (average) wind and mixing by atmospheric turbulence, including both mechanical and thermal.

Emission Factor: Estimation of the release rate of contaminants to the atmosphere by a source.

Flagpole Receptor: Receptor located above ground level.

Inversion:	An increase in ambient air temperature with height.
ISCST:	Industrial Source Complex – Short Term Dispersion Model. The old regulatory model, which preceded AERMOD.
Lee side:	Side of buildings or mountains, which are sheltered from the wind.
Mixing Height:	The height atmospheric contaminants are mixed by dispersive processes, measured from the ground.
Monin-Obukhov Length:	Turbulence length scale parameters where mechanical turbulence prevails over thermal turbulence. The Monin-Obukhov Length, has a negative sign under unstable conditions (upward sensible heat flux), positive for stable conditions.
Approved Model:	The regulatory air dispersion model recommended by the ministry.
Primary Contaminant:	Substance emitted from the source. This term is used to differentiate "Secondary Contaminants", which are formed subsequent from contaminant release from the sources by reactions of the primary contaminants.
Regulatory Model:	Either the approved air dispersion model or specialized model recommended by the ministry.
Screening Technique:	A relatively simple analysis technique to determine if a given source is likely to pose a threat to air quality. Concentration estimates from screening techniques are conservative.
Simple Elevated Terrain:	An area where terrain features are all lower in elevation than the top of the stack of the source.
Surface Roughness:	The height above ground level where the mean logarithmic profile of the wind speed theoretically reaches zero.
Upper Air Data (soundings):	Meteorological data obtained from balloon-borne instrumentation that provides information on pressure, temperature, humidity and wind away from the surface of the earth.
U.S. EPA:	United States Environmental Protection Agency.

APPENDIX A

Development of Saskatchewan Regional Meteorological Data Sets

APPENDIX A

A.0 Development of Saskatchewan Regional Meteorological Data Sets

A.1 Methodology

To prepare the surface (.sfc) and profile (.pfl) meteorological files, AERMET requires input of surface meteorological data, upper air data and surface characteristics based on land use.

As inputs, AERMET requires:

- Surface wind speed and direction;
- Surface temperature and relative humidity;
- Cloud cover and ceiling height;
- Upper air data consisting of wind speed and direction and the height at which each measurement was taken; and,
- Surface characteristics of albedo, Bowen ratio and surface roughness.

AERMET process these inputs through three steps:

- STAGE 1 - the surface and upper air data are put through QA/QC checks and reformatted into the format required for input into STAGE 2;
- STAGE 2 - the surface and upper air data are merged together into a “merged file” that is required for input into STAGE 3; and,
- STAGE 3 - surface characteristic parameters are used to produce the final surface (.sfc) and profile (.pfl) files.

As outputs AERMET produces:

- Sensible heat flux;
- Surface friction velocity;
- Convective velocity scale;
- Vertical potential temperature gradient in the 500 millibar layer;
- Convective mixing height;
- Mechanical mixing height; and,
- Monin-Obukhov length.

To prepare AERMOD ready meteorological files using AERMET it is necessary to have both surface and upper air meteorological station data. Table A-1 presents the surface and upper air meteorological stations used for the five zones.

Table A-1 – Surface and Upper Air Meteorological Stations for Five Zones

Region	Surface Station	Alternate Surface Station	Upper Air Station
Northern	Key Lake Airport	Stony Rapids Airport	The Pas, Manitoba
North Central	Nipawin Airport	Prince Albert Airport	The Pas, Manitoba
Central	Saskatoon Airport	Kindersley Airport	Glasgow, Montana, USA
Southwestern	Swift Current Airport	Moose Jaw/Regina	Glasgow, Montana, USA
Southeastern	Estevan Airport	Regina Airport	Glasgow, Montana, USA

The five Air Dispersion Modelling Zones and the surface and upper air meteorological stations are shown in Figure A-1. Note that all of the meteorological stations used were located at airports.

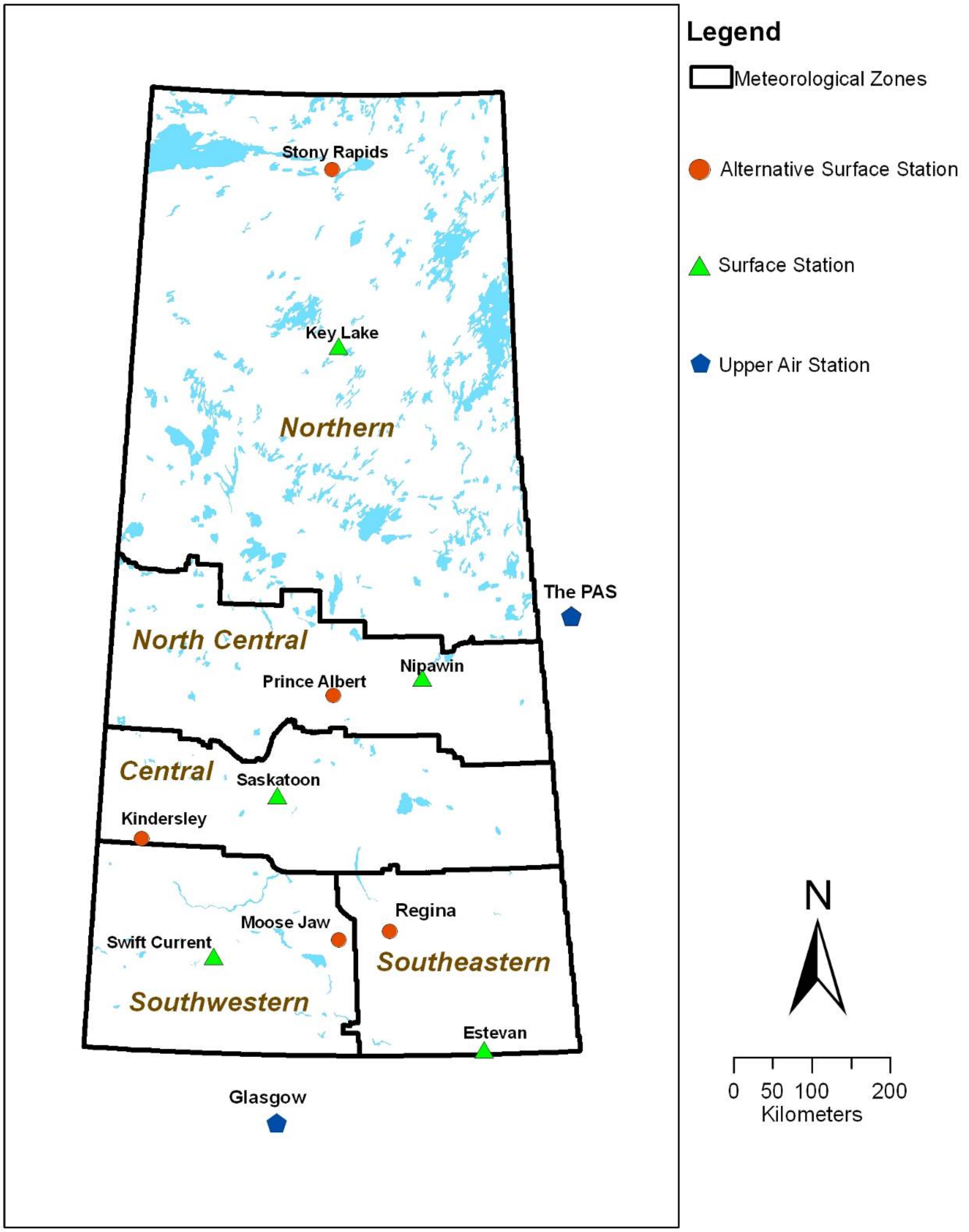

Figure A-1 – Five Air Dispersion Modelling Zones

A.2 Meteorological Inputs

A.2.1 Surface Meteorology

All data for the surface meteorological data stations for the five year period year, 2003-2007, were obtained directly from Environment Canada. These data were reformatted into the CD-144 format that is accepted by AERMET. Missing data were identified by a string of asterisks.

The parameters that are collected at a surface meteorological station are:

- Wind speed;
- Wind direction;
- Temperature;
- Relative humidity;
- Cloud cover; and,
- Ceiling height.

Table A-2 presents the surface stations used for each of the five Air Dispersion Modelling Zones. In any data set there are missing elements within any given hour or some hours may have no data available. Following U.S. EPA protocol, if six consecutive hours or less of any given element were missing, the missing data were infilled using linear interpolation. If more than six consecutive hours of data are missing, data is infilled from the nearest representative surface station. Table A-3 shows the name of the alternate station for each of the surface stations used. The alternate stations used for the replacement of blocks of missing data were stations that had a similar climate. In the case of the Southwestern Air Dispersion Modelling Zone, the closest representative station for the Swift Current Airport is the Moose Jaw Airport. However, since data are collected only during daylight hours at the Moose Jaw Airport, the Regina Airport data is required to infill missing night time data.

Table A-2 – Surface and Alternate Meteorological Stations for Five Zones

Region	Surface Station	Alternate Station	Distance Between Stations (km)
Northern	Key Lake Airport	Stony Rapids Airport	151
North Central	Nipawin Airport	Prince Albert Airport	114
Central	Saskatoon Airport	Kindersley Airport	187
Southwestern	Swift Current Airport	Moose Jaw/Regina	156/220
Southeastern	Estevan Airport	Regina Airport	222

Figure A-1 shows graphically the location of the surface stations used for each of the five Air Dispersion Modelling Zones. The alternate surface stations and upper air stations used are also shown.

A.2.2 Upper Air Meteorology

Upper air soundings are taken globally twice a day at 00:00 GMT and 12:00 GMT. Soundings are typically taken with an instrumented balloon. As the balloon rises, the parameters of wind speed, wind direction and temperature are collected at standard heights (pressures). Each sounding will consist of the recording of the collected elements at a series of pressures.

The data for the Canadian upper air stations was downloaded from Environment Canada. Data was downloaded from the National Climatic Data Center for the upper air stations located in the United States.

A.2.3 Missing Upper Air Data

If an upper air sounding is not available, the convective mixing heights and convective parameters, if required, cannot be calculated during the processing with AERMET. AERMOD will run, but those hours will be reported as missing. Depending on the location and the time of year, a single day may have up to 12 hours of convective conditions. This emphasizes the importance of infilling missing upper air data.

To fill in missing upper air data the following protocol was applied. If a single sounding was missing, the following sounding was copied as a replacement. If more than one sounding was missing, replacement soundings are taken from the alternate upper air station. The alternate upper air data stations are shown in Table A-3. Replacement upper air stations were chosen as the nearest upper air station on approximately the same latitude.

Table A-3 – Upper Air and Alternate Meteorological Stations for Five Zones

Upper Air Station	Alternate Station	Distance Between Stations (km)
Glasgow, MT	Great Falls, MT	373
The Pas, MN	Edmonton, AB	856

A.3 Surface Characteristics

As part of the development of fully processed AERMOD ready Regional Meteorological Data Sets, it was necessary to develop suitable surface characteristics of albedo, surface roughness and Bowen ratio for the five air dispersion modelling zones.

Figure A-2 shows the Global Land Use Data that was used for determining the areas of different type of land use data in the five Air Dispersion Modelling Zones. It can be clearly seen that the Central, Southwestern and Southeastern Air Dispersion Modelling Zones are predominantly agricultural in nature. The Northern Zone is predominantly forest and water but as one heads north the height and density of the trees diminishes. The North Central Zone is a mix of agricultural and forest. All of the zones have some urbanized areas except the Northern Zone which has essentially no urbanized areas.

As a result, for each Air Dispersion Modelling Zone, two fully processed screening meteorological data sets were prepared that represent the predominant land uses in that zone. However, due to the transitional nature of the North Central, it was necessary to prepare three Surface Classes to cover the majority of the land uses in that zone. The Surfaces Classes[28] chosen for each of the Air Dispersion Modelling Zones are shown in Table A-4.

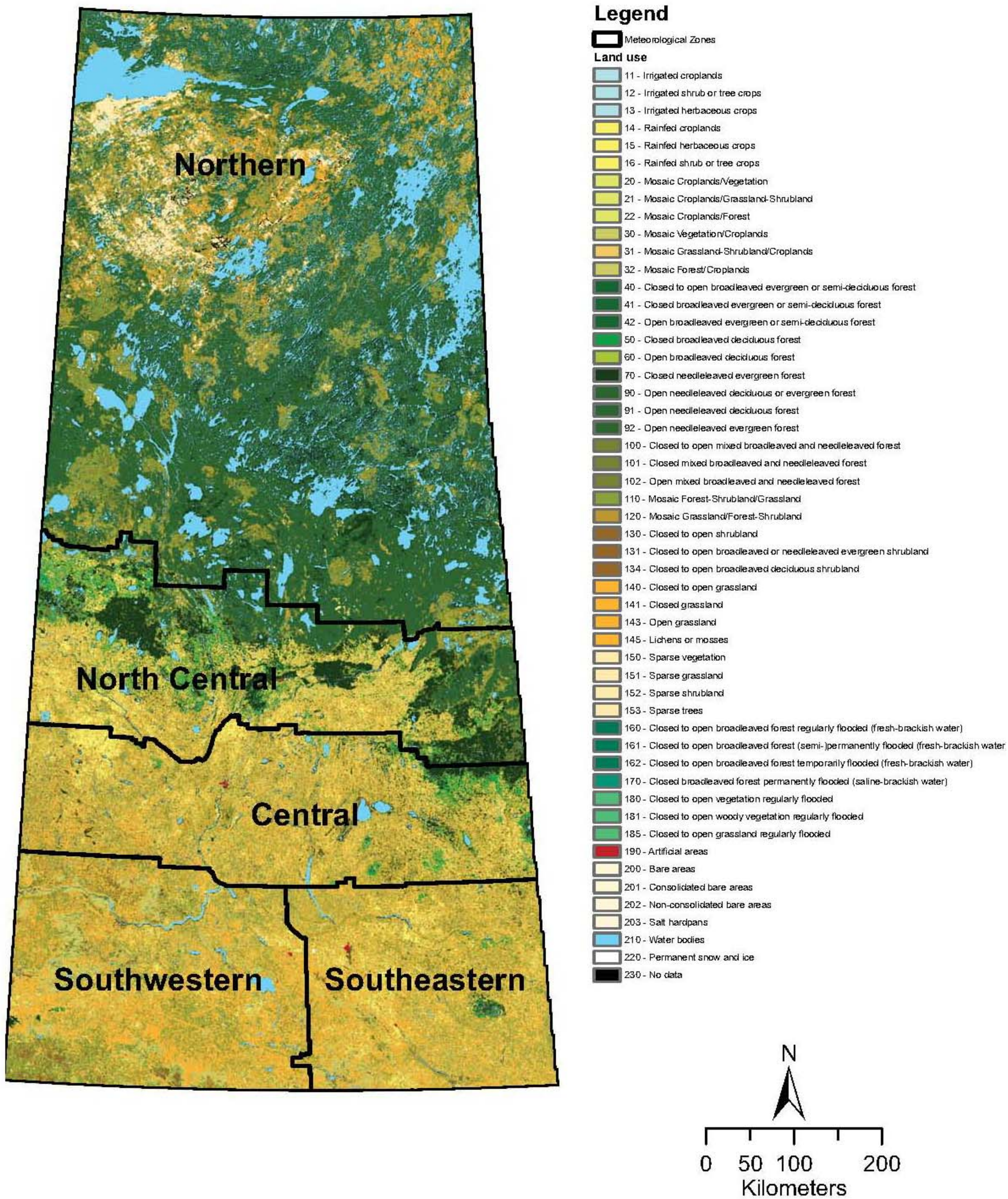

Figure A-2 – GLOBCOVER Land Cover for Saskatchewan

Table A-4 – Air Dispersion Modelling Zone Surface Classes

Air Dispersion Modelling Zone	Surface Class 1	Surface Class 2	Surface Class 3
Northern	Forest 1	Forest 2	-
North Central	Urban	Agricultural	Forest
Central	Urban	Agricultural	-
Southwestern	Urban	Agricultural	-
Southeastern	Urban	Agricultural	-

A.3.1 Selection of Representative Parameters for Fully Processed Files

For each of the Surface Class[28] and Air Dispersion Modelling Zone combinations shown in Table A-4 representative surface characteristic parameters of albedo, Bowen ratio and surface roughness were developed.

Northern Zone

The predominant land uses in the Northern Air Dispersion Modelling Zone are several types of forest, water and shrubland. There are essentially no urbanized areas in this zone. This zone was divided roughly in half into two sub areas (north and south) as shown in Figure A-3. The dividing line of 57.25º N latitude is also shown on the figure.

The Northern Air Dispersion Modelling Zone consists of mixed forest, deciduous forest, coniferous forest, shrubland and water. The Northern Zone was further divided into two sub zones. The surface areas represented by these land use types were determined using GIS techniques. Table A-5 shows the percentage of the various land use types for the two sub zones. That there are differences in the percentages of the various land use categories within the North Forest and South Forest Surface Classes. For the winter season, the water category is represented by Perennial Ice/Snow – 12, since essentially all bodies of water are frozen in the winter in the Northern Air Dispersion Modelling Zone.

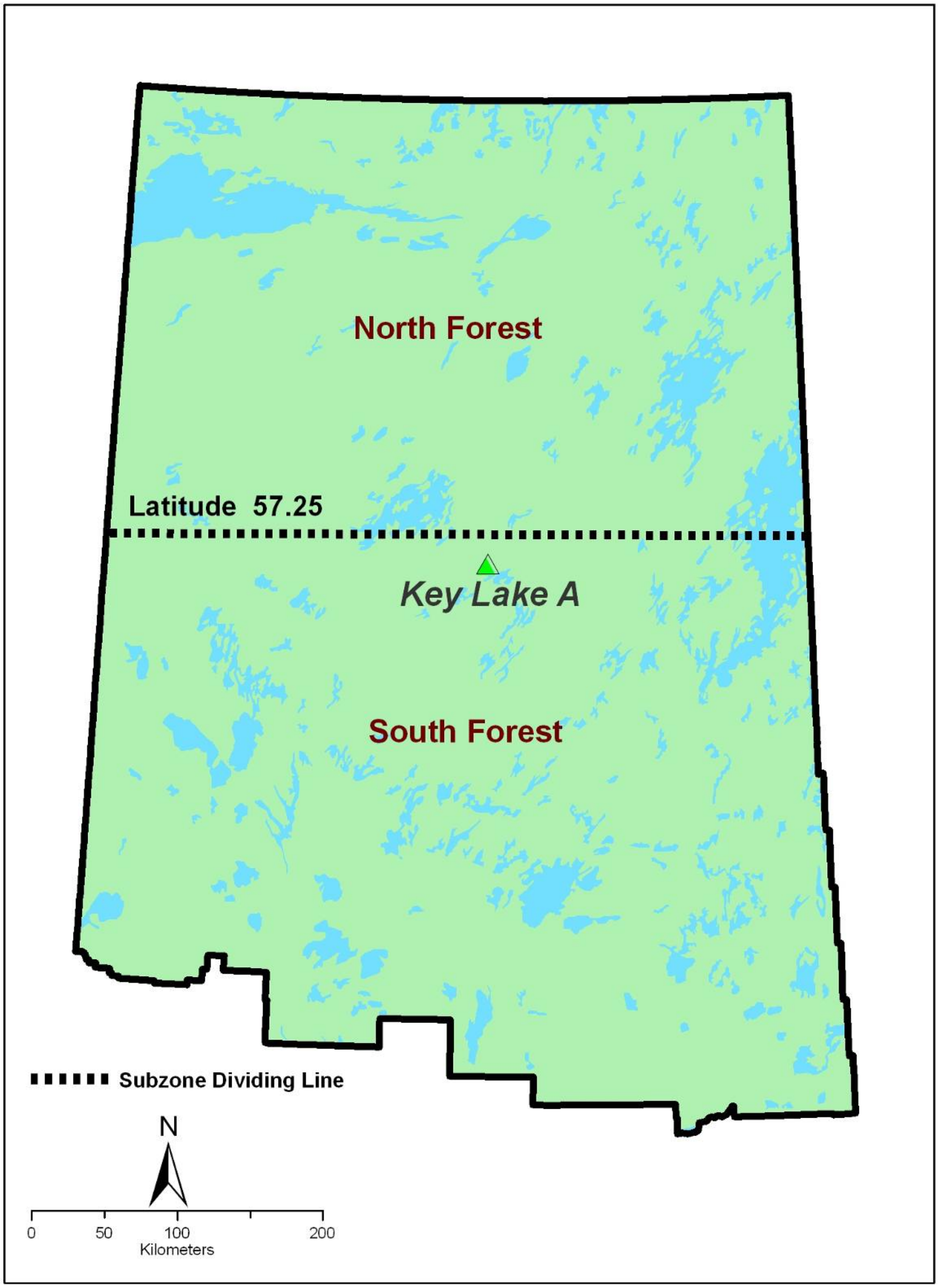

Figure A-3 – Division of Northern Air Dispersion Modelling Zone

Table A-5 – Northern Air Dispersion Modelling Zone Land Use Types

Air Dispersion Modelling Zone	Surface Classes	AERSURFACE Land Use Categories	Percentage of Area (%)
Northern	North Forest – N1	Water – 11 Perennial Ice/Snow-12	23.35
		Deciduous Forest - 41	0.01
		Evergreen Forest – 42	4.12
		Mixed Forest – 43	43.84
		Shrubland -51	28.68
	South Forest – N2	Water – 11 Perennial Ice/Snow-12	15.93
		Deciduous Forest - 41	0.37
		Evergreen Forest – 42	11.72
		Mixed Forest – 43	60.56
		Shrubland -51	11.42

The surface characteristic parameters were developed for the two Surface Classes in the Northern Air Dispersion Modelling Zone by prorating the surface characteristic parameters from the reference tables in the AERSURFACE manual by the percentages in Table A-5. For example, in the North Forest Surface Class, the albedo was calculated using 23.35% of the albedo from water, 0.01% of the albedo from deciduous forest, 4.12% of the albedo from evergreen forest, 43.84% of the albedo from mixed forest and 28.68% of the albedo from shrubland. The calculated values for the Forest North Surface Class are shown in Table A-5.

North Central Zone

The North Central Zone also has a Forest Surface Class and the values for the surface characteristic parameters were determined in the same manner as for the Northern Zone. As shown in Table A-6, the North Central Air Dispersion Modelling Zone has higher percentages of coniferous and deciduous forests compared to the North Forest and South Forest Surface Classes as shown in Table A-5 and Table A-6. For the winter season, the water category was represented by Perennial Ice/Snow – 12, since essentially all bodies of water are frozen in the winter in the North Central Air Dispersion Modelling Zone.

Table A-6 – North Central Air Dispersion Modelling Zone Land Use Types

Air Dispersion Modelling Zone	Surface Classes	AERSURFACE Land Use Categories	Percentage of Area (%)
North Central	Forest	Water – 11 Perennial Ice/Snow-12	6.4
		Deciduous Forest - 41	9.9
		Evergreen Forest – 42	28.7
		Mixed Forest – 43	32.9
		Shrubland -51	22.1
	Agricultural[1]	Pasture/Hay – 81	25
		Row Crops – 82	25
		Small Grains – 83	25
		Fallow - 84	25
	Urban	Low Intensity Residential -21	100

Note: [1] Assumed even split between agricultural type land use

Central, Southwestern and Southeastern Zones

All three of these Air Dispersion Modelling Zones have Urban and Agricultural Surface Classes. The surface characteristic parameters for the Urban Surface Class were generated using the AERSURFACE category for low intensity residential. The Agricultural Surface Class parameters were developed assuming an equal mix (25%) (Table A-7) of the following types of agricultural-related land use categories:

- pasture/hay – 81;
- row crops – 82;
- small grains – 83; and,
- fallow – 84.

Table A-7 – Central, Southwestern and Southeastern Air Dispersion Modelling Zones Land Use Types

Air Dispersion Modelling Zone	Surface Classes	AERSURFACE Land Use Categories	Percentage of Area (%)
Central Southwestern Southeastern	Agricultural[1]	Pasture/Hay – 81	25
		Row Crops – 82	25
		Small Grains – 83	25
		Fallow - 84	25
	Urban	Low Intensity Residential -21	100

Note: [1] Assumed even split between agricultural type land use

A.3.2 Saskatchewan Air Dispersion Modelling Zones Surface Characteristics

The calculated values of albedo, Bowen ratio and surface roughness for the Urban and Agricultural Surface Classes for all Air Dispersion Modelling Zones of Saskatchewan are presented in Table A-8, Table A-9 and Table A-10. These were input into AERMET for the generation of each of the fully processed meteorological files.

Table A-8 – Northern Air Dispersion Modelling Zone Surface Characteristic Parameters

Surface Class	Season	Albedo	Bowen ratio	Surface Roughness
North Forest	Winter	0.505	0.500	0.492
	Spring	0.141	0.646	0.644
	Summer	0.141	0.454	0.710
	Fall	0.141	0.881	0.710
South Forest	Winter	0.466	0.500	0.717
	Spring	0.136	0.639	0.887
	Summer	0.136	0.348	0.979
	Fall	0.136	0.830	0.979

Note: Winter - December, January, February
Spring – March, April, May
Summer – June, July, August
Fall – September, October, November

Table A-9 – North Central Air Dispersion Modelling Zone Surface Characteristic Parameters

Surface Class	Season	Albedo	Bowen ratio	Surface Roughness
Forest	Winter	0.405	0.474	0.752
	Spring	0.142	0.728	0.917
	Summer	0.142	0.441	0.996
	Fall	0.142	0.962	0.996
Urban	Winter	0.450	0.500	0.500
	Spring	0.160	0.800	0.520
	Summer	0.160	0.800	0.540
	Fall	0.160	1.000	0.540
Agricultural	Winter	0.600	0.500	0.010
	Spring	0.150	0.300	0.028
	Summer	0.195	0.500	0.138
	Fall	0.195	0.700	0.138

Note: Winter - December, January, February
Spring – March, April, May
Summer – June, July, August
Fall – September, October, November

Table A-10 – Central, Southwestern and Southeastern Air Dispersion Modelling Zones Surface Characteristic Parameters

Surface Class	Season	Albedo	Bowen ratio	Surface Roughness
Urban	Winter	0.450	0.500	0.500
	Spring	0.160	0.800	0.520
	Summer	0.160	0.800	0.540
	Fall	0.160	1.000	0.540
Agricultural	Winter	0.600	0.500	0.010
	Spring	0.150	0.300	0.028
	Summer	0.195	0.500	0.138
	Fall	0.195	0.700	0.138

Note: Winter - December, January, February
Spring – March, April, May
Summer – June, July, August
Fall – September, October, November

A.4 Wet Deposition Parameters

To calculate wet deposition, it is necessary to incorporate hourly precipitation type and quantities in the AERMOD-ready .sfc file. AERMOD only distinguishes between rain and snow as precipitation types to determine appropriate deposition algorithms. Precipitation quantities must be reported in mm/hr.

Surface meteorological stations at airports collect present weather data (columns 24-31 in CD-144 format). The weather is categorized into several forms of liquid precipitation including rain, rain showers and drizzle, and several forms of solid precipitation including snow, snow pellets, ice crystals, snow showers and ice pellets. No quantities of precipitation are generally available in this format.

Although Saskatchewan is in the process of phasing out any existing standards for particulate deposition, it is sometimes useful to assess wet deposition in support of specialized studies. As a result, the necessary parameters are added to the fully processed Regional meteorological data files. This was not incorporated into the Stage 3 AERMET-ready files. The procedure used to incorporate these parameters into the fully processed files is described in the following paragraphs.

Daily precipitation quantity data is available from airport meteorological stations. Since no more detailed information is available, this daily precipitation quantity is evenly split over all hours for which present weather indicated some form of precipitation using a custom *Fortran* program. This updated CD-144 format surface station file was processed as normal with AERMET.

The stations at Estevan, Saskatoon and Swift Current have a good record of the present weather data for the 2003 to 2007 period. However, the stations at Key Lake and Nipawin have periods where data is missing. This missing data is supplemented with the Stony Rapids and Prince Albert for missing hourly present weather data.

In the processed surface file, the column for precipitation can contain the codes 0, 11, 22. AERMOD distinguishes only between liquid and frozen precipitation; 11 is rain – liquid precipitation, 22 is snow, sleet, ice pellets, etc. – frozen precipitation. 0 means no precipitation.

In some instances it was found the surface file contained cases where the present weather indicated there was precipitation and has a code 11 or 22 but 0 in the precipitation appeared in the amount column. This is acceptable as it means that the amount of precipitation was immeasurable. It was also noted that there were a few hours per year that had a non-zero amount of precipitation, but a code of 0 in precipitation type column. This is caused by AERMET as it only recognized the present weather for rain and snow and not for the other types of precipitation (drizzle, ice pellets, etc.). Using another custom *Fortran* program the processed surface file was searched for these errors and a code of 11 (rain) or 22 (snow) was inserted based on ambient temperature for that hour.

APPENDIX B

Saskatchewan Background Concentrations

APPENDIX B

B.0 Saskatchewan Background Concentrations

Figure B-1 illustrates the location of the ambient air quality monitoring stations within the five air dispersion modelling zones of Saskatchewan.

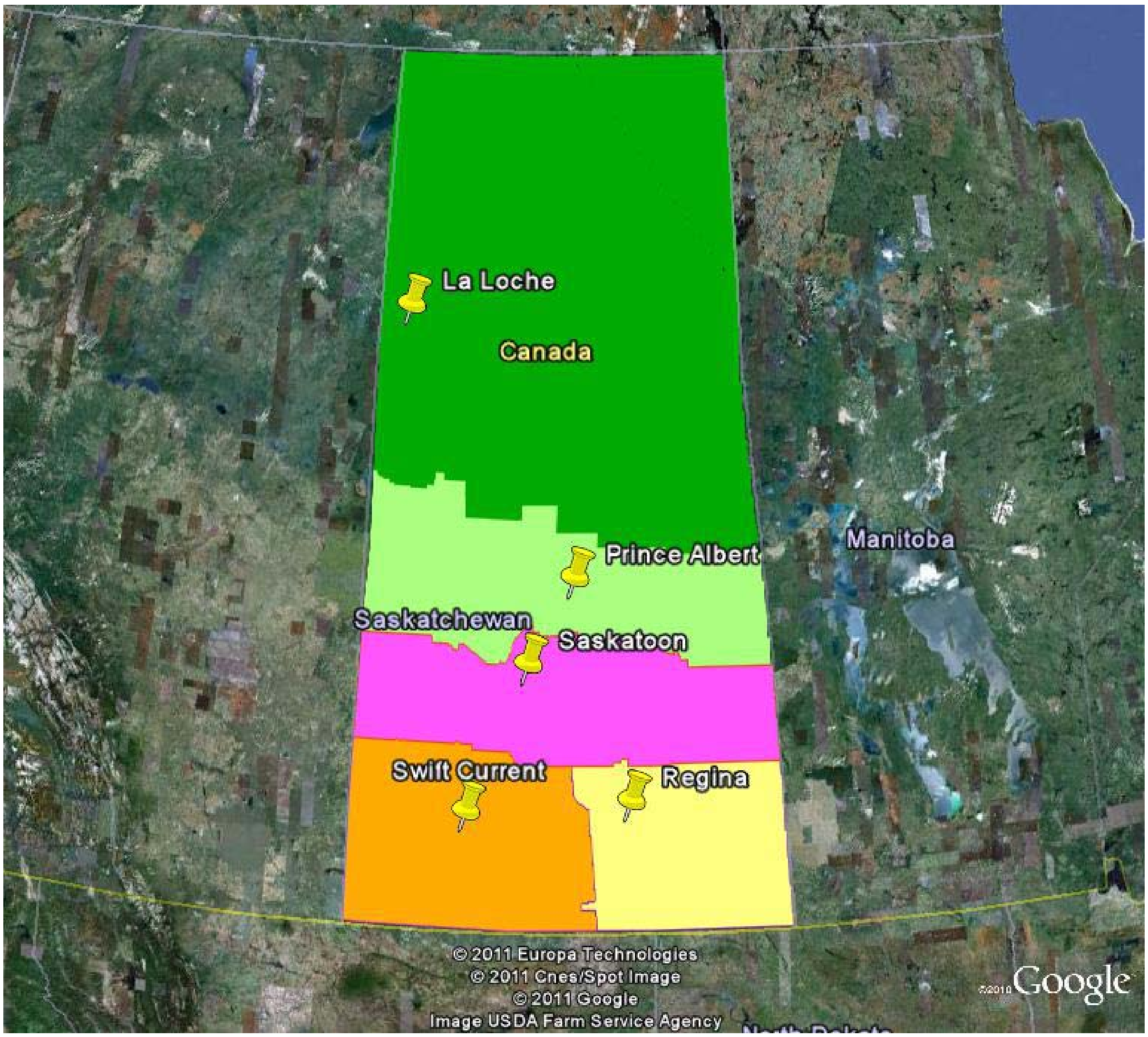

Figure B-1 – Location of Air Monitoring Stations in Saskatchewan

Table B-1 is a summary of the contaminant background air concentrations that are to be used in air dispersion modelling in Saskatchewan. These concentrations are to be added to the ninth highest hourly modelled concentrations, or the second highest day for determination of one-hour and 24-hour compliance respectively.

Table B-1 – Regional Background Air Contaminant Concentrations

Pollutant	Averaging Period	Percentile	Background Concentrations For Air Dispersion Modelling				
			Northern	North Central	Central	Southwestern	Southeastern
Carbon Monoxide (ppm)	1 Hour	90th	0.5		0.5		0.6
		99th	0.8		0.9		1.1
	8 Hour	90th	0.5		0.4		0.6
		99th	0.9		1.0		1.1
Nitrogen Dioxide (ppm)	1 Hour	90th	0.006	0.017	0.021	0.019	0.022
		99th	0.015	0.031	0.037	0.037	0.043
	24 Hour	90th	0.005	0.015	0.017	0.016	0.02
		99th	0.009	0.024	0.026	0.026	0.032
	Annual	50th	0.002	0.003	0.008	0.005	0.01
Sulphur Dioxide (ppm)	1 Hour	90th	0	0.001	0.001	0.001	0.001
		99th	0.002	0.002	0.002	0.002	0.003
	24 Hour	90th	0	0.001	0.001	0.001	0.001
		99th	0.001	0.001	0.002	0.002	0.002
	Annual	50th	0.000	0.000	0.000	0.000	0.000
Fine Particulate Matter ($PM_{2.5}$) (µg/m^3)	24 Hour	90th	6.5	6.6	7.5	6.6	8.3
		99th	13.9	14.3	13.9	8.4	14.7
	Annual	50th	3.1	3.0	3.3	3.3	3.7
Particulate Matter (PM_{10}) (µg/m^3)	24 hours	90th	23.1				36.3
		99th	49.1				63.3

APPENDIX C

Modelling Report Checklist

APPENDIX C

C.0 Modelling Report Checklist

A report describing the air quality analysis performed must be submitted. The purpose of the report is to provide the public and the ministry with ample information to demonstrate that the new or modified source will not adversely affect ambient air quality. The content of the report must be adequate for the reviewer to establish that the analysis was accomplished in a manner consistent and defensible with respect to available modelling guidance.

At a minimum, applicants should refer to the following checklist to ensure the air quality analysis report is complete.

Table C-1– Modelling Report Check List

I	BACKGROUND AND SOURCE INFORMATION
I.A	**Project background requirements:** • General description of the plant processes • Proposed new sources or modification including number and type of sources.
I.B	**Project location requirements**
I.B.i	**Plot plan that includes the following:** • UTMs on horizontal and vertical axis • Property lines, including fence lines • Roads and railroads that pass through property line • Location of all emission sources • Buildings and structures (on or off property) which could cause downwash ✓ Location ✓ Length ✓ Width ✓ Height ✓ Building tiers and tier heights
I.B.ii	**Area map(s) that include the following:** • Map of adjacent area (10 km radius from plant) ✓ UTMs on horizontal and vertical axis ✓ Nearby competing sources ✓ Schools, hospitals, daycares, protected species habitats, lakes and other sensitive receptors within 3 km of facility boundary ✓ Topographic features ✓ Any proposed off-site or on-site meteorological or ambient monitoring stations ✓ Roads and railroads • Regional Map that includes the following (50 km radius from plant) ✓ UTMs on horizontal and vertical axis ✓ Modelled facility ✓ Topography features ✓ Any proposed off-site meteorological or ambient monitoring stations

I.C	Emissions of Proposed New/Modified Source Requirements
I.C.i	**Discussion of potential operating scenarios for emission units** • Maximum emissions scenario • Refined emissions scenario • Startups and shutdowns • Fuel types
I.C.ii	**Emission source characteristics** • Include fugitive & secondary emissions when applicable • Emission source descriptions and capacities (including proposed emission controls) • New structures or modifications to existing structures
I.C.iii	**Parameter tables** Include parameter table(s) for each operating scenario of each emission unit, which may include, but not be limited to the following: • Operating scenario(s) considered • Location (UTM Coordinates) • Point source parameters ✓ Exit temperature ✓ Exit velocity ✓ Stack exit inside diameter ✓ Stack orientation (vertical/horizontal) ✓ Exit height above ground ✓ Emission rate ✓ Emission estimation source/method • Area source parameters • Volume source parameters • Line Sources • Flare Sources
I.C.iv	**Emission calculations** • Describe how emissions were calculated • Include sample supporting calculations
II	**AMBIENT IMPACT ANALYSIS**
II.A	**Standards and criteria** • Saskatchewan Ambient Air Quality Standards • CCME Canada-wide Standards (CWS) and/or Canadian Ambient Air Quality Standards (CAAQS) • Other jurisdictions criteria used as indicator of potential impact
II.B	**Modelling procedure reporting requirements**
II.B.i	**List and discuss the model(s) chosen:** • Dispersion model (including version) used • Supporting models and input programs

II.B.ii	**Meteorological data used** • Identify which ministry prepared Regional Meteorological Data set used and rationale • If using ministry prepared Stage 3 files discuss land use characterization procedures utilized to determine Bowen ratio, albedo, surface roughness • If using other sources of meteorological data, include plan supplied to the ministry and how their comments were incorporated

II.B.iii	**Specify setting utilized within the model(s), which may include:**
	• Default regulatory setting utilized within model
	• Terrain settings and source of terrain data
	  ✓ Simple flat
	  ✓ Simple elevated
	• Conversion factor utilized for converting NO_X to NO_2
	• Include discussion on non-default settings utilized and reasons why

II.C	**Ambient condition requirements, including competing sources** • Discuss the ambient background concentration (which ministry data was used and rationale) • Origin of data if the data provided by the ministry was not used
III	**AMBIENT IMPACT RESULTS DOCUMENTATION**
III.A	**At a minimum, the model results are to be documented as follows:**
III.A.i	**Table(s) of results including:** • Contaminant(s) • Averaging time(s) • Operating scenario • Receptor location of maximum impact (UTM Easting & Northing) • Receptor elevation • Maximum impact from new/modified source • Background concentration • Maximum modelled cumulative concentration (predicted + background) • Applicable ambient air quality standards • Number and frequency of concentrations exceeding the standards • Name of output e-file(s) where data was taken from

III.A.ii	**Figure(s) showing ambient impacts**
	• For each operating scenario and averaging time
	• UTMs on horizontal and vertical axis
	• Modelled facility
	  ✓ Boundary
	  ✓ Buildings (including competing source structures)
	  ✓ Emission points
	• Topography features
	• Isopleths of impact concentrations
	• Location and value of maximum cumulative impact

IV	**AMBIENT IMPACT SUPPORTING DOCUMENTATION**

IV.A	**Electronic Files**
	• list and description of electronic files
	• Required e-files to be submitted with report
	    o Input & output files for models,
	    o Input & output files for pre-processors (if applicable)
	    o Input & output files for post-processors (if applicable)
	    o Digital terrain files
	    o Plot files
	    o Final report

IV.B	**Report shall include a discussion on deviations from the modelling checklist**