# PROPOSED GUIDANCE FOR AIR DISPERSION MODELLING

**Proposal:** **PROVISION OF SERVICES TO DEVELOP GUIDANCE FOR AIR DISPERSION MODELLING**

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**Submitted to:** Ontario Ministry of the Environment

## Disclaimer

*The principles expressed in this document should not be considered to be the official position of the Government of Ontario or of provincial departments and agencies. They are for discussion purposes only.*

*This document is meant as a technical reference for those conducting air dispersion modelling assessments using the United States Environmental Protection Agency (US EPA) models in Ontario. There are a number of reasons for the use of these more refined models, including:*

- *pollution control and equipment design purposes;*
- *assessment of environmental impacts due to pollution incident reports;*
- *to be proactive in the assessment of emissions using more refined air dispersion models.*

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# Proposed Guidance for Air Dispersion Modelling

## 1. INTRODUCTION

The proposed *Guidance for Air Dispersion Modelling* is designed to provide guidance on methods for air dispersion modelling in the Province of Ontario for models that are not currently referenced in Ontario Regulation 346. The use of additional air dispersion models,[1,2] namely United States Environmental Protection Agency (U.S. EPA) SCREEN3 for screening analyses and the U.S. EPA AERMOD and ISC-PRIME for refined analyses, enable more representative assessments that make use of current science. This proposed document will provide insight into recommended modelling approaches and provide consistency in the modelling methods.

The proposed *Guidance for Air Dispersion Modelling (GADM)* is not designed to provide theoretical background on the models it discusses. Technical documents covering these topics can be easily obtained from several U.S. EPA sources and are further outlined in the References section. This document will provide details on performing a successful modelling study including:

- Model Background and Applicability
- Model Selection and Study Approach
- Tiered Approach to Assessing Compliance
- Model Input Data Requirements
- Geographical Information
- Meteorological Data Requirements and Acquisition
- Information for Inclusion in an Assessment

## 2. APPLICATION OF MODELS

### 2.1 Modelling Overview

Air dispersion modelling is the mathematical estimation of pollutant impacts from emissions sources within a study area. Several factors impact the fate and transport of pollutants in the atmosphere including meteorological conditions, site configuration, emission release characteristics, and surrounding terrain, among others.

## 2.2 Preferred Models

Preferred models indicate standard models that are expected to be used for air quality studies. Alternative models may be used if conditions warrant their use. These are outlined in Section 2.5.

The U.S. EPA preferred models include SCREEN3 for screening analyses and AERMOD or ISC-PRIME for refined modelling analyses. A brief overview of each of these models can be found below. For appropriate model selection, please review the section that outlines:

- AERMOD (which includes PRIME algorithms for downwash)
- ISC-PRIME
- SCREEN3

### 2.2.1 AERMOD

The AERMIC (American Meteorological Society/EPA Regulatory Model Improvement Committee) Regulatory Model, AERMOD,(3,4,5) was specially designed to support the U.S. EPA's regulatory modelling programs. AERMOD is the next-generation 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 preferred model for most small scale regulatory applications.(6,7) 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 Plume Rise Model Enhancements (PRIME) model was designed to incorporate two fundamental features associated with building downwash:

1. Enhanced plume dispersion coefficients due to the turbulent wake.

2. 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 ISCST3 model with a few exceptions, which are described below:

- Currently, the model only calculates concentration values. Dry and wet deposition algorithms were not implemented yet at the time this document was written.

- 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 preprocessor program(6).

- 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-preprocessing program(9) can be used to generate hill height scales as well as terrain elevations for all receptor locations.

The options AERMOD has in common with ISCST3 and ISC-PRIME are described in the next section.

### 2.2.2 ISC-PRIME Overview

The ISCST3 dispersion model is a steady-state Gaussian plume model, which can be used to assess pollutant concentrations, and/or deposition fluxes from a wide variety of sources associated with an industrial source complex. The ISCST3 dispersion model from the U.S. EPA was designed to support the EPA's regulatory modelling options, as specified in the *Guidelines on Air Quality Models (Revised)*(10).

The PRIME algorithms have been integrated into the ISCST3 (Version 96113) model. This integrated model is called ISC-PRIME(11). The ISC-PRIME model uses the standard ISCST3 input file with a few modifications in the Source Pathway section. These modifications include three new inputs, which are used to describe the building/stack configuration.

To be able to run the ISC-PRIME model, you must first perform building downwash analysis using BPIP-PRIME (Building Profile Input Program). For more information on building downwash please refer to Section 4.6 - Building Impacts.

Some of the ISCST3/ISC-PRIME modelling capabilities are:

- ISC-PRIME model may be used to model primary pollutants and continuous releases of toxic and hazardous pollutants.

- ISC-PRIME model can handle multiple sources, including point, volume, area, and open pit source types. Line sources may also be modelled as a string of volume sources or as elongated area sources.

- Source emission rates can be treated as constant or may be varied by month, season, hour-of-day, or other optional periods of variation.

These variable emission rate factors may be specified for a single source or for a group of sources.

- The model can account for the effects of aerodynamic downwash due to nearby buildings on point source emissions.

- The model contains algorithms for modelling the effects of settling and removal (through dry deposition) of large particulates and for modelling the effects of precipitation scavenging for gases or particulates.

- Receptor locations can be specified as gridded and/or discrete receptors in a Cartesian or polar coordinate system.

- ISC-PRIME incorporates the COMPLEX1 screening model dispersion algorithms for receptors in complex terrain.

- ISC-PRIME model uses real hourly meteorological data to account for the atmospheric conditions that affect the distribution of air pollution impacts on the modelling area.

- Results can be output for concentration, total deposition flux, dry deposition flux, and/or wet deposition flux. Until AERMOD has incorporated deposition, ISC-PRIME would be the preferred model for applications such as risk assessment where deposition estimates are required.

Unlike AERMOD, the ISC models do not contain a terrain pre-processor. As a result, receptor elevation data must be obtained through alternative means. The use of an inverse distance algorithm for interpolating representative receptor elevations is an effective method.

### 2.2.3 SCREEN3 Overview

The SCREEN model was developed to provide an easy-to-use method of obtaining pollutant concentration estimates. These estimates are based on the document "Screening Procedures for Estimating The Air Quality Impact of Stationary Sources"(12).

SCREEN3, version 3.0 of the SCREEN model, can perform all the single source short-term calculations in the EPA screening procedures document, including:

- Estimating maximum ground-level concentrations and the distance to the maximum.

- Incorporating the effects of 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.
- Determining plume rise for flare releases.

EPA's SCREEN3(13) model 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, including distances out to 100 km for long-range transport.

- 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).

- 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.

## 2.3 Regulation 346 and Refined Models Comparison

The existing Ontario air dispersion models outlined in an appendix to Reg. 346 have been in place for over 30 years and do not reflect the latest scientific advancements in dispersion modelling. As a result, Reg. 346 models may under, or in some cases over, predict maximum ground level concentrations of contaminants at the Point of Impingement (POI). Major differences between 346 and 'refined models' (advantages of the refined models) include:

- Actual meteorological data used in the modelling compared to 'C&D stability' and preselected wind speeds (and other meteorological data) used in 346 models.

- ‘Refined models’ include updated dispersion equations (including building downwash)

- ‘Refined models’ allow for selection of averaging time, from annual down to 1hr (compared to 0.5hr in 346). This allows for both short term and longer term averaging studies.

- ‘Refined models’ allow for calculation of particulate deposition and plume depletion (not yet available in AERMOD but available in ISC).

- ‘Refined models’ do not automatically focus in on the maximum ground concentration; the user selects the receptors where the concentration is calculated.

- ‘Refined models’ allow for entry of terrain data (i.e. for elevated surrounding terrain)

- ‘Refined models’ are almost not limited in number of sources.

- ‘Refined models’ allow for variable emission rate scenarios (i.e. shift or seasonal production changes)

In summary, the improvements available in the refined models increase the accuracy of the results. This increase in accuracy directly translates into a better understanding of risks in the surrounding community, as well as improved compliance assessment of air standards and guidelines, allowing all users to make more informed decisions.

The use of the refined models is particularly important when identifying the major sources of community impacts and in assisting with decisions on the most appropriate approach to mitigate these impacts.

### 2.4 ISC and AERMOD Model Comparison

The ISC and AERMOD models share several similarities:

- Both are steady state plume models
- AERMOD input and output are intentionally similar to ISC for ease of use

AERMOD is a next-generation model, and while input and output may share similarities in format, there are several differences as detailed in the table below.

**Table 2.1** – Differences between ISCST3 and AERMOD.

| ISCST3 | AERMOD |
|---|---|
| Plume is always Gaussian | Plume is non-Gaussian when appropriate |
| Dispersion is function of six stability classes only | Dispersion is function of continuous stability parameters and height |
| Measured turbulence cannot be used | Measured turbulence can be used |
| Wind speed is scaled to stack height | Calculates effective speed through the plume |
| Mixing height is interpolated | Mixing height is calculated from met data |
| Plume either totally penetrates the inversion, or not at all | Plume may partially penetrate the inversion at the mixing height |
| Terrain is treated very simplistically | More realistic terrain treatment, using dividing streamline concept |
| Uses single dispersion for all urban areas | Adjusts dispersion to size of urban area |
| Cannot mix urban and rural sources | Can mix urban and rural sources |

Summary: "This table compares the differences between the ISCST3 and AERMOD Air Dispersion Models."

## 2.5 Alternative Models

The following list contains alternative models that are currently accepted by the Ministry of Environment (MOE) for consideration. Please see Appendix A for terms of appropriate use and required supporting explanations.

- CALPUFF
- CAL3QHCR
- SDM – Shoreline Dispersion Model
- Self Contamination - ASHRAE
- Physical Modelling

## 2.6 Model Validations

The U.S. EPA ISC-PRIME and AERMOD models are some of the most studied and validated models in the world. Studies have typically demonstrated good correlation with real-world values. AERMOD particularly handles complex terrain very well, closely matching the trends of field observations from validation studies.

ISC-PRIME differs from ISCST3 primarily in its use of the PRIME downwash algorithm. A model evaluation study was carried out under the auspices of the Electric Power Research Institute (EPRI). The report[(14)] is available from EPRI and from the U.S. EPA SCRAM website (http://www.epa.gov/scram001). The report analyzed comparisons between model predictions and measured data from four databases involving significant building downwash. This is in addition to 10 additional databases that were used during the development of ISC-PRIME. The study found that ISC-PRIME performed much better than ISCST3 under stable conditions, where ISCST3 predictions were very conservative (high). In general, ISC-PRIME was unbiased or somewhat overpredicting. Also, ISC-PRIME showed a statistically better performance result than ISCST3 for each database in the study.

The U.S. EPA performed the evaluation of AERMOD. A summary of the evaluation studies was prepared by Paine, et al.[(15)] This and more detailed reports can be found at the U.S. EPA SCRAM website. Five databases were used during the development of the model. Five additional non-downwash databases were used in the final evaluation. For cases involving building downwash, four developmental databases were used to check the implementation of PRIME into AERMOD as it was accomplished. Three additional databases were reserved for the final evaluation. AERMOD remained unbiased for complex terrain databases as well as flat terrain, while ISCST3 severely over-predicted for complex terrain databases.

## 3. A TIERED APPROACH FOR ASSESSING COMPLIANCE WITH AIR STANDARDS & GUIDELINES

Air dispersion modelling guidance will enable more representative analyses that make use of current science. The refined models include the following U.S. EPA air dispersion models:

- ISC-PRIME
- AERMOD (which includes PRIME algorithms for downwash)
- AERSCREEN and/or SCREEN3 (Dependent on AERSCREEN availability)

A tiered approach to air dispersion modelling is commonly used and is presented in Figure 3.1. This approach focuses the required level of effort according to site requirements. It should be noted that any of the 3 tiers may be performed and linear progression through each Tier is not necessary. For example, a refined analysis following *Tier 3* can be performed without first executing a *Tier 1* study.

*Tier 1* is a screening level analysis using the U.S. EPA SCREEN3 model, which includes all potential worst case meteorological conditions. If an air quality study passes appropriate standards and/or guidelines there is no need for additional modelling.

Note: At the time of writing this document, AERSCREEN remains unavailable and is currently in development. As a result, the proposed multi-tier approach should incorporate SCREEN3, and its potential substitution with AERSCREEN when it becomes reliably available.

*Tier 2* is a refined modelling analysis that makes use of regional meteorological data. Pre-processed regional meteorological data sets prepared by the Ontario Ministry of the Environment will be available to modellers (see Section 6.3).

*Tier 3* consists of refined modelling analyses that incorporate local meteorological data. This data typically must be pre-processed by the modeller or a Canadian meteorological data provider such as Environment Canada. Local meteorological data sets include site-specific parameters and meteorological characteristics that directly represent the site of consideration with a greater level of detail than most regional data sets. Tier 3 also encompasses modelling analyses that make use of any alternative models.

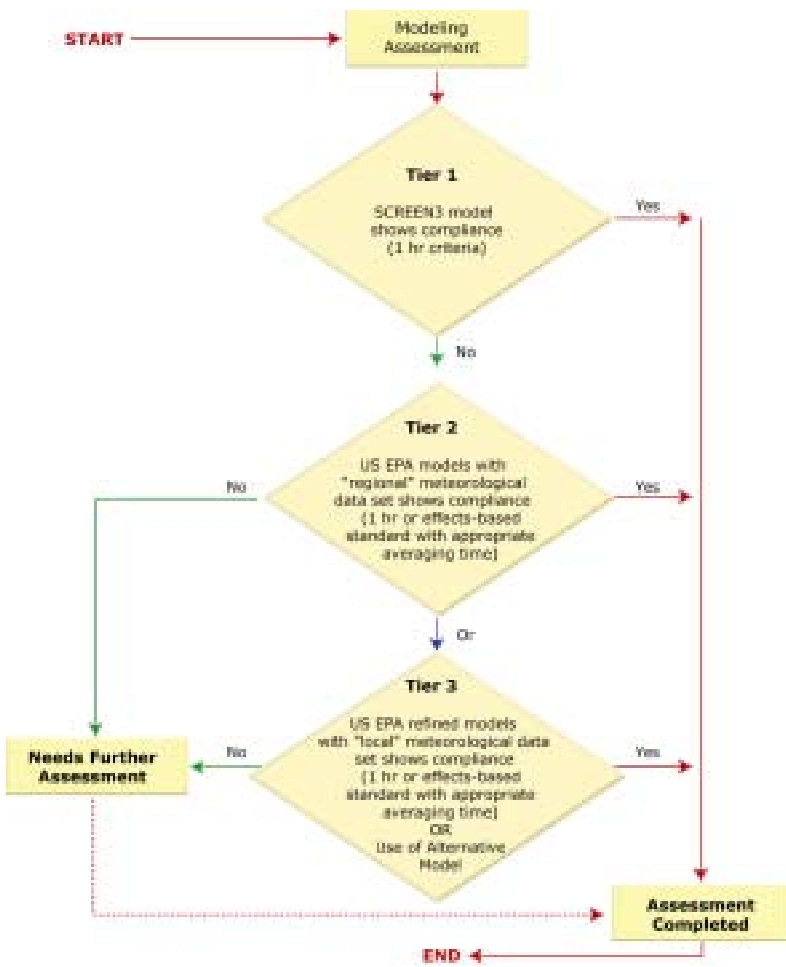



**Figure 3.1**– Sample options in tiered approach.

## 4. MODEL INPUT DATA

### 4.1 Comparison of Screening and Refined Model Requirements

Screening model requirements are the least intensive but produce the most conservative results. The SCREEN3 model has straight-forward input requirements and is further described in the following section.

Refined air dispersion modelling using the U.S. EPA AERMOD or ISC-PRIME models can be broken down into a series of steps. These are outlined in Sections 4.1.2 and 4.1.3.

A general overview of the process typically followed for performing an air dispersion modelling assessment is present in Figure 4.1 below. 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.

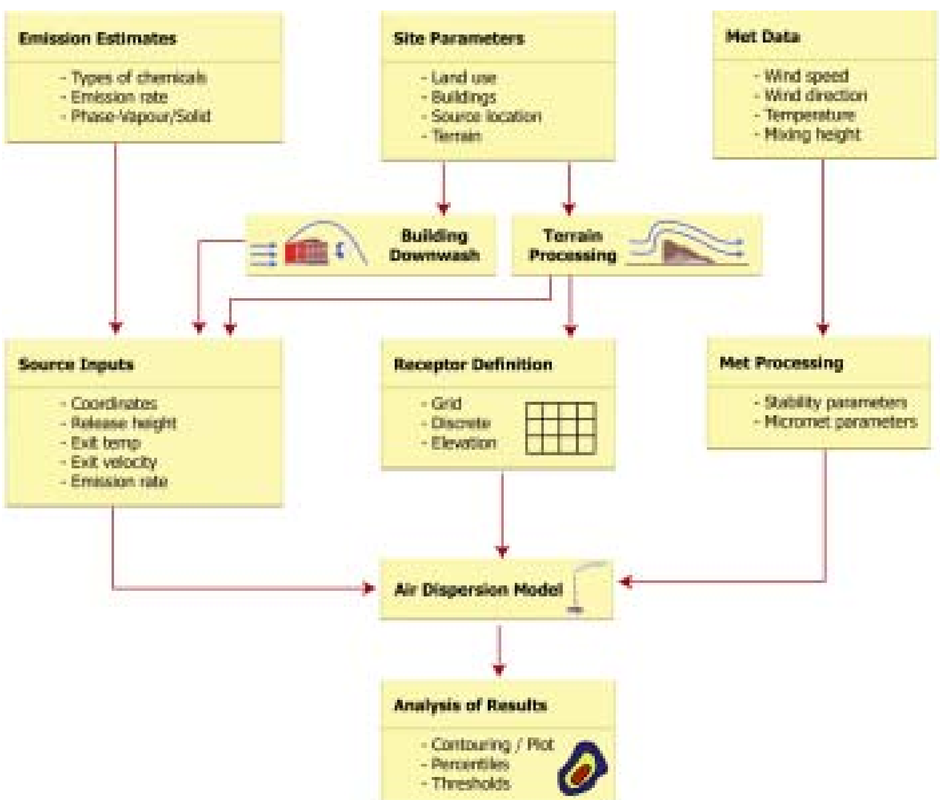



**Figure 4.1** - Generalized process for performing a refined air dispersion modelling assessment.

### 4.1.1 SCREEN3 Air Dispersion Modelling

The SCREEN model[13] was developed to provide an easy-to-use method of obtaining pollutant 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
    - Receptor Height Above Ground
- *Meteorology*: SCREEN3 can consider all conditions, or a specific stability class and wind speed can be provided.
- *Building Downwash*: If this option is used then building dimensions (height, length and width) must be specified.
- *Terrain*: SCREEN3 support flat, elevated and complex terrain. If elevated or complex terrain is used, distance and terrain heights must be provided.
- *Fumigation*: SCREEN3 supports shoreline fumigation. If used, distance to shoreline must be provided.

As can be seen above, 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. The refined models discussed in the following sections, have much more detailed options allowing for greater characterization and more representative results.

### 4.1.2 AERMOD Air Dispersion Modelling

The supported refined models have many input options, and are described further throughout this document as well as in their own respective technical documents.[3,6,7,11] An overview of the modelling approach and general steps for using each refined model are provided below. The general process for performing an air dispersion study using AERMOD includes:

- Meteorological Data Processing - AERMET
- Obtain Digital Terrain Elevation Data (If terrain is being considered)
- Building Downwash Analysis (BPIP-PRIME) – Project requires source and building information
- Final site characterization – complete source and receptor information
- AERMAP – Perform terrain data pre-processing for AERMOD air dispersion model if required.
- AERMOD – Run the model.
- Visualize and analyze results.

As can be seen above, the AERMOD modelling system is comprised of 3 primary components as outlined below and illustrated in Figure 4.2:

1. AERMET – Meteorological Data Preprocessor
2. AERMAP – Digital Terrain Preprocessor
3. AERMOD – Air dispersion model

To successfully perform a complex terrain air dispersion modelling analysis using AERMOD, you must complete the processing steps required by AERMET and AERMAP. See Section 6.3 for more information on meteorological data.

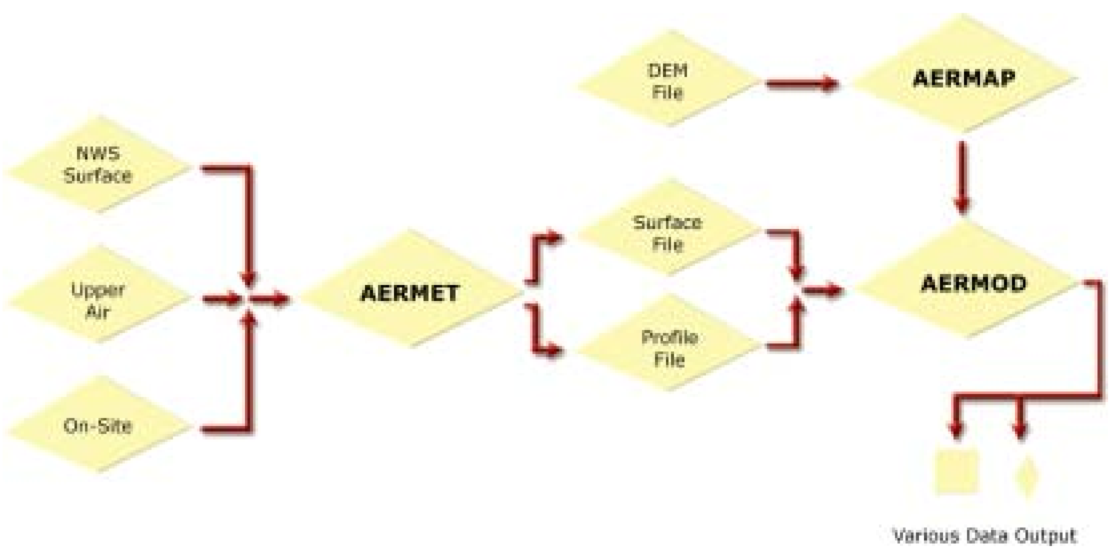



**Figure 4.2** - The AERMOD air dispersion modelling system.

### 4.1.3 ISC-PRIME Air Dispersion Modelling

The ISC-PRIME model has very similar input requirements when compared with AERMOD. These include:

- Meteorological Data Processing - PCRAMMET
- Obtain Digital Terrain Elevation Data (If terrain is being considered)
- Building Downwash Analysis (BPIP-PRIME) – Project requires source and building information
- Final site characterization – complete source and receptor information
- ISC-PRIME – Run the ISC-PRIME model.
- Visualize and analyze results.

As can be seen above, the ISC and AERMOD models follow a very similar approach to performing an air dispersion modelling project. The primary difference in running ISC and AERMOD models is that ISC does not require a terrain preprocessor, such as AERMAP. Furthermore, ISC relies on a different meteorological preprocessor known as PCRAMMET. The components of meteorological data pre-processing using PCRAMMET are illustrated in Figure 4.3 below. For a complete outline on how to obtain Ontario meteorological data and its processing requirements, please see Section 6.3.

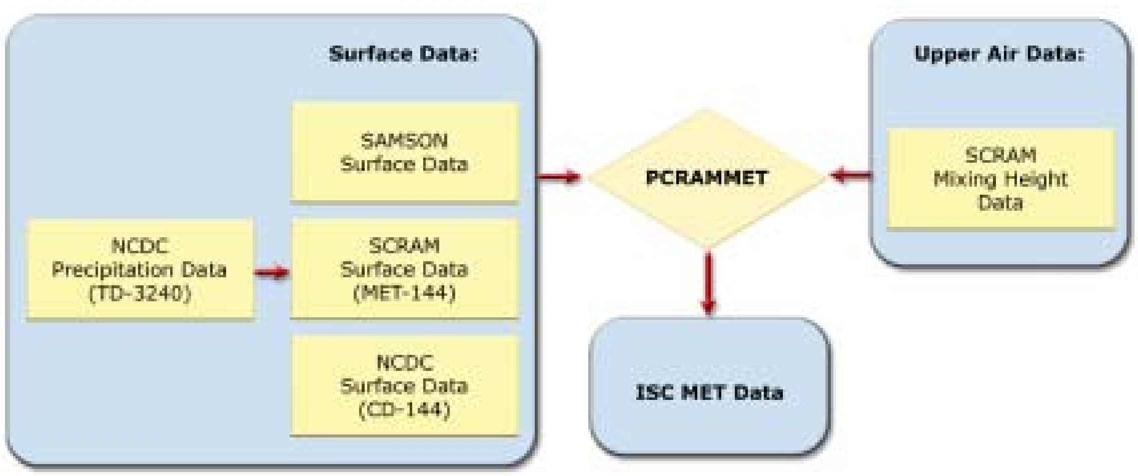



**Figure 4.3** - Meteorological data pre-processing flow diagram for the U.S. EPA ISC models.

## 4.2 Regulatory and Non-Regulatory Option Use

The ISC-PRIME and AERMOD models contain several regulatory options, which are set by default, as well as non-regulatory options. Depending on the model, the non-regulatory options can include:

- No stack-tip downwash (NOSTD)
- Missing data processing routine (MSGPRO)
- Bypass the calms processing routine (NOCALM)
- Gradual plume rise (GRDRIS)
- No buoyancy-induced dispersion (NOBID)
- Air Toxics Options (TOXICS)
- By-pass date checking for non-sequential met data file (AERMOD)
- Flat terrain (FLAT) (AERMOD)

Most regulatory agencies will require the use of any non-regulatory default option(s) to be justified through a discussion in the modelling report.

It is advisable to discuss the use of any non-regulatory options in modelling assessments with the Ministry before submission of a refined modelling report.

## 4.3 Coordinate System

Any modelling assessment will require a coordinate system be defined in order to assess the relative distances from sources and receptors and, where necessary, to consider other geographical features. Employing a standard coordinate system for all projects increases the efficiency of the review process while providing real-world information of the site location. 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 precise definition of specific locations than latitude/longitude.

For more information on coordinate systems and geographical information inputs, see Section 5.

## 4.4 Averaging Times

A key advantage to the more refined air dispersion models is the ability to compare with effects-based standards with appropriate averaging times. Effects-based averaging times means that a contaminant could be assessed using modelled exposure concentrations over the most appropriate averaging period for that contaminant. Refined models allow the input of variable emission rates, where appropriate, for assessing concentrations over longer averaging times.

With the existing Reg. 346 models, assessment of a facility is limited to the maximum ½ hour emissions and corresponding concentrations.

The ability to assess local air quality using a more appropriate effects-based averaging time means the refined air dispersion models provide a more representative assessment of health and environmental impacts of air emissions from a facility.

## 4.5 Defining Sources

### 4.5.1 Selection, Description and Parameters

The U.S. EPA SCREEN3, ISC-PRIME 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 in U.S. EPA,(13) for ISC-PRIME in U.S. EPA,(6,11) and for AERMOD in U.S. EPA(3).

#### 4.5.1.1 Point Sources

Point sources are typically used when modelling releases from sources like stacks and isolated vents. Input requirements for point sources include:

**SCREEN3**

- **Emission Rate:** The emission rate of the pollutant.
- **Stack Height:** The stack height above ground.
- **Stack Inside Diameter:** The inner diameter of the stack.
- **Stack Gas Exit Velocity [m/s or lb/h] or Stack Gas Exit Flow Rate [$m^3$/s or ACFM]:** Either the stack gas exit velocity or the stack gas exit flow rate should be given. The exit velocity can be determined from the following formula:

  $$V_s = 4*V/(\pi*(d_s\hat{}2))$$

  Where,
  *$V_s$ = Exit Velocity*
  *$V$ = Flow Rate*
  *$d_s$ = Stack Inside Diameter*

- **Stack Gas Temperature:** The temperature of the released gas in degrees Kelvin.

- **Ambient Air Temperature:** The average atmospheric temperature (K) in the vicinity of the source. If no ambient temperature data are available, assume a default value of 293 degrees Kelvin (K). For non-buoyant releases, the user should input the same value for the stack temperature and ambient temperature.

- **Receptor Height Above Ground:** This may be used to model impacts at "flagpole" receptors. A flagpole receptor is defined as any receptor 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).

- **Urban/Rural Option:** Specify either Urban or Rural conditions to use the appropriate dispersion coefficient. Section 5.4.5 provides guidance on determining rural or urban conditions.

**AERMOD/ISC-PRIME**

- **Source ID:** An identification name for the source being defined, up to 8 characters in length.

- **X Coordinate:** The x (east-west) coordinate for the source location in meters (center of the point source).

- **Y Coordinate:** Enter here the y (north-south) coordinate for the source location in meters (center of the point source).

- **Base Elevation:** The source base elevation. The model only uses the source base elevation if **Elevated** terrain is being used.

- **Release Height above Ground:** The source release height above the ground in meters.

- **Emission Rate:** The emission rate of the pollutant in grams per second.

- **Stack Gas Exit Temperature:** The temperature of the released gas in degrees Kelvin.

- **Stack Gas Exit Velocity:** The stack gas exit velocity in meters per second or the stack gas flow rate (see above section on SCREEN3).

- **Stack Inside Diameter:** The inner diameter of the stack.

### 4.5.1.2 Area Sources

Area sources are used to model low level or ground level releases where releases occur over an area (e.g., landfills, storage piles, slag dumps, and lagoons). SCREEN3 allows definition of a rectangular area while the ISC-PRIME and AERMOD models accept rectangular areas that may also have a rotation angle specified relative to a north-south orientation, as well as a variety of other shapes.

**SCREEN3**

- **Emission Rate:** The emission rate of the pollutant. The emission rate for area sources is input as an emission rate per unit area (g/(s-m$^2$)).
- **Source Release Height:** The source release height above ground.
- **Larger Side Length of Rectangular Area:** The larger side of the rectangular source in meters.
- **Smaller Side Length of Rectangular Area:** The smaller side of the rectangular source in meters.
- **Receptor Height Above Ground [m or ft]:** This may be used to model impacts at “flagpole” receptors. A flagpole receptor is defined as any receptor that 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).
- **Wind Direction Search Option:** Since the concentration at a particular distance downwind from a rectangular area is dependent on the orientation of the area relative to the wind direction, the SCREEN model provides the user with two options for treating wind direction. The regulatory default option is yes which results in a search of a range of wind directions. See U.S. EPA[16] for more detailed information.

**AERMOD/ISC-PRIME**

- **Source ID:** An identification name for the source being defined, up to 8 characters in length.
- **X Coordinate:** The x (east-west) coordinate for the vertex (corner) of the area source that occurs in the southwest quadrant of the source. Units are in meters.
- **Y Coordinate:** The y (north-south) coordinate for the vertex (corner) of the area source that occurs in the southwest quadrant of the source. Units are in meters.

- **Base Elevation:** The source base elevation. The model only uses the source base elevation if elevated terrain is being used. The default unit is meters.
- **Release Height above Ground [m]:** The release height above ground in meters.
- **Emission Rate [g/(s-m$^2$)]:** Enter the emission rate of the pollutant. The emission rate for Area sources is input as an emission rate per unit area. The same emission rate is used for both concentration and deposition calculations.
- **Options for Defining Area:** In ISC-PRIME the only option for defining the area is a rectangle. The maximum length/width aspect ratio for area sources is 10 to 1. If this is exceeded, then the area should be divided to achieve a 10 to 1 aspect ratio (or less) for all sub-areas. See U.S. EPA(6) for more details on inputting area data. In addition to the rectangular area, AERMOD can have circular or polygon areas defined (see U.S. EPA(3) for details).

**Note:** There are no restrictions on the location of receptors relative to area sources. Receptors may be placed within the area and at the edge of an area. The U.S. EPA models (ISCST3, ISC-PRIME, and 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.

#### 4.5.1.3 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.

**SCREEN3**

- **Emission Rate:** The emission rate of the pollutant in grams per second (g/s).
- **Source Release Height:** The source release height above ground surface.
- **Initial Lateral Dimension:** See Table 4.1 below for guidance on determining initial dimensions. Units are meters.
- **Initial Vertical Dimension:** See Table 4.1 below for guidance on determining initial dimensions. Units are meters.

- **Receptor Height Above Ground [m or ft]:** This may 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).

**Table 4.1** Summary of Suggested Procedures for Estimating Initial Lateral Dimension ($\square_{yo}$) and Initial Vertical Dimension ($\square_{zo}$) for Volume and Line Sources.

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

**Source:** U.S. Environmental Protection Agency, 1995 User’s Guide for the Industrial Source Complex (ISC3) Dispersion Models - Volume I, EPA-454/B-95-003a. U.S. Environmental Protection Agency. Research Triangle Park, NC 27711.

Summary: “This table summarizes the procedure for obtaining the initial lateral dimension for every source type. The first three lines are for the initial lateral dimension, followed by three lines for initial vertical dimension.”

**AERMOD/ISC-PRIME**

- **Source ID:** An identification name for the source being defined, up to 8 characters in length.
- **X Coordinate:** The x (east-west) coordinate for the source location in meters. This location is the center of the volume source.
- **Y Coordinate:** The y (north-south) coordinate for the source location in meters. This location is the center of the volume source.
- **Base Elevation:** The source base elevation. The model only uses the source base elevation if elevated terrain is being used. The default unit is meters.
- **Release Height above Ground:** The release height above ground surface in meters (center of volume).
- **Emission Rate [g/s]:** The emission rate of the pollutant in grams per second. The same emission rate is used for both concentration and deposition calculations.
- **Length of Side:** The length of the side of the volume source in meters. The volume source cannot be rotated and has the X side equal to the Y side (square).
- **Building Height (If On or Adjacent to a Building):** If your volume source is Elevated and is on or adjacent to a building, then you need to specify the building height. The building height can be used to calculate the Initial Vertical Dimension of the source. Note that if the source is surface-based, then this is not applicable.
- **Initial Lateral Dimension [m]:** This parameter is calculated by choosing the appropriate condition in Table 4.1 above. This table provides guidance on determining initial dimensions. Units are in meters.
- **Initial Vertical Dimension [m]:** This parameter is calculated by choosing the appropriate condition in Table 4.1 above. This table provides guidance on determining initial dimensions. Units are in meters.

#### 4.5.1.4 Line Sources

Examples of line sources are conveyor belts and rail lines. SCREEN3, AERMOD and ISC-PRIME do not have a default line source type. However, ISC-PRIME and AERMOD can simulate line sources through a series of volume sources. If line sources are necessary, please follow the methodology outlined in the "Line Source Represented by Separated Volume Sources" as described in Volume II of the *U.S. EPA User's Guide for the Industrial Source Complex (ISC3) Dispersion Models*[7].

For consideration of traffic related pollutants, a traffic air dispersion model such as CAL3QHCR or CALINE4 may need to be considered. Further details on these models can be found in *Appendix A: Alternative Models*.

#### 4.5.1.5 Flare Sources

Flare sources are used as control devices for a variety of sources. SCREEN3 supports flares directly through its flare source type. ISC-PRIME and AERMOD do not have a specific source type option for flare sources, but the method described below can be applied to treat flares in ISC-PRIME or AERMOD.

**SCREEN3**

- **Emission Rate:** The emission rate of the pollutant in grams per second (g/s).
- **Flare Stack Height:** The stack height above ground.
- **Total Heat Release Rate:** The heat release rate in calories per second (cal/s) for the flare.
- **Receptor Height Above Ground:** This may 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:** EPA's SCREEN model calculates plume rise for flares based on an effective buoyancy flux parameter. An ambient temperature of 293K is assumed in this calculation and therefore no ambient temperature is input 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. SCREEN calculates and prints out the effective release height for the flare.

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

## AERMOD/ISC-PRIME

Flare sources can be treated in a similar way as point sources, except that there are buoyancy flux reductions associated with radiative heat losses and a need to account for flame length in estimating plume height(17). 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 to match the radiative loss reduced buoyancy flux.

Due to the high temperature associated with flares, the effective release height of the plume can be calculated as follows(17):

$$H_{sl}=H_s+(4.56x10^{-3})*((H_r/4.1868)\wedge 0.478) \qquad (m)$$

where:

- $H_{sl}$ = effective flare height (m)
- $H_s$ = stack height above ground (m)
- $H_r$ = net heat release rate (J/s)

The net heat release rate is computed as follows:

$$H_r=44.64*V*[\Sigma_{\{i=1 \text{ to } n\}}\{f_i H_i*(1-F_i)\}]$$

where:

- $V$ = volumetric flow rate to the flare ($m^3/s$)
- $f_i$ = volume fraction of each gas component
- $H_i$ = net heating value of each component (J/g-mole)
- $F_r$= fraction of radiative heat loss

The fraction of radiative heat loss depends on the burning conditions of the flare. If there is information specific to the flare that should be used. A heat loss of 25% has been recommended by Alberta Environment as a default(16).

The stack parameters can be estimated by matching the buoyancy flux from the flare. The buoyancy flux from the flare is:

$$F = (g*H_r)/(\pi*\rho*T*C_p) = 8.8 *(10\wedge -6)*H_r$$

where:

- g = acceleration due to gravity ($m/s^2$)
- $\rho$ = density of air ($kg/m^3$)
- T = air temperature (°K)
- $C_p$ = specific heat of dry air constant (J/(Kg °K)

Buoyancy flux for stack releases is:

$F = g*V_s*(r_s\text{^}2)*(T_s-T)/T_s$

where:

$V_s$ = exit velocity (m/s)
$r_s$ = stack inner radius (m)
$T_s$ = stack exit temperature (°K)

Using an estimated stack gas exit temperature (1,273 °K is used in SCREEN3) and the actual exit velocity to the flare, an effective stack radius can be calculated for input to AERMOD and ISC-PRIME.

### 4.5.2 Source Grouping

Source groups enable modelling results for specific groups of one or more sources. The default in AERMOD and ISC-PRIME is the creation of a source group "ALL" that considers all the sources at the same time.

Analysis of individual groups of sources can be performed by using the SRCGROUP option. One example may be assigning each source to determine the maximum concentration generated by each individual source.

### 4.5.3 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.

#### 4.5.3.1 Multiple Stacks

When the plumes from multiple closely-spaced stacks or flues merge, the plume rise can be enhanced. Briggs[19] has proposed equations to account for this. The reader is referred to that document for further details. Most models do not explicitly account for enhanced plume rise from this cause, and most regulatory agencies do not permit it to be accounted for in regulatory applications of modelling, with one exception. That exception is the case of a single stack with multiple flues, or multiple stacks very close together (less than about one stack diameter apart). In these cases, the multiple plumes may be treated as 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.

#### 4.5.3.2 Horizontal Sources and Rain Caps

Both horizontal flues and vertical flues with rain caps have little or no initial vertical velocity. Plume rise calculations in most models (including AERMOD and ISCST3) takes into account both rise due to vertical momentum of the plume as it leaves the stack and the buoyancy of the plume. This may result in an overprediction of the plume rise, and resulting underprediction of ground-level concentrations, in these models.

This problem can be alleviated by modifying the source input parameters to minimize the effects of momentum while leaving the buoyant plume rise calculations unchanged. An approach to modelling this is to modify the source input parameters to minimize the effects of momentum while leaving the buoyant plume rise calculations unchanged. The U.S. EPA outlines such an approach in its Model Clearinghouse Memo 93-II-09(20), and expressed, in part, in Tikvart.(21) This approach is to reduce the stack gas exit velocity to 0.001 m/s, and calculate an equivalent diameter so that the buoyant plume rise is properly calculated. To do this, the stack diameter is specified to the model such that the volume flow rate of the gas remains correct. In the case of horizontal flues, there will be no stack tip downwash, so that option should be turned off for that case. In the case of vertical flues with rain caps, there will be frequent occurrences of stack tip downwash, however the effect of the stack tip downwash (reduction of the plume height by an amount up to three times the stack diameter) may be underestimated in the model. This can be corrected, somewhat conservatively, by turning off the stack tip downwash and lowering the specification of the stack height by three times the actual stack diameter (the maximum effect of stack tip downwash).

With the above references in mind, it should be noted that lower exit velocities can cause issues with PRIME. As a result the Ministry does provide the option of using an exit velocity of 0.1 m/s or 0.01 m/s. This exit velocity still effectively eliminates momentum flux and can produce parameters that will not impede model execution. Furthermore, for cases where exit temperature significantly exceeds ambient temperature then the Ministry may consider use of effective diameter or effective temperature values to account for buoyancy flux. This should be reviewed with the Ministry prior to submission.

A sample step-by-step approach is as follows. In this discussion,

V ≡ actual stack gas exit velocity
V' ≡ stack gas exit velocity as entered into the model (AERMOD or ISCST3)
D ≡ actual stack inside diameter
D' ≡ stack inside diameter as input to the model
H ≡ actual stack height
H' ≡ stack height input to the model

For the source of consideration, modify its parameters as follows:

1. Set V'=0.01 m/s
2. Set D'=D*SQRT(V/V')
3. 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

#### 4.5.3.3 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 pollutant emissions occur from a vent, with some additional contribution from hatches and other fittings. In the case of floating roof tanks, most of the pollutant 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 outlined below.

**Fixed roof tanks:**

Model fixed roof tanks as a point (stack) source (representing the vent), which is usually in the center 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.

**All tanks:**

There is virtually no plume rise from tanks. Therefore, the stack parameters for the stack gas exit velocity and stack diameter should be set to near zero for the stacks representing the emissions. In addition, stack temperature should be set equal to the ambient temperature. This is done in ISCST3 and AERMOD by inputting a value of 0.0 for the stack gas temperature.

Note that 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 all downwash effects are being calculated as building downwash, the additional stack tip downwash calculations would be inappropriate. Since the maximum stack tip downwash effect is to lower plume height by three stack diameters, a very small stack diameter effectively eliminates the stack tip downwash.

**Table 4.2** - Stack parameter values for modelling tanks.

| Velocity | Diameter | Temperature |
|---|---|---|
| Near zero<br>i.e. 0.001 m/s | Near zero<br>i.e. 0.001m | Ambient – 0.0 sets models to use ambient temperature |

Summary: "This table summarizes Diameter and Temperature values for different velocities for use in modelling tanks."

### 4.5.4 Variable Emissions

The ISCST3 and AERMOD models both contain support for variable emission rates. This allows for modelling of source emissions that may fluctuate over time. Emission variations can be characterized for across many different periods including hourly, daily, monthly and seasonally.

#### 4.5.4.1 Wind Erosion

Modelling of emissions from sources susceptible to wind erosion, such as coal piles, can be accomplished using variable emissions.

The ISCST3 and AERMOD models allow for emission rates to be varied by wind speed. This allows for more representative emissions from sources that are susceptible to wind erosion, particularly waste piles that can contribute to particulate emissions. Once a correlation between emissions and wind speed categories is established, the models will then vary the emissions based on the wind conditions in the meteorological data.

#### 4.5.4.2 Non-Continuous Emissions

Sources of emissions at some locations may emit only during certain periods of time. Emissions can be varied within the ISC and AERMOD models by applying factors to different time periods.

For example, 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. Model inputs for variable emissions rates can include the following time periods:

- Seasonally
- Monthly
- Hourly
- By Season and hour-of-day
- By Season, hour-of-day, and day-of-week
- By Season, hour, week

### 4.5.5 Plant Shutdowns and Start-Ups

Plant start-ups and shutdowns can occur periodically due to maintenance or designated vacation periods. The shutdown and subsequent startup processes impact emissions over the related time periods. As an example, process upsets in the combustion units or air pollution control system can also impact emissions, these upsets can often result in the emission of uncombusted waste through the emissions sources. As a result, over short periods of time, upset emissions are often expected to be greater than normal source emissions.[22]

These emission differences can be accounted for by the application of variable emission factors.

#### 4.5.5.1 Seasonal Variations

Industrial processes often fluctuate depending on supply and demand requirements. This affects some sectors seasonally, particularly facilities involved in food processing. For example, soup production makes use of agricultural produce which is at its highest in the late summer. Production schedules for soup production typically ramp up resulting in different emissions during the late summer and early fall, than at mid to late winter.

These emission differences can be accounted for by the application of variable emission factors, with control over the following time periods:

- By Season and hour-of-day
- By Season, hour-of-day, and day-of-week
- By Season, hour, week

## 4.6 Building Impacts

Buildings and other structures near a relatively short stack can have a substantial effect on plume transport and dispersion, and on the resulting ground-level concentrations that are observed. There has long been a “rule of thumb” that a stack should be at least 2.5 times the height of adjacent buildings. Beyond that, much of what is known of the effects of buildings on plume transport and diffusion has been obtained from wind tunnel studies and field studies.

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. Farther downwind, the air flows downward again. In addition, there is more shear and, as a result, more turbulence. This is the turbulent wake zone (see Figure 4.4).

If a plume gets caught in the 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.

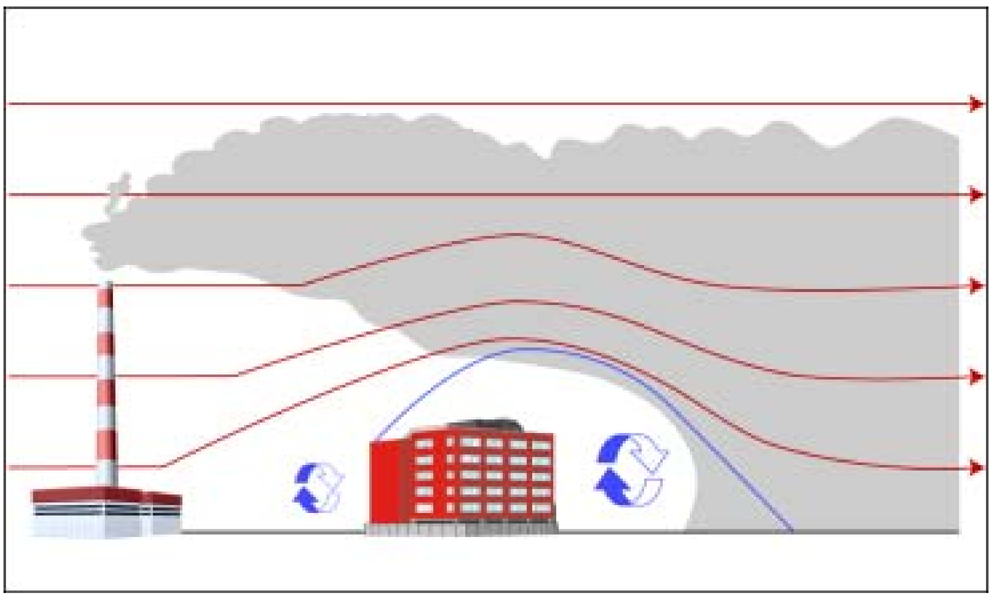


**Figure 4.4 -** The building downwash concept where the presence of buildings forms localized turbulent zones that can readily force pollutants down to ground level.

### 4.6.1 Good Engineering Practice (GEP) Stack Heights and Structure Influence Zones

The U.S. EPA[(23)] states that "If stacks for new or existing major sources are found to be less than the height defined by the EPA's refined formula for determining GEP height, then air quality impacts associated with cavity or wake effects due to the nearby building structures should be determined."

The U.S. EPA's refined formula for determining GEP stack height is:
**GEP Stack Height = H + 1.5L**

where,

**GEP =** Good Engineering Practice
**H =** Building/Tier Height measured from ground to the highest point
**L =** Lesser of the Building Height (PB) or Projected Building Width (PBW)

Building downwash for point sources that are within the **Area of Influence** of a building should be considered. For U.S. EPA regulatory applications, 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.

**$\text{Distance}_{\text{stack-bldg}} <= 5L$**

For point sources within the **Area of Influence**, building downwash information (direction-specific building heights and widths) should be included in your modelling project. Using BPIP-PRIME, you can compute these direction-specific building heights and widths.

**Structure Influence Zone (SIZ):** For downwash analyses with direction-specific building dimensions, wake effects are assumed to occur if the stack is within a rectangle composed of two lines perpendicular to the wind direction, one at **5L** downwind of the building and the other at **2L** upwind of the building, and by two lines parallel to the wind direction, each at **0.5L** away from each side of the building, as shown above. **L** is the lesser of the height or projected width. This rectangular area has been termed a **Structure Influence Zone (SIZ)**. Any stack within the SIZ for any wind direction is potentially affected by GEP wake effects for some wind direction or range of wind directions. See Figure 4.5 and Figure 4.6.

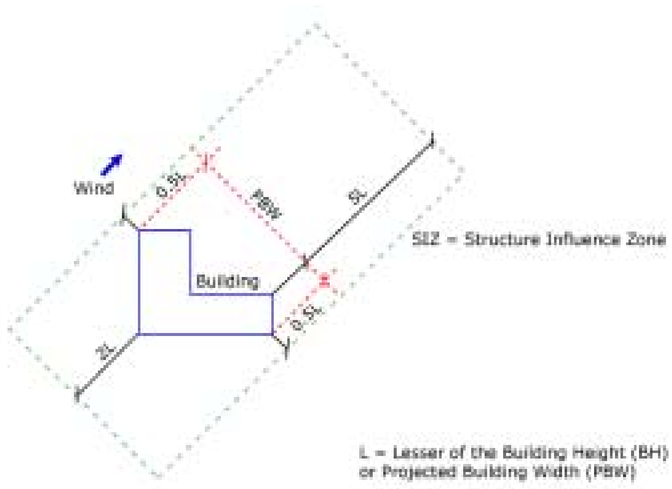



**Figure 4.5 -** GEP 5L and Structure Influence Zone (SIZ) Areas of Influence (after U.S. EPA[24]).

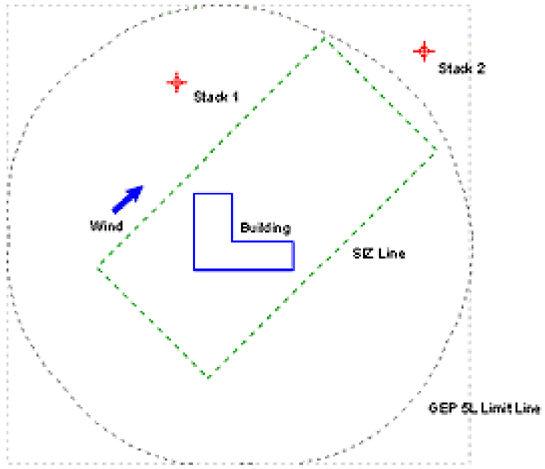



**Figure 4.6 -**GEP 360˚ 5L and Structure Influence Zone (SIZ) Areas of Influence (after U.S. EPA[24]).

### 4.6.2 Defining Buildings

The recommended screening and refined models all allow for the consideration of building downwash. SCREEN3 considers the effects of a single building while AERMOD and ISC-PRIME can consider the effects of complicated sites consisting of up to hundreds of buildings. This results in different approaches to defining buildings as outlined below.

#### 4.6.2.1 SCREEN3 Building Definition

Defining buildings in SCREEN3 is straightforward, as only one building requires definition. The following input data is needed to consider downwash in SCREEN3:

- **Building Height:** The physical height of the building structure in meters.
- **Minimum Horizontal Building Dimension:** The minimum horizontal building dimension in meters.
- **Maximum Horizontal Building Dimension:** The maximum horizontal building dimension in meters.

For **Flare** releases, SCREEN assumes the following:

- an effective stack gas exit velocity ($V_s$) of 20 m/s,
- an effective stack gas exit temperature ($T_s$) of 1,273 K, and
- an effective stack diameter based on the heat release rate.

Since building downwash estimates depend on transitional momentum plume rise and transitional buoyant plume rise calculations, the selection of effective stack parameters could influence the estimates. Therefore, building downwash estimates for flare releases should be used with extra caution.[13]

If using **Automated Distances** or **Discrete Distances** option, wake effects are included in any calculations made. 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. The cavity calculations are summarized at the end of the distance-dependent calculations (see SCREEN3 User's Guide[13] Section 3.6 for more details).

#### 4.6.2.2 AERMOD and ISC-PRIME Building Definition

The inclusion of the PRIME (Plume Rise Model Enhancements) algorithm[25] to compute building downwash has produced more accurate results in air dispersion models. Unlike the earlier algorithms used in ISC3, the PRIME algorithm

1) accounts for the location of the stack relative to the building;

2) accounts for the deflection of streamlines up over the building and down the other side;

3) accounts for the effects of the wind profile at the plume location for calculating plume rise;

4) accounts for pollutants captured in the recirculation cavity to be transported to the far wake downwind (this is ignored in the earlier algorithms); and

5) avoids discontinuities in the treatment of different stack heights, which were a problem in the earlier algorithms.

Refined models allow for the capability to consider downwash effects from multiple buildings. AERMOD and ISC-PRIME require building downwash analysis to first be performed using BPIP-PRIME.[25] The results from BPIP-PRIME can then be incorporated into the modelling studies for consideration of downwash effects.

The U.S. EPA Building Profile Input Program – Plume Rise Model Enhancements (BPIP-PRIME) was designed to incorporate enhanced downwash analysis data for use with the U.S. EPA ISC-PRIME and current AERMOD models. Similar in operation to the U.S. EPA BPIP model, BPIP-PRIME uses the same input data requiring no modifications of existing BPIP projects. The following information is required to perform building downwash analysis within BPIP:

- X and Y location for all stacks and building corners.

- Height for all stacks and buildings (meters). For building with more than one height or roofline, identify each height (tier).

- Base elevations for all stacks and buildings.

The BPIP User's Guide[24] 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,[26] 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[27,28] and Lee.[29] 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 of BPIP, 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.

For a more detailed technical description of the EPA BPIP-PRIME model and how it relates to the EPA ISC-PRIME model see the *Addendum to ISC3 User's Guide.*[30]

## 4.7 Multiple Pollutants

### 4.7.1 Standard Approaches to Modelling Multiple Pollutants from Multiple Sources

Industrial processes often emit multiple pollutants through one or several emission sources. The U.S. EPA models are not equipped to automatically perform modelling of different pollutants that may share the same emission source but have unique emission rates.

Traditional approaches to this scenario resulted in modellers performing separate model runs for each specific pollutant type, even though all other model site parameters remain the same. For projects consisting of many pollutants, this approach results in the modeller needing not only to be extremely organized but also requiring high levels of computer resources as the project would need to be run separately for each pollutant scenario.

An alternative approach is applying unitized emission rate and summation concepts, which drastically reduce the computational time for large multiple pollutant projects.

### 4.7.2 Unitized Emission Rate and Summation Concepts

It is a well-known fact that air dispersion modelling is a non-linear process. The modelled site may have random meteorological variations, the dispersion process is non-linear, and the terrain elevations at the site may assume unlimited shapes. However, once the calculations to a receptor in space are complete, all chemical concentration levels are proportional to their source release rate. Figure 4.7 helps visualize this concept, by describing an emission rate of 1 g/s.

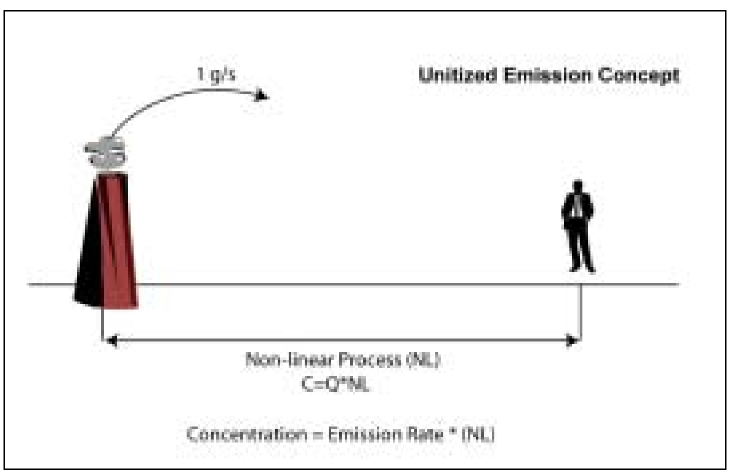



**Figure 4.7** - Unitized Emission Rate Concept (1 g/s).

The Unitized Emission Rate Concept only applies to single sources. For assessments with multiple sources the authors recommend that each source be modelled independently, using unitized emission rate (1 g/s). The concentration at the receptor can then be multiplied by the actual chemical emission rate, and the final result from all the sources will be superimposed. This is called the Summation Concept, where the concentration and deposition fluxes at a receptor are the linear addition of the resulting values from each source. Figure 4.8 depicts the Summation concept.

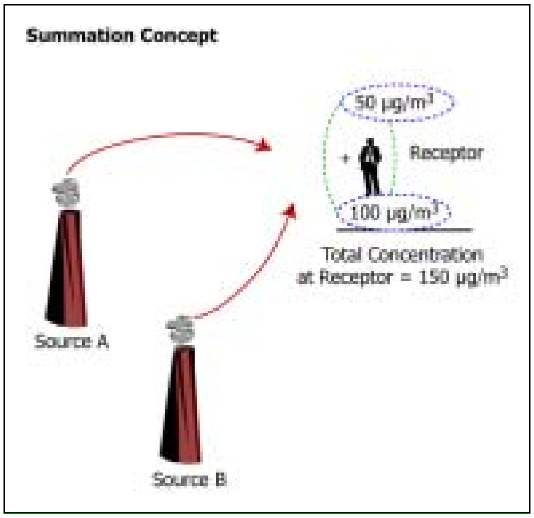



**Figure 4.8** - The Summation Concept for two sources.

A post-processor is needed to effectively process model results that have been performed using unitized emission rate and summation concepts. Final output will provide results for pollutant specific scenarios from multiple sources.

## 5. GEOGRAPHICAL INFORMATION INPUTS

### 5.1 Comparison of Screening and Refined Model Requirements

Geographical information requirements range from basic for screening analyses to advanced for refined modelling. SCREEN3 makes 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 and ISC-PRIME models make use of complete three-dimensional geographic data with support for digital elevation model files and real-world spatial characterization of all model objects.

## 5.2 Coordinate System

### 5.2.1 Local

Local coordinates encompass coordinate systems that are not based on a geographic standard. For example, a facility may reference its coordinate system based on a local set datum, such as a predefined benchmark. All site measurements can relate to this benchmark which can be defined as the origin of the local coordinate system with coordinates of 0,0 m. All facility buildings and sources could then be related spatially to this origin.

However, local coordinates do not indicate where in the actual world the site is located. For this reason, it is advantageous to consider a geographic coordinate system that can specify the location of any object anywhere in the world with precision. The coordinate system most commonly used for air dispersion modelling is the Universal Transverse Mercator system.

### 5.2.2 UTM

As described earlier, the Universal Transverse Mercator (UTM) coordinate system uses meters as its basic unit of measurement and allows for more precise definition of specific locations than latitude/longitude.

Ensure 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.

## 5.3 Terrain

### 5.3.1 Terrain Concerns in Short-Range Modelling

Terrain elevations 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. Terrain elevation is the elevation relative to the facility base elevation.

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

### 5.3.2 Flat and Complex Terrain

The models consider three different categories of terrain as follows:

- **Complex Terrain:** as illustrated in Figure 5.1, where terrain elevations for the surrounding area, defined as anywhere within 50 km from the stack, are above the top of the stack being evaluated in the air modelling analysis.

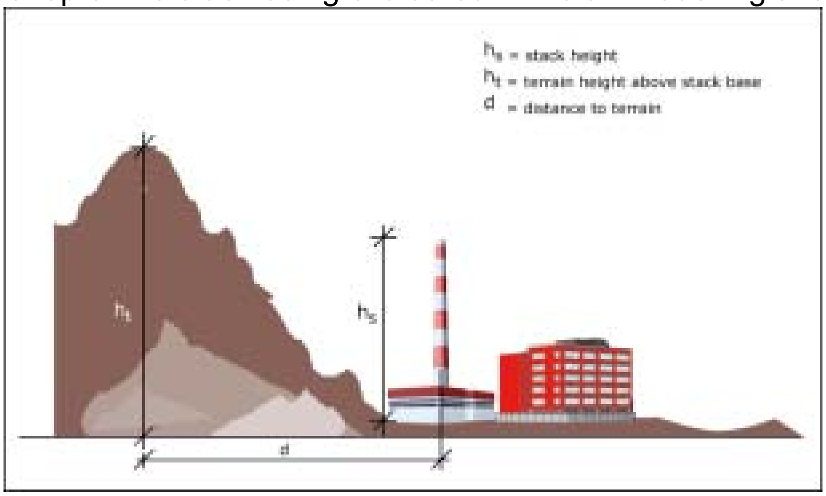



**Figure 5.1** - Sample complex terrain conditions.

- **Simple Terrain:** where terrain elevations for the surrounding area are not above the top of the stack being evaluated in the air modelling analysis. The "Simple" terrain can be divided into two categories:

  - **Simple Flat Terrain** is used where terrain elevations are assumed not to exceed stack base elevation. If this option is used, then terrain height is considered to be 0.0 m.

  - **Simple Elevated Terrain**, as illustrated in Figure 5.2 is used where terrain elevations exceed stack base but are below stack height.

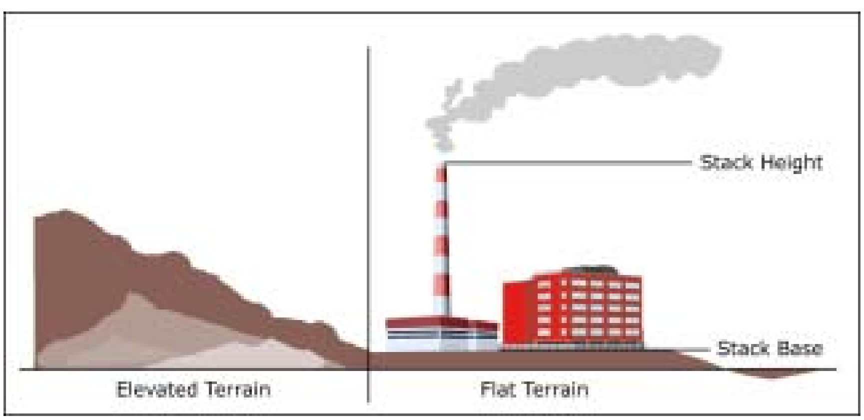



**Figure 5.2** – Sample elevated and flat terrain conditions.

### 5.3.3 Criteria for Use of Terrain Data

Evaluation of the terrain within a given study area is the responsibility of the modeller. At first glance it may be inferred that much of Ontario is flat, but it should be remembered that complex terrain is any terrain within the study area that is above the source release height.

The appropriate terrain environment can be determined through the use of digital elevation data or other geographic data sources. It should be noted that the refined models, ISC-PRIME and AERMOD, have similar run times regardless of whether or not terrain data is used. However AERMAP, the terrain pre-processor for AERMOD, does require additional time. If analysis of the terrain environment is performed using digital terrain data, minimal resources are required to execute a model run using that digital terrain dataset.

### 5.3.4 Obtaining Terrain Data

Terrain data that are input into the AERMOD and ISC-PRIME models should be provided in electronic form. Digital elevation terrain data is available for Ontario from a variety of vendors in several different formats.

Digital elevation model (DEM) data covering Ontario is available through the MOE Environmental Modelling and Reporting Branch (EMRB) for air dispersion applications. Request for this data should be sent to Dr. Robert Bloxam at Robert.Bloxam@ene.gov.on.ca or Dr. Jinliang (John) Liu at Jinliang.Liu@ene.gov.on.ca. The UTM coordinates along with the city name (or closest city) where the property to be modelled is located should be included in the request. Also indicate the extent of the proposed modelling domain.

Digital terrain data is also available in a format called CDED (Canadian Digital Elevation Data). The Ministry of Natural Resources also makes available Canadian DEM (Digital Elevation Model) data in an alternative format. These formats are summarized below:

| Format Name | Resolution | Data Availability |
|---|---|---|
| CDED | 1-degree (1:250,000) | Centre for Topographic Information in Sherbrooke |
| CDED | 15-minute (1:50,000) | Centre for Topographic Information in Sherbrooke |
| MNR(Post-Anudem) | 10m & 20m | Ministry of Natural Resources (MNR) |

Summary: “This table summarizes the Resolution and Data Availability for three types of Digital terrain Formats.”

The data contacts listed above can be found at the web sites below:

- **Centre for Topographic Information in Sherbrooke (CDED)** - **http://www.cits.rncan.gc.ca**

- **Ontario Ministry of Natural Resources (MNR)** **http://www.lio.mnr.gov.on.ca/liohome.cfm** The digital elevation model data was developed as part of the *Water Resources Information Project: Provincial Watershed Project*.

### 5.3.5 Preparing Terrain Data for Model Use

AERMAP is the digital terrain pre-processor for the AERMOD model. It analyzes and prepares digital terrain data for use within an air dispersion modelling project. AERMAP requires that the digital terrain data files be in native (non SDTS) USGS 1-degree or 7.5-minute DEM format.

The CDED format is very similar to the USGS DEM format. The CDED 1-degree data type can be used directly with AERMAP without the need for any conversions. However, 1-degree data does not contain optimal resolution for most air dispersion modelling analyses. The remaining data types both require conversion to an AERMAP compatible format.

A digital terrain converter has been made available by *Lakes Environmental Software* to the general public, specifically to address the need for higher-resolution Canadian terrain data in a format compatible with the AERMAP terrain pre-processor. This terrain converter is available for download from *Lakes Environmental Software* at http://www.weblakes.com.

## 5.4 Land Use Characterization

Land use plays an important role in air dispersion modelling from meteorological data processing to defining modelling characteristics such as urban or rural conditions. Land use data can be obtained from digital and paper land-use maps.

These maps will provide an indication into the dominant land use types within an area of study, such as industrial, agricultural, forested and others. This information can then be used to determine dominant dispersion conditions and estimate values for parameters such as surface roughness, albedo, and Bowen ratio.

- **Surface Roughness Length [m]:** The surface roughness length, also referred to surface roughness height, is a measure of the height of obstacles to the wind flow. Surface roughness affects the height above local ground level that a particle moves from the ambient air flow above the ground into a "captured" deposition region near the ground. This height is not equal to the physical dimensions of the obstacles, but is generally proportional to them. Table 5.1 lists typical values for a range of land-use types as a function of season.

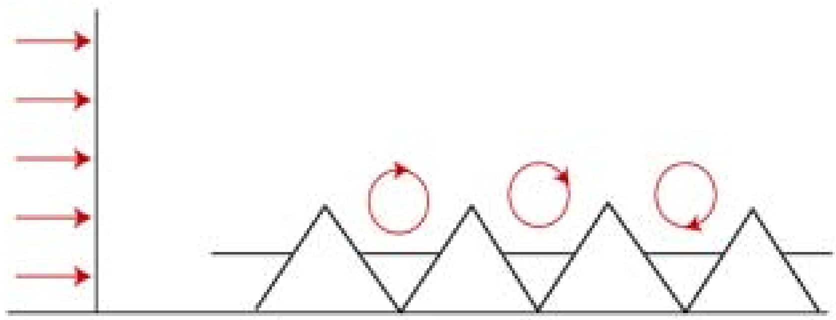


**Figure 5.3** - For many modelling applications, surface roughness can be considered to be on the order of one tenth of the height of the roughness elements.

The following method was proposed in the *U.S. EPA OSW Human Health Risk Assessment Protocol*[22] to determine the surface roughness length for use with the ISC-PRIME/ISCST3 model at the application site:

1) Draw a radius of 3 Km from the center of the stack(s) on the site map.
2) Classify the areas within the radius according to the land use type categories listed in Table 5.1 (e.g., water surface, deciduous forest, etc.).
3) Calculate the wind rose directions from the 5 years of meteorological data to be used for the risk analysis.
4) Divide the area into 16 sectors of 22.5 degrees, corresponding to the wind rose directions.
5) Identify a representative surface roughness length for each sector, based on an area-weighted average of the land use within the sector.
6) Calculate the site surface roughness by computing an average surface roughness length weighted with the frequency of wind direction occurrence for each sector.

AERMOD allows wind direction dependent surface characteristics to be used in the processing of the meteorological data. The AERMET procedure also uses the area-weighted average of the land use with 3 km of the site. The selection of wind direction dependent sectors is described in sections 5.4.1 to 5.4.3.

Alternative methods of determining surface roughness height may be proposed. The regulatory agency should review proposed values prior to use.

**Table 5.1 - Surface Roughness Heights for Land Use Types and Seasons (meters)[31]**

| | SEASONS | | | |
|---|---|---|---|---|
| LAND USE TYPE | Spring | Summer | Autumn | Winter |
| Water surface | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Deciduous forest | 1.00 | 1.30 | 0.80 | 0.50 |
| Coniferous forest | 1.30 | 1.30 | 1.30 | 1.30 |
| Swamp | 0.20 | 0.20 | 0.20 | 0.05 |
| Cultivated land | 0.03 | 0.20 | 0.05 | 0.01 |
| Grassland | 0.05 | 0.10 | 0.01 | 0.001 |
| Urban | 1.00 | 1.00 | 1.00 | 1.00 |
| Desert shrubland | 0.30 | 0.30 | 0.30 | 0.15 |

Summary: "This table charts the values of seasonal Surface Roughness Heights for different types of land use. The first column contains the type of land use, and the next four columns contain spring, summer, autumn and winter Surface Roughness Height values respectively."

- **Noon-Time Albedo:** Noon-time albedo is the fraction of the incoming solar radiation that is reflected from the ground when the sun is directly overhead. Table 5.2 lists typical albedo values as a function of several land use types and season. For practical purposes, the selection of a single value for noon-time albedo to process a complete year of meteorological data is desirable. If other conditions are used, the regulatory agency should review the proposed noon-time albedo values used to pre-process the meteorological data.

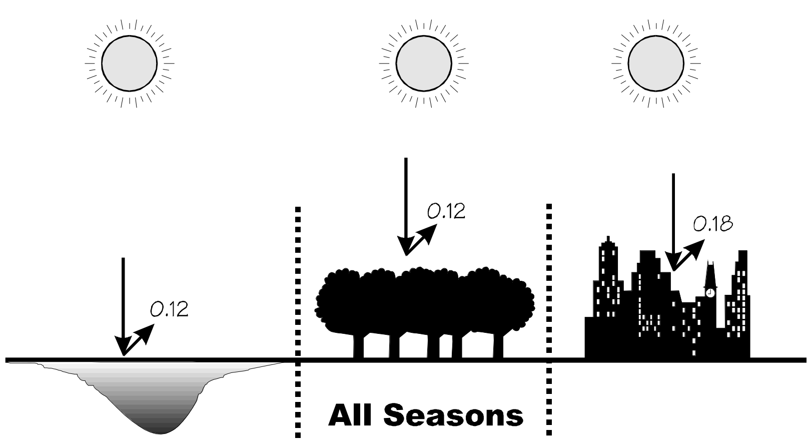


**Table 5.2 - Albedo of Natural Ground Covers for Land Use Types and Seasons**[32]

| | SEASONS | | | |
|---|---|---|---|---|
| LAND USE TYPE | Spring | Summer | Autumn | Winter |
| Water surface | 0.12 | 0.10 | 0.14 | 0.20 |
| Deciduous forest | 0.12 | 0.12 | 0.12 | 0.50 |
| Coniferous forest | 0.12 | 0.12 | 0.12 | 0.35 |
| Swamp | 0.12 | 0.14 | 0.16 | 0.30 |
| Cultivated land | 0.14 | 0.20 | 0.18 | 0.60 |
| Grassland | 0.18 | 0.18 | 0.20 | 0.60 |
| Urban | 0.14 | 0.16 | 0.18 | 0.35 |
| Desert shrubland | 0.30 | 0.28 | 0.28 | 0.45 |

Summary: “This table charts seasonal Albedo values for different types of land use. The first column contains the type of land use, and the next four columns contain spring, summer, autumn and winter Albedo values respectively.”

- **Bowen Ratio:** The Bowen ratio is a measure of the amount of moisture at the surface. The presence of moisture at the earth’s surface alters the energy balance, which in turn alters the sensible heat flux and Monin-Obukhov length. Table 5.3 lists Bowen ratio values as a function of land-use types, seasons and moisture conditions. Bowen ratio values vary depending on the surface wetness. Average moisture conditions would be the usual choice for selecting the Bowen ratio. If other conditions are used the regulatory agency should review the proposed Bowen ratio values used to pre-process the meteorological data.

**Table 5.3 - Daytime Bowen Ratios by Land Use, Season, and Precipitation Conditions[33]**

| LAND USE TYPE | SEASONS | | | |
|---|---|---|---|---|
| | Spring | Summer | Autumn | Winter |
| | **Dry Conditions** | | | |
| Water (fresh and salt) | 0.1 | 0.1 | 0.1 | 2.0 |
| Deciduous forest | 1.5 | 0.6 | 2.0 | 2.0 |
| Coniferous forest | 1.5 | 0.6 | 1.5 | 2.0 |
| Swamp | 0.2 | 0.2 | 0.2 | 2.0 |
| Cultivated land | 1.0 | 1.5 | 2.0 | 2.0 |
| Grassland | 1.0 | 2.0 | 2.0 | 2.0 |
| Urban | 2.0 | 4.0 | 4.0 | 2.0 |
| Desert shrubland | 5.0 | 6.0 | 10.0 | 2.0 |

Summary: "This table charts seasonal Daytime Bowen Ratios for different types of land use. The first column contains the type of land use, and the next four columns contain spring, summer, autumn and winter values respectively. This table is for Dry Precipitation Conditions."

| LAND USE TYPE | SEASONS | | | |
|---|---|---|---|---|
| | Spring | Summer | Autumn | Winter |
| | **Average Conditions** | | | |
| Water (fresh and salt) | 0.1 | 0.1 | 0.1 | 1.5 |
| Deciduous forest | 0.7 | 0.3 | 1.0 | 1.5 |
| Coniferous forest | 0.7 | 0.3 | 0.8 | 1.5 |
| Swamp | 0.1 | 0.1 | 0.1 | 1.5 |
| Cultivated land | 0.3 | 0.5 | 0.7 | 1.5 |
| Grassland | 0.4 | 0.8 | 1.0 | 1.5 |
| Urban | 1.0 | 2.0 | 2.0 | 1.5 |
| Desert shrubland | 3.0 | 4.0 | 6.0 | 6.0 |

Summary: "This table charts seasonal Daytime Bowen Ratios for different types of land use. The first column contains the type of land use, and the next four columns contain spring, summer, autumn and winter values respectively. This table is for Average Precipitation Conditions."

| LAND USE TYPE | SEASONS | | | |
|---|---|---|---|---|
| | Spring | Summer | Autumn | Winter |
| | **Wet Conditions** | | | |
| Water (fresh and salt) | 0.1 | 0.1 | 0.1 | 0.3 |
| Deciduous forest | 0.3 | 0.2 | 0.4 | 0.5 |
| Coniferous forest | 0.3 | 0.2 | 0.3 | 0.3 |
| Swamp | 0.1 | 0.1 | 0.1 | 0.5 |
| Cultivated land | 0.2 | 0.3 | 0.4 | 0.5 |
| Grassland | 0.3 | 0.4 | 0.5 | 0.5 |
| Urban | 0.5 | 1.0 | 1.0 | 0.5 |
| Desert shrubland | 1.0 | 5.0 | 2.0 | 2.0 |

Summary: "This table charts seasonal Daytime Bowen Ratios for different types of land use. The first column contains the type of land use, and the next four columns contain spring, summer, autumn and winter values respectively. This table is for Wet Precipitation Conditions."

### 5.4.1 Wind Direction Dependent Land Use

AERMET also provides the ability to specify land characteristics for up to 12 different contiguous, non-overlapping wind direction sectors that define unique upwind surface characteristics. The following properties of wind sectors must be true:

- The sectors are defined clockwise as the direction *from which the wind is blowing*, with north at 360°.
- The sectors must cover the full circle so that the end value of one sector matches the beginning of the next sector.
- The beginning direction is considered part of the sector, while the ending direction is not.

Each wind sector can have a unique albedo, Bowen ratio, and surface roughness. Furthermore, these surface characteristics can be specified annually, seasonally, or monthly to better reflect site conditions.

### 5.4.2 Mixed Land Use Types

Study areas may contain several different regions with varying land use. This can be handled by AERMET through the use of wind sector specific characterization, as described in the previous section.

For models such as ISC-PRIME that do not take advantage of sector-specific characterization, the most representative conditions should be applied when land use characteristics are required.

The approach taken by the Ontario Ministry of the Environment in the generation of the Regional meteorological data sets can also be performed for local meteorological data pre-processing. This approach assumes that surface conditions are the weighted average over a radius of 3 km from the facility in all directions.

This is performed by assessing the land use across the facility study area and applying the appropriate values to the land characteristic parameters. A weighted average is then computed based on the area of each land use category.

### 5.4.3 Seasonal Land Use Characterization

Land use characteristics can be susceptible to seasonal variation. For example, winter conditions can bring increased albedo values due to snow accumulation.

AERMET allows for season-specific values for surface roughness, albedo, and Bowen ratio to be defined. Other models, such as ISC-PRIME, do not support multiple season surface characteristics to be defined. In such a case, the most representative conditions should be applied when land use characteristics are required.

### 5.4.4 Standard and Non-Default Surface Characteristics

The generation of local meteorological data files can incorporate site-specific surface characteristics. It should be noted that any local meteorological files generated for air dispersion modelling should provide a clear reasoning for the values used to describe surface characteristics. The regulatory agency should review the proposed surface characteristics prior to submission of a modelling report.

### 5.4.5 Defining Urban and Rural Conditions

The classification of a site as urban or rural can be based on the Auer method specified in the EPA document *Guideline on Air Quality Models (40 CFR Part 51, Appendix W).*[(34)] From the Auer's method, areas typically defined as **Rural** include:

- Residences with grass lawns and trees
- Large estates
- Metropolitan parks and golf courses
- Agricultural areas
- Undeveloped land
- Water surfaces

Auer defines an area as **Urban** if it has less than 35% vegetation coverage or the area falls into one of the following use types:

| **Urban Land Use** | | |
|---|---|---|
| **Type** | **Use and Structures** | **Vegetation** |
| I1 | Heavy industrial | Less than 5 % |
| I2 | Light/moderate industrial | Less than 5 % |
| C1 | Commercial | Less than 15 % |
| R2 | Dense single / multi-family | Less than 30 % |
| R3 | Multi-family, two-story | Less than 35 % |

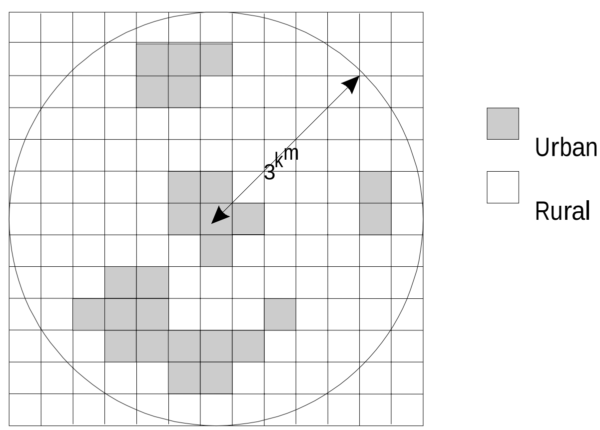
Summary: "This table classifies land use and percentage vegetation into an urban land use type, as defined by Auer above. The first column contains the land use type; the second column defines the land use and structures; and the third column defines the maximum percentage vegetation for that type."

Follow the Auer's method, explained below, for the selection of either urban or rural dispersion coefficients:

**Step 1:** Draw a circle with a radius of 3 km from the center of the s tack or centroid of the polygon formed by the facility stacks.

**Step 2:** If land use types I1, I2, C1, R2, and R3 account for 50 % or more of the area within the circle, then the area is classified as **Urban**, otherwise the area is classified as **Rural**.

To verify if the area within the 3 km radius is predominantly rural or urban, overlay a grid on top of the circle and identify each square as primarily urban or rural. If more than 50 % of the total number of squares is urban than the area is classified as urban; otherwise the area is rural.[35]




An alternative approach to Urban/Rural classification is the **Population Density Procedure:** Compute the average population density, ***p***, per square kilometer with ***A***o as defined above,

(a) If ***p*** > 750 people/km$^2$, select the **Urban** option,

(b) If ***p*** <= 750 people/km$^2$, select the **Rural** option.

Of the two methods above, the land use procedure is considered a more definitive criterion. The population density procedure should be used with caution and should not be applied to highly industrialized areas where the population density may be low and thus a rural classification would be indicated, but the area is sufficiently built-up so that the urban land use criteria would be satisfied. In this case, the classification should already be **Urban** and **Urban** dispersion parameters should be used.

# 6. METEOROLOGICAL DATA

## 6.1 Comparison of Screening and Refined Model Requirements

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

SCREEN3 provides 3 methods of defining meteorological conditions:

1. **Full Meteorology:** SCREEN will examine all six stability classes (five for urban sources) and their associated wind speeds. SCREEN 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.

2. **Single Stability Class:** The modeller can select the stability class to be used (A through F). SCREEN will then examine a range of wind speeds for that stability class only.

3. **Single Stability Class and Wind Speed:** The modeller can select the stability class and input the 10-meter wind speed to be used. SCREEN will examine only that particular stability class and wind speed.

## 6.2 Preparing Meteorological Data for Refined Modelling

AERMOD and ISC models require actual hourly meteorological conditions as inputs. The refined models require pre-processed meteorological data that contains information on surface characteristics and upper air definition. This data is typically provided in a raw or partially processed format that requires processing through a meteorological pre-processor. The ISC models make use of a pre-processor called PCRAMMET, while AERMOD uses a pre-processor known as AERMET described further in the following sections.

### 6.2.1 Hourly Surface Data

Hourly surface data is supported in several formats including:

1. **CD-144 – NCDC Surface Data:** This file is composed of one record per hour, with all weather elements reported in an 80-column card image. Table 6.1 lists the data contained in the CD-144 file format that is needed to pre-process your meteorological data.
2.

**Table 6.1** – CD-144 Surface Data Record (80 Byte Record)

| Element | Columns |
|---|---|
| Surface Station Number | 1-5 |
| Year | 6-7 |
| Month | 8-9 |
| Day | 10-11 |
| Hour | 12-13 |
| Ceiling Height (Hundreds of Feet) | 14-16 |
| Wind Direction (Tens of Degrees) | 39-40 |
| Wind Speed (Knots) | 41-42 |
| Dry Bulb Temperature (°Fahrenheit) | 47-49 |
| Opaque Cloud Cover | 79 |

Summary: "This table identifies the column numbers that contain each element defined in the CD-144 Surface Data Record. The first column contains the data element, and the second column contains the range of columns where that element is located in the record. For example, every record is a row of data and consists of 80 columns. The Surface Station Number is located in columns 1 to 5 of that record (row); followed by Year which is located in columns 6 and 7; etc. (i.e., SSSSSYYMMDDHH…)."

3. **MET-144 – SCRAM Surface Data:** The SCRAM surface data format is a reduced version of the CD-144 data with fewer weather variables (28-character record). Table 6.2 lists the data contained in the SCRAM file format.

**Table 6.2 -** SCRAM Surface Data Record (28 Byte Record)

| Element | Columns |
|---|---|
| Surface Station Number | 1-5 |
| Year | 6-7 |
| Month | 8-9 |
| Day | 10-11 |
| Hour | 12-13 |
| Ceiling Height (Hundreds of Feet) | 14-16 |
| Wind Direction (Tens of Degrees) | 17-18 |
| Wind Speed (Knots) | 19-21 |
| Dry Bulb Temperature (° Fahrenheit) | 22-24 |
| Total Cloud Cover (Tens of Percent) | 25-26 |
| Opaque Cloud Cover (Tens of Percent) | 27-28 |

Summary: "This table identifies the column numbers that contain each element defined in the SCRAM Surface Data Record. The first column contains the data element, and the second column contains the range of columns where that element is located in the record (as described for the previous table)."

The SCRAM data do not contain the following weather variables, which are necessary for dry and wet particle deposition analysis:

1. **Surface pressure:** for dry and wet particle deposition;
2. **Precipitation type:** for wet particle deposition only; or
3. **Precipitation amount:** for wet particle deposition only.

3. **SAMSON Surface Data:** The SAMSON data contains all of the required meteorological variables for concentration, dry and wet particle deposition, and wet vapor deposition.

If the processing of raw data is necessary, the surface data must be in one of the above formats in order to successfully pre-process the data using PCRAMMET or AERMET. Canadian hourly surface data can be obtained from Environment Canada. Regional preprocessed meteorological data sets can be obtained from the Ontario Ministry of the Environment.

### 6.2.2 Mixing Height and Upper Air Data

Upper air data, also known as mixing height data, are required for pre-processing meteorological data required to run the ISC-PRIME models. It is recommended that only years with complete mixing height data be used. In some instances, mixing height data may need to be obtained from more than one station to complete multiple years of data.

Mixing height data are available from:

1. **SCRAM BBS –** download free of charge, mixing height data for the U.S. for years 1984 through 1991.

2. **Environment Canada –** purchase mixing height data for appropriate regions.

3. **WebMET.com –** download free of charge, mixing height and upper air data from across North America, including Ontario.

Table 6.3 lists the format of the mixing height data file used by PCRAMMET.

**Table 6.3** - Upper Air Data File (SCRAM / NCDC TD-9689 Format)

| Element | Columns |
|---|---|
| Upper Air Station Number (WBAN) | 1-5 |
| Year | 6-7 |
| Month | 8-9 |
| Day | 10-11 |
| AM Mixing Value | 14-17 |
| PM Mixing Value (NCDC) | 25-28 |
| PM Mixing Value (SCRAM) | 32-35 |

Summary: “This table identifies the column numbers that contain each element defined in the Upper Air Data File. The first column contains the data element, and the second column contains the range of columns where that element is located in the record (as described for the previous table 6.2).”

AERMOD requires the full upper air sounding, unlike ISC-PRIME, which only require the mixing heights. The upper air soundings must be in the NCDC TD-6201 file format or one of the FSL formats. This data is readily available from the Ontario Ministry of Environment.

### 6.2.3 AERMET and the AERMOD Model

The AERMET program is a meteorological preprocessor which prepares hourly surface data and upper air data for use in the U.S. EPA air quality dispersion model AERMOD. AERMET was designed to allow for future enhancements to process other types of data and to compute boundary layer parameters with different algorithms.

AERMET processes meteorological data in three stages:

1. The first stage (Stage1) extracts meteorological data from archive data files and processes the data through various quality assessment checks.

2. The second stage (Stage2) merges all data available for 24-hour periods (surface data, upper air data, and on-site data) and stores these data together in a single file.

3. The third stage (Stage3) reads the merged meteorological data and estimates the necessary boundary layer parameters for use by AERMOD.

Out of this process two files are written for AERMOD:

1. A Surface File of hourly boundary layer parameters estimates;

2. A Profile File of multiple-level observations of wind speed, wind direction, temperature, and standard deviation of the fluctuating wind components.

### 6.2.4 PCRAMMET and the ISC Models

The PCRAMMET program is a meteorological preprocessor which prepares NWS data for use in the various U.S. EPA air quality dispersion models such as ISC-PRIME.

PCRAMMET is also used to prepare meteorological data for use by the CAL3QHCR model, and for use by the CALPUFF puff dispersion model when used in screening mode.

The operations performed by PCRAMMET include:

- Calculating hourly values for atmospheric stability from meteorological surface observations;

- Interpolating the twice daily mixing heights to hourly values;

- Optionally, calculating the parameters for dry and wet deposition processes;

- Outputting data in the standard (PCRAMMET unformatted) or ASCII format required by regulatory air quality dispersion models.

The input data requirements for PCRAMMET depend on the dispersion model and the model options for which the data is being prepared. The minimum input data requirements for PCRAMMET are:

- The twice-daily mixing heights,
- The hourly surface observations of: wind speed, wind direction, dry bulb temperature, opaque cloud cover, and ceiling height.

For dry deposition estimates, station pressure measurements are required. For wet deposition estimates, precipitation type and precipitation amount measurements for those periods where precipitation was observed are required.

The surface and upper air stations should be selected to ensure they are meteorologically representative of the general area being modelled.

## 6.3 MOE Regional Meteorological Data

The Ministry has prepared regional meteorological data sets for use in Tier 2 modelling in several formats:

- o Regional pre-processed model ready data for AERMOD, with land characteristics for CROP, RURAL and URBAN conditions.

- o Regional Merge files enabling customized surface characteristics to be specified and processed through AERMET Stage3.

- o Hourly surface data and upper air data files allowing for complete processing through AERMET.

The above data sets are available online and provide a unique, easily accessible resource for air dispersion modellers in the province of Ontario. The availability of standard meteorological data will reduce inconsistencies in data quality and requests to the regulatory agency on obtaining data.

The surface meteorological sites used were Toronto (Pearson Airport), London, Sudbury and Ottawa along with International Falls, MN and Massena, NY. The following meteorological elements were used in AERMET processing for the 5 year period from 1996 to 2000: ceiling height, wind speed, wind direction, air temperature, total cloud opacity and total cloud amount.

The upper air stations used were Maniwaki, QU, White Lake, MI, Buffalo, NY, Albany, NY and International Falls, MN. Table 6.4 gives the locations of the surface meteorological sites and lists the upper air station used for each site. The locations of the upper air sites are given in Table 6.5.

**Table 6.4 -** Surface meteorological sites location and upper air stations to use.

| Surface station | ID | Latitude | Longitude | Height above sea level, m | Province/ State | UA to use |
|---|---|---|---|---|---|---|
| SUDBURY | 6068150 | 46.62 | -80.8 | 348 | ONT | White Lake |
| OTTAWA | 6106000 | 45.32 | -75.67 | 114 | ONT | Maniwaki |
| LONDON | 6144475 | 43.03 | -81.15 | 278 | ONT | White Lake |
| TORONTO | 6158733 | 43.67 | -79.6 | 173 | ONT | Buffalo |
| MASSENA | 72622 (94725) | 44.9 | -74.9 | 65 | NY | Albany |
| INT. FALLS | 72747 (14918) | 48.57 | -93.37 | 359 | MN | Int. Falls |

Note: Anemometer height is 10 meters for all stations

Summary: "This table charts the meteorological site information and related upper air stations for Ontario's meteorological Surface Stations. The First column defines the name of the Surface Station, which is associated with the city where the station is located. The second column is the station identification number. The third and fourth columns are the geographical latitude and longitude defining the location of the surface station respectively. The fifth column defines the altitude or Height of that particular station above sea level (in meters), and the sixth column contains the abbreviation of the province (if in Canada) or the State (if in the United States) where the station is located. The last column (seventh column) contains the name of the upper air station name that is to be used for each of the given surface stations. Finally, all stations have an anemometer height of 10 meters."

**Table 6.5** - The location of upper air sites.

| UA station | ID | Latitude | Longitude |
|---|---|---|---|
| Buffalo | 725280 | 42.93 | -78.73 |
| Maniwaki | 7034480 | 46.23 | -77.58 |
| Albany | 725180 | 42.75 | -73.8 |
| White Lake | 726320 | 42.7 | -83.47 |
| Int. Falls | 727470 | 48.57 | -93.37 |

Summary: "This table provides the details of the upper air stations that are referenced in the table above. The table charts the upper air station name in the first column, and lists the Station Identification Number (ID), latitude and longitude for each station in second, third and fourth columns respectively."

### 6.3.1 Pre-Processing Steps

The MOE Regional data for AERMOD is provided in 2 forms:

- **Merged:** Data has been processed through Stage2 of AERMET (AERMET stages are described in Section 6.2.3) to produce a "Merge" file. This file can then be processed through AERMET Stage3 with custom surface condition data to produce a meteorological data set specific to the site for use with AERMOD (Tier 3).

- **Regional:** Data has been processed through Stage3 of AERMET with predefined Land Use characteristics for "Urban", Forest", and Crop" environments. The data is ready for use with AERMOD (Tier 2).

#### 6.3.1.1 Regional Meteorological Data Processing Background

Regional meteorological datasets are generated in AERMET, Stage3 processing step, using different wind independent surface conditions, called "URBAN", "FOREST", "CROPS". It is assumed that surface conditions are the weighted average over a radius of 3 km from the facility in all directions. The surface conditions needed are the albedo (A), the Bowen ratio (Bo) and the surface roughness (Zo). The parameter values in Table 6.6, Table 6.7, and Table 6.8 below were derived from data in Tables 4.1, 4.2b (albedo for average conditions) and 4.3 of the AERMET User's Guide.(8)

"URBAN" – all surface parameters are set to urban values, as in Table 6.6.

**Table 6.6 -** URBAN surface conditions.

| SEASON | PARAMETER | | |
|---|---|---|---|
| | **A** | **Bo** | **Zo** |
| Winter | 0.35 | 1.5 | 1 |
| Spring | 0.14 | 1 | 1 |
| Summer | 0.16 | 2 | 1 |
| Fall | 0.18 | 2 | 1 |

Summary: "This table charts Urban surface condition parameter values for each season. The first column lists the four seasons, and the subsequent three columns list the Albedo, the Bowen and the Surface Roughness ratios for each season respectively."

"FOREST" – all surface parameters are set to the mixture of coniferous and deciduous forests in the ratio (50%)/(50%) as in Table 6.7.

**Table 6.7 -** FOREST surface conditions.

| SEASON | PARAMETER | | |
|---|---|---|---|
| | **A** | **Bo** | **Zo** |
| Winter | 0.42 | 1.5 | 0.9 |
| Spring | 0.12 | 0.7 | 1.15 |
| Summer | 0.12 | 0.3 | 1.3 |
| Fall | 0.2 | 0.9 | 1.05 |

Summary: "This table charts Forest surface condition parameter values for each season. The first column lists the four seasons, and the subsequent three columns list the Albedo, the Bowen and the Surface Roughness ratios for each season respectively."

"CROPS" – all surface parameters are set to the mixture of Grassland, Cultivated Land, Coniferous and Deciduous forest in the ratio: (45%)/(45%)/(5%)/(5%) as in Table 6.8.

**Table 6.8** - CROPS surface conditions.

| SEASON | PARAMETER | | |
|---|---|---|---|
| | **A** | **Bo** | **Zo** |
| Winter | 0.6 | 1.5 | 0.095 |
| Spring | 0.16 | 0.35 | 0.15 |
| Summer | 0.19 | 0.65 | 0.265 |
| Fall | 0.19 | 0.85 | 0.13 |

Summary: "This table charts Crops surface condition parameter values for each season. The first column lists the four seasons, and the subsequent three columns list the Albedo, the Bowen and the Surface Roughness ratios for each season respectively."

### 6.3.2 Availability and Use of Ministry of Environment Meteorological Data

The Ministry of Environment meteorological datasets in pre-processed, merge, and unprocessed formats are freely available online at WebMET.com: http://www.webmet.com/Canada/Ontario/

The Ministry of Environment meteorological data provides a standard data set that can be used for air quality studies using AERMOD. The regional data sets should not be modified. Use of custom meteorological data that is locally representative of site conditions can be created and applied for Tier 3 modelling analyses.

The application of the regional meteorological data sets across Ontario is described in Table 6.9. This table lists the MOE region and districts for which each of the meteorological data sets is most applicable. A map of the districts can be found in Figure 6.1.

**Table 6.9 -** Application of regional meteorological data sets for MOE regions and districts.

| Meteorological Data Set | MOE Region | MOE District/Area |
|---|---|---|
| Toronto | Central | Toronto, York-Durham, Halton-Peel |
| | Southwestern | Barrie, Owen Sound |
| London | Southwestern | London, Windsor, Sarnia |
| | West Central | Hamilton, Niagara, Guelph |
| Ottawa | Eastern | Ottawa, Peterborough, Belleville |
| Sudbury | Northern | Sudbury, North Bay, Sault Ste. Marie, Timmins |
| Int. Falls | Northern | Thunder Bay, Kenora |
| Massena | Eastern | Kingston, Cornwall |

Summary: "This table lists the six (6) meteorological data sets available in the first column, and the corresponding Ministry of the Environment Region in the second column. The third column lists the Ministry district or area offices that are located within each of the defined regions. To select the applicable Meteorological data set, identify the city in the third column that is either the city, or is closest to the city, where the facility being modelled is located."

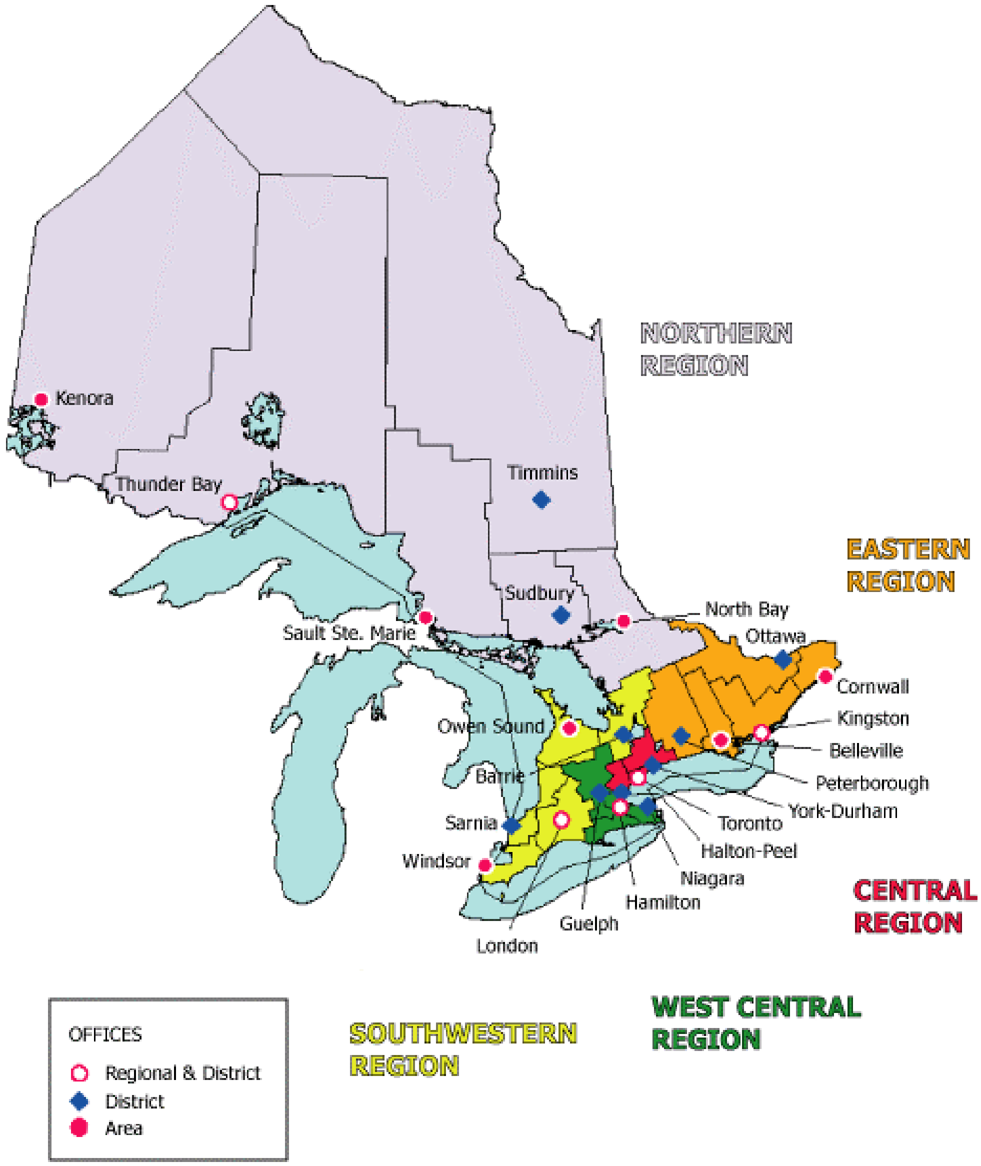



**Figure 6.1** – Ontario Ministry of Environment Regions and their offices.

## 6.4 Data Assessment: Reliability, Completeness and Representativeness

Meteorological data quality is of critical importance, particularly for reliable air dispersion modelling using refined models such as AERMOD. Meteorological data should be collected, processed and analyzed throughout the entire creation phase for completeness and quality control. Missing meteorological data and calm wind conditions can be handled in an approach similar to that used for the generation of the regional meteorological data sets. For all calm conditions (where the wind speed and wind direction are equal to zero) the wind direction is set to a missing value. Hours with zero or very low wind speeds are set to minimum speeds of ≈ 1 m/s.

For each meteorological element linear interpolation was then applied if the number of the missing hours is up to six in a row. Missing data at the very beginning and at the very end of the data set are left as “missing” (no extrapolation is applied). If the number of consecutive hours with missing values for the element is more then 6, the values are left as ”missing”.

There are four factors that affect the representativeness of the meteorological data. These are: 1) the proximity of the meteorological site to the area being modelled, 2) the complexity of the terrain, 3) the exposure of the meteorological measurement site and 4) the time period of the data collection. It should be emphasized that *representativeness* (both spatial and temporal) of the data is the key requirement. One factor alone should not be the basis for deciding on the representativeness of the data.

The meteorological data that is input to a model should be selected based on its appropriateness for the modelling project. More specifically, the meteorological data should be representative of the wind flow in the area being modelled, so that it can properly represent the transport and diffusion of the pollutants being modelled.

## 6.5 Expectations for Local Meteorological Data Use

Local meteorological data must be quality reviewed and the origin of the data and any formatting applied to the raw data must be outlined. The regulatory agency should review the plans to use local meteorological data prior to submission of a modelling report.

The sources of all of the data used including cloud data and upper air data must be documented. The proponent also needs to describe why the site chosen is representative for the modelling application. This would include a description of any topographic impacts or impacts from obstructions (trees, buildings etc.) on the wind monitor. Information on the heights that the wind is measured is also required. The time period of the measurements along with the data completeness and the percentage of calm winds should be reported.

In preparing regional meteorological data sets, the Ministry treated calms winds and missing data as described in Section 6.4. A discussion of the data QA/QC along with the treatment of calm wind and missing data is needed if local meteorological data is processed.

Wind roses showing the wind speed and directions should be provided with the modelling assessment. If wind direction dependent land use was used in deriving the final meteorological file, the selection of the land use should be described.

## 7. RECEPTOR LOCATIONS

The ISC and AERMOD series of air dispersion models compute the concentrations of substances based on user-specified spatial points. Modellers commonly refer to these points as receptors. Receptor selection is critical to capturing the maximum point of impact and proper placement of receptors can be achieved through several approaches. The types of receptors and receptor grids are described below followed by a discussion on the grid extents and receptor densities required to capture maximum concentrations.

### 7.1 Receptor Types

The refined models, AERMOD and ISC-PRIME, support a variety of receptor types that allow for considerable user control over calculating pollutant concentrations. The major receptor types and grid systems are described in the following sub-sections. Further details on additional receptor types can be found in the appropriate documentation for each model.

#### 7.1.1 Cartesian Receptor Grids

Cartesian receptor grids are receptor networks that are defined by an origin with receptor points evenly (uniform) or unevenly (non-uniform) spaced receptor points in x and y directions. Figure 7.1 illustrates a sample uniform Cartesian receptor grid.

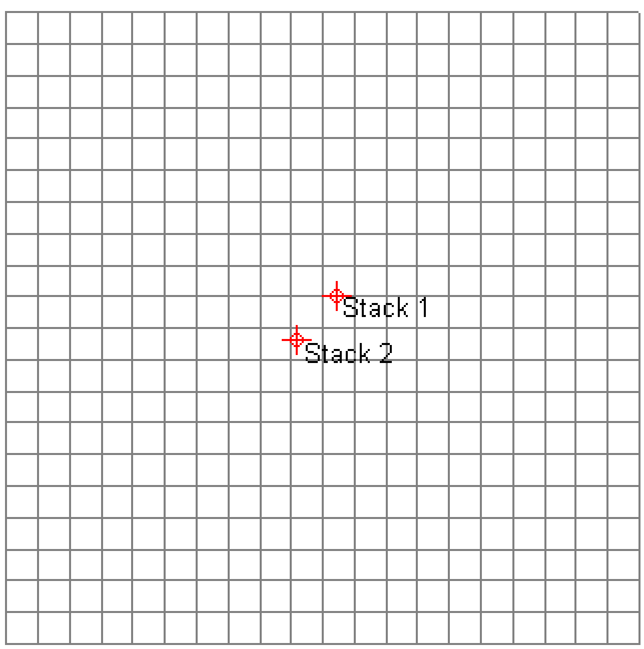



**Figure 7.1** – Example of a Cartesian grid.

### 7.1.2 Polar Receptor Grids

Polar receptor grids are receptor networks that are characterized by an origin with receptor points defined by the intersection of concentric rings, which have defined distances in meters from the origin, with direction radials that are separated by a specified degree spacing.  Figure 7.2 illustrates a sample uniform polar receptor grid.

Polar grids are a reasonable choice for facilities with only one source or one dominant source.  However, for facilities with a number of significant emissions sources, receptor spacing can become too coarse when using polar grids.  As a result, polar grids should generally be used in conjunction with another receptor grid, such as a multi-tier grid, to ensure adequate spacing.

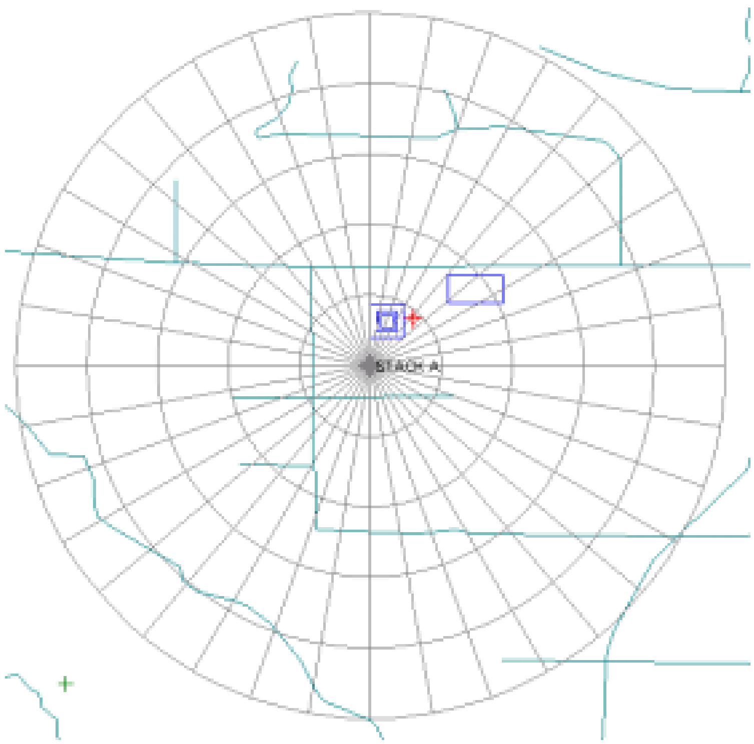


**Figure 7.2** – Example of a polar grid.

### 7.1.3 Multi-Tier Grids

Each receptor point requires computational time.  Consequently, it is not optimal to specify a dense network of receptors over a large modelling area; the computational time would negatively impact productivity and available time for proper analysis of results.  An approach that combines aspects of coarse grids and refined grids in one modelling run is the multi-tier grid.

The multi-tier grid approach strives to achieve proper definition of points of maximum impact while maintaining reasonable computation times without sacrificing sufficient resolution. Figure 7.3 provides an example of a multi-tier grid.

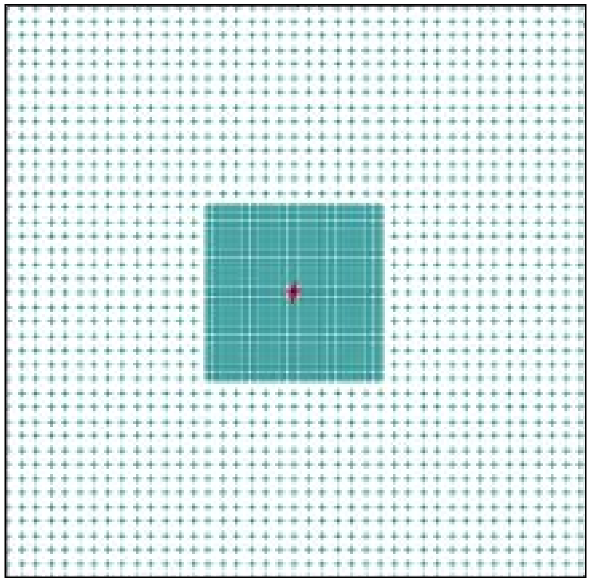


**Figure 7.3** - Sample Multi-Tier Grid with 2 tiers of spacing.

### 7.1.4 Fenceline Receptors

With the exception of self-contamination scenarios, dispersion modelling for on-site receptors, or within the property boundary, is not necessary. As a result property boundaries are typically delineated in projects and model results are not required for those areas. However, receptors must be placed along the plant boundary to demonstrate compliance at the nearest reportable geographical locations to the sources.

A receptor network based on the shape of the property boundary that has receptors parallel to the boundaries is often a good choice for receptor geometry. The receptor spacing can then progress from fine to coarse spacing as distance increases from the facility, similar to the multi-tier grid.

### 7.1.5 Discrete & Sensitive Receptors

Receptor grids do not always cover precise locations that may of interest in modelling projects. Specific locations of concern can be modelled by placing single receptors, or additional refined receptor grids, 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 found at ground level.

Common locations of sensitive receptors can include, among others, the following:

- Apartments
- Residential zones
- Schools
- Apartment buildings
- Day care centers
- Air intakes on nearby buildings
- Hospitals
- Parks

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

## 7.2 Minimum Receptor Requirements for Capturing and Assessing Maxima

Receptor definition must ensure coverage to capture the maximum pollutant concentration. For facilities with more than one emission source, the receptor network should include Cartesian or multi-tier grids to ensure that maximum concentrations are obtained. Screening model runs (i.e., SCREEN3, AERSCREEN) for the most significant sources on a facility can be used to determine the extent of the receptor grids. Tall stacks could require grids extending 20 to 25 km while ground level maxima for emissions from shorter stacks (10 - 20 m) might be obtained using grids extending a km or less from the property line.

The densities of the receptors can progress from fine resolution near the source, centroid of the sources, or most significant source (not from the property line) to coarser resolution farther away. Model runs with the below receptor densities would ensure that maximum ground level off property concentrations are captured:

- 20 m spacing within 200 m of the emission sources, centroid of sources, or major sources
- 50 m spacing from 200 to 500 m
- 100 m spacing from 500 to 1000 m
- 200 m spacing from 1000 to 2000 m
- 500 m spacing from 2000 to 5000 m
- 1000 m spacing beyond 5000 m

The model could be first run with a coarser grid and then run with finer grids in the areas showing the highest impacts. If this method were used, finer grids, as described above, should be used for all areas with high concentrations not just the single highest area. Figure 7.4 illustrates the application of the above receptor densities to a sample site.

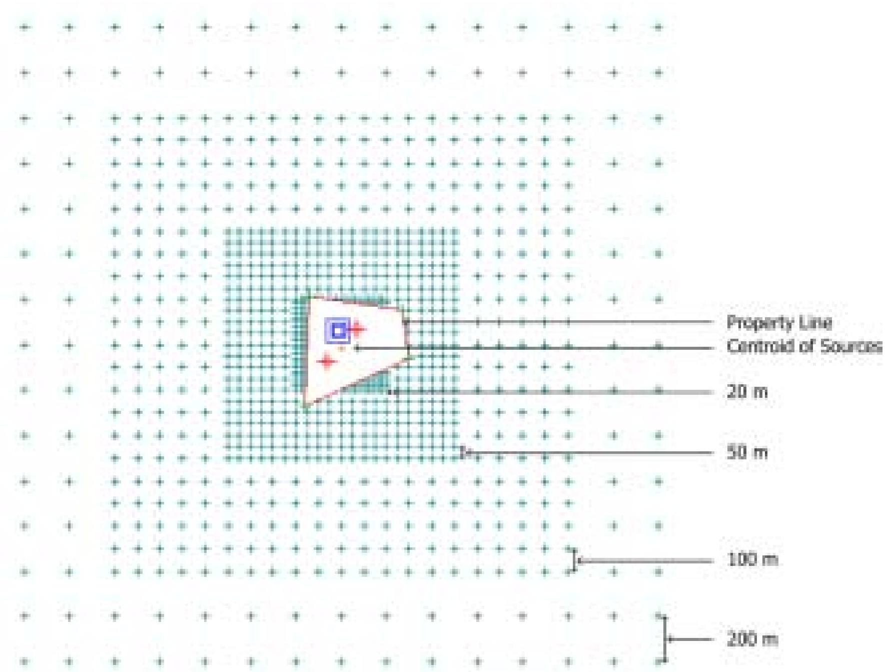



**Figure 7.4** – Sample receptor grid layout for capturing maxima.

Receptors should also be placed along the property boundaries. The spacing of these receptors depends on the distance from the emission sources to the facility boundaries. For cases with emissions from short stacks or vents and a close property line, a receptor spacing of 10 m might be required. For other distances the spacing described above could be used.

Discrete receptors are required at locations where there are elevated points of impact such as apartment buildings and air intakes on nearby buildings. These are needed to ensure that maximum impacts are obtained. Other discrete receptors are required for sensitive receptors such as schools and hospitals.

The above are minimal requirements to aid the modeller in defining adequate receptor coverage. The final extent and details are the responsibility of the modeller who must demonstrate that the maximum has been reached and ensure the levels have dropped well below the standard and/or the guideline of the contaminant being studied. Certain stack characteristics, such as tall stacks, may inherently require larger receptor coverage.

# 8. OTHER MODELLING CONSIDERATIONS

## 8.1 Explanation for Alternative Model Use

Due to some limitations inherent in AERMOD (and most other plume models), there are some situations where the use of an alternative model may be appropriate. Acceptable Alternative Models and their use are further described in Appendix A.

AERMOD is a steady-state plume model. For the purpose of calculating concentrations, the plume is assumed to travel in a straight line without significant changes in stability as the plume travels from the source to a receptor. At distances on the order of tens of kilometers downwind, changes in stability and wind are likely to cause the accuracy to deteriorate. For this reason, AERMOD should not be used for modelling at receptors beyond 50 kilometers. AERMOD may also be inappropriate for some near-field modelling in cases where the wind field is very complex due to terrain or a nearby shoreline.

AERMOD does not treat the effects of shoreline fumigation. Shoreline fumigation may occur along the shore of the ocean or large lake. When the land is warmer than the water, a sea breeze forms as the warmer, lighter air inland rises. As the stable air from over the water moves inland, it is heated from below, resulting in a turbulent boundary layer of air that rises with downwind distance from the shoreline. The plume from a stack source located at the shoreline may intersect the turbulent layer and be rapidly mixed to the ground, a process called "fumigation," resulting in high concentrations. In these and other situations, the use of alternative models may be desired.

The use of any alternative model should first be reviewed by the regulatory agency for suitability to the study application. If an alternative model is used the reasons and argument for its use over a preferred model must be discussed. An understanding of the alternative model, its data requirements, and the quality of data applied with the model must be demonstrated.

## 8.2 Use of Modelled Results in Combination with Monitoring Data

Monitoring and modelling should be considered complementary assessment tools to assess potential impacts on the local community.

Monitoring data could be used to provide verification of model results if sufficient monitoring data is available at locations impacted by facility emissions. Decisions on the adequacy of the monitoring data would be made on a case-by-case basis. Comparisons between measured and modelled results would depend on the amount of monitored data available. Pre-consultation with the regulatory agency is advisable if a comparison of model results with monitoring data is undertaken.

If model results do not agree with measured data, the facility source characteristics and emission data should be reviewed.

For cases where reliable information is available on the emission rates and source characteristics for a facility, modelled results can identify maximum impact areas and concentration patterns that could assist in locating monitoring sites. Model runs using a number of years of meteorological data would show the variations in the locations and the magnitude of maximum concentrations and can also provide information on the frequency of high concentrations.

The U.S. EPA Guideline on Air Quality Models states that modelling is the preferred method for determining concentrations and that monitoring alone would normally not be accepted for determining emission limitations.

When monitoring data are used to verify modelling results for averaging times from 1 to 24 hours, more robust comparisons would be achieved using a percentile of the data rather than only the maximum concentrations. Percentile comparisons reduce the impacts of outliers in either the monitoring or the model results. For some contaminants, the impact of background sources on measured concentrations might need to be taken into consideration.

## 8.3 Information for Inclusion in a Modelling Assessment

A suggested checklist designed to provide an overview of all information that should be submitted for a refined air dispersion modelling assessment is outlined in Appendix B.

The checklist should not be considered exhaustive for all modelling studies – it provides the essential requirements for a general assessment. All sites can have site-specific scenarios that may call for additional information and result in a need for different materials and data to be submitted.

It is the responsibility of the submitter to ensure proper completion and analysis of any air dispersion modelling assessment delivered for review.

## 9. 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:** **A**merican Meteorological Society/**E**nvironmental Protection Agency **R**egulatory **M**odel **I**mprovement **C**ommittee.

**AERMOD:** A new air dispersion model developed by AERMIC. It is intended to replace the ISCST model.

**Air Emissions:** Release of pollutants into the air from a source.

**Albedo:** Portion of the incoming solar radiation reflected and scatter back to space.

**Ambient Air:** Air that is accessible to the public.

**AMS:** American Meteorological Society.

**AP-42:** EPA Document Number AP-42, *Compilation of Air Pollutant Emission Factors*, Environmental protection Agency, Research Triangle Park, North Carolina. Supplements are published regularly. This document includes process description and emission factors for a broad range of criteria pollutant emission sources.

**Background Concentration:** Concentration already present and due to natural or man made sources.

**Calm:** Cessation of horizontal wind.

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

**Dalton's Law of Particles Pressures:** Each gas in a gaseous mixture exert pressure independently of the others. The partial pressure of each gas is proportional to its volume fraction in the mixture.

**DEM –** Digital Elevation Model. Digital files that contain terrain elevations typically at a consistent interval across a standard region of the Earth's surface.

**Dispersion Model:** A group of related mathematical algorithms used to estimate (model) the dispersion of pollutants in the atmosphere due to transport by the mean (average) wind and small scale turbulence.

**Diurnal:** Daytime period.

**Emission Factor:** An estimate of the rate at which a pollutant is released to the atmosphere

**Episode:** High increase in pollution levels caused by stagnation.

**Flagpole Receptor:** Any receptor located above ground level.

**Fugitive Dust:** Dust discharged to the atmosphere in a stream such as that from unpaved roads, storage piles and heavy construction operations.

**GMT:** Greenwich Mean Time, the time at the 0 $^{o}$ meridian.

**Graham's Law:** The diffusion rate of the gas on another is inversely proportional to the square root of their densities.

$$\frac{Dg_1}{\sqrt{\rho g_2}} = \frac{Dg_2}{\sqrt{\rho g_1}}$$

**HAP:** Hazardous air pollutant.

**Henry's Law:** The weight of a gas dissolved in a liquid is proportional to the pressure that it exerts above the liquid.

$C_g = k_H * P_g$

Where,

| | | |
|---|---|---|
| $C_g$ | = | Concentration of gas in liquid |
| $k_H$ | = | Henry's Constant |
| $P_g$ | = | Gas Pressure above the liquid |

**Henry's Constant:** Constant that correlates the Pressure of gas, above the liquid, and its concentration on the liquid.

**Inventory**: A compilation of source, control device, emissions and other information relating to sources of a pollutant or group of pollutants.

**Inversion:** An increase in ambient air temperature with height. This is the opposite of the usual case.

**IRIS:** Integrated Risk Information System Database.

**ISCST:** Industrial Source Complex – Short Term Dispersion Model.

**Lee side:** The lee side of a building is the side that is sheltered from the wind.

**Mixing Height:** Top of the neutral or unstable layer and also the depth through which atmospheric pollutants are typically mixed by dispersive processes.

**MOE:** Ontario Ministry of the Environment.

**Monin-Obukhov Length:** A constant, characteristic length scale for any particular example of flaw. It is negative in unstable conditions (upward heat flux), positive for stable conditions, and approach infinity as the actual lapse rate for ambient air reaches the dry adiabatic lapse rate.

**MSDS:** Material Safety Data Sheet.

**NWS:** National Weather Service. A U.S. government organization associated with the National Oceanic and Atmosphere Administration.

**Pasquill Stability Categories:** A classification of the dispersive capacity of the atmosphere, originally defined using surface wind speed, solar insolation (daytime) and cloudness (night time). They have since been reinterpreted using various other meteorological variables.

**PCRAMMET:** Meteorological program used for regulatory applications capable of processing twice-daily mixing heights (TD-9689 FORMAT) and hourly surface weather observations (CD-144 format) for use in dispersion models such as ISCST, CRSTER, MPTER and RAM.

**Potential Temperature:** Useful concept in determining stability in the atmosphere. It identifies the dry adiabatic to which a temperature and pressure is related.

If $\theta$ increases with height$\rightarrow$stable$\rightarrow$atmosphere

If $\theta$ decreases with height$\rightarrow$unstable$\rightarrow$atmosphere

$\theta = T * (P/P_o)^{0.286}$

Where:

$T$ = temperature [degrees kelvin]

$P_o$ = reference pressure = 1000 milli-bar

$P$ = point pressure [milli-bar]

The temperature a gas would have if it were compressed, or expanded, adiabatically from a given state (P,T) to a pressure of 1000mb.

**Preferred Model:** A refined model that is recommended for a specific type of regulatory application.

**Primary Pollutant:** Substance emitted from the source.

**Regulatory Model:** A dispersion model that has been approved for use by the regulatory offices of the U.S. EPA, specifically one that included in Appendix A of the Guideline on Air Quality Models (Revised), such as the ISC model.

**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 Terrain:** An area where terrain features are all lower in elevation than the top of the stack of the source.

**Stagnation:** A calm lasting more then 36 hours.

**Upper Air Data (or 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.

**Vertical Potential Temperature Gradient:** The change of potential temperature with height, used in modelling the plume rise through a stable layer, and indicates the strength of the stable temperature inversion. A positive value means that potential temperature increases with height above ground and indicates a stable atmosphere.

**Wind Profile Component:** The value of the exponent used to specify the profile of wind speed with height according to the power law.

**Worst Case:** The maximum exposure, dose, or risk that can conceivably happen to specific receptors.

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## 11. NOTE ON MATERIAL SOURCES

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# APPENDIX A

# ALTERNATIVE MODELS

# APPENDIX A: ALTERNATIVE MODELS

## 1. ACCEPTABLE ALTERNATIVE MODELS

The following list contains alternative models that are currently accepted by the Ministry of Environment (MOE) for consideration.

- CALPUFF
- CAL3QHCR
- SDM – Shoreline Dispersion Model
- Self Contamination - ASHRAE
- Physical Modelling

## 2. ALTERNATIVE MODEL USE

### 2.1 Use of CALPUFF

CALPUFF(1) is a puff model that is capable of fully accounting for hour-by-hour and spatial variations in wind and stability. Puff models, in general, perform well at downwind distances from a few kilometers to more than 100 km. CALPUFF contains additional algorithms that allow it to emulate AERMOD (or ISCST3) at short distances where puff models are generally less reliable. Further, CALPUFF has been evaluated and found to be reasonably accurate at distances up to 300 km. Thus, CALPUFF can be recommended for use for all distances up to 300 km. CALPUFF is particularly useful in modelling situations that involve long-range transport (up to 300 km, light wind and calm conditions, wind reversals such as land–sea (or lake) breezes and mountain–valley breezes, and complex wind situations found in very rugged terrain). The decision as to whether the use of CALPUFF is justified requires competent meteorological judgment. There are no hard and fast rules that can be applied.

Because of its complexity and increased meteorological data requirements, CALPUFF is often costly to setup and run. Thus, the potential benefits should be weighed against the cost of running the model and the possible non-availability of adequate meteorological data to drive the model.

### 2.2 Use of CAL3QHCR

CAL3QHCR(2,3) is a roadway dispersion model that can process a year of hourly meteorological data, with corresponding emissions, traffic and intersection signalization data. At signalized intersections, it accounts for idling emission rates from vehicles. CAL3QHCR calculates the concentrations in the vicinity of a roadway or intersection at averaging times from 1 hour to annual. CAL3QHCR can accommodate up to 120 "links," including both free-flowing roads and signalized intersections, and predict concentrations of carbon monoxide (CO), particulates (PM) and other inert pollutants within a few kilometers of the roadway. Its regulatory use in the U.S. is for CO concentrations near roads and intersections.

A link may constitute a (nearly) straight section of road, a signalized intersection, a bridge, an elevated road on fill, or a cut (depressed) roadway. A curved road can be represented as a series of links. Traffic data can be either as a general function of hour-of-day and day-of-week, or every hour of the year, depending on the detail required. CAL3QHCR is particularly useful when the worst case meteorological conditions are not known in advance, requiring a year of meteorology to be run to identify a worst case. It is also useful for obtaining averaging times longer than 1 hour (e.g., 8-hour, 24-hour, etc.) directly from the computations, without the need for conservative averaging time conversions. CAL3QHCR is particularly recommended for modelling of intersections.

## 2.3 Use of CALINE-4

CALINE4[(4)] is a roadway model designed to calculate a single 1-hour average concentration for a defined single hour of meteorological data for local roadways including intersections. This is most useful when a worst-case 1-hour meteorology (e.g. light wind parallel to the roadway) is known. If a worst case meteorology is not known, or direct calculation of longer averaging times is required, the CAL3QHCR model would be a better choice.

## 2.4 Use of Shoreline Dispersion Model

SDM (Shoreline Dispersion Model) can calculate a year or more of hourly concentrations calculating the effect of shoreline fumigation on plumes from stack sources at a shoreline due to shoreline fumigation when that event is likely to occur. At other times, it calculates concentrations based on a standard Gaussian plume model. SDM is relatively easy to use, and is appropriate for sources located at a shoreline. The data requirements and ease of use are typical of Gaussian plume models. More complicated situations may require the use of CALPUFF, which requires substantial time and data resources.

## 2.5 Use of ASHRAE Self-Contamination Model

Improper stack design and configuration can lead to impacts beyond ground level contamination. The influence of buildings on pollutant emissions has already been examined in the building downwash section of this guide. The interactions between sources and buildings can also lead to situations of emission re-entry into nearby buildings.

Many buildings have air-handling units located on their rooftops. As a result, it is important to ensure that emissions from rooftop sources do not allow plume impact on their rooftops, or nearby buildings.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) describes a methodology for proper stack design to avoid re-entrainment of pollutants. Chapter 43 in the ASHRAE Applications Handbook(5) provides analytical approaches for determining impacts on receptors (in this case, typically air intakes) for a series of stack/rooftop configurations including:

- Strong Jets in Flow Recirculation Cavity
- Strong Jets on Multiwinged Buildings
- Exhausts with Zero Stack Height

Self-contamination becomes especially important within industrial parks, where emissions from one unit can impact neighbouring units (or the same unit as the emission source) through air intakes, open doors, or windows.

Use of the self-contamination model and its implementation should first be reviewed with the MOE prior to submission of an air dispersion modelling assessment.

## 2.6 Use of Physical Modelling

Physical modelling is a term that comprises modelling in a wind tunnel or water channel. Some situations are so complex that the available computer models cannot be relied upon. In such cases, the use of physical modelling may be considered. Physical modelling is without question the most costly of any modelling approach. Further, it can account for only one meteorological event at a time. Often, only neutral and stable conditions can be modelled. Even with these limitations, physical modelling can provide useful information for complex situations that cannot be reliably modelled by computer models.

## 3. EXPLANATION OF USE REQUIREMENTS

### 3.1 CALPUFF

CALPUFF should be run using input data from three or more surface and upper air meteorological stations, as a minimum. In addition, output from the MM5 prognostic atmospheric model may be used to improve CALPUFF performance. It should be noted, however, that this improvement may come at considerable cost. Running CALPUFF in one of its screening modes, or with a single meteorological data source, defeats the benefits of CALPUFF's ability to account for spatial variations in the wind field. It still accounts for time variations in wind and stability, however, so there may, in some few cases, be a benefit in running CALPUFF in this mode. It should, however, be run using several meteorological stations in the majority of cases.

Whenever possible, five years of meteorological data should be used to drive CALPUFF. However, if adequate data is sparse or, in the case of the use of MM5 data, cost-prohibitive, a shorter period of data may be used. Under no conditions should less than one year of data be used. Further, if there are breaks in the meteorological data, care should be taken that all months are adequately represented so that seasonal variations in meteorology are adequately accounted for.

CALPUFF also requires files of terrain and land use data.

CALPUFF has a large number of input options available. An applicant should be strongly encourage to consult with the regulatory agency to determine the current recommendations for the input options to be used, as well as the selection of meteorological data to be used. In general, the recommendations of the Interagency Workgroup on Air Quality Modelling (IWAQM) Phase 2 report[(6)], or any more recent recommendations, should be followed. The IWAQM recommendations notwithstanding, the MPDF option should be set to "1," i.e., "yes," so that CALPUFF will emulate AERMOD in the near field. The MPDF in CALPUFF selects the use of a probability density function (pdf) instead of a Gaussian function to describe the pollutant distribution through the plume in the vertical during convective (i.e., unstable) conditions for near-field calculations. This is the approach used in AERMOD.

It is highly advisable that applicants that intend to run CALPUFF themselves should come to a written agreement with the regulatory agency on the options to be set and the meteorological data to be used.

## 3.2 CAL3QHCR

CAL3QHCR requires one year of meteorological data preprocessed using MPRM, RAMMET or PCRAMMET. If possible, CAL3QHCR should be run for five years of meteorology. If on-site data are used, this requirement may be relaxed. In the U.S. EPA regulations, one year of on-site data is acceptable. In no case should less than one year of data be used. In the case of data sets from a broken period of record, care should be taken that all months of the year are adequately represented so that seasonal changes are properly accounted for. In addition, surface roughness coefficients (derived from land use information), and, for modelling particulates, settling and deposition velocities are also required.

CAL3QHCR can model up to 120 links and 60 receptors. Each link must be defined with Cartesian coordinates of the endpoints of each link and coordinates of each of the receptors.

Traffic variables required by the model include the following:

- traffic volume for each link (vehicles per hour);
- traffic speed for each link (miles per hour);
- average signal cycle length for each intersection (seconds);
- average red light time length for each approach (seconds);
- clearance lost time (seconds);
- saturation flow rate (vehicles per hour);
- signal type (pre-timed, actuated, or semi-actuated); and
- arrival rate (worst, below average, average, above average, best progression).

Traffic volumes may, optionally, be input as a function of hour-of-day and day-of-week to give more realistic modelling results. In cases where diurnal and weekly traffic patterns are different during one season than another, CAL3QHCR would be run during each season separately with the appropriate pattern.

Emission variables required by CAL3QHCR include the following:

- Composite running emission factor for each free flow link (grams per vehicle-mile); and
- Idle Emission Factor for each queue link (grams per vehicle-hour).

## 3.3 Shoreline Models

In situations where shoreline affects the meteorology of the area significantly, CALPUFF would be the model of choice. However, CALPUFF requires substantial resources in terms of data, computer power and time. In the case where the dominant sources are located on a shoreline, and other sources in the area are clearly secondary, the SDM (Shoreline Dispersion Model) may be used. SDM is a far simpler and less costly model to use than CALPUFF. It is a matter of professional judgement as to when shoreline effects are sufficient to warrant a shoreline model. For this reason, and for the reason that the model of choice may be a costly model to run (CALPUFF), it is important that an agreement is reached between the regulatory agency and the applicant before modelling is initiated.

### 3.4 Line Source/ Traffic Dispersion Models

If roadway contributions to concentrations in a specific area are clearly secondary, traffic emissions can be adequately included in AERMOD or CALPUFF modelling of a region. This may be the case for particulate matter. In this case, traffic sources may be treated as area sources (if their impact is minimal) or as elongated area sources (in AERMOD) or line sources (in CALPUFF) if the impacts of individual streets or roads are more significant.

If the local increase in concentrations of a proposed road or expansion of a road (e.g., adding more lanes with higher expected traffic volume) is proposed, CALINE-4 or CAL3QHCR can be used to assess the effects of the proposed road or expansion alone. This would be appropriate if existing concentrations of a pollutant from other sources (e.g., CO) are either low or are well defined. If a “worst case” meteorology is defined (e.g., one meter per second wind speed parallel to the roadway, at F stability), then CALINE-4 can be used to predict the worst case 1-hour average concentration. This can be used as a screening estimate of maximum concentrations at longer averaging times (e.g., 8-hour, 24-hour) by applying averaging time conversion factors. However, refined modelling for longer averaging times must be accomplished using CAL3QHCR when the road traffic emissions dominate the concentrations. This is especially the case for carbon monoxide (CO).

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# APPENDIX B

# REFINED AIR DISPERSION MODELLING CHECKLIST

# APPENDIX B: AIR DISPERSION MODELLING CHECKLIST

This checklist is designed to provide an overview of the type of information that should be submitted for a refined air dispersion modelling assessment.

This checklist should not be considered exhaustive for all modelling studies – it provides the essential requirements for a general assessment.  All sites can have site-specific scenarios that may call for additional information and result in a need for different materials and data to be submitted.

It is the responsibility of the submitter to ensure proper completion and analysis of any air dispersion modelling assessment delivered for review.

## General Information

Submittal Date:

Facility Name:

Facility Location:

Modeller Name:

## Air Dispersion Model Options

*1. Model Selection:*

- ☐ AERMOD – most recent version
- ☐ Other Model – Specify Name, Version and Reason for Use:

*2. Regulatory Options Used:*

- ☐ Yes.
- ☐ No. Provide justification for use of non-regulatory options. Note that use of non-regulatory options requires prior approval from the regulatory agency.

*3.Dispersion Coefficients:*

- ☐ Urban
- ☐ Rural

Urban or Rural conditions can be determined through the use of an Auer Land Use or Population Density analysis.

*4.Coordinate System*

- ☐ UTM Coordinates
- ☐ Local Coordinates
- ☐ Other

AERMOD requires UTM coordinates be used to define all model objects. Use of an alternative coordinate system requires pre-consultation with the regulatory agency.

## Source Information

*1. Source Summary*

Summarize the locations, emission rates and release parameters for all point, area, and volume sources included in the modelling analysis. Information required is summarized in the tables below, each of which can be repeated as often as needed:

***Point Sources Summary***

Source Name:

Location: X(m): Y(m):

| Name of Pollutant Modelled | Emission Rate [g/s] |
|---|---|
| *1)* | |
| *2)* | |
| *3)* | |
| *4)* | |
| *5)* | |

Note: If additional pollutants are modelled, provide a tabular emission summary similar to the above for all pollutants.

Stack Height [m]:

Stack Diameter [m]:

Stack Exit Temperature [K]:

Stack Exit Velocity [m/s]:

☐ Horizontal Stack ☐ Rain Cap Present

If the stack is either horizontal in orientation or has a rain cap, stack parameters must be adjusted as per guidance.

Summary: "The above table is a form that is to be filled for Point Sources that summarizes all the information required for input into the air dispersion model."

***Area Sources Summary***

Source Name:

Location (Southwest Vertex): X(m): Y(m):

| Name of Pollutant Modelled | Emission Rate [g/(s-m$^2$)] |
|---|---|
| *1)* | |
| *2)* | |
| *3)* | |
| *4)* | |
| *5)* | |

Note: If additional pollutants are modelled, provide a tabular emission summary similar to the above for all pollutants.

Source Height [m]:

Easterly Dimension [m]:

Northerly Dimension [m]:

Initial Vertical Dimension [m]:

Angle From North [degrees]:

Summary: "The above table is a form that is to be filled for Area Sources that summarizes all the information required for input into the air dispersion model."

| ***Volume Sources Summary***<br><br>Source Name:<br><br>Location (Center of Source): X(m): Y(m): | |
|---|---|
| **Name of Pollutant Modelled** | **Emission Rate [g/s]** |
| *1)* | |
| *2)* | |
| *3)* | |
| *4)* | |
| *5)* | |
| Note: If additional pollutants are modelled, provide a tabular emission summary similar to the above for all pollutants. | |
| Source Height (m):<br><br>Initial Horizontal Dimension (m):<br><br>Initial Vertical Dimension (m): | |

Summary: "The above table is a form that is to be filled for Sources that summarizes all the information required for input into the air dispersion model."

*2. Source Parameter Selection*

- ☐ Summarize the reasoning for all emission rate and source parameter values used assumptions, locations, emission rates and release parameters for all point, area, and volume sources included in the modelling analysis.

*3. Variable Emissions Potential Emissions during Abnormal Operations Start-Up or Shutdown*

- ☐ If variable emission rates are used, such as potential emissions during abnormal operations start-up or shutdown, summarize time variations for each relevant source, the period of emissions, and a description of the condition.

*4. Building Downwash – Is the stack(s) located within 5L of a structure that is at least 40% of the stack height? (L is the lesser of the height or the maximum projected building width for a structure).*

- ☐ No.

☐ Yes. Perform a building downwash analysis using the current version of the Building Profile Input Program – PRIME (BPIP-PRIME) and include results in air dispersion modelling assessment.

*5. Scaled Plot Plan*

☐ Provide a scaled plot, preferably in electronic format, displaying source, structure and related locations including:

☐ Emission Release Locations
☐ Buildings (On site and neighboring)
☐ Tanks (On site and neighboring)
☐ Property Boundary
☐ Model Receptor Locations
☐ Sensitive Receptors

## Receptor Information

*1. The following minimal receptor configuration must be met:*

☐ Receptor definition must ensure coverage to capture the maximum pollutant concentration. Please refer to Section 7.2 of this Guidance for Air Dispersion Modelling document for a complete discussion of receptor approaches. Model runs with the following receptor densities would ensure that maximum ground level off property concentrations are captured:

- 20 m spacing within 200 m of the emission sources
- 50 m spacing from 200 to 500 m
- 100 m spacing from 500 to 1000 m
- 200 m spacing from 1000 to 2000 m
- 500 m spacing from 2000 to 5000 m
- 1000 m spacing beyond 5000 m

*2. Fenceline Receptors*

☐ Receptors must have no more than 50 meter spacing along property lines.

*3. Sensitive Receptors*

☐ If applicable, provide a summary describing the location and nature of any nearby sensitive receptors (e.g. apartments, schools, etc.).

*4. Capture of Maximum*

- ☐ Demonstrate that the maximum has been reached and ensure the levels have dropped well below the standard and/or the guideline of the contaminant being studied. Describe the receptor coverage used to achieve this requirement.

## Terrain Conditions

*1. Does the modelled area contain elevated or complex terrain?*

- ☐ No.
- ☐ Yes.

In both cases, provide a discussion on the approach used to determine terrain characteristics of the assessment area.

*2. Digital Terrain Data*

- ☐ CDED 1-degree
- ☐ CDED 15-minute
- ☐ USGS 7.5-minute Ontario dataset
- ☐ Other:

*3. Elevation data import*

- ☐ Describe the technique used to determine elevations of receptors and related model entities such as sources.

## Meteorological Data

*1. Was Pre-processed Regional Meteorological data used?*

☐ No.

☐ Yes. Specify what 1996-2000 data set was used from the table below and note the period of the record used:

| Check Box | Meteorological Data Set | MOE region | MOE district/area |
|---|---|---|---|
| ☐ | Toronto | Central | Toronto, York-Durham, Halton-Peel |
| ☐ | | Southwestern | Barrie, Owen Sound |
| ☐ | London | Southwestern | London, Windsor, Sarnia |
| ☐ | | West Central | Hamilton, Niagara, Guelph |
| ☐ | Ottawa | Eastern | Ottawa, Peterborough, Belleville |
| ☐ | Sudbury | Northern | Sudbury, North Bay, Sault Ste. Marie, Timmins |
| ☐ | Int. Falls | Northern | Thunder Bay, Kenora |
| ☐ | Massena | Eastern | Kingston, Cornwall |

Summary: "The above table is a form that is to be filled by identifying (marking) for Point Sources that summarizes all the information required for input into the air dispersion model."

*2. Was a Regional Meteorological Merge data file used?*

☐ No.

☐ Yes. Specify the Meteorological Data Set Merge file used and summarize land characteristics specified in its processing. This information should be reviewed by the Ontario Ministry of the Environment prior to submission of a modelling report.

*3. Were hourly surface data and upper air Regional Meteorological data files used?*

- ☐ No.
- ☐ Yes. Specify the Meteorological Data files used and summarize all steps and values used in processing these standard meteorological data files. This information should be reviewed by the Ontario Ministry of the Environment prior to submission of a modelling report.

*4. Was local meteorological data used?*

- ☐ No.
- ☐ Yes. Specify the source, reliability, and representativeness of the local meteorological data as well as a discussion of data QA/QC and processing of data. State the time period of the measurements, wind direction dependent land use (if used), and any topographic or shoreline influences. This information should be reviewed by the Ontario Ministry of the Environment prior to submission of a modelling report.

*5. Wind Information – the following items should be provided and discussed where applicable:*

- ☐ Speed and direction distributions (wind roses)
- ☐ Topographic and/or obstruction impacts
- ☐ Data completeness
- ☐ Percentage of calms

*5. Temperature, clouds, and upper air data – the following items should be provided and discussed where applicable:*

- ☐ Data completeness
- ☐ Mixing layer heights, diurnal and seasonal variations

*6. Turbulence – the following should be provided and discussed if site data is being used:*

- ☐ Direct measurements – frequency distributions, diurnal and seasonal variations

## Results – Dispersion Model Predictions

*1. Model files – the following electronic model input and output files are to be provided:*

- ☐ BPIP-PRIME Input and Output files.
- ☐ ISC-PRIME or AERMOD Input and Output files.
- ☐ ISC-PRIME or AERMOD Plot files

- ☐ SCREEN3 Input and Output files if applicable

*2. Meteorological Data – the following electronic meteorological data files must be provided:*

- ☐ Pre-processed data files.
- ☐ If files other than the Regional Pre-processed meteorological data files were used, you must include all meteorological data files as well as the AERMET input and output files.

*3. Terrain Data*

- ☐ If elevated or complex terrain was considered, include the digital elevation terrain data files.

*4. Plots and Maps – include the following:*

- ☐ Drawing/site plan with modelling coordinate system noted (digital format preferred.
- ☐ Plots displaying concentration/deposition results across study area.

*5. Emission Summary*

- ☐ An emission summary table should be provided.

*6. Discussion – The results overview should include a discussion of the following items, where applicable:*

- ☐ The use of alternative models
- ☐ Use of any non-default model options
- ☐ Topographic effects on prediction
- ☐ Predicted 30-minute average.
- ☐ 1-hour, 24-hour or other averaging period maximum if used
- ☐ Comparison with existing standards