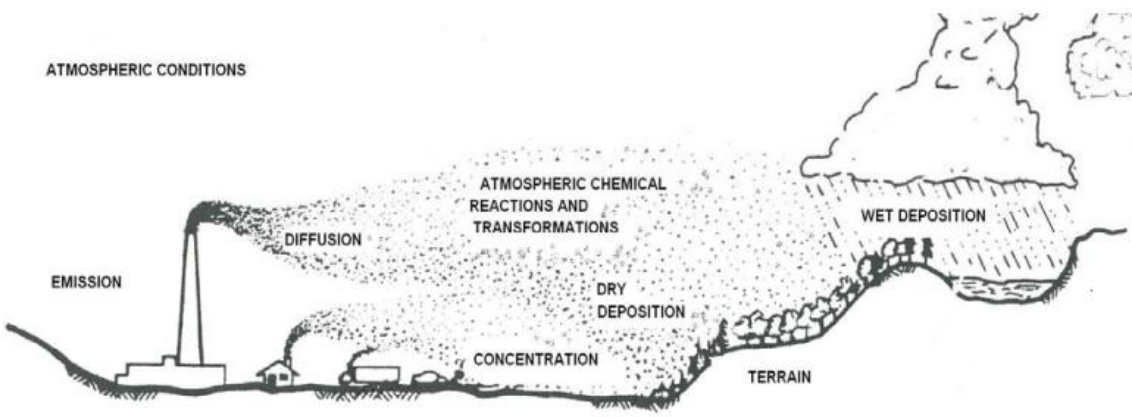
# A Primer on the British Columbia Air Quality Dispersion Modelling Guideline



**Introduction**

The Ministry, with the assistance of experts in government and private industry, has developed the British Columbia Air Quality Dispersion Modelling Guideline. Since this document is quite technical (as it is intended for those who set-up, apply and interpret dispersion models), this Primer is intended to help non-experts understand the key messages of the Guideline.

**What is an air quality dispersion model?**

An air quality dispersion model is a system of science-based equations that mathematically describe (or simulate) the behaviour of gases/particles emitted into the air. It provides a cause-effect link between emissions into the air and the resulting ambient concentrations. Figure 1 illustrates relationship between reality and how it is treated by an air quality dispersion model.

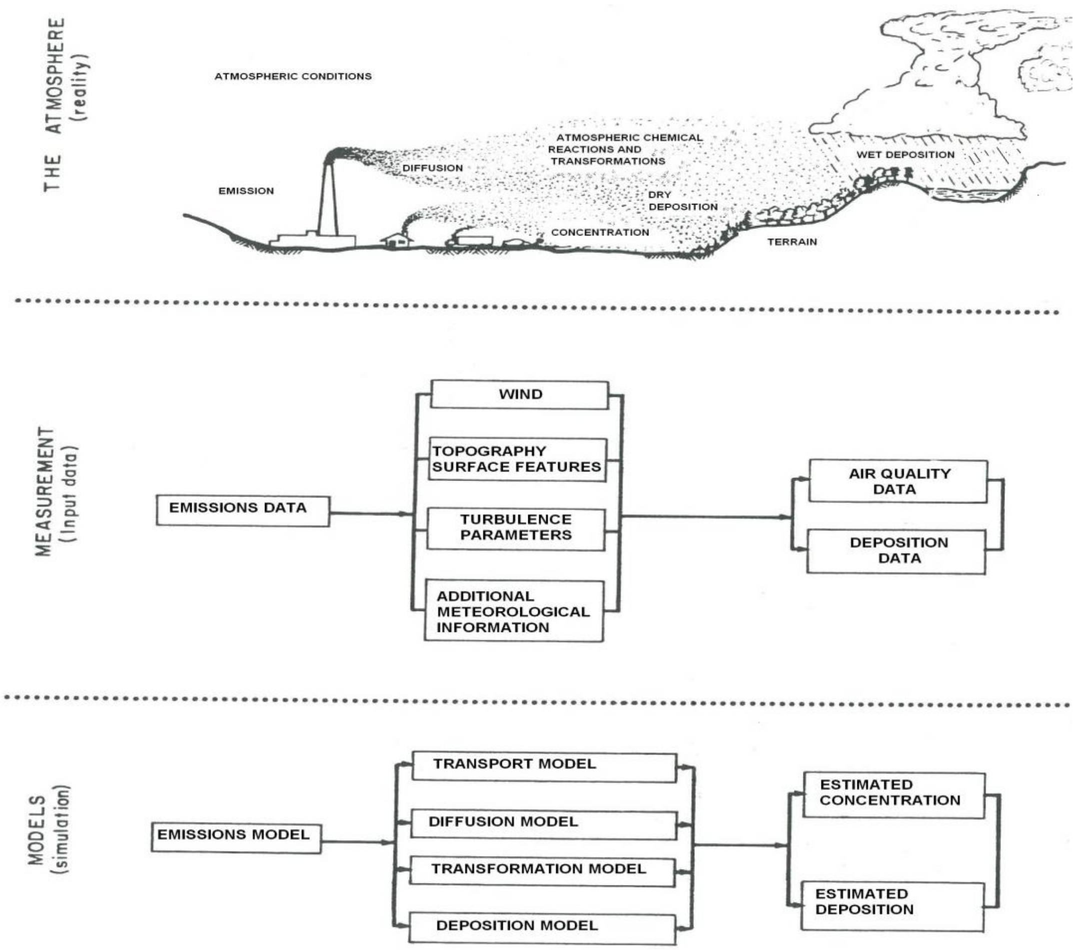



**Figure 1. Dispersion in the Atmosphere and the Corresponding Dispersion Model Components**

**Why are dispersion models important?**

Air quality is of growing concern in communities across BC because it can affect our health and the environment. It is often assumed that air quality is determined by how much is emitted into the air; however other factors such as topography, atmospheric conditions, and the source location and type (emissions from a stack or over an area) can have a greater effect. These factors conspire to make air quality management very challenging as it is not always obvious what sources contribute to poor air quality, nor is it obvious what changes in air quality would result from a change in emissions. For example, large reductions in emissions from a stack located on a hill above a community may have a very small effect on the community air quality (since the plume is so high it never reaches the ground). However, the air quality in a community downwind may be improved considerably (where the plume's greatest impact is felt).

Obviously it would help matters if there was a technique to account for these influences in a scientific and objective fashion, otherwise considerable resources could be wasted on controlling sources or developing policies and programs that may have little effect on achieving air quality goals. Fortunately an air quality dispersion model is one such technique that provides a scientific basis for air management decisions.

**What is the role of dispersion models in air quality management?**

Air quality management often involves examination of difficult questions such as:

- If current air quality is frequently poor, how can it be improved?
- Which source(s) or source sectors should be targeted for emissions reductions?
- Will a proposed new source result in a substantial degradation in air quality?
- Where should new sources be located to minimize their air quality impacts?
- For sources that require an air emission permit, what permit conditions would help ensure that the air quality impacts would be minimized?

Well-informed air quality management decisions require an air quality assessment. This involves a characterization of the current air quality situation and a prediction (or forecast) on how the air quality would change as a result of different emission scenarios. These scenarios can be simple (such as determining the air quality changes associated with different permit conditions for a single source), to very complex (involving a cost-benefit analysis related to the development of a suite of control policies for a mix of industrial, transportation and residential types of sources).

Such scenario assessments are often expensive, difficult, or destructive to do in the real world. For example, it would not be possible to stop vehicle use in a city just to measure the air quality changes that occur under a zero vehicle emission scenario. Air quality dispersion models use a computer to simulate the results of these scenario experiments. As such they are often the only or the only cost-effective method to understand the interaction between existing or future sources, meteorology, topography, and existing air quality. Because of this ability, they are widely accepted and an integral part of air management programs around the world.

**Why is a Guideline needed?**

There are dozens of dispersions models available – like a models supermarket where a number of possible models (ranging from simple to complex) could be used for a given situation. Each model in turn has its own unique features that are defined by switch settings, different options on the way different processes are treated, and different data inputs. Thus the predicted concentrations produced by the model can be highly dependent on both model selection and set-up. Without such guidance on how to select, set-up, run and interpret the models, there will be:

- differences in predicted concentrations for the same modelling situation due to inconsistencies in model selection and application,
- professional disagreement on technical details (differences in model switch settings and inputs which can result in differences in model results),
- model misapplication (for example, a complex model is used where a simple model be sufficient or where a model is applied in a situation that it cannot handle),
- the absence of modelling in situations where it would provide valuable information,
- lack of transparency to stakeholders on the tools used to inform decision-making, and
- ultimately poor and/or inconsistent decisions.

**What is the purpose of the Guideline?**

The purpose of the Guideline is to ensure that dispersion modelling that is done for air quality assessments as part of a regulatory process (such as Environmental Assessment Processes, permitting and approvals, and airshed management) are:

- appropriate for the needs of the application,
- applied correctly and consistently using accepted scientific techniques, and
- used to reliably inform air quality management decisions

**What topics does the Guideline cover?**

In order to achieve the purpose of the Guideline, the following topics are covered:

- expectations for ministry technical requirements for dispersion modelling
- identification of the level of effort recommended for a modelling study
- selection of an appropriate dispersion model
- a stepwise approach to good modelling practice
- a graduated approach that starts with simpler models and moves to more advanced models if warranted

**Why does BC need its own Guideline?**

Regulatory agencies around the world have modelling guidelines, each reflecting the agency unique information requirements (for example different permitting systems that require different information), different decision making criteria (certain model output is required in some situations, others not), and different geophysical and emission characteristics. BC in particular has challenging topographical influences on dispersion that need to be accounted for – thus the Guideline emphasizes those models with this particular ability. In addition, there are geophysical, meteorological and air quality data unique to BC that are important to consider when conducting modelling in the province.

**Which dispersion models can be used in BC?**

The Guideline limits the model possibilities to those endorsed by the United States Environmental Protection Agency (Environment Canada does not develop and support models this type). These models have been subject to numerous technical evaluations, stakeholder review and are used across Canada and internationally. The advantages of using the EPA models include:

- open source code that can be evaluated and technically critiqued by anyone,
- detailed user documentation,
- developed, performance evaluated and reviewed by experts,
- free availability through the internet, and
- wide user community (government, private industry/consulting) experience with the models and their output in decision making.

**Are all models equal?**

There is no one single model that is able to handle all geophysical, atmospheric and source situations as well as a range of applications. Thus the Guideline recommends models that can be categorized as Screening, Refined and Advanced.

A *Screening* model provides a quick way to calculate and "flag" the "worst case" concentration that might possibly occur. It requires very little input as it has a built-in set of meteorological conditions. This type of model is useful to identify those sources which may require more focussed effort (either for control actions, or more detailed modelling to confirm whether or not they are a concern).

A *Refined* model includes more science than a Screening model and requires more input and expertise to run. It needs hourly measures of meteorology over a period (a year is common) that represent the conditions experienced by the emission and thus makes predictions that are site specific and more detailed. The output consists of concentration predictions for a range of time averages (1 hour to annual) at specified locations. These provide a rich dataset of information from which to understand the air quality impacts that reflect the meteorological conditions experience by the emission.

An *Advanced* model includes comprehensive treatments of the physics and chemistry of emissions in the atmosphere, and thus requires considerable expertise and computer resources to set-up, run and interpret the results. Advanced models are not covered in the Guideline although they are typically used to assess air quality impacts from large areas (such as cities) and over broad emission sectors for a selected time period (a few days is typical).

**Are some models used more frequently than others?**

Most situations can be handled by a recommended handful of models ("Core Models"). However, there are other situations which, due to their unique source configurations and geophysical settings require a model specifically designed for this situation (that Core models are unable to handle) or the model offers a simpler alternative to the Core model and will produce information adequate for the user needs. These are called "Special Circumstances" models.

**Are all air quality assessments the same?**

Sometimes all that is required is a quick estimate of the worst case scenario (i.e. the poorest air quality that could potentially occur). Sometimes very detailed information is desired (for example a large emission source near a populated area in a twisting valley where more information and realism is required to assess the impacts of the source). The Guideline outlines this range of information needs and provides three different levels of air quality assessment:

- Level 1 for the simplest (screening) type assessments
- Level 2 for more output detail and realism on routine modelling applications
- Level 3 for more complicated source/meteorological situations where there are large emissions with potentially significant environmental and human health implications are assessed

Selection of these levels is important as it helps clarify the objectives of the modelling work, the selection of the model and the inputs required to drive it.

**How is a model selected?**

Although the Guideline focuses on a handful of EPA models, the selection of a particular model depends on the needs of the modelling assessment (what are the questions that need to be answered) and the physical context of the application (what processes are important to be treated by a model such as complex flows through mountain valleys, chemical transformations of emitted gasses). The Guideline facilitates decisions on model selection by providing a list of model abilities and direction on different types of models for different applications.

**What does a model need as input?**

The old adage of "garbage in = garbage out" certainly applies to dispersion models. In other words, a model will not magically correct input data that is missing, inadequate or of poor quality and produce perfect results.

There is considerable effort required to acquire the information required by dispersion models, and some of the more complicated models have large data requirements consisting of multiple parameters and thousands of lines of data. As illustrated in Figure 1, the input can be categorized according to the following:

*Emissions:* Information on source characteristics are required such as the type (point source such as a stack, an area source like a sewage lagoon, a line source like a highway), emission rates, exit conditions (temperature, flow rates) and the physical release dimensions. The Guideline recommends different methods that can be used to establish these parameters.

*Atmospheric Conditions:* A dispersion model requires a description of the atmosphere given that the transport and mixing of the contaminant depends on the atmospheric conditions. The Guideline reviews the meteorological input requirements of the different recommended models, the sources of such data from different agencies and the format differences that need to be considered when using US EPA models with data from Canadian sources.

*Geophysical Description:* The underlying topography and land characteristics must be specified. The Guideline reviews these data requirements for the different models, the sources of such data (US, Federal and BC agencies) and the format issues involved in using them.

*Model Options/Switches:* A model may have different ways in which the physics and chemistry are treated. The selection of a particular treatment is controlled by specifying options. The Guideline recommends options/switches (many of which are defined already by the models as "regulatory" default values) in order to establish consistency in the way the models are applied throughout BC.

**When should the Ministry be engaged during the preparation of an air quality assessment?**

The simple answer is: early and often. Although the Guideline provides direction on model selection, set-up and application, there can be difference in professional opinion in these areas. These differences may be significant enough so that the Ministry (or other interested parties) will not accept the modelling results. This means delays, a waste of time/resources and confusion among those who have a stake in the decisions based on the modelling results.

In order to avoid this unfortunate situation, the Guideline recommends the submission and Ministry agreement on a dispersion modelling plan for the modelling project. The Guideline provides a plan template to facilitate this practice.

**Is existing air quality important to consider?**

The models described in the Guideline predict the *incremental* change in concentrations due to the source(s) modelled. There is always an existing level (or "baseline") due to sources not included in the model predictions. Some of these sources may be so far away or so diverse and complex that it is not possible to include them all in the model. The Guideline reminds modellers to include the baseline level if total air quality changes are to of interest and provides recommendations on how to establish this level using existing air quality monitoring data.

**What steps should be taken to make sure modelling is done properly?**

The backbone of the Guideline is based on the *11 Steps to Good Modelling Practice.* A summary of these steps are listed here:

1. **Set the Context:** The purpose of the modelling effort must be clear along with the specific questions that need to be answered through the use of dispersion modelling.

2. **Characterize Sources/Emissions:** The sources and specific emissions of interest need to be identified
3. **Characterize Physical and Meteorological Setting:** The terrain and land use features within the area of interest must be defined, along with a general assessment of the complexity of the flows and dispersion for the area of interest.
4. **Determine the Assessment Level:** The amount of information required from the model can vary considerably depending on specific purposes of the modelling exercise (the questions and goals outlined in Step 1). Based on Step 1, the modeller should indicate which level of assessment would be appropriate (Level 1, 2 or 3).
5. **Select a Model:** Model selection from either the Core or Special Circumstance categories of models depends on the results of Steps 1-4.
6. **Determine Model Inputs (Source, Meteorology, and Geophysical Information):** The Guideline dedicates considerable content on how to obtain this data, assess its appropriateness, and how to treat it (for example, to deal with issues such as missing time periods in data).
7. **Determine Baseline Air Quality:** Since models predict the incremental impact of the air quality due to the source(s) modelled, in order to understand the implications of a source on the actual air quality, guidance is provided on how to establish the existing background (or baseline) air quality.
8. **Submit Dispersion Modelling Plan to the Ministry for Review:** Once all the details of the models, the inputs, the data treatments and background concentrations are identified, then a description of the details on how this is to be conducted should be approved before modelling commences. A plan template is provided to ease this description.
9. **Prepare Input Files and Execute Models:** Different pre-processor programs ease the preparation of input files for these models. The Step involves recommendations on their use, as well as some very model specific switch settings and options.
10. **Exercise Quality Assurance and Quality Control:** Constant vigilance is required to ensure that the input files (which can contain thousands of the lines), model options/switches are selected correctly and that the model is behaving consistently with atmospheric processes.
11. **Prepare Output and Submit Documentation:** The model output should be provided in a way that addresses the information needs of the decision maker, and points to the objectives of the modelling study and indicated in Step 1.

**Are dispersion models a reliable source of information?**

The processes in the atmosphere are inherently chaotic and impossible to predict exactly every time even with a perfect model – so variance with reality is expected to occur. However there is a lot a modeller can do to minimize the uncertainty associated with the model output. The Guideline summarizes the results of EPA studies on model performance (where model output is compared to actual measurements) and points out that poor model performance (i.e. unreliable output) is sometimes not the fault of the model, but rather due to errors by the modeller.

By following the *11 Steps to Good Modelling Practice*, modellers (through their diligence) have a systematic approach minimize model errors. In doing so, model performance is expected to be similar to the results of a number of tests conducted by the EPA. Such studies have found that the models produce results that are suitable for regulatory decisions (where maximum concentrations are of most interest).

**Are there some issues that require special attention?**

The Guideline identifies certain situations that require special treatment. This includes recommended methods that can be applied in order to estimate $NO_2$ concentrations (based on predicted NO), what to do for prolonged light wind or calm conditions (a very challenging situation for a model to treat properly), how to treat shoreline/coastal situations (which have complex layers and affect the dispersion process), and what to consider for wet and dry sulphur and nitrogen deposition modelling. Finally, the method on what is required for well-test flaring is detailed. This situation requires special attention given the large amounts of $SO_2$ that are released over a short period of time.

**In what other ways will be Guideline help modellers?**

The Guideline provides a list of modelling resources, ministry contacts and sources of geophysical and meteorological data required for model inputs. Various issues associated with data formats unique to each dataset and model are also discussed. This will save time, reduce errors and ensure a level of consistency in the way models are applied.

**Will the Guideline be updated?**

Yes. Although the Guideline is the result of considerable effort and thought, changes will be needed as modelling practice and science progresses, and to deal with issues that will inevitably arise as user experience with the Guideline grows. As such it is important for Guideline users to register their document (instructions are provided in the Guideline) so that notification on changes can be made. In addition, comments from the user community will be critical in the Guideline updating process. Submit comments by email to: bcdispersion.model@gov.bc.ca

For questions, clarification and discussion on various topics please contact:

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