Air Dispersion Modeling
Where Is It Open to Challenge?

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I. OVERVIEW

The purpose of this paper is to provide an overview of air dispersion modeling by identifying and describing key components of a modeling analysis. These components also will be examined to determine which are most influential on the results, and accordingly which aspects of a modeling analysis are most open to challenge. Ultimately the reader will gain an overall understanding of the key decision points of an air dispersion modeling analysis which will enable him/her to better determine whether or not an analysis is defensible, and it is the author's hope that this paper becomes a reference document on air dispersion modeling for the reader in the future.

II. INTRODUCTION

Air dispersion modeling is the mathematical simulation of the transport and dispersion of air pollutants in the atmosphere. Modeling is typically conducted using air dispersion models which are computer programs that consider source characteristics, emission rates, meteorology, and topography to describe the behavior of air pollutants in the atmosphere. Air dispersion modeling is a tool frequently used in various environmental permitting efforts, as well situations that do not involve permitting directly (e.g., litigation scenarios in which a model can help characterize pollutant impacts at a plaintiff location).

It is important to note that air dispersion models are developed primarily as regulatory tools in that they are designed to demonstrate compliance with air quality standards with a reasonable margin of error. To that end there is a certain amount of conservatism inherent in a dispersion model, and it is incumbent upon the user to understand the strengths, weaknesses, and overall tendencies of the model being used.

The remainder of this paper addresses various key components of an air dispersion modeling analysis. Important aspects of each component are described, including those which are key decision points in the setting up and execution of the model. In addition, the degree to which a particular component is open to challenge is discussed. Because the paper is written for the Pennsylvania Bar Institute, specific references to the air dispersion modeling policies of the Pennsylvania Department of Environmental Protection (PADEP) are also provided.

Finally, it should be emphasized that air dispersion modeling is both a science and an art, so all decisions on model setup and execution are not always clear-cut. Accordingly, while this paper addresses the key components of a modeling analysis, in many instances there may be additional facets of a modeling analysis that could be challenged.

III. COMPONENTS OF AN AIR MODELING ANALYSIS

The following sections address six key components of an air dispersion modeling analysis: model selection, model setup, emissions inventory, meteorological data, receptors, and background concentrations.

A. Model Selection

1. Discussion

a. EPA-approved air dispersion models

There are a host of air dispersion models available for use, and the choice of which model to use is paramount to the success of the analysis. The United States Environmental Protection Agency (EPA) maintains a list of models approved for use in regulatory applications, in particular for State Implementation Plans and the New Source Review/Prevention of Significant Deterioration programs. This list, presented in the Guideline on Air Quality Models (GAQM)[1] as well as on the Support Center for Regulatory Atmospheric Modeling (SCRAM) website[2], includes six models:

(1) AERMOD

(2) Buoyant Line and Point Source Dispersion Model (BLP)

(3) CALINE3

(4) CALPUFF

(5) Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations (CTDMPLUS)

(6) Offshore and Coastal Dispersion Model (OCD).

Each model has specific features that make it unique, so it is important to choose a model that is best-suited for a particular application. For instance, BLP was designed specifically to handle certain unique aspects of aluminum plants, so when modeling an aluminum plant BLP should be given strong consideration. On the other hand, BLP would likely not be an appropriate model to use when modeling a power plant.

b. Alternative models available for use

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[1] Appendix A to 40 CFR 51, Appendix W
[2] http://www.epa.gov/scram001/

There are also a host of alternative models available, which can be used in lieu of the approved/recommended models presented in the GAQM. However, the use of these models in a regulatory context must be approved by EPA on a case-by-case basis. In order to make a case to EPA for the use of an alternative model it must be evaluated on a theoretical and performance basis.

2. Opportunity for challenge

There is typically not much opportunity to challenge the choice of the dispersion model, as AERMOD is almost always used.

That having been said, there are instances in which a certain model may perform better than another due to technical differences. For instance, CALPUFF may be a better model from a technical standpoint than AERMOD for an industrial facility located in a steep valley because CALPUFF is better-suited to handle complex wind patterns such as those found in that kind of terrain. However, as noted above, if the modeling is being conducted in a regulatory context this point is likely moot, as EPA would very likely require the use of AERMOD. On the other hand, if the modeling is being conducted solely for evaluating pollutant impacts (e.g., in a court case and not in a permitting sense), CALPUFF may be the appropriate model to use.

B. Model Setup/Switches

1. Discussion

Every dispersion model has a variety of decisions to be made, commonly called "switches," which invoke certain features of the model. Models have a set of standard options, called "Regulatory Options," that if invoked do not require any approval by the regulatory authority.

There are non-regulatory options available as well, the use of which can sometimes be beneficial (for instance, there are non-regulatory options for calculating nitrogen dioxide (NO_2)/NO ratio concentrations that in many instances will lead to lower predicted NO_2 concentrations). Typically, prior approval for the use of these options from the regulator is required.

Many, but not all, States have compiled State-specific air dispersion modeling guidelines. These documents address unique aspects of conducting air dispersion modeling within a given State. It is imperative that before conducting any dispersion modeling within a given State that any such guidance be consulted.

In 2008 PADEP developed a draft checklist for an air dispersion modeling protocol[3]. While focused on what should be included in a modeling protocol (a document often provided to State agencies to establish the parameters/methodologies of a proposed

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[3] DRAFT Checklist for Air Quality Modeling Protocol, Prevention of Significant Deterioration Analysis, Pennsylvania Department of Environmental Protection, Bureau of Air Quality. October 8, 2008.

modeling analysis), it contains useful information in terms of what PADEP would like to see in a modeling analysis. Even though this document is not available on PADEP's website, it would be made available to an interested party if requested.

2. Opportunity for challenge

There typically is not much opportunity to challenge the model switches, as in the vast majority of cases the regulatory default options are invoked. In many cases, invoking non-regulatory options simply uses techniques that, while recognized by the scientific community, have not yet been fully vetted by EPA. So even in those instances, there likely is little opportunity for challenge.

If there is an opportunity to challenge model switches most likely it would be in a CALPUFF analysis, as there are a tremendous number of switches in CALPUFF (and its associated meteorological preprocessing program, CALMET), some of which can have a very substantial effect on predicted concentrations.

C. Emissions Inventory

1. Discussion

The emissions inventory contains information about the sources to include in the model. Typically this information is provided by the applicant or its engineering/design firm.

In addition to the source being addressed, in some instances other nearby sources are included in the emissions inventory as well. The determination of which sources to include frequently depends on the magnitude of the impacts of the source being addressed. Typically information for the offsite inventory is obtained from State files, such as Title V applications and annual emissions inventories. In some instances a State will provide an applicant with an emissions inventory.

PADEP does not provide an applicant with an offsite emissions inventory.

In air dispersion modeling there are three common ways to characterize an emissions source. Those source types, and their associated required inputs, are given below.

a. Required source inputs

(1) Point sources (e.g., stack)

(a) Location

(b) Base elevation

(c) Stack height (above ground)

(d) Inner stack diameter

(e) Exit velocity

(f) Exit temperature

(g) Emission rate

(2) Volume sources (e.g., fugitive roadway dust generated from truck traffic, roof vents)

(a) Location

(b) Base elevation

(c) Release height

(d) Horizontal and vertical dimensions

(3) Area sources (e.g., storage piles)

(a) Location

(b) Base elevation

(c) Release height

(d) Length/width

b. Emission rates

Guidance for deriving emission rates to be modeled in the analysis is given in the GAQM[4]. When calculating the modeled emission rates it is particularly important to consider the averaging period being addressed, as a short-term averaging period needs to be modeled with a short-term emission rate, while an annual averaging period can be addressed with a longer-term emission rate.

Regarding the offsite inventory to be modeled, even though the GAQM specifies that potential emissions be addressed, it is commonplace for States to be able to provide only actual emission rates. In some States it is acceptable to submit a modeling analysis based on actual emissions for offsite sources, but some States require the applicant to address potential emissions from these offsite sources.

[4] Tables 8-1 and 8-2 of 40 CFR 51, Appendix W.

PADEP requires that the applicant calculate potential emissions for all offsite sources included.

2. Opportunity for challenge

There are a host of opportunities for challenge regarding the emissions inventory, with some of them having a potentially substantial impact on the results of the analysis.

a. Has the modeling analysis accounted for all of the appropriate sources?

(1) Fugitive sources (e.g., storage piles, fugitive dust from roadways) from source being permitted/addressed.

(2) Offsite sources.

b. Does the modeling analysis address the proper emission rates?

(1) Proper averaging periods.

(2) Emission rates, especially 1-hr NO_2 and SO_2, properly calculated for source being permitted/addressed.

(3) Startup/shutdown emissions as well as upset emissions need to be addressed.

(4) Offsite sources' emission rates based on potential emissions.

D. Meteorological Data

1. Discussion

Meteorological data are required for most air dispersion models used today (there are simple models that do not require meteorological data as an input). Typically the requisite meteorological data include wind speed and direction, temperature, along with a host of other variables that are calculated by meteorological data preprocessors. For more advanced models like CALPUFF, weather forecasting programs are also sometimes used to generate the necessary meteorological data for air dispersion modeling.

Generally speaking the meteorological data used must be the most recent, readily available data and must be representative of meteorological conditions of the area being modeled. EPA has established rules governing the choice of a representative meteorological dataset to be used in air dispersion modeling[5]. Details concerning the determination of what is a representative dataset are given below.

a. Spatial proximity (i.e., typically the dataset to use is from the closest National Weather Service (NWS) station, usually the closest airport).

b. Complexity of terrain (i.e., if a mountain isolates the nearest airport from the area being modeled, it may be appropriate to use data from an airport that is further away).

c. Exposure of the meteorological monitoring site.

   (1) The meteorological monitoring station must be situated in a manner such that it is not influenced by nearby structures/obstacles.

   (2) This is not an issue if the data being used are from a NWS station.

   (3) This may be an issue if the data being used are from an onsite meteorological tower.

d. Period of time during which meteorological data are collected.

   (1) The most recent, readily available data are preferred.

   (2) For NWS data, typically a 5-year dataset is used.

   (3) For onsite data, typically a 1-year dataset is used.

EPA also requires that the dataset be sufficiently complete for use in air dispersion modeling[6]. Specifically, the dataset must be 90% complete on a quarterly basis, with the 90% requirement applying to wind direction, wind speed, and temperature.

For most air dispersion models there are typically two sources of potential meteorological data: a nearby NWS station or an onsite meteorological tower. While data from an onsite meteorological tower are preferred, frequently these data are not available and it is not cost-effective to erect a meteorological data monitor. Therefore, the majority of modeling analyses use data from a nearby NWS station.

Some states publish a map that clearly indicates which meteorological dataset should be used based on where the modeling analysis is taking place. Furthermore, some states also maintain a library of processed meteorological data ready for use in a modeling analysis. The state regulatory agency should be consulted prior to ascertain what, if any, meteorological data are preferred/available.

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[5] Section 8.3 of 40 CFR 51, Appendix W

[6] Section 5.3.2 of *Meteorological Monitoring Guidance for Regulatory Modeling Applications*, EPA-454/R-99-005. February 2000.

PADEP typically does not provide meteorological data for applicants, nor does it specify which dataset to use in a certain area. That having been said, PADEP does possess some meteorological data already processed from private meteorological towers, and because those data are not publicly available it is important to check with PADEP for the availability of such data before proceeding with NWS data.

Regardless of whether data from a local airport or an onsite tower are used, PADEP requires the applicant submit a rigorous demonstration of the representativeness/completeness of a proposed meteorological dataset for air modeling.

If data from an onsite tower are used it is imperative to confirm that these data were obtained in accordance with guidance put forth by EPA[7]. EPA's guidance addresses the recording of the data, the performance of the system, the processing of the data, the data reporting and archiving, and the quality assurance and quality control (QA/QC) of the data.

Finally, while in most cases it is fairly straightforward to determine the appropriate set of meteorological data to use, there are some instances in which it is debatable as to which dataset is more appropriate. In those cases one possible approach is to run the model separately with each dataset, and then select the one that produces the higher predicted concentrations.

2. Opportunity for challenge

While in most modeling analyses there is not much opportunity for challenge regarding the meteorological data used, in some instances there can be substantial opportunity for challenge, sometimes with potentially significant consequences on the results of the analysis. If one wishes to challenge the representativeness of a meteorological dataset the points most likely to be scrutinized are:

a. Spatial proximity.

b. Complexity of terrain.

If the analysis is using meteorological data obtained from an onsite tower there are a multitude of opportunities for errors in the collection and processing of those data which would render the dataset unfit for regulatory use. The issues most likely open for challenge are:

a. Exposure of the meteorological monitoring site.

b. QA/QC of the data.

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[7] *Meteorological Monitoring Guidance for Regulatory Modeling Applications*, EPA-454/R-99-005. February 2000.

c. Completeness of the dataset.

E. Receptors

1. Discussion

Receptors are user-defined points at which the user wants to the model to predict a concentration. A receptor is defined by its X and Y coordinates as well as its elevation above sea level. Typically receptors are placed at ground-level, although in some instances they may be placed above-ground at locations such as roof tops or on elevated bridges.

Notes on the establishment of modeled receptors are given below.

a. Receptor placement

Receptors are placed in "ambient air"[8,9] only, which excludes, by EPA definition,

(1) An area owned or controlled by the source, and

(2) An area to which public access is precluded by a fence or other effective physical barrier.

Over the years there has been much debate concerning what constitutes a physical barrier to public access. Examples of what does and does not constitute a physical barrier are as follows:

(3) Sufficient for physical barrier

(a) Chain link fence

(b) Sufficiently steep/inaccessible terrain (open to interpretation)

(4) Insufficient for a physical barrier

(a) Split rail fence

(b) Posting "No Trespassing" signs

(c) Boundary patrolled by guard

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[8] 40 CFR 50.1(e)

[9] Memo, "Interpretation of "Ambient Air" in Situations Involving Leased Land Under the Regulations for Prevention of Significant Deterioration (PSD)," Steven D. Page, EPA. June 22, 2007.

Note that a public roadway passing through a source's property is considered ambient air and should therefore have receptors placed on it in a modeling analysis.

b. Receptor spacing

(1) Along fenceline/ambient air boundary (for determining the proper receptor spacing)

(2) More dense close to source, less dense with increasing distance from source

(3) Typically a grid of receptors is established over the area being modeled; individual receptors can be placed at specific points of interest (e.g., schools, hospitals, etc.)

(4) 100 m typically accepted as minimum receptor spacing, sometimes as small as 25 m spacing

(5) Receptor network must adequately refine the controlling predicted concentration[10] (e.g., the controlling predicted concentration should not be located at the edge of a receptor grid)

An illustration showing the variation of receptor spacing with distance from the modeled source is given in Figure 1 below.

[10] The controlling predicted concentration is the concentration predicted by the model that is compared to the standard being addressed. The form of the controlling predicted concentration varies by pollutant and averaging period; in some instances it is the highest concentration predicted, in some instances one discounts the highest predicted concentration and compares the second-highest concentration against a standard, and in other cases it is a much more complicated calculation.

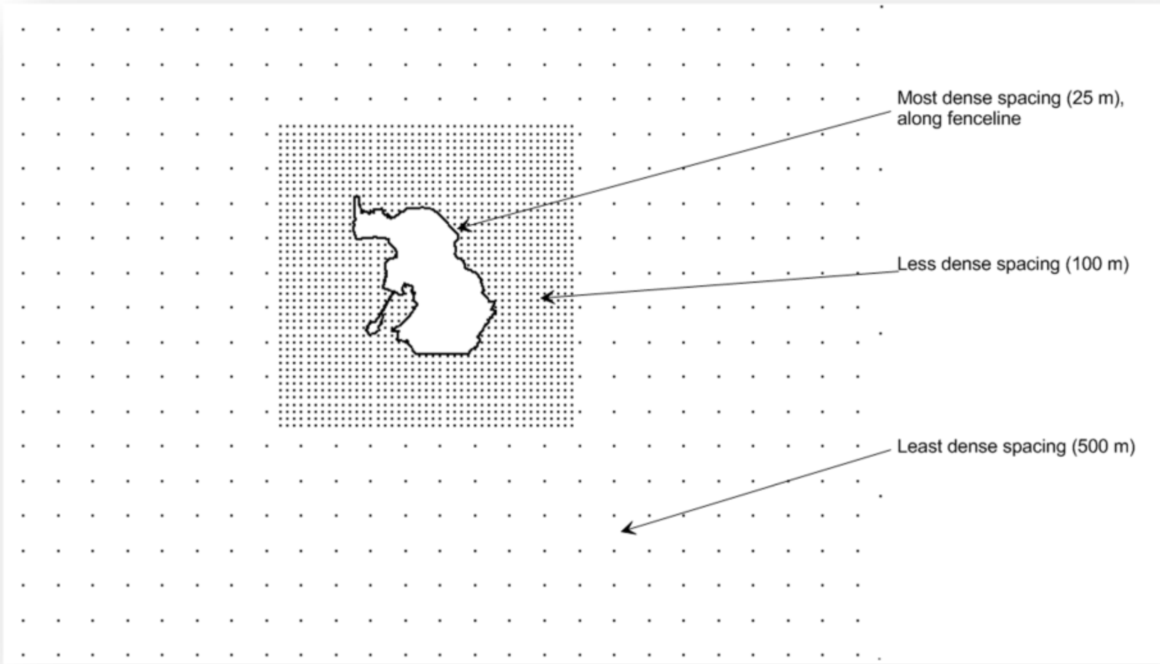

Figure 1
Example Receptor Spacing

One of the last steps of a modeling analysis is to ensure that the controlling predicted concentration is sufficiently refined in space. Typically a regulator requires that the controlling predicted concentration be located within an area covered by receptor spacing of no more than 100 m.

PADEP recommends that fenceline/ambient air boundary receptor spacing be no more than 25 m.

2. Opportunity for challenge

   If controlling predicted concentrations are found to be close to the source being modeled, the location of the fenceline/ambient air boundary is of particular importance. Often the exact placement of the fenceline/ambient air boundary is open to interpretation and therefore can represent an opportunity to challenge an air modeling analysis.

   Issues to consider when establishing the fenceline/ambient air boundary include the following:

   a. Do the receptors placed along the fenceline/ambient air boundary represent the ambient air boundary as defined by EPA (i.e., physical barriers to public access)?

b. Is the receptor spacing along the fenceline/ambient air boundary of sufficient density?

If the controlling predicted concentration is found to be elsewhere in the receptor grid, it is important to ensure that the accompanying receptor spacing is no more than 100 m.

F. Background Concentrations

1. Discussion

In some modeling analyses (e.g., analyses demonstrating compliance with the NAAQS), the predicted concentrations must be added to a background concentration to determine the total concentration. The background concentration is included to account for impacts from natural sources, nearby sources not included in the modeled inventory, and unidentified sources.

The GAQM[11] includes guidance on how to obtain and process background concentrations. Under most circumstances background concentrations are derived from a monitor in the vicinity of the source being modeled. In many respects the choice of a monitor to provide a representative background concentration is similar to that of the choice of a source of representative meteorological data in terms of proximity, siting, and timeliness.

a. Sources of monitor data which can be used to calculate background concentrations

(1) EPA's AirData (http://www.epa.gov/airdata/)

(2) Individual States sometimes maintain their own monitors/data separate from EPA.

PADEP maintains a website which houses ambient monitoring data, along with other data, in some instances back to 2004[12].

b. Methods to calculate background concentrations

There are many different ways to calculate background concentrations. The most conservative approach is to simply select the highest monitored concentration and add that to the controlling predicted concentration, but in many instances that worst-case approach leads to a concentration greater than the NAAQS.

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[11] Section 8.2 of 40 CFR 51, Appendix W

[12] http://www.portal.state.pa.us/portal/server.pt/community/principal_pollutants/21822/principal_pollutants_monitoring_sites/1897714

Therefore, there are a variety of techniques available to calculate a more refined background concentration, including methods for excluding the impacts of nearby sources from background concentrations, along with different mathematical approaches for deriving a background concentrations. Key sources for detailed discussions of these approaches include the following:

(1) Sections 8.2.2 and 8.2.3 of 40 CFR 51 Appendix W address calculating background concentrations for isolated single-source and multi-source areas.
(2) "Modeling Procedures for Demonstrating Compliance with $PM_{2.5}$ NAAQS", Memorandum from Stephen D. Page, EPA. March 23, 2010.
(3) "Applicability of Appendix W Modeling Guidance for the 1-hour SO_2 National Ambient Air Quality Standard," Memorandum from Tyler Fox, EPA. August 23, 2010.
(4) "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hr NO_2 National Ambient Air Quality Standard," Tyler Fox, EPA. March 1, 2011.

2. Opportunity for challenge

In a modeling analysis in which the predicted concentration is close to an applicable standard, the calculation of the background concentration can often be a very critical component of the overall analysis. Because the calculation of the background concentration is based in part on many subjective decisions, there can be ample opportunity to challenge the chosen background concentration.

Facets of the background concentration often open for challenge include the following:

a. Selection of representative monitor

(1) Is the monitor selected nearby and representative of background concentrations within the modeling domain?

(2) Was the monitor sited properly (e.g., far enough away from nearby obstructions)?

(3) Are the data used from a recent time period?

b. Gathering of monitor data

There are a host of procedures that must be followed for monitor data to be considered valid. As a result, there are many opportunities for oversights that can lead to the invalidation of data.

(1) Were the data QA/QC'd properly?

(2) Were the appropriate audits/calibrations performed?

(3) Were the data handled/processed correctly?

(4) In many instances co-located monitors are required to ensure the validity of the data.

c. Processing of monitor data

There are a host of possible approaches for processing monitor data to calculate a background concentration. Accordingly, it is quite easy to use an approach that does not result in a conservative background concentration. As a result, there can be ample opportunity to challenge the calculation of a background concentration.

IV. CONCLUSION

In executing an air dispersion modeling analysis there are a multitude of decisions that have to be made. Some of those decisions can have a significant impact on the results of the modeling analysis, and therefore should be scrutinized carefully.

Some of the key points of a modeling analysis that can be challenged are as follows:

A. Model switches: typically not worthy of detailed scrutiny unless in a CALPUFF analysis

B. Emissions inventory

1. Are the proper sources included?

2. Are the proper emission rates modeled?

C. Meteorological data

1. Are the meteorological data representative of the area being modeled?

2. If the data used are from an onsite tower, were they gathered/processed properly?

D. Receptors

1. Does the receptor spacing meet regulatory requirements?

2. Is the controlling predicted concentration located in an area of adequate receptor spacing?

E. Background concentrations

   1. Is the monitor used representative of background concentrations in the area?

   2. Is the calculation methodology used to derive the background concentration appropriate and sufficiently conservative?

Whether advocating for a modeling analysis or debating its merits, there are always aspects of the analysis that are open to interpretation. Understanding the relative influence of those different aspects will help focus one's scrutiny and identify areas which can potentially be challenged. Ultimately this will lead to a greater confidence in the validity of an air dispersion modeling analysis.