8.4 **AN ANALYSIS OF AERMOD SENSITIVITY TO INPUT PARAMETERS IN THE SAN FRANCISCO BAY AREA**

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1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) plans to replace its current air quality guideline model, ISC3, with a new guideline model, AERMOD (EPA, 2003). AERMOD includes newly developed and current state-of-the-science modeling techniques (EPA, 2002). The incorporation of these techniques requires significantly more input parameters compared to ISC3, such as urban population, albedo, Bowen ratio, surface roughness, cloud cover, solar radiation, and height at which ambient temperature is measured.

In the San Francisco Bay Area (Bay Area), meteorological data are available from over sixty operating stations and from historical archives of dozens of closed sites. Operators of these stations include the Bay Area Air Quality Management District (BAAQMD), airports, state agencies, municipalities, universities, utilities, refineries, and other public and private entities. A small number of these meteorological sites are located at emission sources. Roughly half of the stations do not meet EPA standards for ISC3 modeling, mainly due to siting concerns, inadequate maintenance, data completeness or lack of a key parameter.

The BAAQMD evaluates over six hundred different facilities every year for new permits, permit renewals, prevention of significant deterioration analyses and risk assessments. Based upon the nature of the evaluation, modeling may be required. Facilities requiring a modeling analysis usually obtain meteorological data from available archives. Because of the large number of facility evaluations, preparation of inputs for ISC3 is mostly automated. It is also desired to automate the preparation of inputs for AERMOD. However, some input parameters for AERMOD are not directly measured, while others are only measured at select meteorological sites.

Current modeling guidance does not completely address the type, accuracy and location of additional measurements needed to apply AERMOD successfully. For example, specifying surface roughness, a parameter not directly measured at meteorological stations, is somewhat subjective and there are no clear guidelines for determining values. Guidance does not clearly address the preferred type of solar radiation, net or total, or if solar measurements are to be taken at or near every site where AERMOD is applied or at locations deemed representative of larger domains. Guidance is also incomplete in addressing issues arising from meteorological sites not at the pollutant(s) release location and how sensitive AERMOD is to the differences in surface characteristics of the emission site versus the meteorological site.

Since a number of the AERMOD input parameters are not currently measured at existing Bay Area meteorological monitoring stations, one objective of this study is to find out how accurately input parameters need to be specified. By knowing the relative percent change in AERMOD concentration predictions when an input parameter is changed, one can then determine the accuracy needed for specifying that parameter and better estimate which parameters should be measured at each location. Another objective of this study is to investigate how the results from the proposed AERMOD model compare with the existing ISC3 model.

2. METHODOLOGY

The most recent release of the AERMOD modeling system (EPA, 2002), including AERMAP and AERMET (version 02222), was installed and benchmarked on a 1.8 GHz desktop computer running Windows 2000. Possible source locations and source types were considered as well as the investigation of available meteorological data. This paper focuses on the sensitivity of AERMOD to albedo, Bowen ratio, surface roughness, cloud cover, solar radiation, ambient temperature, ambient temperature probe height and urban population, as listed in Table 1. With the exception of ambient temperature, these parameters were not required inputs for the ISC3 model. A range of variation was considered for each input parameter and AERMOD was individually run for each input parameter change. Because AERMOD sensitivity could vary by concentration averaging period, the 1-hour, 3-hour, 8-hour, 24-hour and annual average concentrations were examined.

2.1 *Meteorology Data*

A complete onsite yearlong meteorological dataset was compiled for 1992 to serve as the meteorological base year. The onsite data consisted of wind speed, wind direction, and temperature. The onsite data was augmented with 1992 cloud cover data from the San Francisco International Airport (SFO), Oakland National Weather Service upper air soundings, and total solar radiation data from a neighboring meteorological station. Shown in Figure 1 is a Bay Area map specifying the locations of the meteorological data collection and the hypothetical project site.

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Table 1. AERMOD input parameters and sensitivity analysis variation.

Parameter	Variation*
Albedo	0.25 to 4 times bc
Ambient Temperature	± 6 °C
Bowen Ratio	0.5 to 2 times bc
Cloud Cover	± 50 percent
Solar Radiation	0.25 to 4 times bc
Surface Roughness	0.25 to 4 times bc
Temperature Probe Height	2.5 to 15 m
Urban Population	± 75 percent of bc

*bc refers to base case

2.2 *Source Description*

For the analysis, several hypothetical typical emission sources in an industrial section of San Francisco were modeled. Because AERMOD sensitivity could vary for different source types, three different typical sources were considered: a turbine source (elevated), a backup diesel generator (ground level point source), and a gas dispensing facility (volume source).

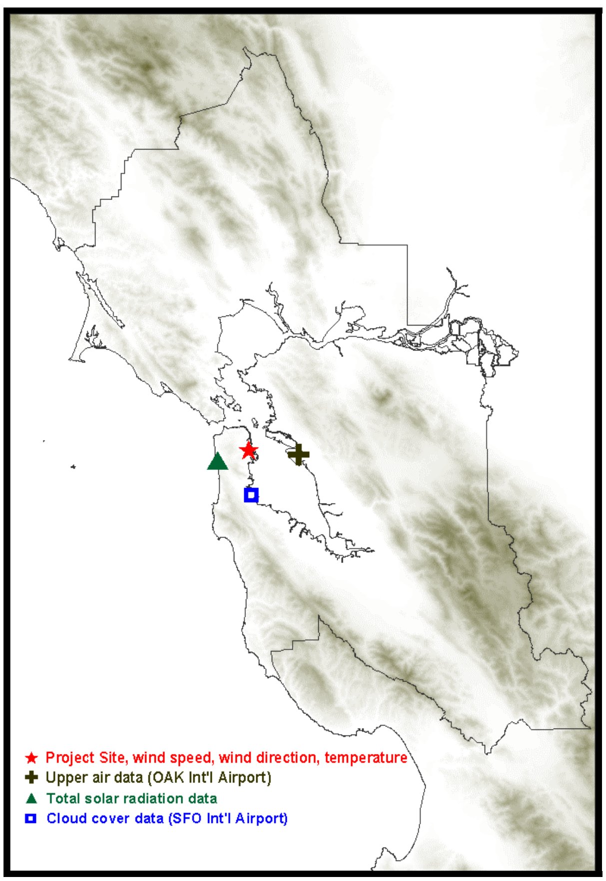

Figure 1. Locations of meteorological stations and hypothetical project site.

The typical turbine source exhaust gas was modeled with a temperature of 79 °C, a stack height of 49 m, a stack diameter of 5.5 m, and a stack exit velocity of 5.5 m/s.

The exhaust gas from the typical backup diesel generator was 443 °C, a stack height of 0 m, a stack diameter of 0.15 m, and a stack exit velocity of 66.3 m/s.

The spillage from a typical gas dispensing facility (GDF) was modeled as a volume source at a release height of 0 m, a side length of 5 m, an initial lateral dimension of 1.16 m, and an initial vertical dimension of 1.86 m.

3. SENSITIVITY RESULTS

AERMOD sensitivity was investigated for the eight input parameters listed in Table 1. Also shown are the ranges of variation for the parameters. The ranges were chosen to represent the possible variation of the parameters for site-specific projects in the Bay Area. While Table 1 shows the range of the input parameter variation, intermediate values were also included in the modeling runs. Over 400 runs were made during the investigation.

3.1 *Typical Turbine*

Table 2 summarizes the results of the sensitivity analysis for the typical turbine. Shown in the table are the maximum percent concentration changes. The typical turbine source was the most sensitive to changes in surface roughness and showed increased sensitivity

Table 2. Ranked AERMOD sensitivity to input parameters for a typical turbine.

Parameter	Variation*	Max. change	Averaging period
Surface Roughness	0.25 x bc	-18 %	annual
	4 x bc	104 %	annual
Solar Radiation	0.25 x bc	-53 %	annual
	4 x bc	50 %	annual
Albedo	0.25 x bc	6 %	annual
	4 x bc	-33 %	annual
Urban Population	- 75 %	25 %	24 hour
	+ 75 %	-5 %	24 hour
Bowen Ratio	0.5 x bc	-8 %	annual
	2 x bc	6 %	annual
Ambient Temp.	- 6 °C	-6 %	annual
	+ 6 °C	7 %	annual
Cloud Cover	- 50 %	-3 %	annual
	+ 50 %	5 %	annual
Temp. Probe Height	2.5 m	0 %	all
	15 m	0 %	all

*bc refers to base case

with longer averaging periods. In general, decreased surface roughness decreased the maximum average concentration, while increased surface roughness increased the maximum average concentration. The second most sensitive parameter was solar radiation data. A factor of 4 change in the radiation data could lead to a 50 percent change in the predicted concentration. In general, a decrease in solar radiation lead to a decrease in predicted concentration. The results showed a nonlinear response to changes in surface roughness with an 18 percent decrease and 104 percent increase in concentrations. In contrast the model appeared to be linear in its response to negative and positive variations in solar radiation with a 53 percent decrease to a 50 percent increase in predicted concentration. Note that the maximum changes for surface roughness and solar radiation occurred for annual averages.

3.2 Typical Backup Generator

Table 3 summarizes the results of the sensitivity analysis for a typical backup generator. Shown in the table are the maximum percent concentration changes. Predictions for the backup generator were the most sensitive to changes in surface roughness: reducing the surface roughness by a factor of four resulted in a 52 percent increase in the predicted concentration. This was the opposite affect from the typical turbine, where a factor of four reduction in the surface roughness resulted in a decrease in the predicted concentration. In contrast to the typical turbine, the typical backup generator showed a stronger sensitivity to decreased surface roughness, but for the 3-hour averaging period. The second most sensitive parameter was solar radiation data. A factor of 4 increase in the radiation data led to a 9 percent decrease in the predicted concentration. Note that model response to the changes in both surface roughness and solar radiation was also nonlinear.

Table 3. Ranked AERMOD sensitivity to input parameters for a typical backup generator.

Parameter	Variation*	Max. change	Averaging period
Surface Roughness	0.25 x bc	52 %	3 hour
	4 x bc	-21 %	24 hour
Solar Radiation	0.25 x bc	3 %	24 hour
	4 x bc	-9 %	8 hour
Cloud Cover	- 50 %	-4 %	8 hour
	+ 50 %	8 %	3 hour
Urban Population	- 75 %	8 %	1 hour
	+ 75%	-4 %	1 hour
Ambient Temp.	- 6°C	-3 %	3 hour
	+ 6 °C	3 %	3 hour
Albedo	0.25 x bc	-2 %	8 hour
	4 x bc	3 %	24 hour
Bowen Ratio	0.5 x bc	-0.5 %	annual
	2 x bc	0.4 %	annual
Temp. Probe Height	2.5 m	0 %	all
	15 m	0 %	all

***bc refers to base case**

3.3 Typical Gas Dispensing Facility

Table 4 summarizes the results of the sensitivity analysis for spillage from a typical gas dispensing facility (GDF). Shown in the table are the maximum percent concentration changes. Predictions for the GDF were the most sensitive to changes in surface roughness: reducing the surface roughness by a factor of four resulted in an 85 percent increase in the predicted concentration. Similar to the typical backup generator, AERMOD showed a stronger sensitivity to a decrease in surface roughness. The second most sensitive parameter was cloud cover data. A 50 percent increase in cloud cover led to an 18 percent decrease in the predicted concentration. Sensitivity to cloud cover and urban population was greater than sensitivity to solar radiation for this case.

Table 4. Ranked AERMOD sensitivity to input parameters for spillage from a typical GDF.

Parameter	Variation*	Max. change	Averaging period
Surface Roughness	0.25 x bc	85 %	Annual
	4 x bc	-67 %	Annual
Cloud Cover	- 50 %	16 %	24 hour
	+ 50 %	-18 %	1 hour
Urban Population	- 75 %	19 %	1 hour
	+ 75%	-7 %	1 hour
Solar Radiation	0.25 x bc	19 %	24 hour
	4 x bc	-4 %	Annual
Albedo	0.25 x bc	1 %	1 hour
	4 x bc	6 %	24 hour
Ambient Temp.	- 6°C	-1 %	1 hour
	+ 6 °C	0.6 %	24 hour
Bowen Ratio	0.5 x bc	0.7 %	24 hour
	2 x bc	-0.5 %	24 hour
Temp. Probe Height	2.5 m	0 %	All
	15 m	0 %	All

***bc refers to base case**

4. COMPARISON OF AERMOD WITH ISC3

AERMOD base case runs were also compared with ISC3 predictions. Only the base case runs were compared since ISC3 does not allow for the input of seven of the eight parameters varied in the AERMOD sensitivity study. The runs were performed for all three sources and for all five averaging periods.

Table 5 summarizes the percent difference of the maximum ISC3 and maximum AERMOD concentrations. Except for the 1-hour maximum GDF source, AERMOD consistently predicts lower concentrations than ISC3.

Table 5. Percent difference* of maximum ISC3 and maximum AERMOD concentrations. (Negative values indicate AERMOD maximum concentrations are smaller than ISC3 maximum concentrations.)

Averaging Period	Turbine	Generator	GDF
1 hour	-41 %	-62 %	0 %
3 hour	-63 %	-70 %	-20 %
8 hour	-57 %	-68 %	-27 %
24 hour	-41 %	-70 %	-52 %
Annual	-20 %	-60 %	-34 %

Percent difference defined as -100([ISC3]-[AERMOD])/[ISC3].

5. DISCUSSION AND SUMMARY

This modeling analysis showed that for all three typical source types, AERMOD was the most sensitive to surface roughness. Surface roughness lengths for specific land use types can vary from 0.0001 m for water to 1 m for urban areas, a span much larger than the factor of 4 used in this study. Of special concern was the nonlinear response AERMOD displayed as a function of surface roughness change and source type. For the typical turbine, AERMOD was almost five times more sensitive to increasing surface roughness than decreasing. For the typical backup generator, AERMOD was the most sensitive to decreased surface roughness. For the typical GDF AERMOD showed the most sensitivity for decreased surface roughness, but with a more linear response between positive and negative changes than the typical turbine. Since determining surface roughness is a subjective process, it is imperative that much care and detail be used when specifying the site-specific surface roughness for a project.

AERMOD showed contrasting sensitivity rankings among the three source types. For example, a factor of four change in surface roughness, solar radiation and albedo for the turbine source showed AERMOD was twice as sensitive to surface roughness as it was to solar radiation, and three times as sensitive to surface roughness as it was to albedo. In contrast, for the GDF a factor of four change for the same input parameters showed AERMOD was four times as sensitive to surface roughness as it was to both solar radiation and urban population. AERMOD was also sensitive to the solar radiation and cloud cover parameters. This illustrates the complex interaction of AERMOD with the many input parameters as a function of source type.

In general, for all three source types AERMOD was less conservative than ISC3.

6. REFERENCES

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