Air Dispersion Modeling Analysis
to
Support the Modeling Thresholds
and Associated Language in Section 2
of the
Colorado Modeling Guideline for Air Quality Permits
(January 2002, April 2010)

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1. Preface

The Air Pollution Control Division (Division) participated in a review of the "Colorado Modeling Guideline for Air Quality Permits" (Colorado Modeling Guideline). The review process resulted in revisions to the modeling guideline based on comments from a technical peer review conducted in 2000 and 2001, public comments, and comments from several stakeholder meetings. A public hearing on the guideline was held on December 20, 2001.

As part of the review process, the Division performed air quality modeling to help in the development of appropriate language and emission modeling thresholds for Table 1 of the Colorado Modeling Guideline. This report provides the results of the Division's modeling study. While the body of this report is focused on point source modeling, a series of graphical images are provided in the appendix to illustrate the magnitude and spatial extent of strong concentration gradients near fugitive sources. All of the fugitive source modeling is based on a continuous emission rate of 15 tons per year, which is the PM-10 modeling threshold in Table 1 of the Colorado Modeling Guideline.

Table 1 from the January 1, 2002 version of the Colorado Modeling Guideline and associated language in Section 2.5 – Modeling Thresholds - is presented on the next two pages. The Colorado Modeling Guideline was updated on December 27, 2005 to reflect revisions to Colorado AQCC Regulation No. 3 and EPA's Appendix W to 40 CFR Part 51 - Guideline on Air Quality Models and did not result in any material change to Table 1 or its associated language in Section 2.5.

[Excerpts from the January 1, 2002 version of the Colorado Modeling Guideline.]

Section 2.5 Modeling Thresholds

The modeling thresholds in this section are applicable for sources located in nonattainment and attainment areas (see sections2.1, 2.2, and 2.3). The thresholds were not developed to address situations such as those described in section 2.4.

The modeling thresholds were developed to identify new sources and modifications that would have relatively small impacts and do not warrant further analysis with respect to applicable air quality standards. The development of these thresholds is intended to assist the Division Staff, permit applicants, air quality consultants, and others decide when modeling is warranted to determine the impact from a source. This section introduces de minimis emissions, which have a low probability of causing or contributing to an exceedance of an air quality standard. By using this approach, permitting costs associated with the impact analysis required by Regulation No. 3 can be minimized.

Air quality modelers developed the modeling thresholds in Table 1 during a technical peer review of the Division's modeling practices. The Division performed dispersion modeling to help demonstrate that the thresholds in Table 1 are appropriate.[1] Permit applicants and the Division should try to avoid situations where the decision to perform modeling takes longer than actually performing a screening-level modeling analysis (screening-level models can often be run quickly with minimal cost).

For a given pollutant, modeling is usually warranted if the long-term (tons per year) or short-term (pounds per hour, etc.) **requested emission rate** *for a new source or the facility-wide net emissions increase for a modification is above the applicable emission threshold in Table 1. If the requested emission rate and/or the facility-wide net emissions increase is below both of the thresholds, modeling is usually not warranted unless one of the situations at the bottom of Table 1 applies. If there is doubt regarding the need for modeling, the applicant should consult with the Division.*

[1] The Division's modeling study shows that the thresholds are appropriate in situations where a source has reasonably good dispersion characteristics. In situations where a source has poor dispersion characteristics or in areas with poor existing air quality, the thresholds might not be appropriate. In these situations, the Division will work with the source to determine an appropriate threshold.

Table 1 [January 1, 2002]. Modeling Thresholds*. Modeling is usually warranted to quantify the impact if the emission rate is equal to or greater than these long-term (tons per year) and/or short-term (pound per hour, etc.) emission thresholds. If the emission rate is less, a qualitative description of the impact is adequate unless there is a situation that warrants modeling.* (1)

Pollutant	Requested Emission Rate from a New Source or Facility-Wide Net Emissions Increase from a Modification
Carbon Monoxide (CO)	100 tons per year or 23 pounds per hour
Nitrogen Oxides (NO_x)	40 tons per year[2]
Sulfur Dioxide (SO_2)	40 tons per year or 27 pounds per 3-hours
Particulate Matter (PM-10)	15 tons per year or 82 pounds per day
Lead (Pb)	0.6 tons per year or 100 pounds per month

(1) Modeling is usually warranted, even though the source or modification does not exceed the modeling thresholds in Table 1, if it is reasonable to believe the source will cause or contribute to a violation of applicable ambient air quality standards in circumstances such as:

(a) Sources of SO_2, PM-10, CO, or Pb where a substantial portion of the new or modified emissions have poor dispersion characteristics (e.g., rain caps, horizontal stacks, fugitive releases, [3] or ***building downwash***[4]) in close proximity to ***ambient air*** at the site boundary;

(b) Sources of SO_2, PM-10, CO, or Pb located in ***complex terrain*** (e.g., terrain above stack height in close proximity to the source);

(c) Sources located in areas with poor existing air quality;

(d) Modifications at existing major stationary sources, including grandfathered sources that have never been modeled before.

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[2] For new sources or modifications, including those with poor dispersion characteristics, that emit less than 40 tons per year (tpy) of NO_x, modeling is usually warranted only in the situations described in caveats (1)(c) and (1)(d), provided that most (e.g., >85%) of the NO_x is emitted as nitric oxide (NO). That is, because of near-field chemical transformation assumptions, NO_2 impacts from a 40 tpy NO_x source are usually expected to be below the NO_2 ambient air quality standard. Thus, modeling is only warranted in situations where existing NO_2 levels are high enough that the ***significant impact*** from the new source or modification might "contribute" to a modeled violation of the NO_2 air quality standard.

[3] For sources without stacks (e.g., fugitive releases from area or volume sources), modeling may be warranted at levels less than those in Table 1 if most of the emissions are from sources located less than 250-meters from the limit to public access. The 250-meter recommendation is based on a modeling study performed by the Division.

[4] For sources with emission rates below those in Table 1 where the stack height is less than the U.S. EPA's ***good engineering practice (GEP) stack height,*** modeling may be warranted; however, the presence of a non-GEP stack height does not mean that modeling is automatically warranted. The degree (e.g., severity) of the downwash effects, existing air quality levels, the distance to the boundary of ambient air, and any other relevant factors should be considered.

Table 1 was updated in April 2010 to address NAAQS changes for lead, particulate matter less than 2.5 microns, and nitrogen dioxide (the associated language in section 2.5 – Modeling Thresholds remains unchanged since January 1, 2002).

[Excerpts from the April 2010 update of Table 1 in the Colorado Modeling Guideline.]

***Table 1 [April 2010]. Modeling Thresholds**. Modeling is usually warranted to quantify the impact if the emission rate is equal to or greater than these emission thresholds. If the emission rate is less, a qualitative description of the impact is adequate unless there is a situation that warrants modeling.[(1)] [Note: The long-term (tons per year) thresholds apply to modeling decisions regarding annual average ambient air quality standards. The short term (pound per hour) thresholds apply to modeling decisions for short-term standards (i.e., ≤ 24-hr average).]*

Pollutant	Requested Emission Rate from a New Source or Facility-Wide Net Emissions Increase from a Modification
Carbon Monoxide (CO)	100 tons per year or 23 pounds per hour
Nitrogen Oxides (NO_X)	40 tons per year[5] or 0.46 pound per hour
Sulfur Dioxide (SO_2)	40 tons per year or 27 pounds per 3-hours
Particulate Matter < 10 µm (PM_{10})	15 tons per year or 82 pounds per day
Particulate Matter < 2.5 µm ($PM_{2.5}$)	5 tons per year of primary $PM_{2.5}$ or 11 pounds per day of primary $PM_{2.5}$
Lead (Pb)	25 pounds per 3-months

(1) Modeling is usually warranted, even though the source or modification does not exceed the modeling thresholds in Table 1, if it is reasonable to believe the source will cause or contribute to a violation of applicable ambient air quality standards in circumstances such as:
(a) Sources where a substantial portion of the new or modified emissions have poor dispersion characteristics (e.g., rain caps, horizontal stacks, fugitive releases[6], or ***building downwash***[7]) in close proximity to ***ambient air*** at the site boundary;
(b) Sources located in ***complex terrain*** (e.g., terrain above stack height in close proximity to the source);
(c) Sources located in areas with poor existing air quality;
(d) Modifications at existing major stationary sources, including grandfathered sources that have never been modeled before.

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[5]For new sources or modifications, including those with poor dispersion characteristics, that emit less than 40 tons per year (tpy) of NO_X, modeling for the annual NO_2 NAAQS is usually warranted only in the situations described in caveats (1)(c) and (1)(d), provided that most (e.g., >85%) of the NO_X is emitted as nitric oxide (NO). That is, because of near-field chemical transformation assumptions, NO_2 impacts from a 40 tpy NO_X source are usually expected to be below the annual NO_2 ambient air quality standard. Thus, modeling is only warranted in situations where existing annual NO_2 levels are high enough that the significant impact from the new source or modification might "contribute" to a modeled violation of the annual NO_2 air quality standard.

[6]For sources without stacks (e.g., fugitive releases from area or volume sources), modeling may be warranted at levels less than those in Table 1 if most of the emissions are from sources located less than 250-meters from the limit to public access. The 250-meter recommendation is based on a modeling study performed by the Division.

[7]For sources with emission rates below those in Table 1 where the stack height is less than the U.S. EPA's ***good engineering practice (GEP) stack height,*** modeling may be warranted; however, the presence of a non-GEP stack height does not mean that modeling is automatically warranted. The degree (e.g., severity) of the downwash effects, existing air quality levels, the distance to the boundary of ambient air, and any other relevant factors should be considered.

2. Introduction

In determining compliance with Ambient Air Quality Standards (AAQS), impacts from new/modified emission unit(s) are estimated with an air dispersion model. If estimated impacts from the new/modified emission unit(s) are above modeling significance levels, they are added to impacts from other emission units located at the facility, impacts from emission units located nearby, if appropriate, and a background concentration to determine total ambient air concentrations for compliance with the National Ambient Air Quality Standards (NAAQS) and Colorado Ambient Air Quality Standards (CAAQS). If the estimated impacts from the new/modified emission unit(s) are below modeling significance levels, the new/modified emission unit(s) is not considered to have a significant impact in ambient air[8] and no further analysis is necessary. Table 2 lists the modeling significance levels and AAQS for nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and fine particulate matter (PM_{10}).

Table 2 [January 2002]. Modeling Significance Levels and AAQS for NO_2, SO_2, and PM_{10}

	Modeling Significance Level (μg/m³)			NAAQS (μg/m³)			CAAQS (μg/m³)		
Pollutant	**3-hr**	**24-hr**	**Annual**	**3-hr**	**24-hr**	**Annual**	**3-hr**	**24-hr**	**Annual**
NO_2			1			100			100
SO_2	25	5	1	1300*	365	80	700		
PM_{10}		5	1		150	50		150	50

*Secondary NAAQS

Table 2 lists the modeling significance levels and AAQS for nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter less than 10 microns (PM_{10}), particulate matter less than 2.5 microns ($PM_{2.5}$) effective in April 2010.

Table 2 [April 2010]. Modeling Significance Levels and AAQS for NO_2, SO_2, PM_{10}, $PM_{2.5}$

	Modeling Significance Level (μg/m³)				NAAQS (μg/m³)				CAAQS (μg/m³)
Pollutant	**1-hr**	**3-hr**	**24-hr**	**Annual**	**1-hr**	**3-hr**	**24-hr**	**Annual**	**3-hr**
NO_2	4[a]			1	~189			100	
SO_2		25	5	1		1300[b]	365	80	700
PM_{10}			5	1			150		
$PM_{2.5}$			1.2[c]	0.3 [c]			35	15	

[a]Interim modeling significance level developed by the Division
[b]Secondary NAAQS
[c]Interim modeling significance level developed by the Division based on level proposed by EPA for NAAQS only

[8] "Ambient air" is defined as "that portion of the atmosphere, external to the source, to which the general public has access."

The "Colorado Modeling Guideline for Air Quality Permits" (Colorado Modeling Guideline) does not require a quantitative impact analysis for every new source/modification. The Colorado Modeling Guideline provides threshold emission levels that would trigger a quantitative impact analysis. Some of the public comments argue that only new/modified emission units emitting pollutants greater than Prevention of Significant Deterioration (PSD) Significant Emission Rates (shown below in Table 3) should trigger a quantitative impact analysis. Others also support raising the PM_{10} emission threshold level from 15 tons per year (tpy) to 40 tpy. This implies that new/modified emission units with emission rates equivalent to or greater than the PSD Significant Emission Rates would not cause or contribute to an exceedence of the AAQS.Table 3. Current (1998) and proposed (2001) modeling emission rate thresholds in tons per year, tpy. The proposed levels are the same as the PSD Significant Emission Rates of Criteria Pollutants in Regulation No. 3 **[Note: One exception is that the fugitive PM_{10} threshold would remain at 5 tpy].**

Pollutant	Current Emission Rate (tpy) Thresholds (Table 1; 12/23/98 Guideline)	Proposed Emission Rate (tpy) Thresholds (Table 1; 2/14/01 Guideline)
CO	50 attainment, 25 nonattainment	100
NO_X	20	40
SO_2	20	40
PM_{10} (Stack)	5	15
PM_{10} (Fugitive)	5	5
Pb	0.1	0.6

The January 2002 modeling analysis was performed to determine if a point source emitting 40 tpy of NO_X[9], SO_2, or PM_{10} or 15 tpy of PM_{10} would have a significant impact in ambient air (refer to Sections 4, 5, and 6).

The April 2010 modeling analysis (refer to Section 7) was performed to determine if the emission rate thresholds in Table 3 (above) are adequate to indicate when a quantitative impact analysis is necessary to demonstrate if the proposed modification or source will or will not cause or contribute to a violation of a recently promulgated NAAQS [24-hr and annual $PM_{2.5}$ (December 18, 2006, includes retaining the 24-hr revoking of the annual PM_{10} standard), 3-month rolling Pb (January 12, 2009), and 1-hr NO_2 (April 12, 2010)].

3. Effects on Ambient Air Impact Estimations

Ambient air impacts are a function of atmospheric dispersion. Various factors affect atmospheric dispersion, including plume rise, building wake effects, and meteorological

9 The ambient air standards are for nitrogen dioxide (NO_2), not oxides of nitrogen (NO_x). NO_x includes both nitric oxide (NO) and NO_2. While some NO_2 is directly emitted from the stacks of stationary sources, a significant portion of the emissions usually occur as nitric oxide (NO). The NO is converted to NO_2 by chemical mechanisms in the atmosphere. To account for possible chemical conversion in the atmosphere, the total NO_x emission rate is used in Table 2 instead of only the primary NO_2 emission rate.

conditions. Plume rise is due to the momentum or buoyancy of the exhaust gases. Factors that hinder plume rise are stack-tip downwash and building wake effects.

3.1. Buoyancy

Stack gases exhausted into the atmosphere having a density less than that of ambient air will experience plume rise due to buoyancy. Lower molecular weight or high stack gas exit temperature will result in a stack gas density lower than that of ambient air. In most regulatory air models, buoyancy is a function of the difference between stack gas exit temperature and ambient temperature. Model inputs used to determine the magnitude of buoyant forces are stack gas exit temperature, ambient temperature, stack diameter, and stack gas exit velocity. The larger of buoyancy force and momentum force is used to determine the effective plume height.

3.2. Momentum

The force imparted on the stack gases provides the momentum necessary for successful exhaustion into the atmosphere. Momentum is important if the temperature of the stack gases is within a few degrees of ambient temperature or subject to building wake effects. Obstructions at the top of a vertical stack, such as a rain cap, can reduce or eliminate vertical momentum and affect plume rise. Horizontal discharges also have essentially no momentum plume rise. Model inputs that affect momentum are stack gas exit velocity and stack diameter. Depending on meteorological conditions, stack gas exit temperature and ambient temperature also affect momentum calculations.

3.3. Stack-Tip Downwash

Stack-tip downwash occurs when the stack gas plume is drawn down to the low pressure or slight vacuum region downwind of the stack. The area of low pressure/slight vacuum is cause by wind flowing past the stack. Stack-tip downwash can be eliminated if exit velocities are greater than or equal to 150% of the wind speed at the stack top. Model inputs that affect stack-tip downwash are stack gas exit velocity and wind speed. Stack diameter is also used to determine the effective plume height.

3.4. Building Downwash

Wind flow around a building creates turbulent eddies downwind of the building. Plumes released near buildings can be caught in the turbulent wake of the building. For elevated releases, plumes subject to building downwash usually result in increased ground-level concentrations. To avoid the effect of building downwash, the general rule is to design a stack that is 2.5 times the lesser of the height or projected width of nearby buildings.[10] This is known as the Good Engineering Practice (GEP) height. Building dimensions are input into modeling systems to determine if the stack gas plume will be affected by downwash.

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[10] A building is considered to be nearby if it is within 5L (five times L, where L is the lesser of the building height or the projected width of the building) of a building or structure [see 40 CFR 51.100 (jj)(1)].

4. Methodology (January 2002 Analysis)

Multiple model runs were performed using a range of values in stack parameters. The Industrial Source Complex Model (ISCST3 version 00101) was used with 1989 Denver Stapleton Meteorological Data. The emission rate used for all runs is 1.15 g/s (40 tpy) to determine NO_X, SO_2, and PM_{10} concentration levels. Since modeling was performed for only one emission unit and concentration is directly proportional to emission rate, concentration levels determined with a 40 tpy emission rate are scaled to obtain PM_{10} concentrations at 15 tpy.

Table 5 summarizes the values of each parameter for each model run. Stack characteristics were selected to illustrate the effects of each/combination of parameter(s) on impact estimates. The range of values in Table 5 is not intended to represent all possible stack characteristics and combinations. In practice, many emission units have stack parameters that are lower or higher than the range of values used in this study.

4.1. Receptor Spacing

The receptor network is described in Table 4 below.

Table 4. Receptor spacing and location

Distance from Source Location	Receptor Spacing
Fenceline	8 receptors spaced 50 m, 30 m, or 15 m (see Table 5) apart forming a square perimeter with source location in the center; spacing varies per run
50 m	8 receptors spaced 50 m apart forming a square perimeter with source location in the center
0 to 5000m	100 m Cartesian grid
5000 m to 10,000 m	250 m Cartesian grid

4.2. Model Runs

4.2.1. Sensitivity Analysis (Runs 1 through 10)

A base case (Run 1) was selected to compare with Runs 2 through 10. The sensitivity analysis consists of 9 runs where each run differed from the base case by only one modeling parameter. The parameters are stack height, urban dispersion, stack diameter, stack gas exit velocity, and stack gas exit temperature. These runs assume that the plume is not subject to building downwash.

4.2.2. Building Downwash (Runs 11 through 18)

Runs 11 through 18 were performed to examine the effects of building downwash effects on the impacts and their location from the source. The footprint of the building is 9.14 m x 9.14 m (30 ft x 30 ft). Building height of 50% and 75% of the stack height were used. Runs 13 and 14 use urban instead of rural dispersion coefficients. Runs 15 through 18 with urban dispersion include fenceline receptors closer to the source.

4.2.3. Multiple changes in Stack Characteristics with Building Downwash (Runs 19 through 22)

Runs 19 through 22 represent vertical unobstructed stacks with stack and building configurations that hinder plume rise.

4.2.4. Horizontal Stack (Runs 23 through 25)

The stack inputs were modified to follow EPA guidance for modeling horizontal stacks (July 9, 1993 memo from Joseph A Tikvart to Ken Eng). Stack diameter is set to 0.001 m. Actual stack height is used.

4.2.5. Capped Stack (Runs 26 through 28)

The stack inputs were modified to follow EPA guidance for modeling capped stacks (July 9, 1993 memo from Joseph A. Tikvart to Ken Eng). Stack diameter is set to 0.001 m. Stack height is reduced by 3 times the actual stack diameter.

4.2.6. Minimum and Maximum Range of Values (Runs 29 and 30)

Run 29 represents a vertical stack with no obstruction that is subject to building downwash with the lowest stack parameters in Table 4. Run 30 represents a vertical stack with no obstruction and no downwash effects with the highest stack parameters in Table 4.

4.3. Comparison with Modeling Significance Levels and AAQS

According to U.S. EPA guidance, the highest impact concentration of any averaging period should be used to determine whether the emission unit will have a significant impact in ambient air. That is, the modeling significance level is used to determine if a source "contributes" to a modeled violation of AAQS. When impacts are significant for an averaging period at a specific receptor, the impacts from the emission unit are added to the impacts from nearby sources, if appropriate, and a reasonable background concentration to determine the total ambient air concentration for the compliance demonstration with the AAQS. The maximum annual and highest-2nd-highest (H2H) short-term SO_2 and PM_{10} (the allowance of one exceedence of the 24-hr PM_{10} when using one year of meteorological data) total ambient air concentrations are compared to the AAQS. For simplicity in this modeling analysis, H2H short-term SO_2 and PM_{10}, and maximum annual concentrations are compared to the modeling significance level for significance determination and used to determine whether the impact itself would exceed the AAQS.

5. Results (January 2002 Analysis)

The results are presented in tabular format for all runs by emission rate and averaging period in Table 6. The 24-hr results of model Runs 1 through 10 are also presented in Figure 1 through Figure 5 to examine the magnitude and location of impacts. Since no chemical transformations or conversion factors were used, the impacts listed below apply to any pollutant.

Table 5. Summary of stack, building and fenceline parameters for each model run

Model Run[1]	Dispersion[2]	Stack Height (m)	Stack Diameter (m)	Stack Gas Exit Temperature (K)	Stack Gas Exit Velocity (m/s)	Stack Orientation[4]	Building Height (m)[3]	Fenceline Distance (m)
1 - Base Case	R	6.10	0.31	644	25.4	V	0	50
2 - Height Decrease	R	3.05	0.31	644	25.4	V	0	50
3 - Height Increase	R	9.14	0.31	644	25.4	V	0	50
4 - Urban	U	6.10	0.31	644	25.4	V	0	50
5 - Diameter Decrease	R	6.10	0.15	644	25.4	V	0	50
6 - Diameter Increase	R	6.10	0.46	644	25.4	V	0	50
7 - Velocity Decrease	R	6.10	0.31	644	9.14	V	0	50
8 - Velocity Increase	R	6.10	0.31	644	76.2	V	0	50
9 - Temperature Decrease	R	6.10	0.31	477	25.4	V	0	50
10 - Temperature Increase	R	6.10	0.31	811	25.4	V	0	50
11- BH 50% SH	R	6.10	0.31	644	25.4	V	3.05	50
12 - BH 75% SH	R	6.10	0.31	644	25.4	V	4.58	50
13 - BH 50% SH, urban	U	6.10	0.31	644	25.4	V	3.05	50
14 - BH 75% SH, urban	U	6.10	0.31	644	25.4	V	4.58	50
15 - BH 50% SH, urban, 30 m FL	U	6.10	0.31	644	25.4	V	3.05	30
16 - BH 75% SH, urban, 30 m FL	U	6.10	0.31	644	25.4	V	4.58	30
17 - BH 50% SH, urban, 15 m FL	U	6.10	0.31	644	25.4	V	3.05	15
18 - BH 75% SH, urban, 15 m FL	U	6.10	0.31	644	25.4	V	4.58	15
19 - T/D/V Decrease, BH 75% SH, 30 m FL	R	6.10	0.15	477	10	V	4.58	30
20 - H/T/D/V Decrease, BH 67% SH, 30 m FL	R	4.58	0.15	477	10	V	3.05	30
21 - T/D/V Decrease, BH 75% SH, urban, 30 m FL	U	6.10	0.15	477	15	V	4.58	30
22 - H Decrease, BH 100% SH, urban, 30 m FL	U	3.05	0.31	644	25.4	V	3.05	30
23 - Horizontal[5]	R	6.10	0.001	644	0.001	H	0	50
24 - Horizontal, BH 50% SH[5]	R	6.10	0.001	644	0.001	H	3.05	50
25 - Horizontal, BH 50% SH, 30 m FL [5]	R	6.10	0.001	644	0.001	H	3.05	30
26 - Capped[6]	R	5.17	0.001	644	0.001	C	0	50
27 - Capped, BH 50% SH[6]	R	5.17	0.001	644	0.001	C	3.05	50
28 - Capped, BH 50% SH, 30 m FL [6]	R	5.17	0.001	644	0.001	C	3.05	30
29 - Low range of values, Building 100% SH	R	3.05	0.15	477	9.14	V	3.05	30
30 - High range of values	R	9.14	0.46	811	76.2	V	0	30

[1]Model Run Codes: BH = Building Height, SH = Stack Height, D = Diameter, V = Exit Velocity, T = Exit Temperature, FL = Fenceline.
[2]Dispersion Codes: R = Rural, U = Urban.
[3]Building Footprint Dimensions: 9.14 m x 9.14 m (30 ft x 30 ft).
[4]Stack Orientation Codes: V = Vertical, H = Horizontal, C = Capped, Vertical Obstructed.
[5]Stack parameters adjusted according to EPA Guidance (July 9, 1993 memo from Joseph A Tikvart to Ken Eng)
[6]Stack parameters adjusted according to EPA Guidance (July 9, 1993 memo from Joseph A Tikvart to Ken Eng), assumes D = 0.31 m
Shaded Values – Values different than base case

Table 6. Summary of impacts for 40 tpy and 15 tpy emission rates. [Note: In a compliance demonstration with ambient air quality standards (AAQS),[11] impacts from nearby sources, if appropriate, and background sources would be added to these results.]

Model Run	Impact Concentration (μg/m^3)				
	40 tpy H2H 3-hr	40 tpy H2H 24-hr	40 tpy Max Annual	15 tpy H2H 24-hr	15 tpy Max Annual
1 - Base Case	88.26	28.15	3.74	10.56	1.40
2 - Height Decrease	148.08	37.90	5.57	14.21	2.09
3 - Height Increase	61.71	17.88	2.68	6.71	1.01
4 - Urban	161.08	71.03	9.77	26.64	3.66
5 - Diameter Decrease	283.71	76.96	12.21	28.86	4.58
6 - Diameter Increase	46.37	12.35	1.55	4.63	0.58
7 - Velocity Decrease	203.94	59.79	8.75	22.42	3.28
8 - Velocity Increase	36.12	9.05	1.07	3.39	0.40
9 - Temperature Decrease	118.95	35.72	5.16	13.40	1.94
10 - Temperature Increase	74.16	24.62	3.14	9.23	1.18
11- BH 50% SH	128.26	28.35	3.77	10.63	1.41
12 - BH 75% SH	308.61	83.93	6.47	31.47	2.43
13 - BH 50% SH, urban	196.43	71.42	9.80	26.78	3.68
14 - BH 75% SH, urban	544.72	237.69	35.92	89.13	13.47
15 - BH 50% SH, urban, 30 m FL	208.77	71.42	9.80	26.78	3.68
16 - BH 75% SH, urban, 30 m FL	949.60	317.85	54.00	119.19	20.25
17 - BH 50% SH, urban, 15 m FL	196.43	71.42	9.80	26.78	3.68
18 - BH 75% SH, urban, 15 m FL	1045.30	237.69	35.92	89.13	13.47
19 - T/D/V Decrease, BH 75% SH, 30 m FL	1487.95	463.76	99.96	173.91	37.49
20 - H/T/D/V Decrease, BH 67% SH, 30 m FL	1444.40	582.41	109.67	218.40	41.13
21 - T/D/V Decrease, BH 75% SH, urban, 30 m FL	1683.62	626.98	114.99	235.12	43.12
22 - H Decrease, BH 100% SH, urban, 30 m FL	1606.12	654.28	101.58	245.36	38.09
23 – Horizontal[5]	1341.46	377.22	54.20	141.46	20.33
24 - Horizontal, BH 50% SH[5]	4308.35	1138.81	188.96	427.05	70.86
25 - Horizontal, BH 50% SH, 30 m FL [5]	5676.34	1546.20	239.56	579.83	89.84
26 - Capped[6]	1824.50	480.88	80.05	180.33	30.02
27 - Capped, BH 50% SH[6]	5990.40	1577.67	252.12	591.63	94.55
28 - Capped, BH 50% SH, 30 m FL [6]	8643.41	2357.32	364.89	884.00	136.83
29 - Low range of values, Building 100% SH	8693.97	2037.43	487.96	764.04	182.99
30 - High range of values	9.38	2.30	0.31	0.86	0.12

[11] Modeling Significance Levels and AAQS for NO_2, SO_2, and PM_{10}

	Modeling Significance Level (μg/m^3)			NAAQS (μg/m^3)			CAAQS (μg/m^3)		
Pollutant	3-hr	24-hr	Annual	3-hr	24-hr	Annual	3-hr	24-hr	Annual
NO_2			1			100			100
SO_2	25	5	1	1300	365	80	700		
PM_{10}		5	1		150	50		150	50

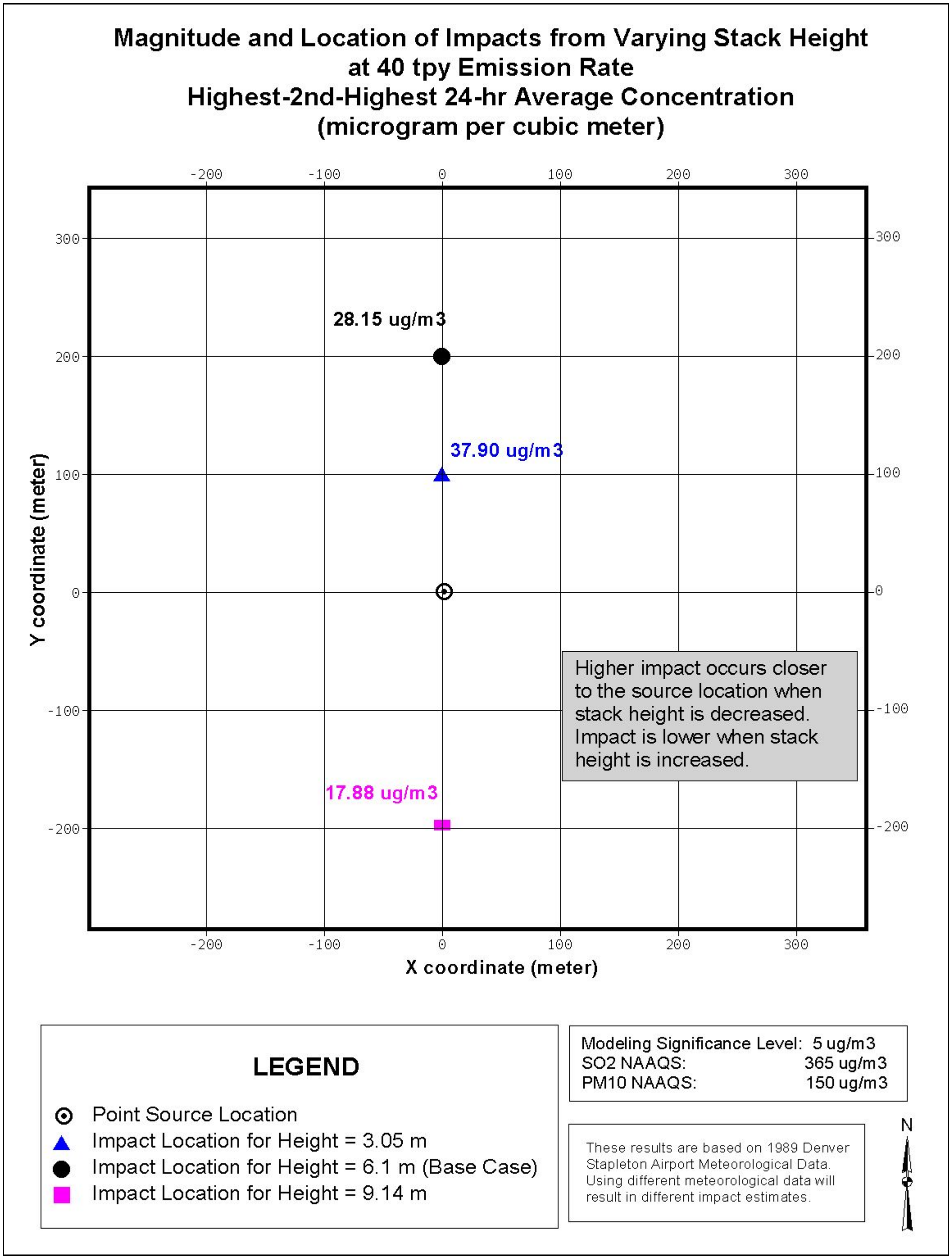


Figure 1. Magnitude and Location of Impacts from Varying Stack Height

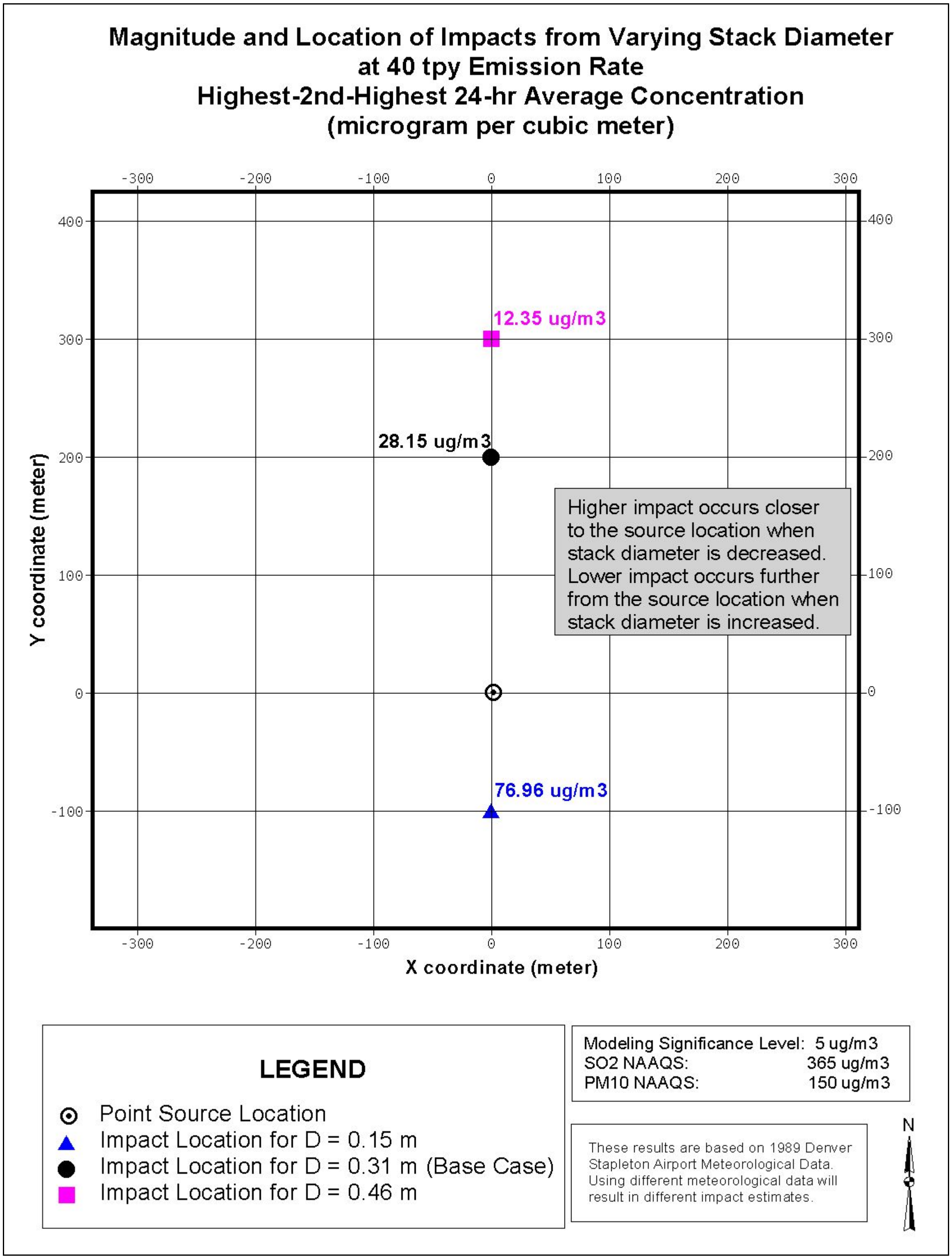


Figure 2. Magnitude and Location of Impacts from Varying Stack Diameter

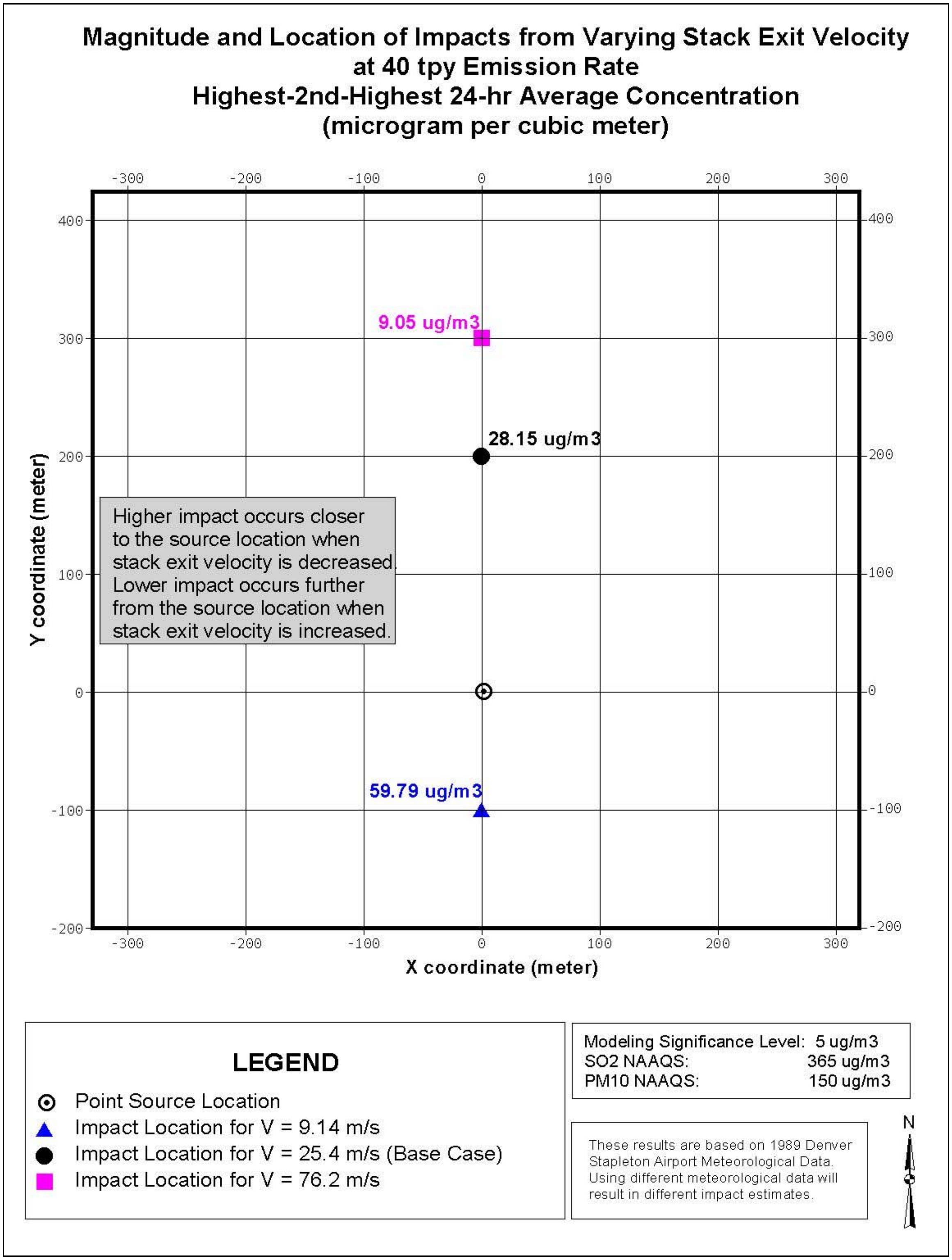


Figure 3. Magnitude and Location of Impacts from Varying Stack Exit Velocity

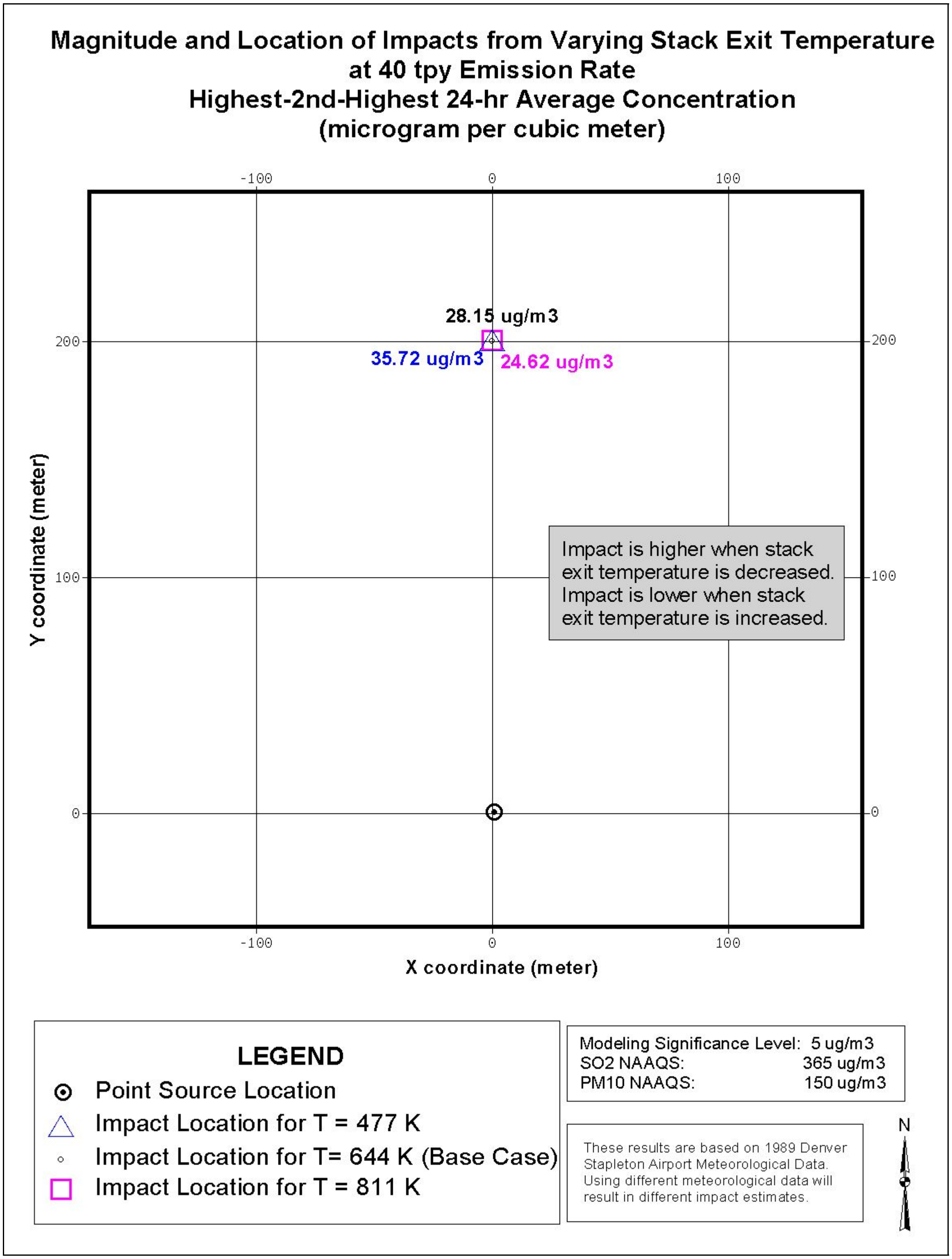


Figure 4. Magnitude and Location of Impacts from Varying Stack Gas Exit Temperature

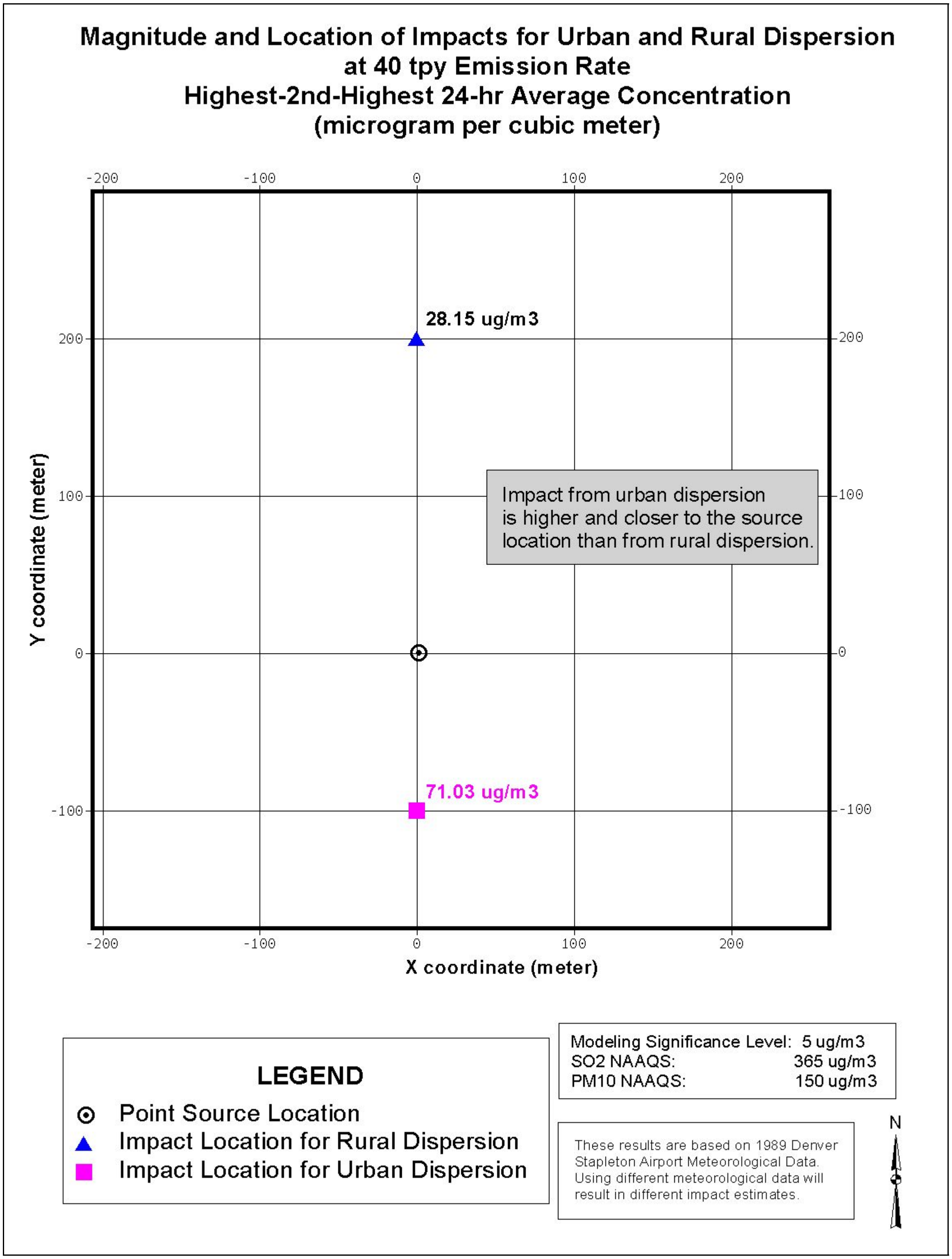


Figure 5. Magnitude and Location of Impacts for Urban and Rural Dispersion

6. Discussion (January 2002 Analysis)

6.1. Sensitivity Analysis (Runs 2 through 10)

The results show that increases in stack height, stack diameter, stack gas exit velocity, and stack gas exit temperature decrease ambient pollutant concentration levels and increase the distance of impact from the source. Decreases in stack height, stack diameter, stack gas exit velocity, and stack gas exit temperature increase ambient pollutant concentration levels and decrease the distance of impact from the source. Tall and wide stacks with high velocity and temperature promote plume rise. Short and narrow stacks with low velocity and temperature impede plume rise. The modeling parameters used for these runs with an emission rate of 40 tpy resulted in exceedances of the modeling significance levels for all averaging periods for SO_2, NO_2, and PM_{10}. All impact concentrations for 15 tpy PM_{10}, except for diameter and velocity increases, are above the modeling significance levels for both averaging periods for PM_{10}.

6.2. Building Downwash (Runs 11 through 18)

Increase in building height increases the magnitude of impact and decreases the distance of impact from the source. Examining the concentrations for runs 13 through 18 in Table 7 reveals the relationship between maximum impacts and fenceline receptors. The maximum impacts obtained for a given emission unit can vary with the location of the fenceline. Thus, the fenceline location is important because it usually determines the ambient air boundary.[12] For example, the maximum annual concentration for an emission unit subject to downwash from a building height equal to 75% of the stack height with a fenceline at 50 m is 35.92 $\mu g/m^3$. If the same emission unit has a fenceline at 30 m, the maximum annual concentration is 54.00 $\mu g/m^3$, a 50% increase. For the emission unit subject to downwash from a building height equal to 50% of the stack height, the H2H 24-hr and maximum annual concentrations are the same for all fenceline distances used. The modeling parameters used for these runs with an emission rate of 40 tpy resulted in exceedences of the modeling significance levels for all averaging periods for SO_2, NO_2, and PM_{10}. All impact concentrations for 15 tpy PM_{10} are above the modeling significance levels for both averaging periods for PM_{10}. The 3-hr SO_2 CAAQS is exceeded by the source impacts.

Table 7. Impacts from 40 tpy by fenceline distance from source

Fenceline Distance from Source	Impact Concentration from 40 tpy ($\mu g/m^3$)					
	Building Height = 50% Stack Height			Building Height = 75% Stack Height		
	H2H 3-hr	H2H 24-hr	Max Annual	H2H 3-hr	H2H 24-hr	Max Annual
50 m	196.43	71.42	9.8	544.72	237.69	35.92
30 m	208.77	71.42	9.8	949.60	317.85	54.00
15 m	196.43	71.42	9.8	1045.30	237.69	35.92

6.3. Multiple Changes in Stack Characteristics with Building Downwash (Runs 19 through 22)

These runs were performed to determine impact concentrations resulting from vertical, unobstructed stacks subject to building downwash with poor dispersion characteristics (low temperature, velocity and stack diameter). Short stacks with fairly good dispersion can have high impacts due to an overwhelming effect from building downwash. The modeling parameters used for these runs with an emission rate of 40 tpy resulted in exceedances of the modeling significance levels for all averaging periods for SO_2, NO_2, and PM_{10}. All impact concentrations for 15 tpy PM_{10} are above the modeling significance levels for both averaging periods for PM_{10}. The SO_2 AAQS and 24-hr PM_{10} NAAQS (at 40 tpy and 15 tpy) have been exceeded by the

[12] Ambient air quality standards apply only in "ambient air." That is, it is not necessary to place receptors (e.g., to estimate impacts) within property owned or controlled by the facility if public access is precluded by a fence or physical barrier.

source impacts. The NO_2 impacts, using a 75% annual conversion to NO_2 from NO_X, range from 75 $\mu g/m^3$ to 86 $\mu g/m^3$, greater than 75% of the NO_2 NAAQS.

6.4. Horizontal Stack (Runs 23 Through 25) and Capped Stack (Runs 26 through 28)

Horizontal and capped stacks do not promote plume rise. This is illustrated by the exceedances of the modeling significance levels for all averaging periods as well as most of the AAQS for SO_2, NO_2, and PM_{10} with a few exceptions (annual NAAQS for runs with no building downwash).

6.5. Minimum and Maximum Range of Values (Runs 29 and 30)

These runs were performed to determine the range of impact concentrations for the range of stack and building characteristics used in this modeling analysis. Run 29 is the poor dispersion example with all impact concentrations exceeding the modeling significance levels and AAQS. Run 30 is a good dispersion example with all impact concentrations below the modeling significance levels.

6.6. Other Modeling Variables Not Examined in this Modeling Analysis

There are other parameters used in modeling that are not examined here, such as different meteorological data sets, elevated terrain, and background concentrations. Typical yearly variations of meteorological data at one location can result in modeled design concentration differences of up to 25% or even higher in some locations.[13] Higher impacts may result when plume rise is insufficient to clear nearby terrain.

Contributors to ambient air concentration for determining compliance with AAQS are impacts from the source of interest and nearby sources, and the background concentration. Even though impacts are just above modeling significance levels or only a small fraction of the AAQS, a complete compliance demonstrate must also take existing air pollutant concentration levels into account. This may mean that, in addition to adding a background concentration, nearby sources with strong concentration gradients should be included in the modeling. Since it's not reasonable to model all sources, it is necessary to add a background concentration to account for the emissions from all sources that have not been explicitly included in the modeling. Background concentrations vary by geographic area. For areas with high background concentrations (and/or strong concentration gradients from nearby sources) near the AAQS, a source impact that is greater than the modeling significance levels, but still a relatively small percentage of the AAQS, can result in a modeled violation of the AAQS.

[13] In a recent study conducted in Alaska, it was found that the modeled maximum annual average concentration varied by as much as 200% over a five (5) year period at one particular site, depending on which year of meteorological data was used in the model. At two other sites, the maxima varied by 139% and 122%, respectively. For short-term (24-hour) concentrations, the maximum modeled concentration varied by 161%, 148%, and 121% at three different sites, depending on which one of the five years of meteorological data were used. In addition to the variation in the maximum modeled impact, the location (geographic location) of the modeled maxima varied significantly from one year to the next. [Reference: Presentation by Alan Schuler, Alaska Department of Environmental Conservation, 2001 EPA/State/Local Modeler's Workshop, Chicago]

7. Methodology, Results, and Discussion of the April 2010 Analysis

7.1. Methodology

Annual, 24-hr, and 1-hr impacts for 22 individual point source scenarios using 48 one-year periods of hourly meteorology were estimated with AERMOD (09292) and SCREEN3 for a range of emission rates. Since no chemical transformations or conversion factors were used, the impacts in Figures #-# below are applicable for any pollutant. Urban effects were not modeled.

7.1.1. Meteorology

The following meteorological data (station/years) were used in this analysis.

DEN (Denver Stapleton) 1990-1994
Greely (Greeley) 2002-2006
Akron (Akron) 1990-1994
Pueblo (Pueblo Memorial Airport) 2002-2006
COSprings (Colorado Springs) 1987-1991
Sydney (Sydney) 2003-2007
Kodak 1993-1997
PRPA06 (Platte River Power-Rawhide)
Thermo/Ft Lupton
FtStVrain (Fort St Vrain Power)
PuebloDepot (Peublo Chemical Depot) 1998-2000
Portland
Asarco1993, 1994, 1998-2000
Naturita

7.1.2. Receptor Network

Receptors were placed every 10 degrees at the following distances (meters) from the point source: 30, 50, 75, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, 2200, 2300, 2400, 2500, 2600, 2700, 2800, 2900, 3000, 3100, 3200, 3300, 3400, 3500, 3600, 3700, 3800, 3900, 4000, 4100, 4200, 4300, 4400, 4500, 4600, 4700, 4800, 4900, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 9500, 10000. Flat terrain was assumed.

7.1.3. Point Sources

Table 8 summarizes the point source parameters (building dimensions, where applicable) for each scenario/model run. The range of source types in this analysis (points, with and without building downwash) is not intended to represent all possible stack characteristics and combinations but is intended to illustrate the effects of each/combination of parameter(s) on impact estimates.

Table 8. Summary of Point Source Inputs

Source ID	Emissions Rate (g/s)	Stack Height (m)	Temp (K)	Exit Velocity (m/s)	Stack Diameter (m)	Bldg Height (m)	Bldg Width (m)	Bldg Length (m)	Location of Bldg
B1	100	10	293	1	2.4				
B2	100	35	293	11.7	2.4				
B3	100	35	432	11.7	2.4				
B4	100	100	416	18.8	4.6				
B5	100	150	425	26.5	5.6				
B6	100	200	425	26.5	5.6				
BC08	100	8	377	10	0.7				
BC10	100	10	300	15	0.2				
BCMD	100	40	325	10	1.5				
BCLG	100	91.4	467.6	17.1	4.57				
CO1	100	6	400	15	0.5				
ASOS1	100	55	432	11.7	2.4				
D1	100	10	293	1	2.4	34	60	120	NE bldg corner = stack location
D2	100	10	293	1	2.4	34	60	120	NE bldg corner SW of stack (-96 m, -96 m)
D3	100	35	432	11.7	2.4	34	60	120	NE bldg corner = stack location
D4	100	35	432	11.7	2.4	34	60	120	NE bldg corner SW of stack (-96 m, -96 m)
D5	100	100	416	18.8	4.6	50	60	120	NE bldg corner = stack location
D6	100	100	416	18.8	4.6	50	60	120	NE bldg corner SW of stack (-140 m, -140 m)
BC08D	100	8	377	10	0.7	6	10	6	North side of building centered on stack
BC10D	100	10	300	15	0.2	8	10	6	NE bldg corner located 4 m south of stack
CO1D	100	6	400	15	0.5	4	4.5	9	North side of building centered on stack
ASOS1D	100	55	432	11.7	2.4	34	60	120	NE bldg corner = stack location

7.2. Results and Discussion

Predicted concentrations from AERMOD and SCREEN3 for various emission rates are compared to the NAAQS for Pb (3-month), $PM_{2.5}$ (24-hr and annual), and NO_2 (1-hr) in the subsequent subsections. The SCREEN3 concentrations do not include estimates in the cavity region, consistent with past and present Division practice.

7.2.1. 1-hr Concentrations

Figure 6 through Figure 9 present the 1-hr concentrations for emission rates of 9.13 pounds per hr (annual NO_X emission rate threshold equivalent - 40 tpy), 2.28 pounds per hr, 1.14 pounds per hour, and 0.46 pound per hr. Based on these results, the 1-hr NO_2 NAAQS could be threatened by an individual emission unit with an emission rate around or greater than 2.28 pounds per hour. At a point source emission rate of 1.14 pounds per hour (with or without building downwash), it is reasonable to believe the source will cause or contribute to a violation of the 1-hr NO_2 NAAQS. For a point source with an emission rate of 0.46 pound per hour with poor dispersion, there will be situations (Table 1 footnotes and Section 7.2.5) when the modeling significance level is exceeded and it is reasonable to believe the source will cause or contribute to a violation of the 1-hr NO_2 NAAQS.

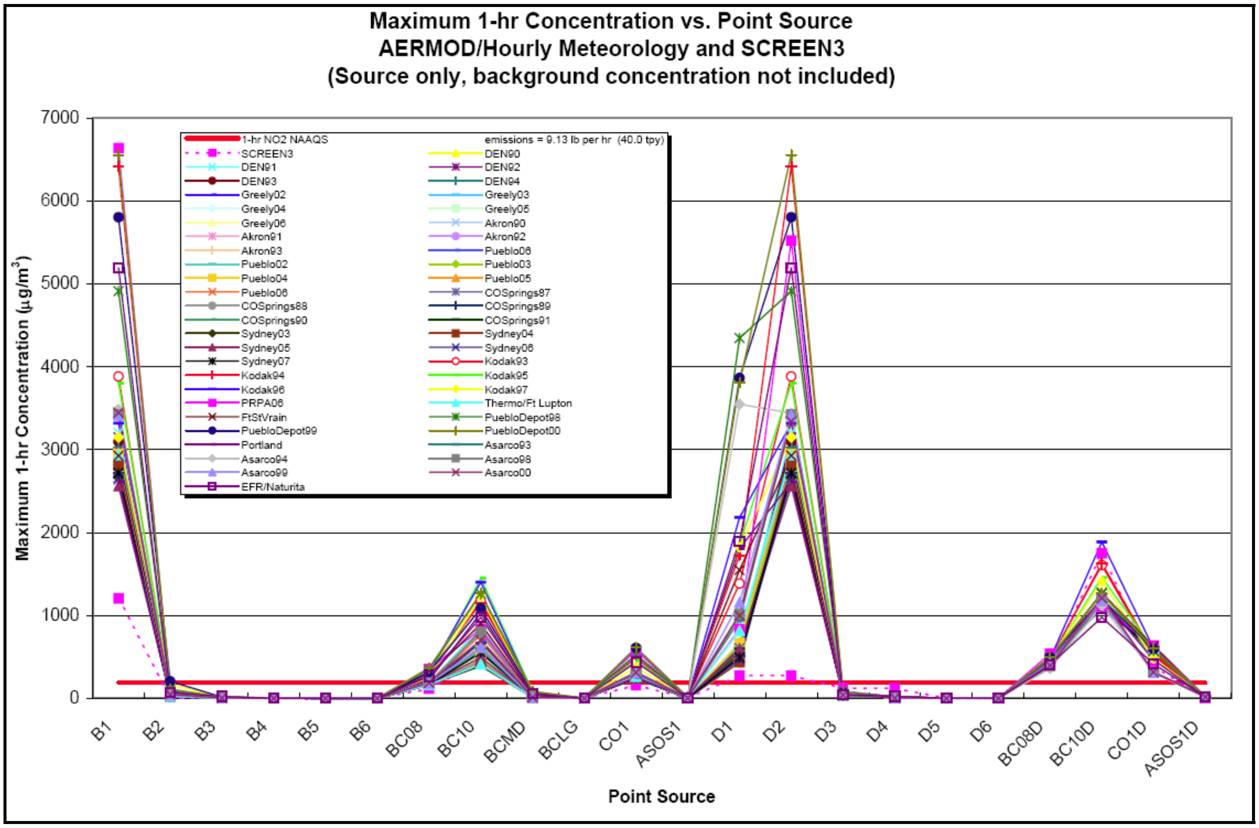


Figure 6. Maximum 1-hr Concentrations - 9.13 pounds per hr (40 tpy equivalent)

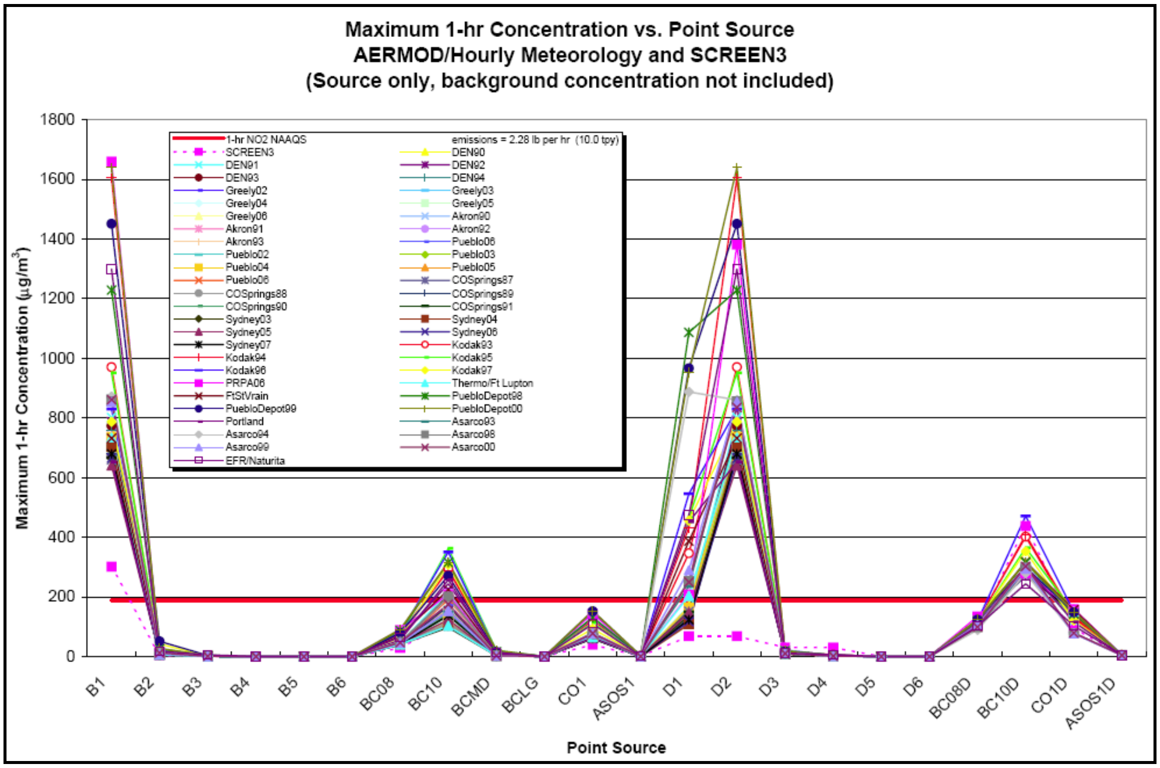


Figure 7. Maximum 1-hr Concentrations -2.28 pounds per hr (10 tpy equivalent)

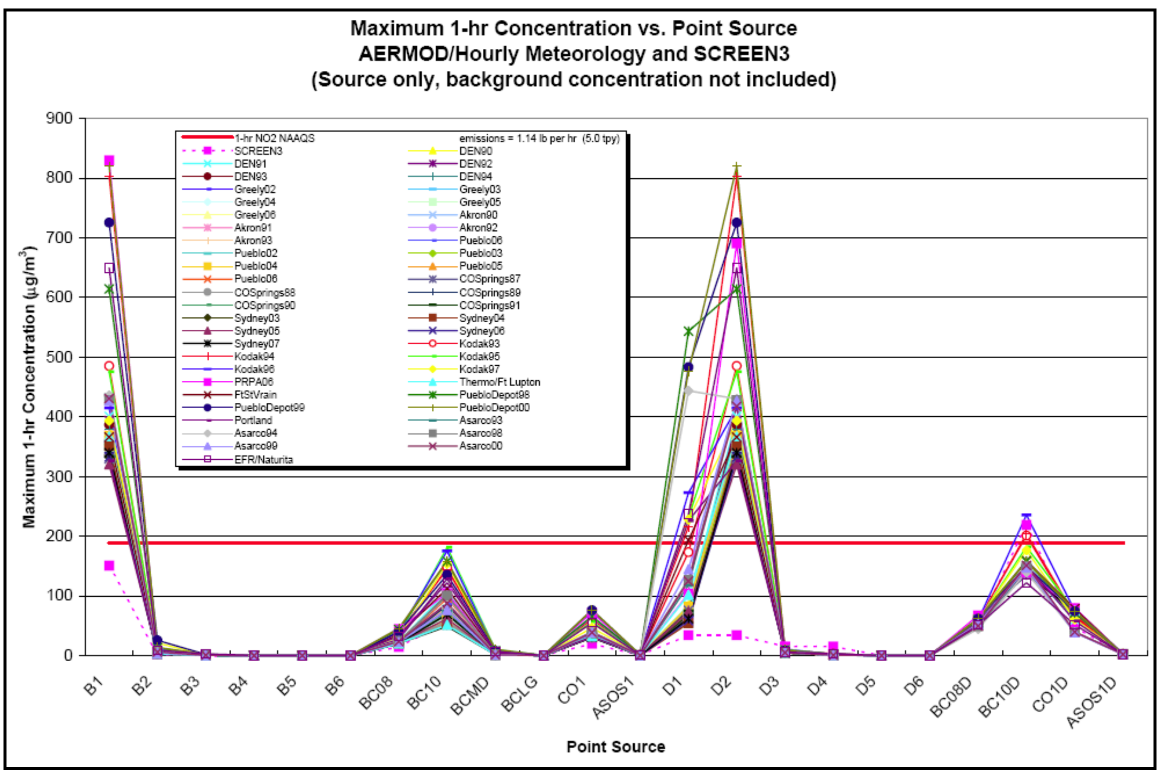


Figure 8. Maximum 1-hr Concentrations - 1.14 pounds per hr (5 tpy equivalent)

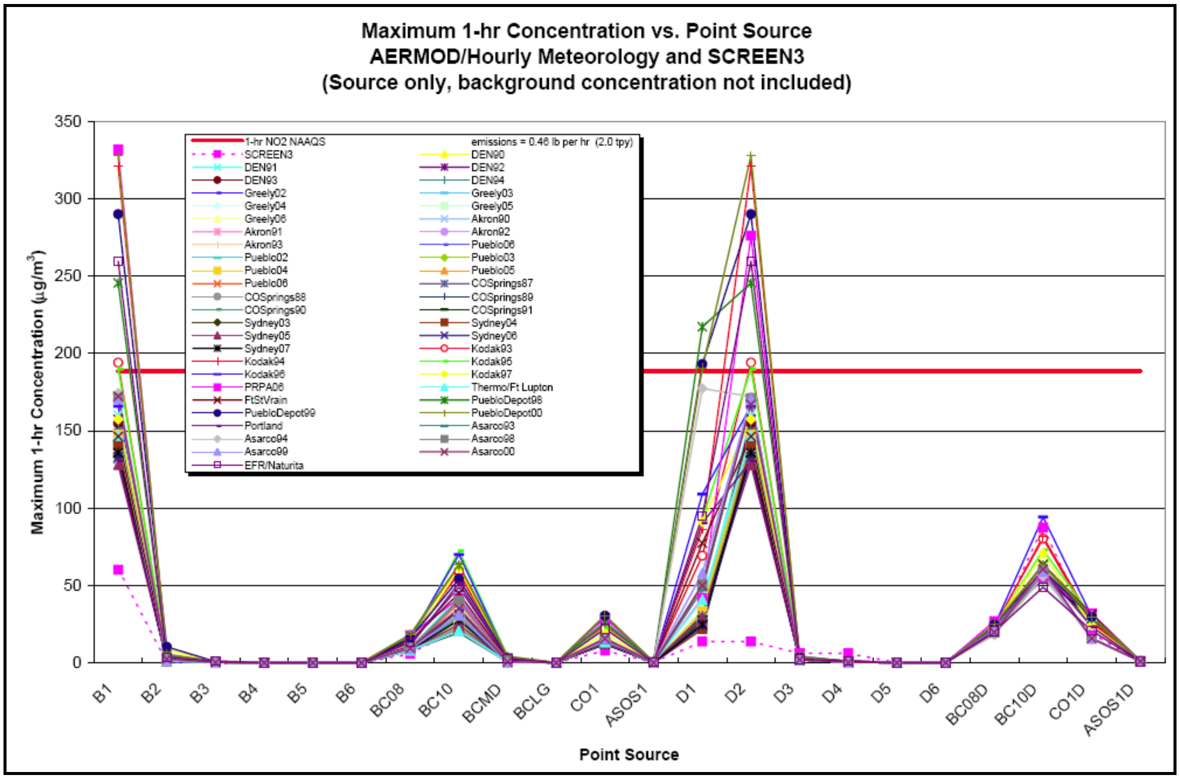


Figure 9. Maximum 1-hr Concentrations - 0.46 pound per hr (2 tpy equivalent)

7.2.2. 24-hr Concentrations

Figure 10 through Figure 12 present the 24-hr concentrations for emission rates of 82 pounds per day (24-hr PM_{10} emission rate threshold), 27 pounds per day, and 11 pounds per day. Based on these results, the 24-hr $PM_{2.5}$ NAAQS could be threatened by an individual emission unit with poor dispersion and an emission rate around or greater than 27 pounds per day. For a point source with an emission rate of 11 pounds per day with poor dispersion, there will be situations (Table 1 footnotes and Section 7.2.5) when the modeling significance level is exceeded and it is reasonable to believe the source will cause or contribute to a violation of the 24-hr $PM_{2.5}$ NAAQS.

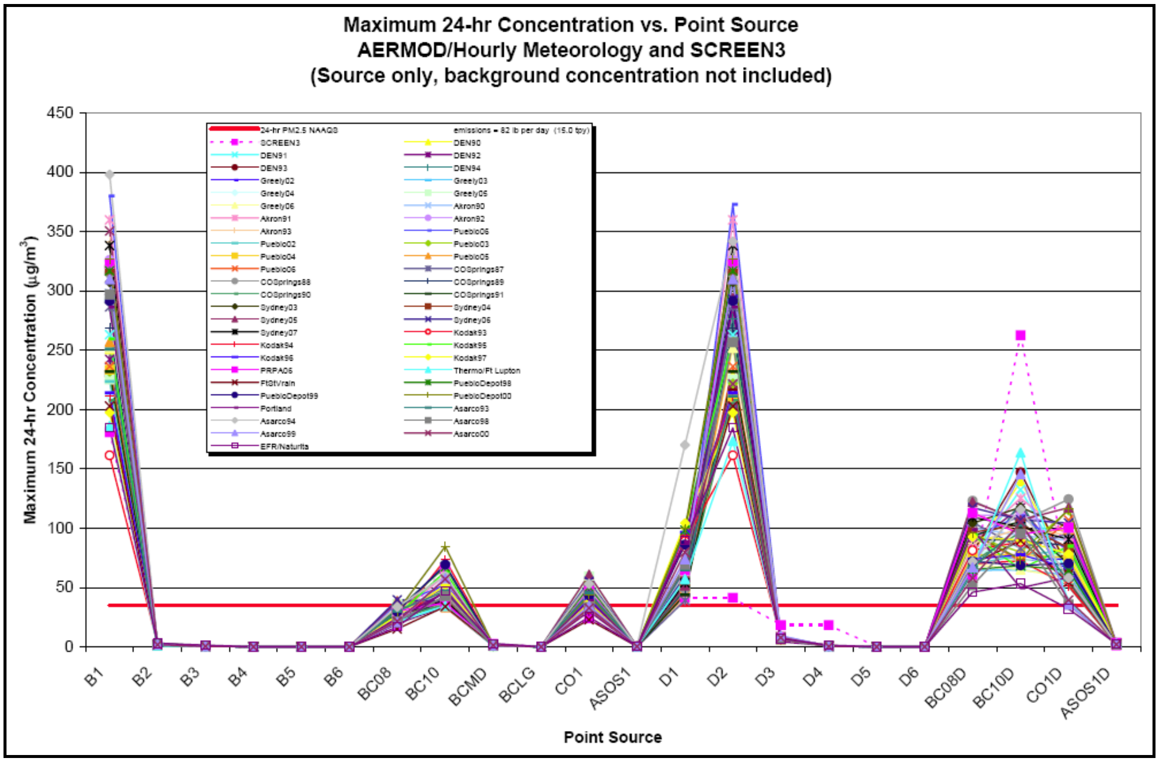


Figure 10. Maximum 24-hr Concentration - 82 lb per day (15 tpy equivalent)

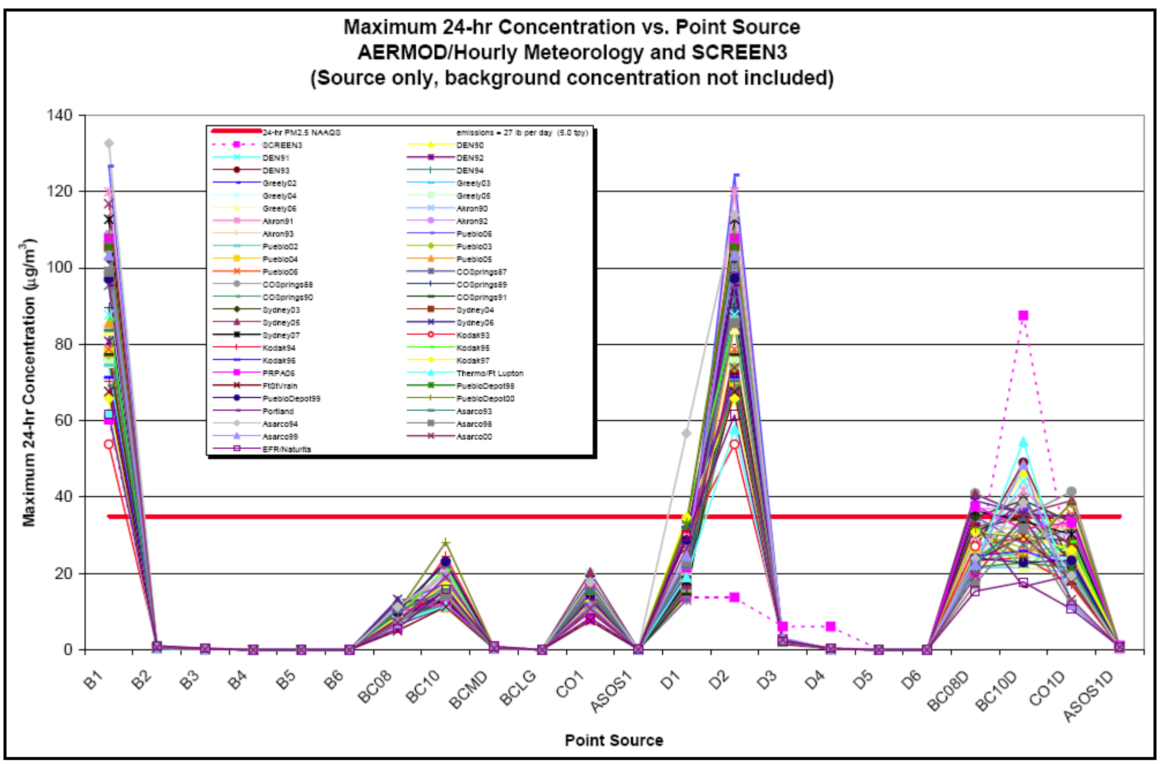


Figure 11. Maximum 24-hr Concentration - 27 lb per day (5 tpy equivalent)

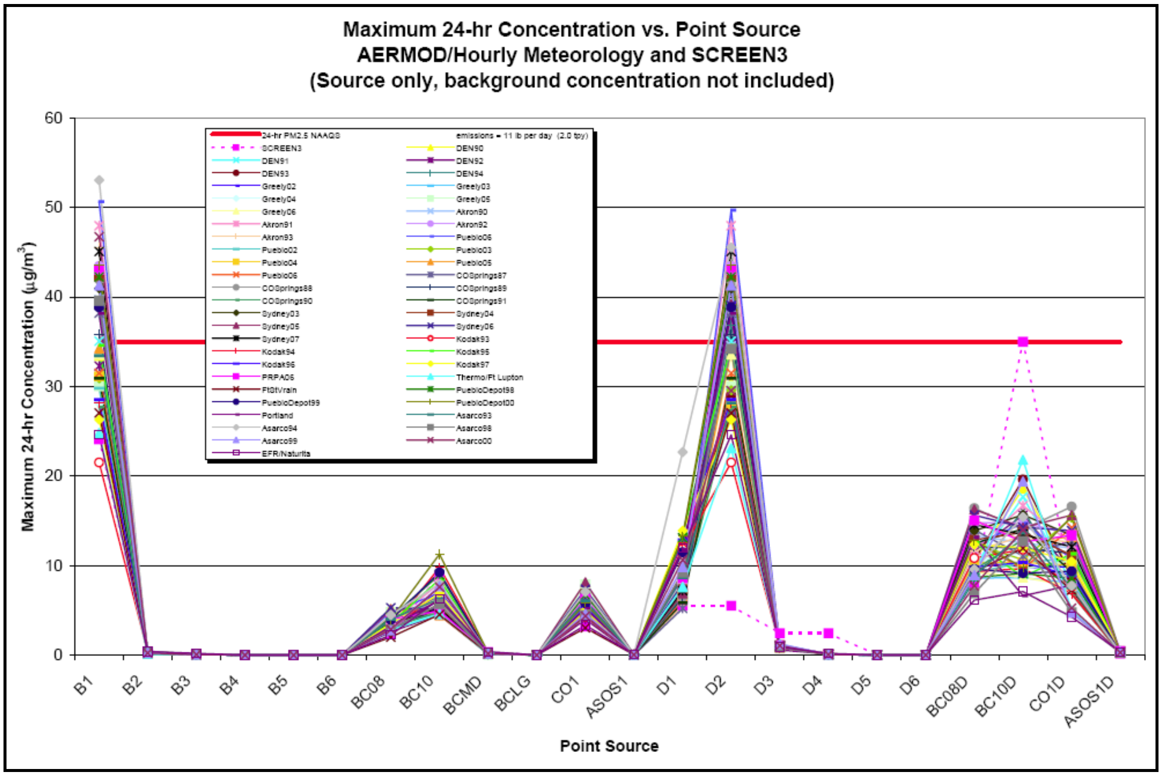


Figure 12. Maximum 24-hr Concentration - 11 lb per day (2 tpy equivalent)

7.2.3. Annual Concentrations

Figure 13 through Figure 15 present the annual concentrations for emission rates of 15 tpy, 10 tpy, and 5 tpy. Based on these results, the annual $PM_{2.5}$ NAAQS could be threatened by an individual emission unit with poor dispersion and an emission rate around or greater than 10 tpy. For a point source with an emission rate of 5 tpy with poor dispersion, there will be situations (Table 1 footnotes and Section 7.2.5) when the modeling significance level is exceeded and it is reasonable to believe the source will cause or contribute to a violation of the 24-hr $PM_{2.5}$ NAAQS.

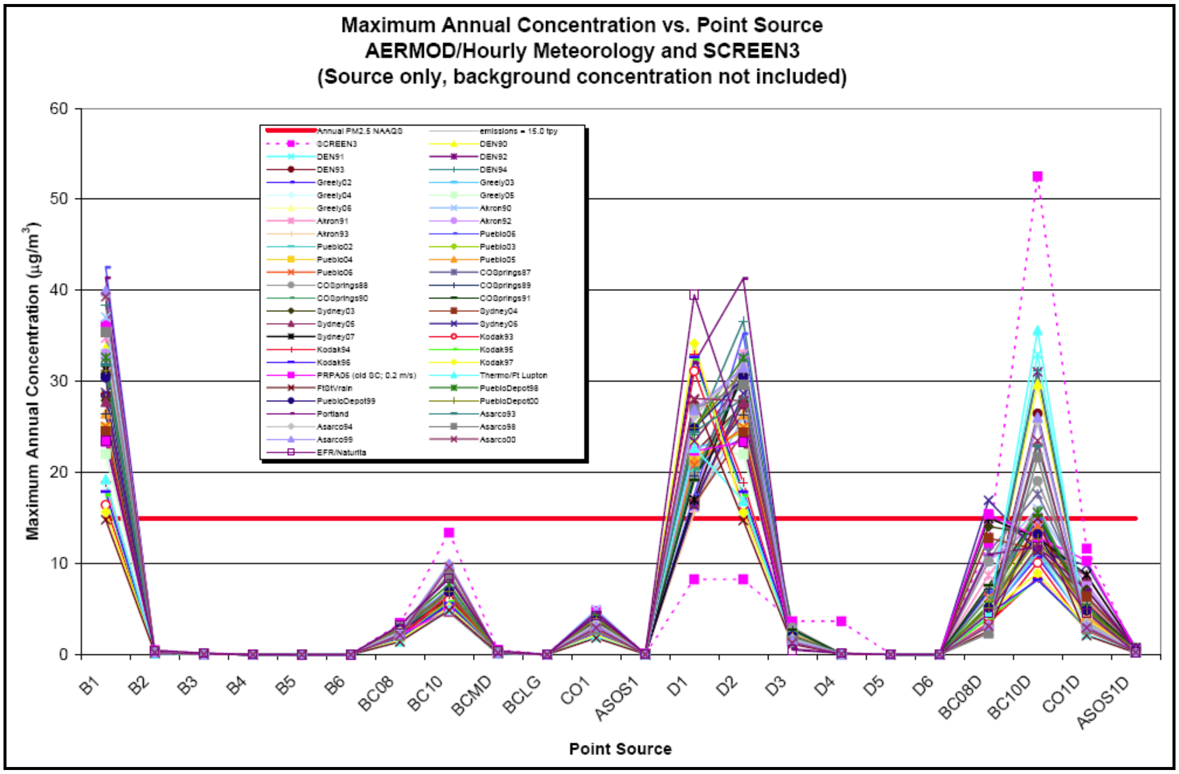


Figure 13. Maximum Annual Concentrations - 15 tpy

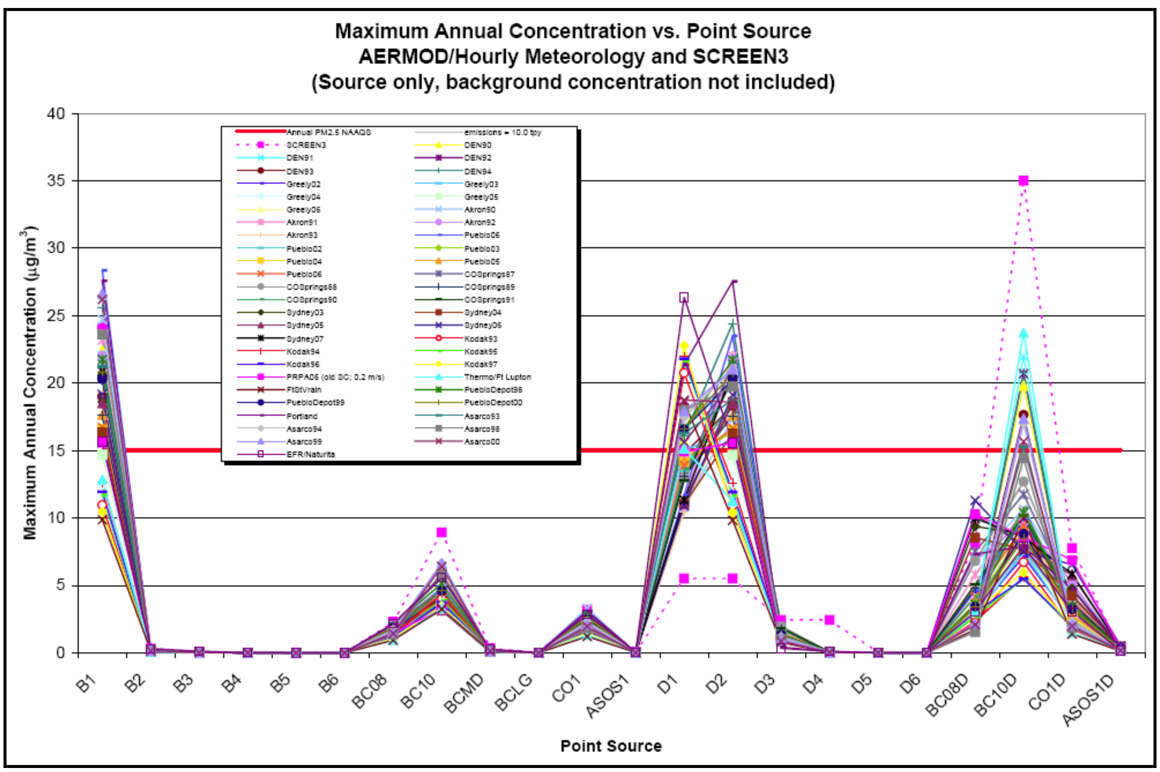


Figure 14. Maximum Annual Concentrations - 10 tpy

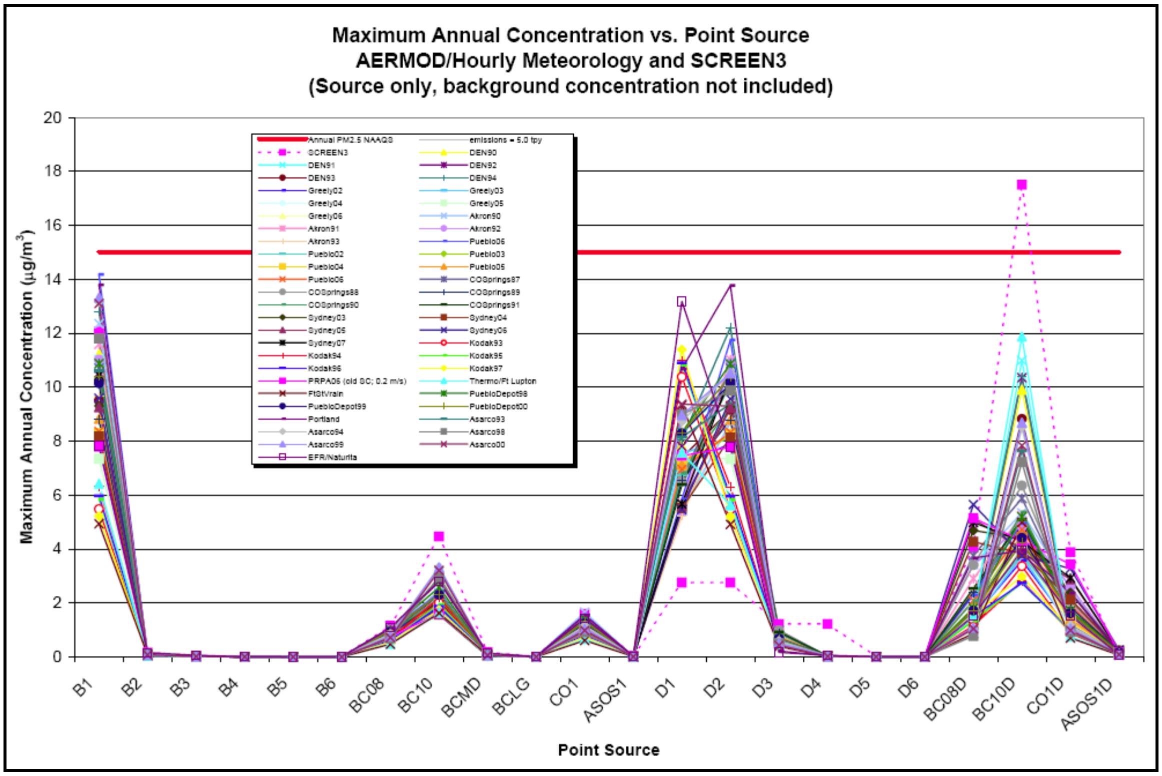


Figure 15. Maximum Annual Concentrations - 5 tpy

7.2.4. 3-month Concentrations

For the rolling 3-month Pb NAAQS, the annual and 24-hr concentrations (monthly average concentrations were not obtained from the model) were reviewed for emission rates of 0.6 tpy/300 pounds per 3-months (Figure 16 and Figure 17), 0.1 tpy/50 pounds per 3-months (Figure 18 and Figure 19), and 0.05 tpy/25 pounds per 3-months (Figure 20 and Figure 21). Concentrations for a 3-month average are greater than the annual average but less than the 24-hr average. Based on these results, the 3-month Pb NAAQS could be threatened by an individual emission unit with poor dispersion and an emission rate around or greater than 0.1 tpy/50 pounds per 3-months. For a point source with an emission rate of 0.05 tpy/25 pounds per 3-months with poor dispersion, there will be situations (Table 1 footnotes and Section 7.2.5) when it is reasonable to believe the source will cause or contribute to a violation of the rolling 3-month Pb NAAQS.

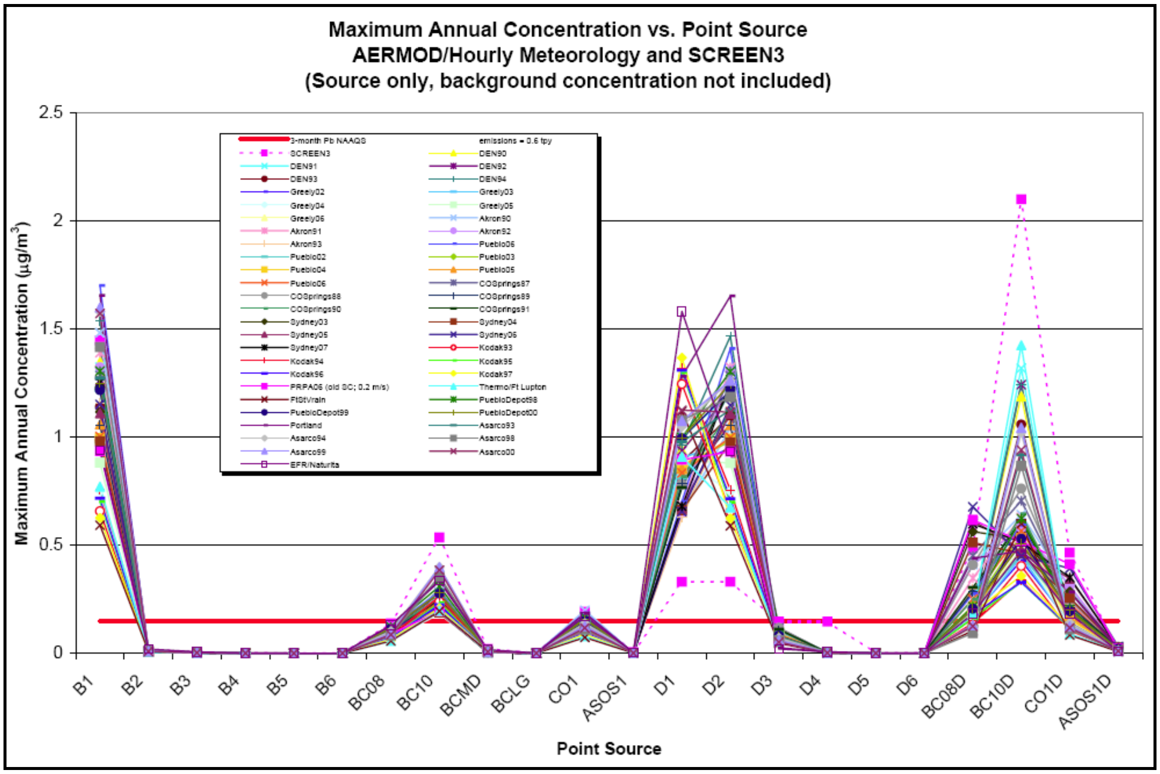


Figure 16. Maximum Annual Concentrations - 0.6 tpy

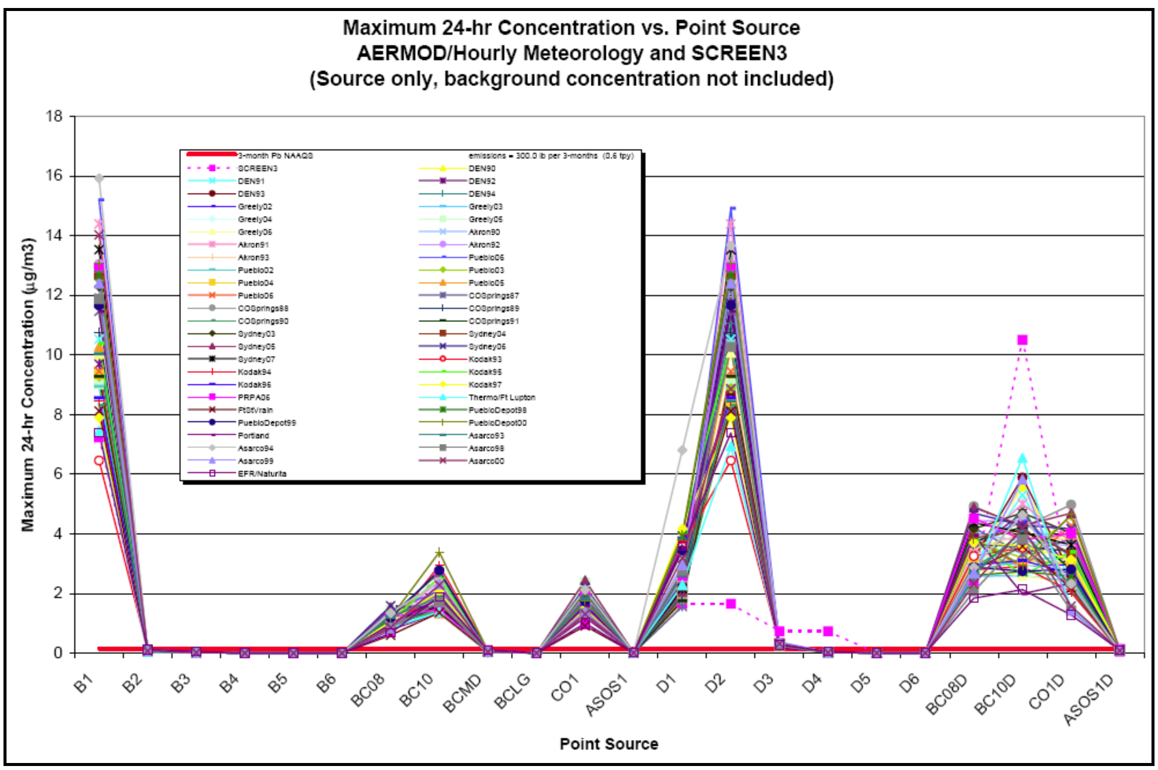


Figure 17. Maximum 24-hr Concentrations - 300 pounds per 3-months

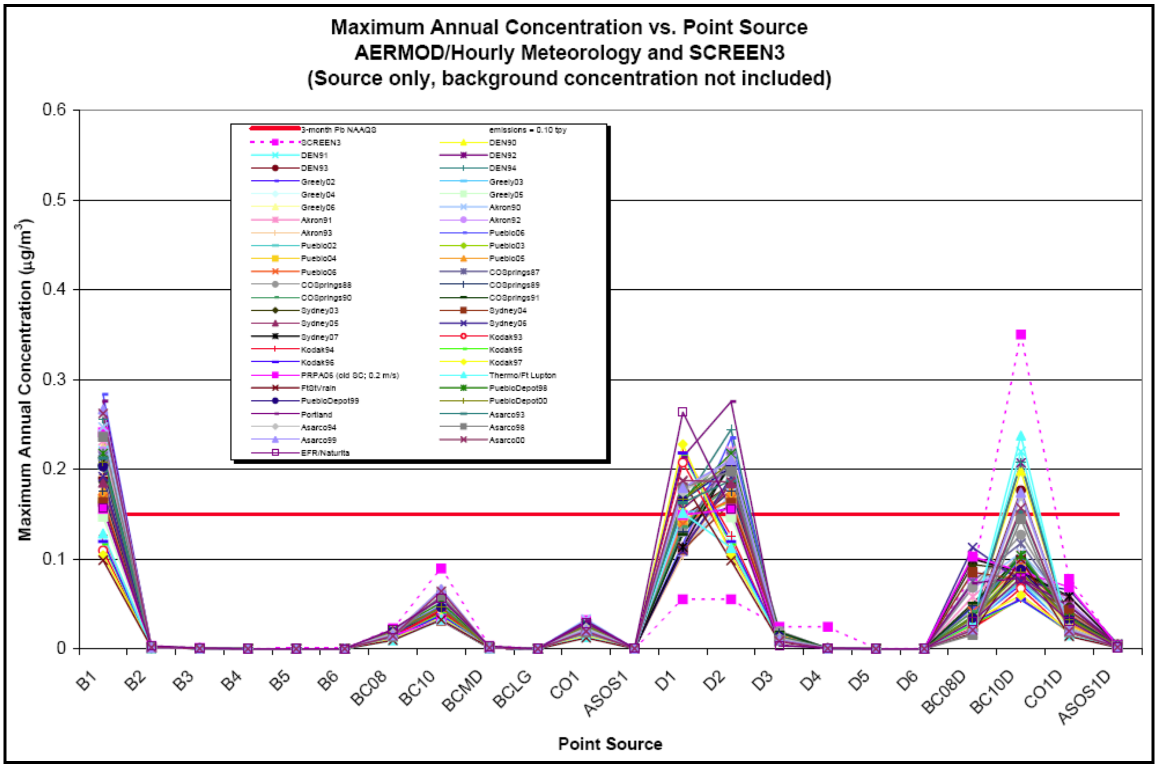


Figure 18. Maximum Annual Concentrations - 0.1 tpy

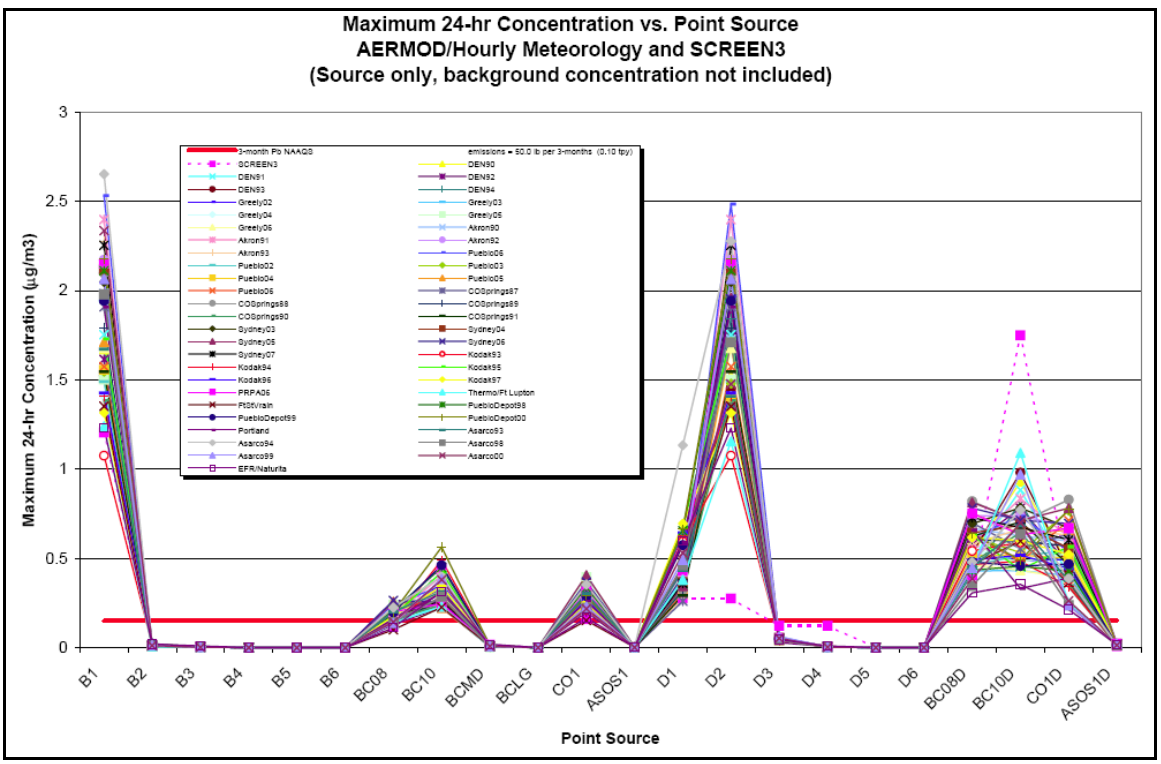


Figure 19. Maximum 24-hr Concentrations - 50 pounds per 3-months

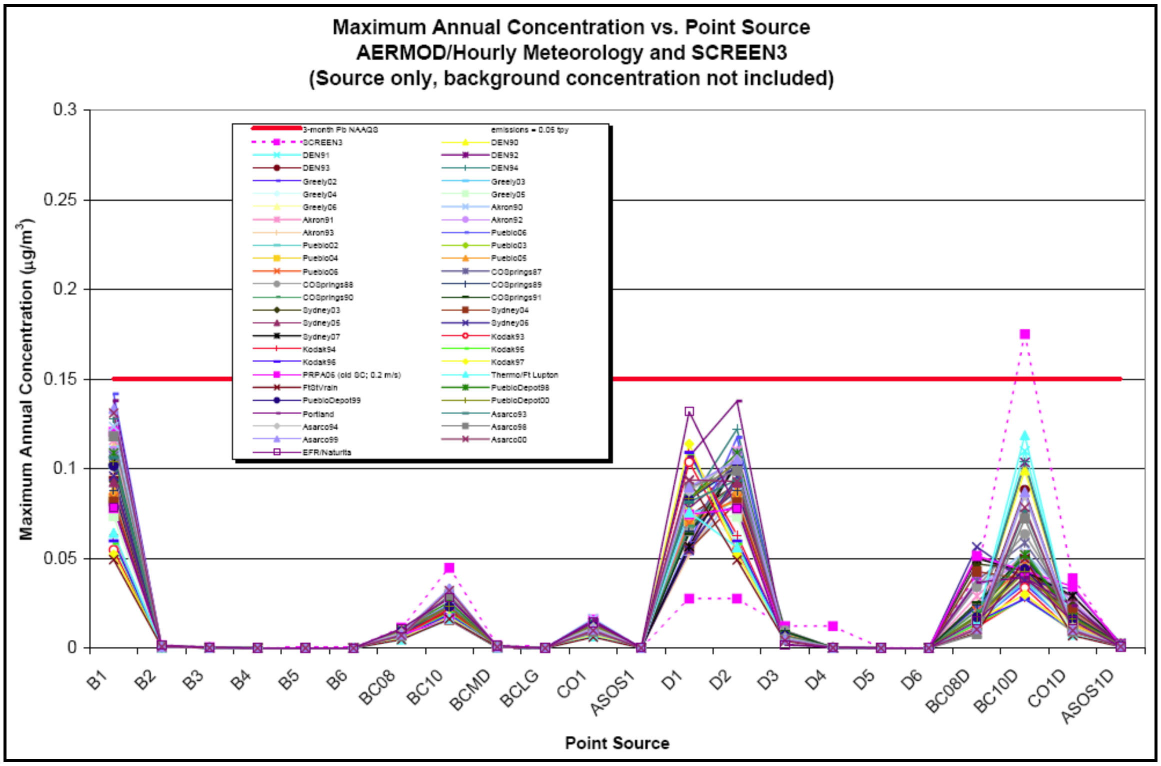


Figure 20. Maximum Annual Concentrations - 0.05 tpy

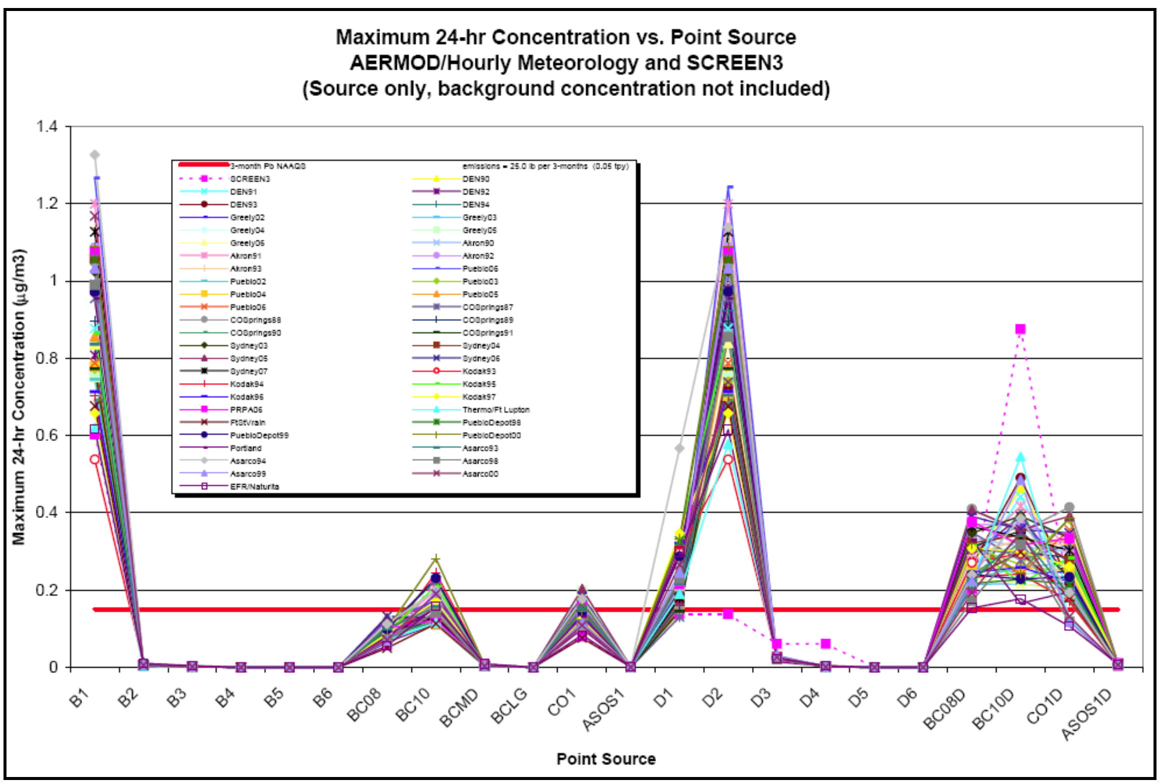


Figure 21. Maximum 24-hr Concentrations - 25 pounds per 3-months

7.2.5. Other Modeling Variables Not Examined in this Modeling Analysis

There are other parameters used in modeling that are not examined here, such as elevated terrain, urban effects, and background concentrations. Higher impacts may result when plume rise is insufficient to clear nearby terrain. As discussed in EPA's AERMOD Implementation Guide (March 19, 2009), plumes emitted or entrained into an urban air mass would be affected by the dispersive nature of the "convective-like" boundary layer that forms during nighttime conditions due to the urban heat island effect. Contributors to ambient air concentration for determining compliance with AAQS are impacts from the source of interest and nearby sources, and the background concentration. Even though impacts are just above modeling significance levels or only a small fraction of the AAQS, a complete compliance demonstrate must also take existing air pollutant concentration levels into account. This may mean that, in addition to adding a background concentration, nearby sources with strong concentration gradients should be included in the modeling. Since it's not reasonable to model all sources, it is necessary to add a background concentration to account for the emissions from all sources that have not been explicitly included in the modeling. Background concentrations vary by geographic area. For areas with high background concentrations (and/or strong concentration gradients from nearby sources) near the AAQS, a source impact that is greater than the modeling significance levels, but still a relatively small percentage of the AAQS, can result in a modeled violation of the AAQS.

8. Conclusion

The results in the January 2002 study demonstrate that a point source emitting 40 tons per year of nitrogen oxides (NO_X), sulfur dioxide (SO_2), or fine particulate matter (PM_{10}) or 15 tons per year of PM_{10} could have a significant impact in ambient air, and in certain stack and building configurations, exceed ambient air quality standards by itself. Lead (Pb) modeling was not investigated as part of this study. When compounding factors such as the presence of nearby sources and existing air pollution levels are considered, it is reasonable to conclude that even sources with relatively small emission rates (much lower than those in Table 1 of the Modeling Guideline) could cause or contribute to modeled violations of ambient air quality standards.

The results in the April 2010 study demonstrate that a point source emitting 0.46 pounds per hour of NO_X, 5 tons per year of $PM_{2.5}$, 11 pounds per day of $PM_{2.5}$, or 25 pounds per 3-months of Pb could have a significant impact in ambient air, and in certain stack and building configurations, exceed ambient air quality standards by itself.

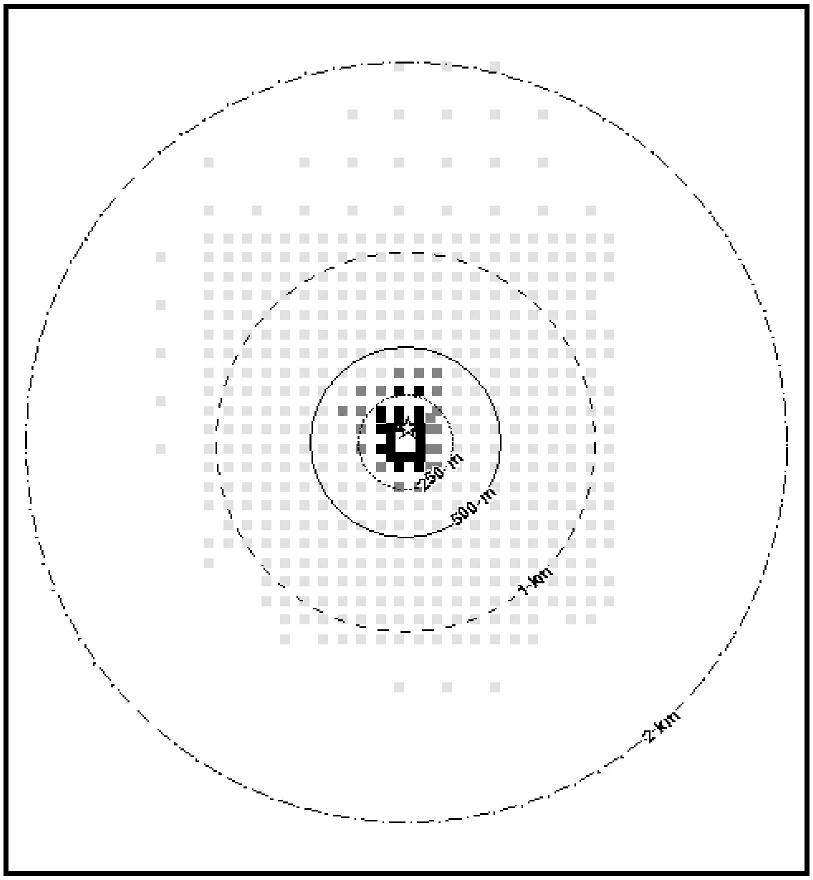
Clearly, these studies show that it is problematic to use only emission rates to determine when modeling is warranted. Many factors (including dispersion characteristics of the proposed source) should be considered in the decision to perform modeling. Consequently, the Division opposes the adoption of bright line exemptions from modeling that are based solely on emission rates. Furthermore, due to the complexity of pollution dispersion in the atmosphere, it is not realistic to develop a simple look-up table that adequately accounts for all of the important factors that affect air pollution dispersion.

The study shows that, in cases where a source has good dispersion characteristics and the existing air quality is well below ambient air quality standards, there is a low probability that the source will cause or contribute to a modeled violation of ambient air quality standards. Thus, it is reasonable to conclude that modeling is not warranted for minor sources and minor modifications with good dispersion at emission rates below the thresholds in Table 1 of the Colorado Modeling Guideline.

Appendix

Air Dispersion Modeling Analysis of Fugitive Sources

Magnitude and Location of Impacts from an Area Source
1 Square Acre and Release Height of 0 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)



LEGEND

Highest-6th-Highest Concentration

☆ 613 ug/m3

6th-Highest Concentration

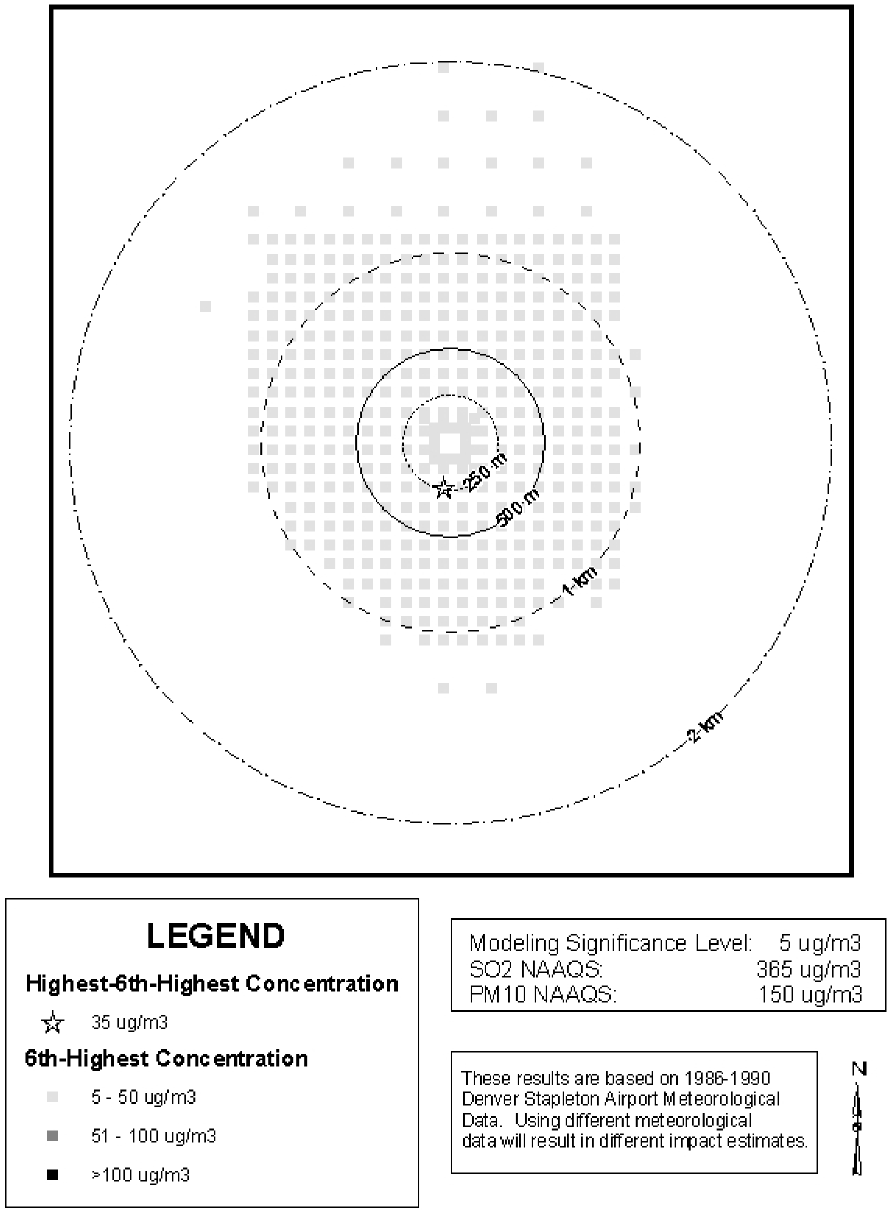
- 5 - 50 ug/m3
- 51 - 100 ug/m3
- > 100 ug/m3

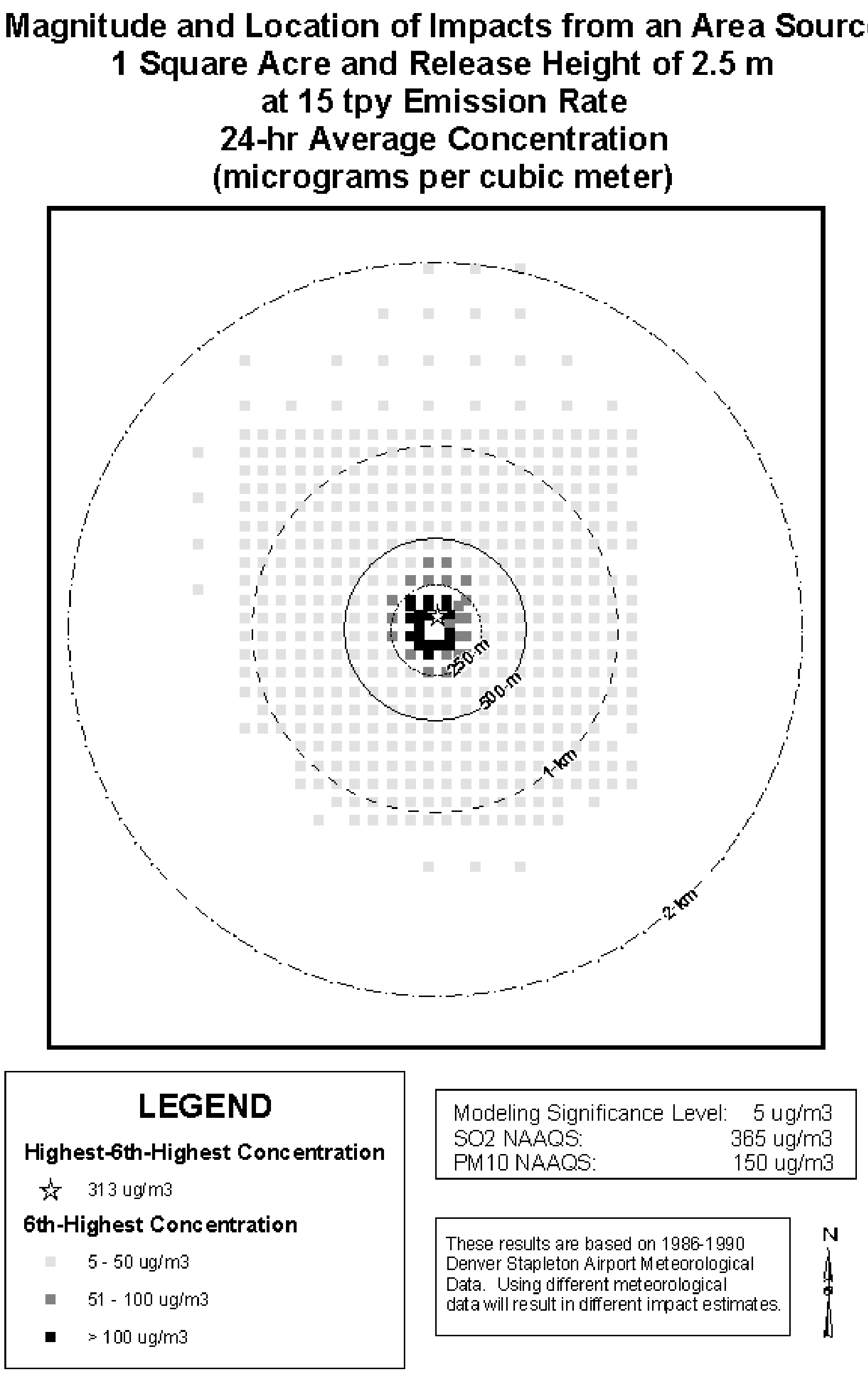
Modeling Significance Level:	5 ug/m3
SO2 NAAQS:	365 ug/m3
PM10 NAAQS:	150 ug/m3

These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

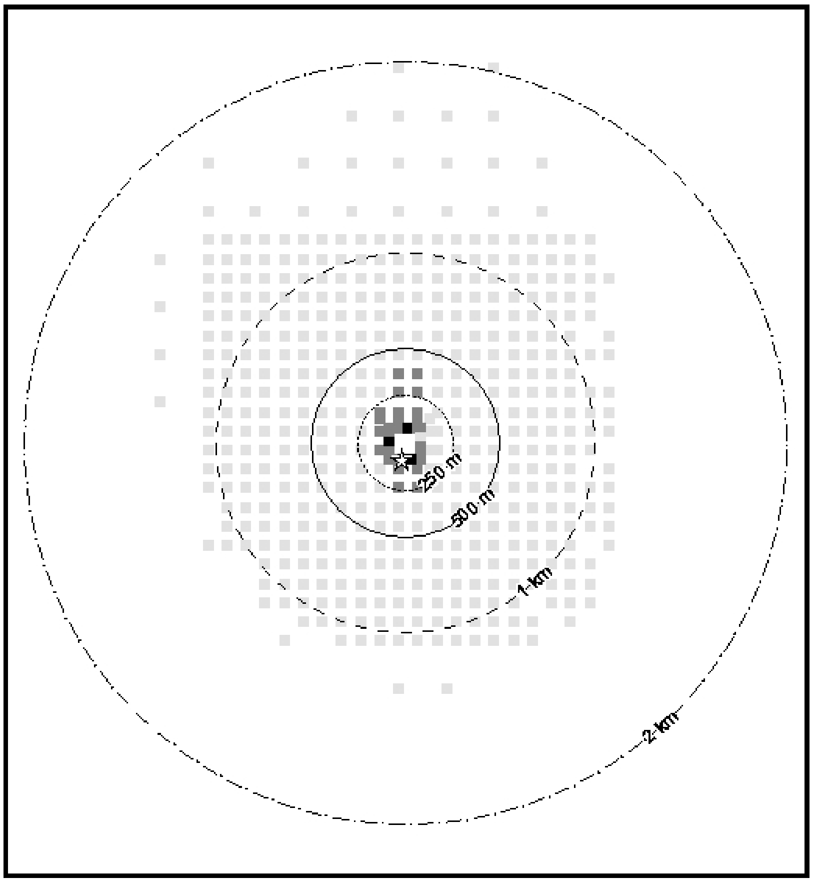
N

Magnitude and Location of Impacts from an Area Source
1 Square Acre and Release Height of 10 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)




Magnitude and Location of Impacts from an Area Source
1 Square Acre and Release Height of 2.5 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)
250 m
500 m
1 km
2 km
LEGEND
Highest-6th-Highest Concentration
313 ug/m3
6th-Highest Concentration
5 - 50 ug/m3
51 - 100 ug/m3
> 100 ug/m3
Modeling Significance Level: 5 ug/m3
SO2 NAAQS: 365 ug/m3
PM10 NAAQS: 150 ug/m3
These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.
N

Magnitude and Location of Impacts from an Area Source
1 Square Acre and Release Height of 5 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)



LEGEND

Highest-6th-Highest Concentration

☆ 124 ug/m3

6th-Highest Concentration

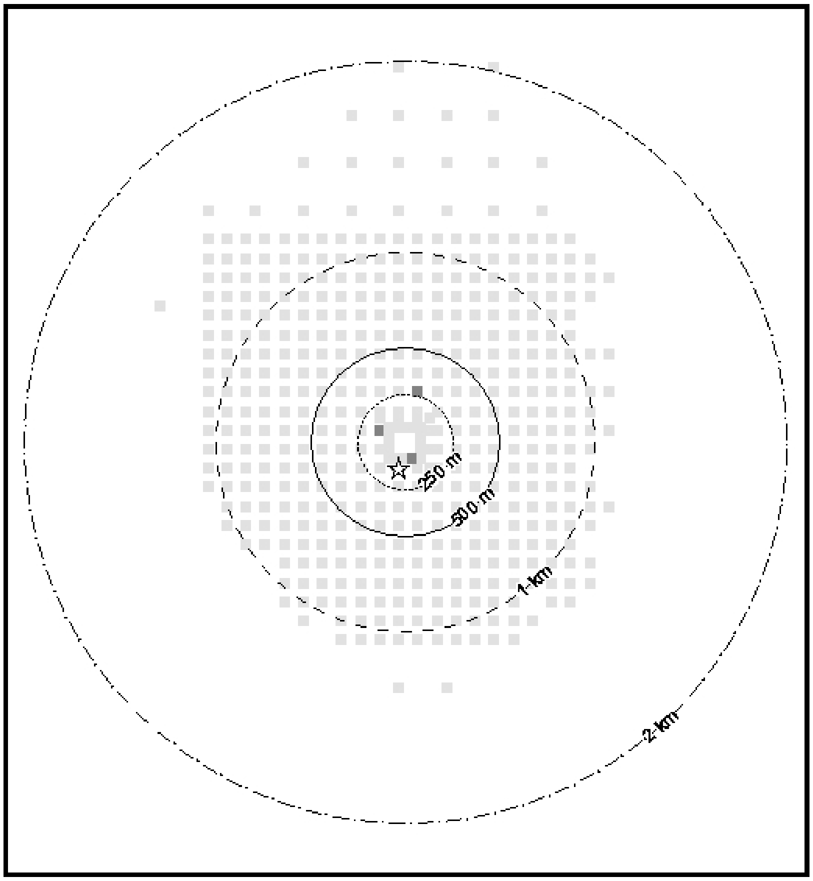
- 5 - 50 ug/m3
- 51 - 100 ug/m3
- > 100 ug/m3

Modeling Significance Level:	5 ug/m3
SO2 NAAQS:	365 ug/m3
PM10 NAAQS:	150 ug/m3

These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

N

Magnitude and Location of Impacts from an Area Source 1 Square Acre and Release Height of 7.5 m at 15 tpy Emission Rate 24-hr Average Concentration (micrograms per cubic meter)



LEGEND

Highest-6th-Highest Concentration

☆ 59 ug/m3

6th-Highest Concentration

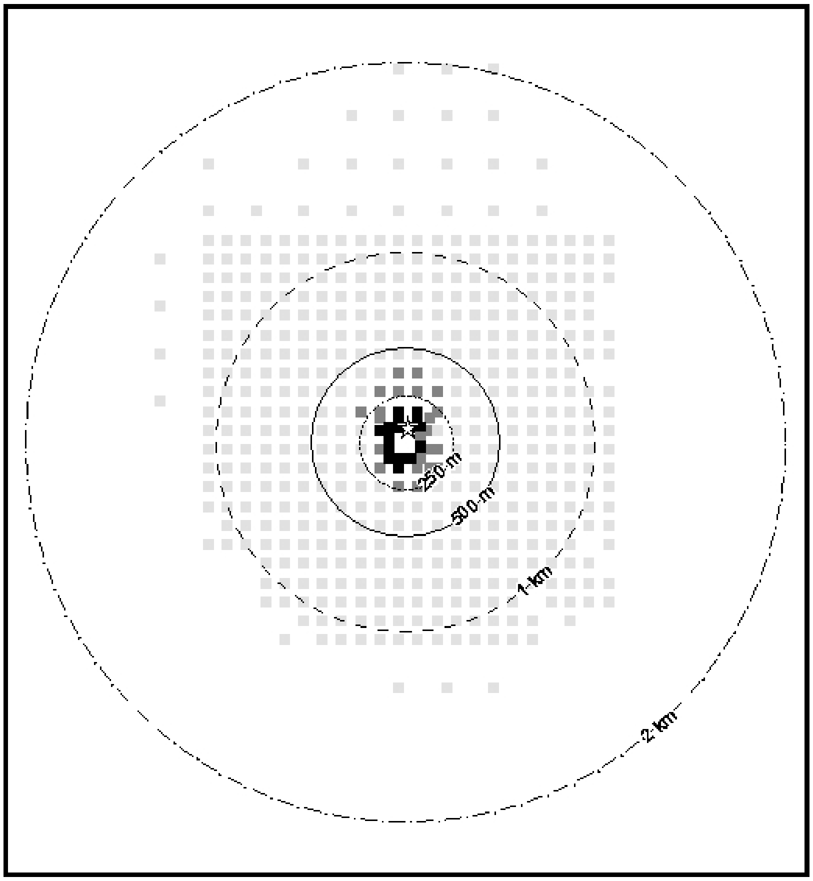
- 5 - 50 ug/m3
- 51 - 100 ug/m3
- > 100 ug/m3

Modeling Significance Level:	5 ug/m3
SO2 NAAQS:	365 ug/m3
PM10 NAAQS:	150 ug/m3

These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

N

Magnitude and Location of Impacts from an Area Source
1 Square Acre, Release Height of 2 m, and
Initial Vertical Dispersion of 3 m at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)



LEGEND

Highest-6th-Highest Concentration

☆ 324 ug/m3

6th-Highest Concentration

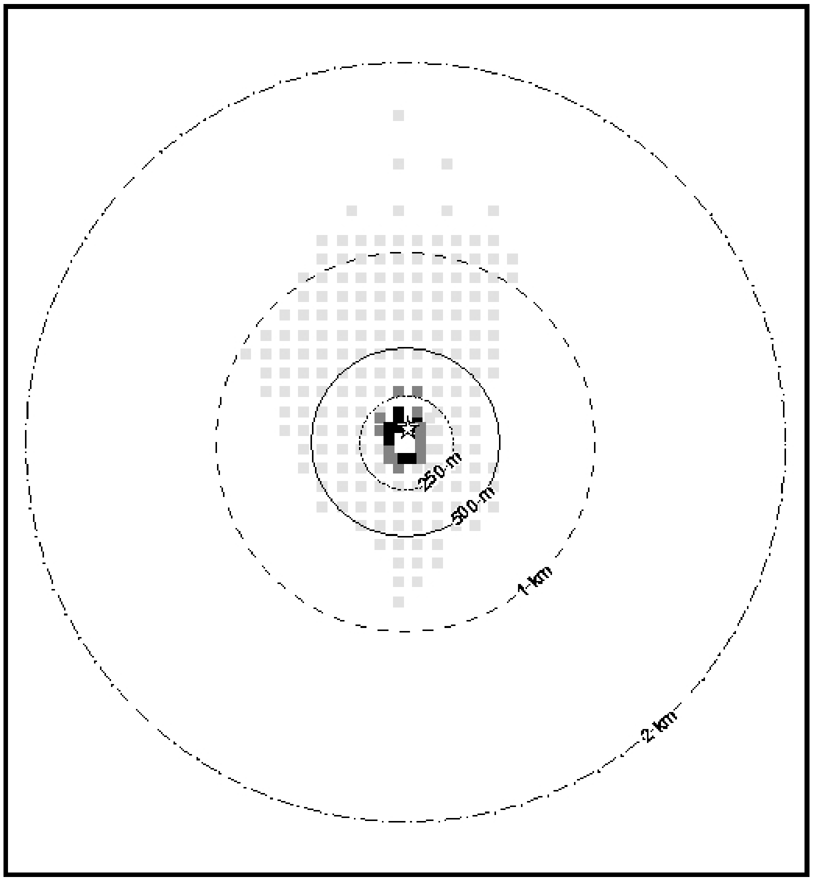
- 5 - 50 ug/m3
- 51 - 100 ug/m3
- > 100 ug/m3

Modeling Significance Level:	5 ug/m3
SO2 NAAQS:	365 ug/m3
PM10 NAAQS:	150 ug/m3

These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

N

Magnitude and Location of Impacts from an Area Source 1 Square Acre, Release Height of 2 m, and Initial Vertical Dispersion of 3 m at 15 tpy Emission Rate Annual Average Concentration (micrograms per cubic meter)



LEGEND

Maximum Annual Concentration

☆ 98 ug/m3

Annual Concentration

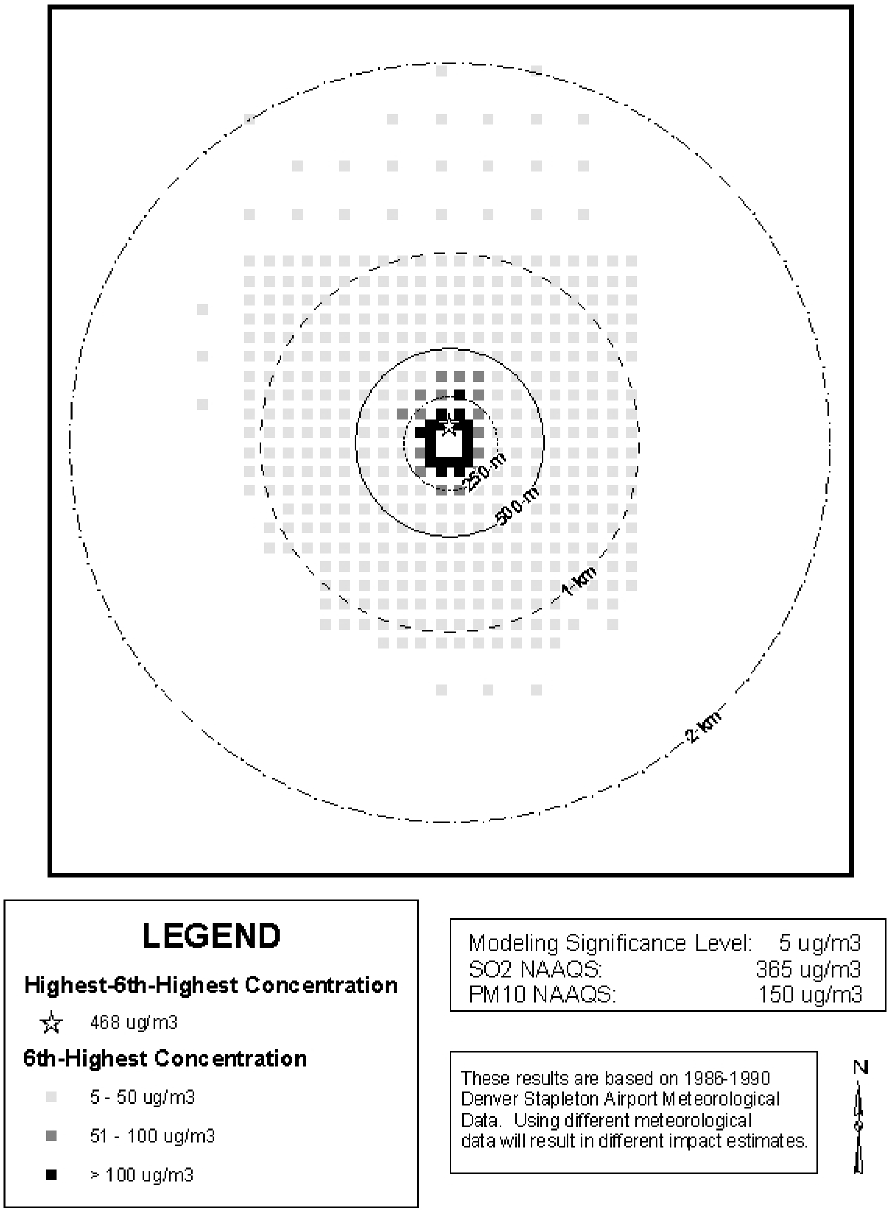
- 1 - 15 ug/m3
- 16 - 30 ug/m3
- > 30 ug/m3

Modeling Significance Level:	1 ug/m3
NO2 NAAQS:	100 ug/m3
SO2 NAAQS:	80 ug/m3
PM10 NAAQS:	50 ug/m3

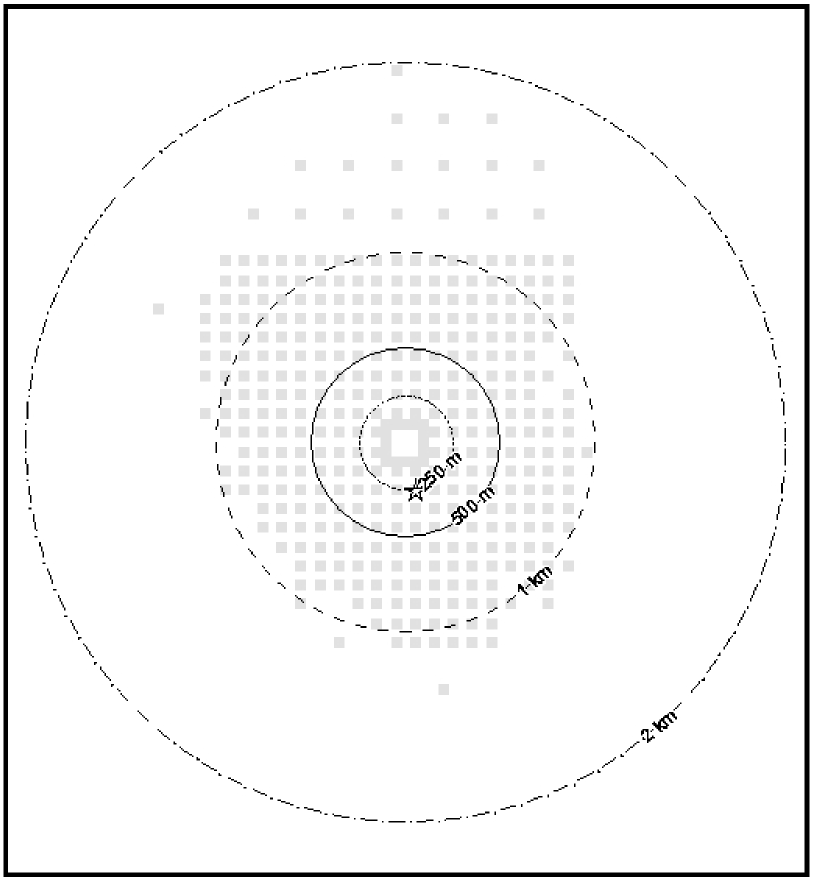
These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

N

Magnitude and Location of Impacts from an Area Source
2 Square Acres and Release Height of 0 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)



Magnitude and Location of Impacts from an Area Source 2 Square Acres and Release Height of 10 m at 15 tpy Emission Rate 24-hr Average Concentration (micrograms per cubic meter)



LEGEND

Highest-6th-Highest Concentration

☆ 31 ug/m3

6th-Highest Concentration

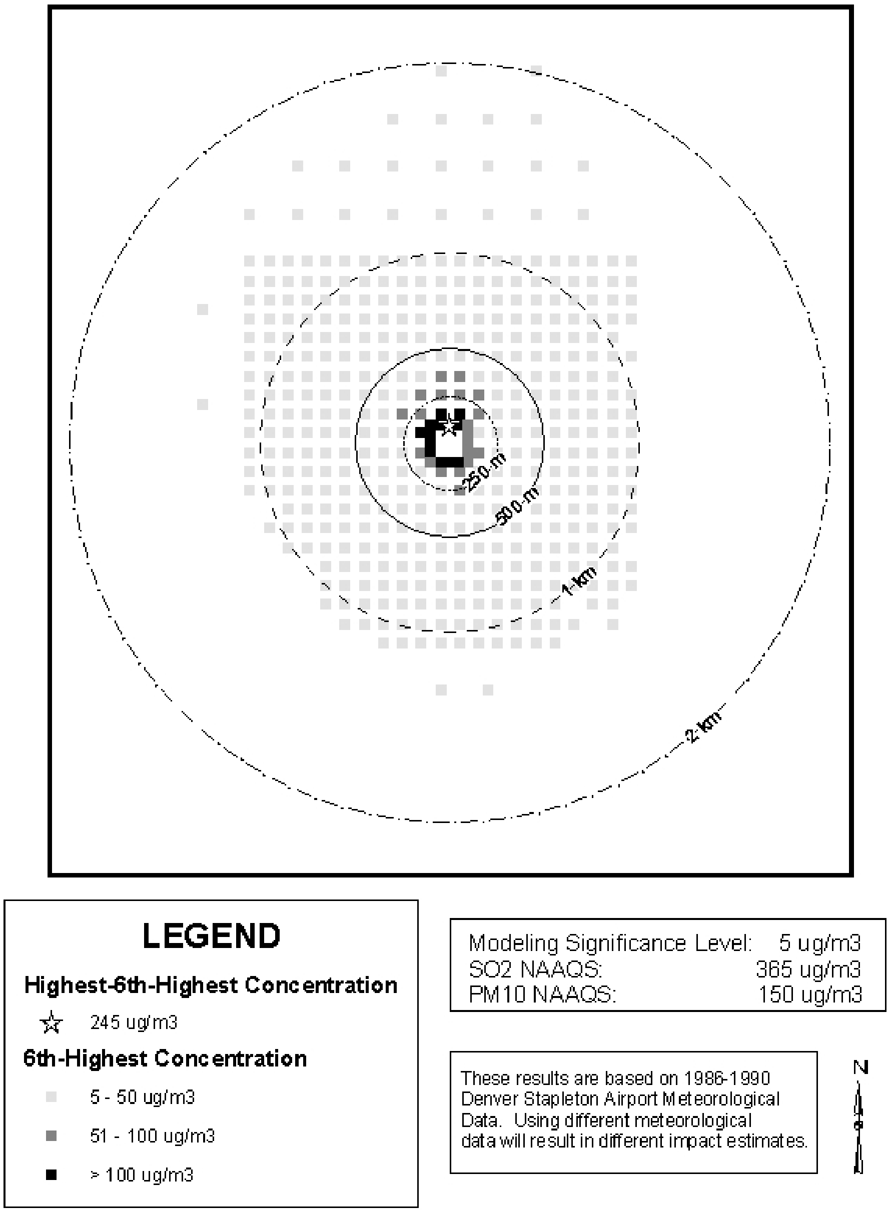
- 5 - 50 ug/m3
- 51 - 100 ug/m3
- > 100 ug/m3

Modeling Significance Level:	5 ug/m3
SO2 NAAQS:	365 ug/m3
PM10 NAAQS:	150 ug/m3

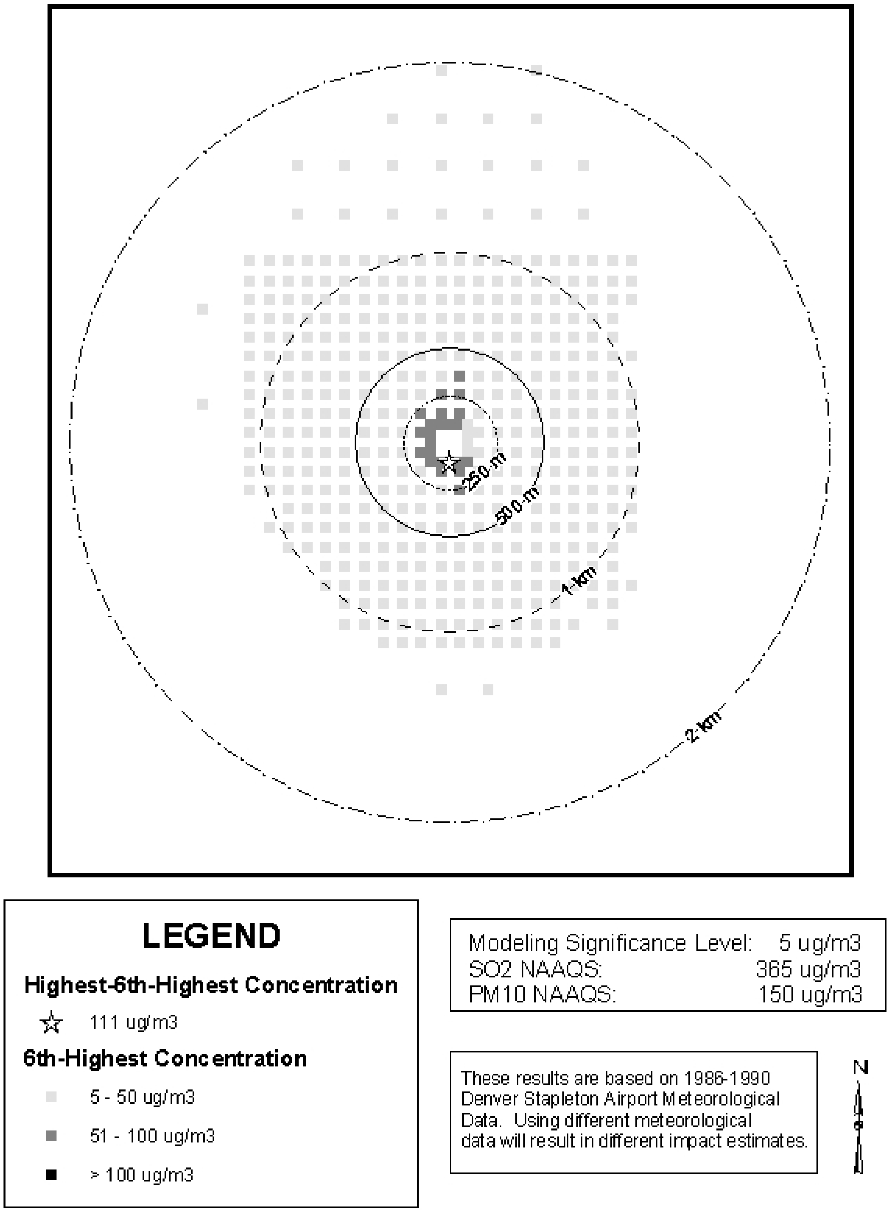
These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

N

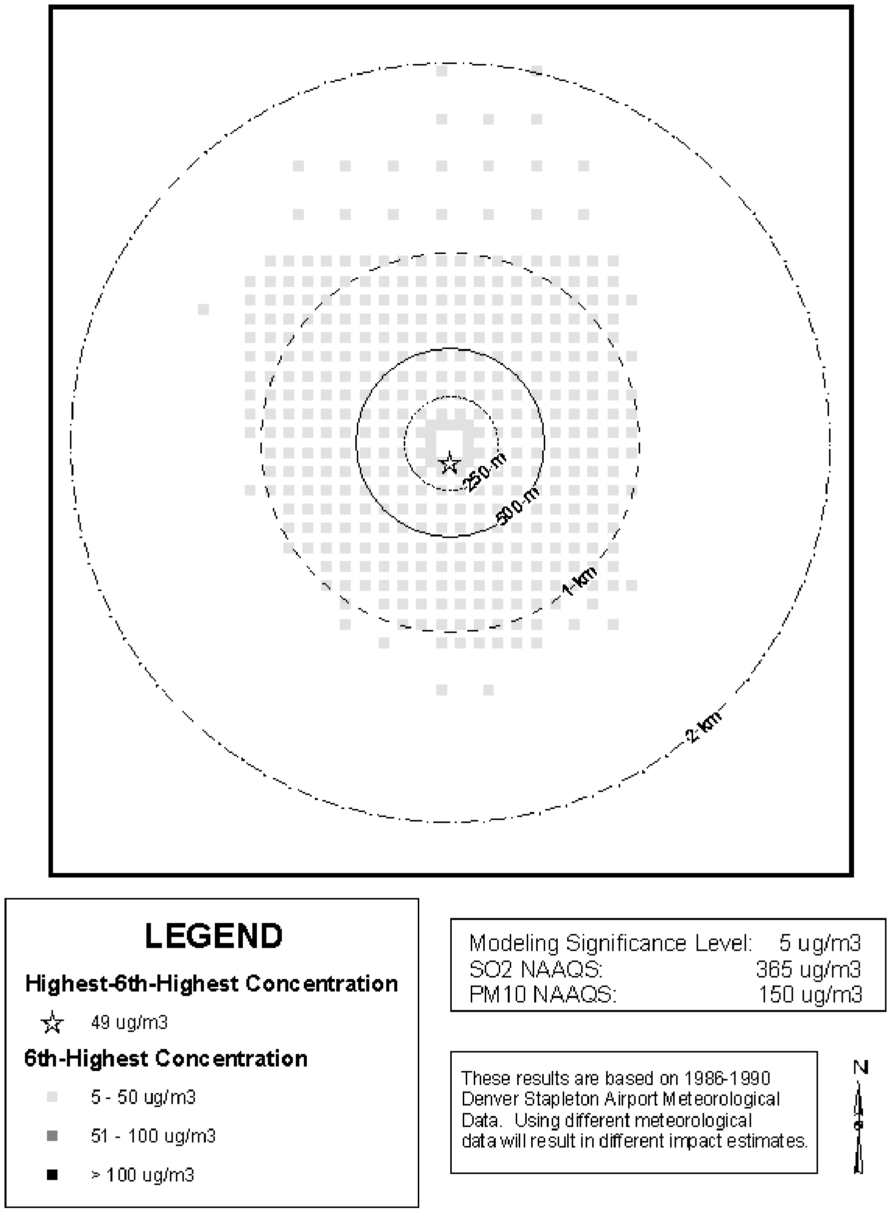
Magnitude and Location of Impacts from an Area Source
2 Square Acres and Release Height of 2.5 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)



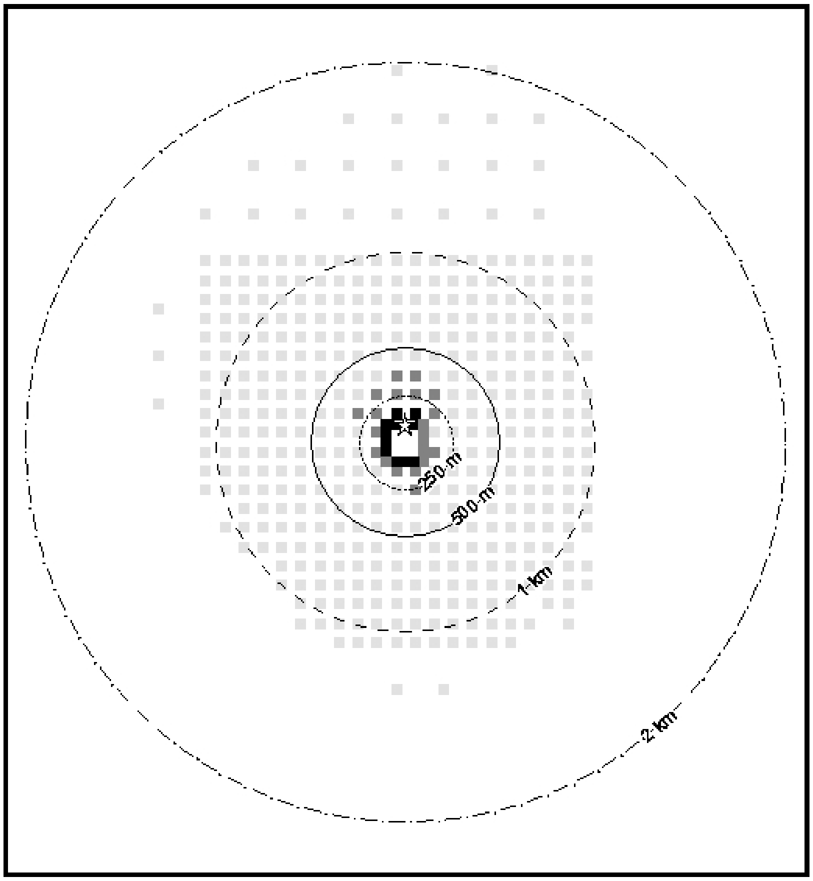
Magnitude and Location of Impacts from an Area Source
2 Square Acres and Release Height of 5 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)



Magnitude and Location of Impacts from an Area Source
2 Square Acres and Release Height of 7.5 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)



Magnitude and Location of Impacts from an Area Source 2 Square Acres, Release Height of 2 m, and Initial Vertical Dispersion of 3 m at 15 tpy Emission Rate 24-hr Average Concentration (micrograms per cubic meter)



LEGEND

Highest-6th-Highest Concentration

☆ 248 ug/m3

6th-Highest Concentration

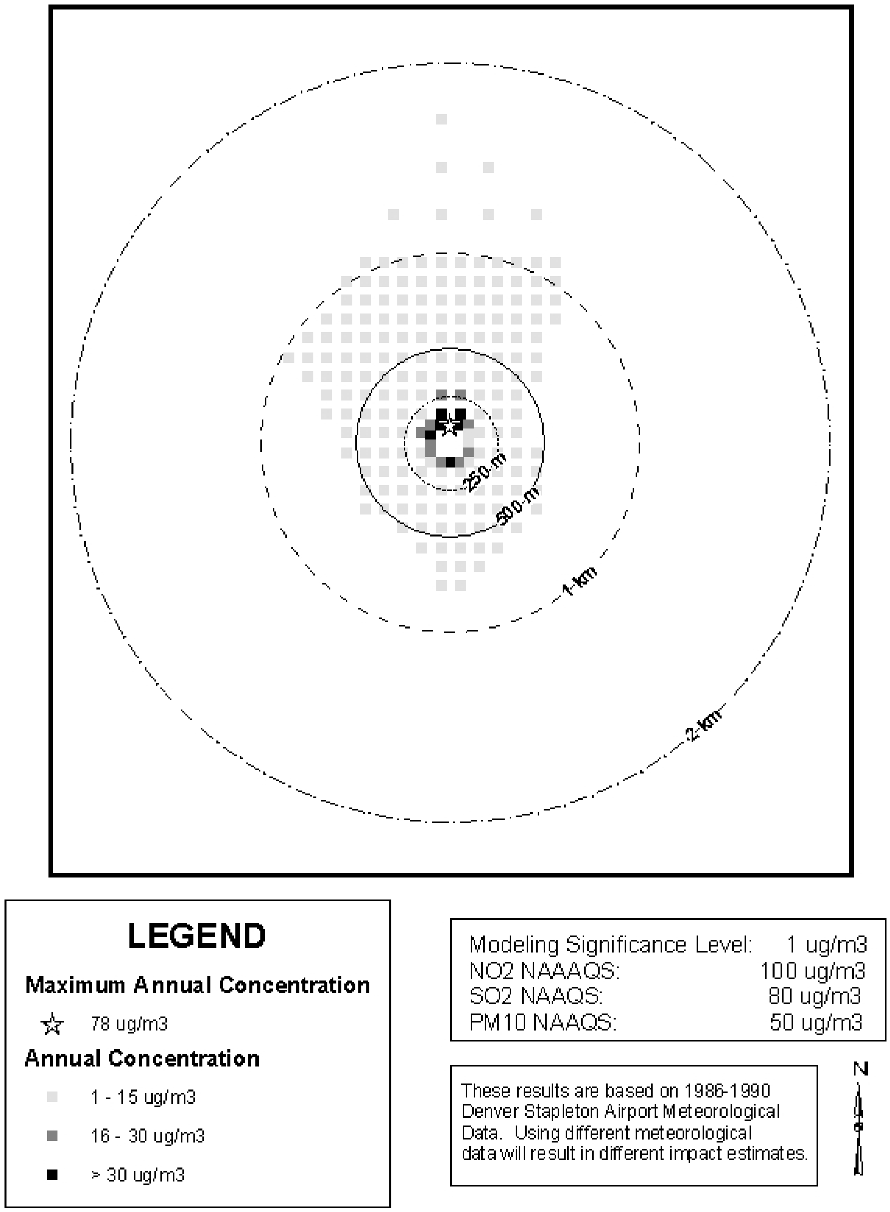
- 5 - 50 ug/m3
- 51 - 100 ug/m3
- > 100 ug/m3

Modeling Significance Level:	5 ug/m3
SO2 NAAQS:	365 ug/m3
PM10 NAAQS:	150 ug/m3

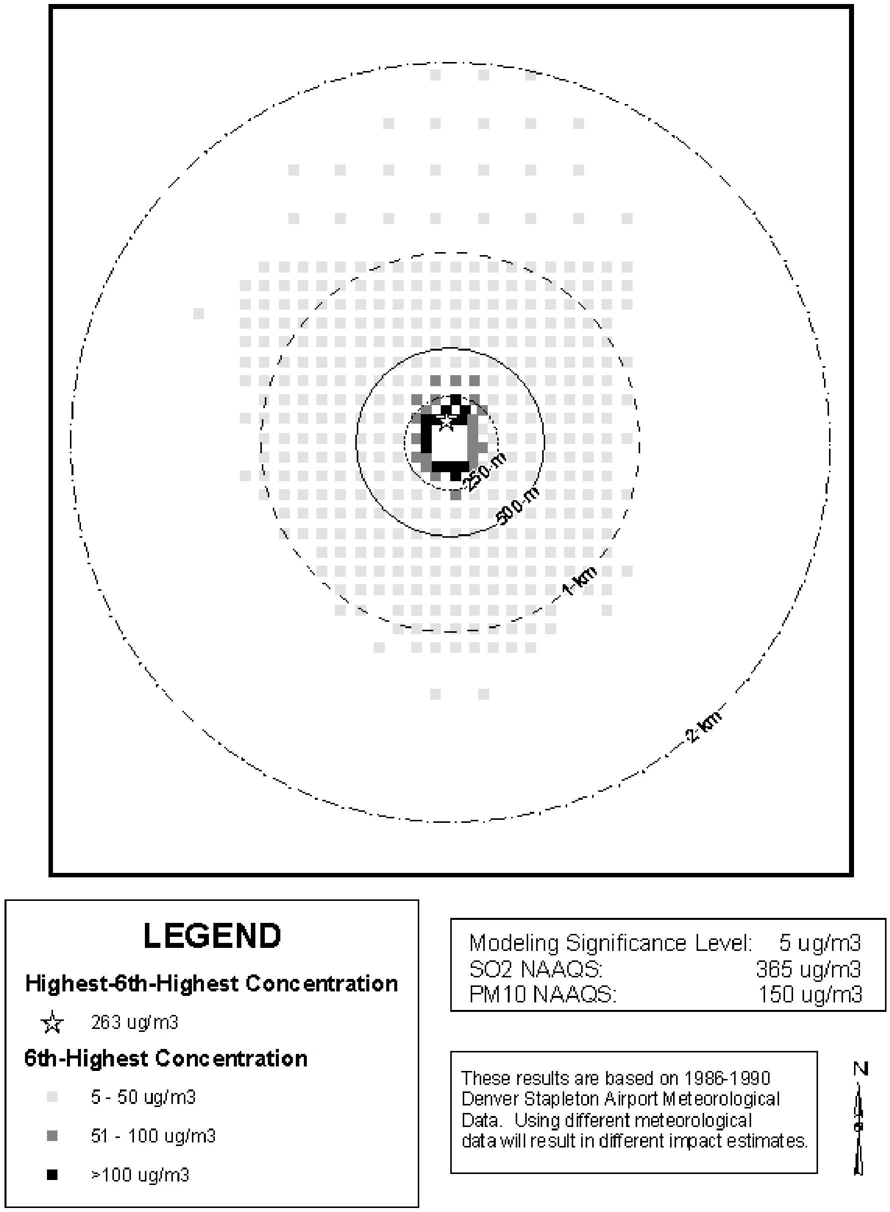
These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

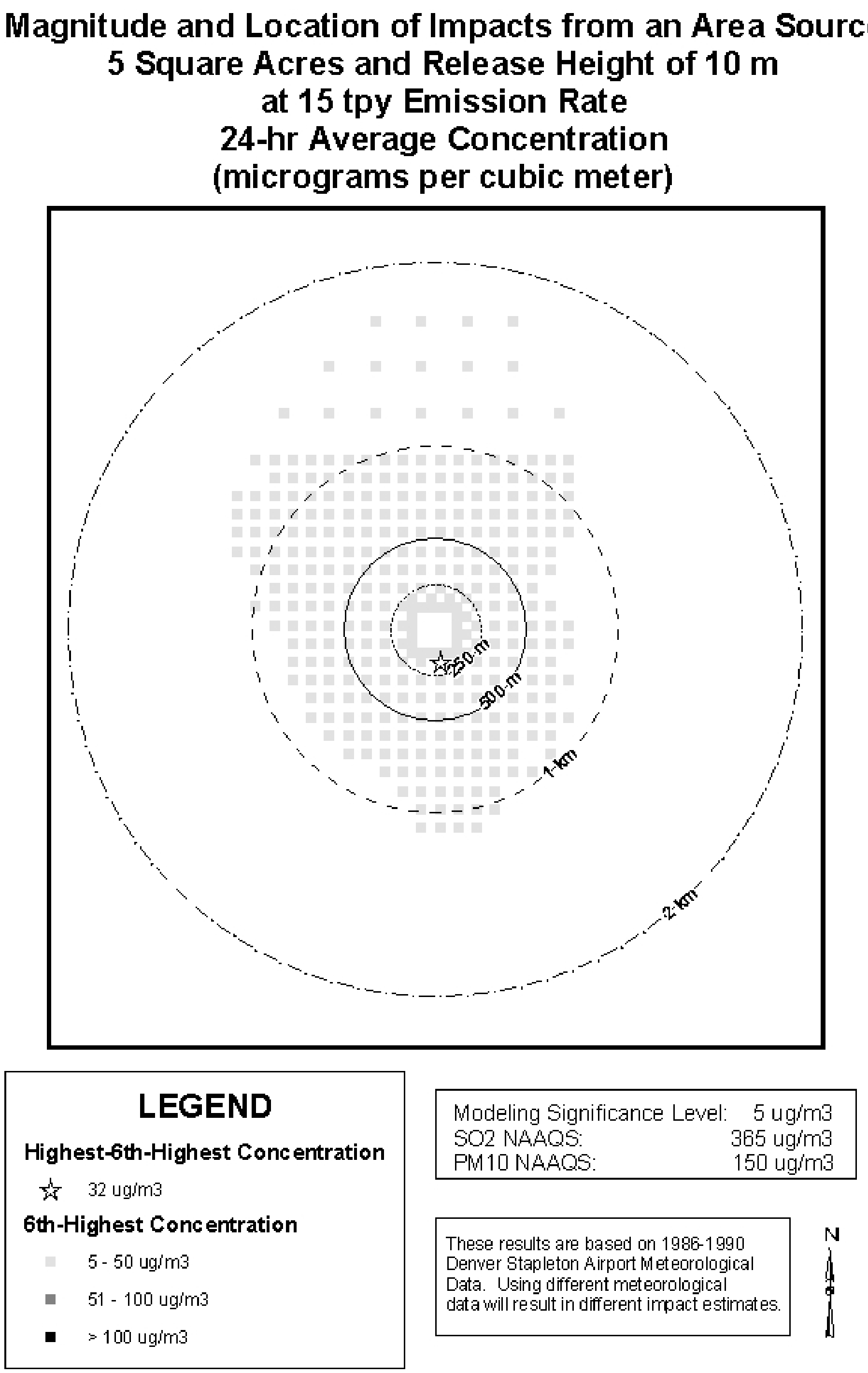
N

Magnitude and Location of Impacts from an Area Source 2 Square Acres, Release Height of 2 m, and Initial Vertical Dispersion of 3 m at 15 tpy Emission Rate Annual Average Concentration (micrograms per cubic meter)

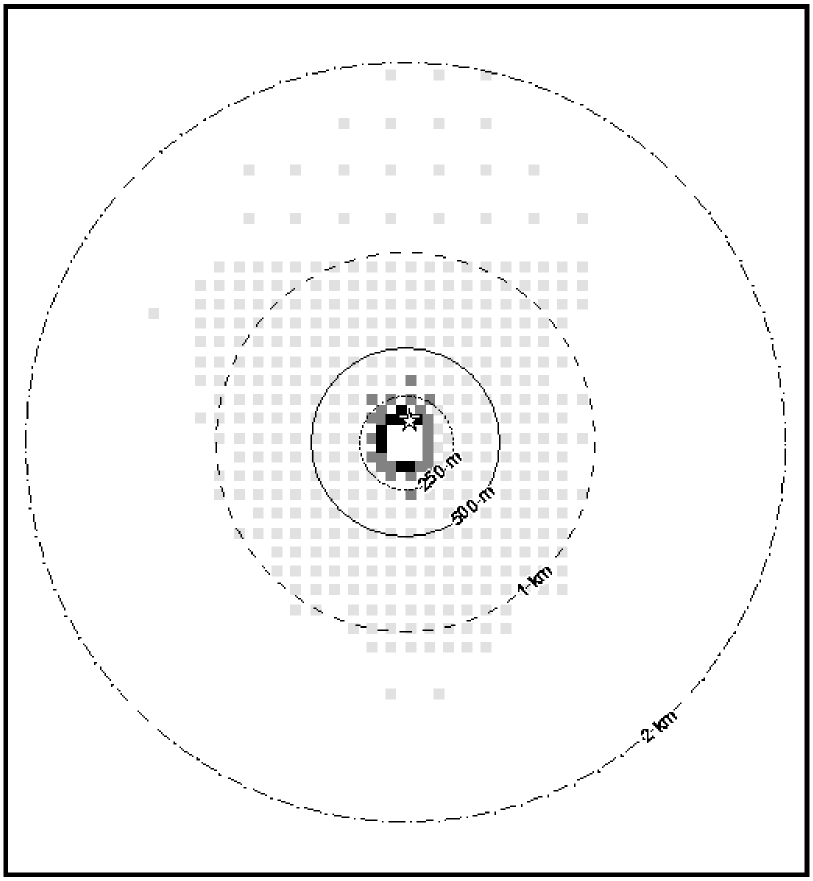


Magnitude and Location of Impacts from an Area Source 5 Square Acres and Release Height of 0 m at 15 tpy Emission Rate 24-hr Average Concentration (micrograms per cubic meter)




Magnitude and Location of Impacts from an Area Source
5 Square Acres and Release Height of 10 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)
250 m
500 m
1 km
2 km
LEGEND
Highest-6th-Highest Concentration
32 ug/m3
6th-Highest Concentration
5 - 50 ug/m3
51 - 100 ug/m3
> 100 ug/m3
Modeling Significance Level: 5 ug/m3
SO2 NAAQS: 365 ug/m3
PM10 NAAQS: 150 ug/m3
These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.
N

Magnitude and Location of Impacts from an Area Source
5 Square Acres and Release Height of 2.5 m
at 15 tpy Emission Rate
24-hr Average Concentration
(micrograms per cubic meter)



LEGEND

Highest-6th-Highest Concentration

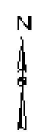
☆ 158 ug/m3

6th-Highest Concentration

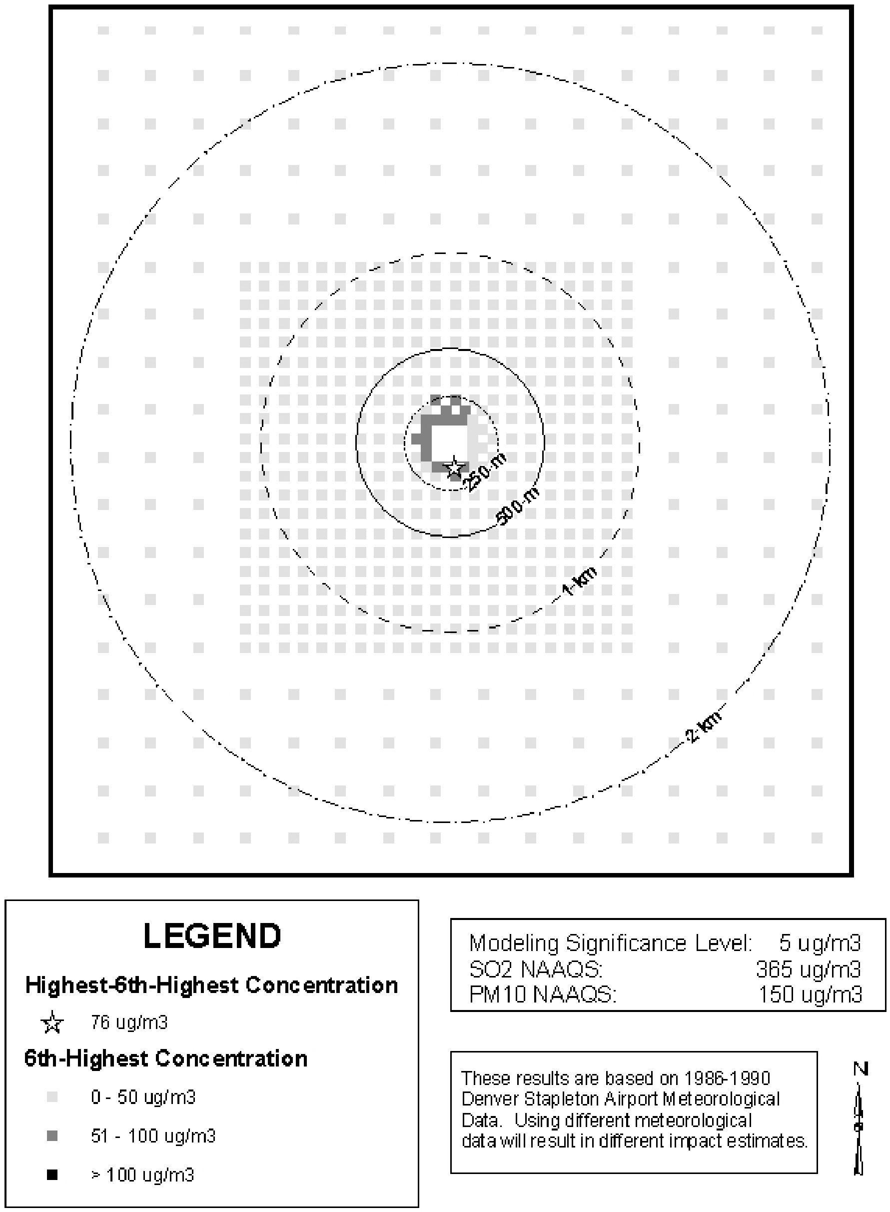
- 5 - 50 ug/m3
- 51 - 100 ug/m3
- > 100 ug/m3

Modeling Significance Level:	5 ug/m3
SO2 NAAQS:	365 ug/m3
PM10 NAAQS:	150 ug/m3

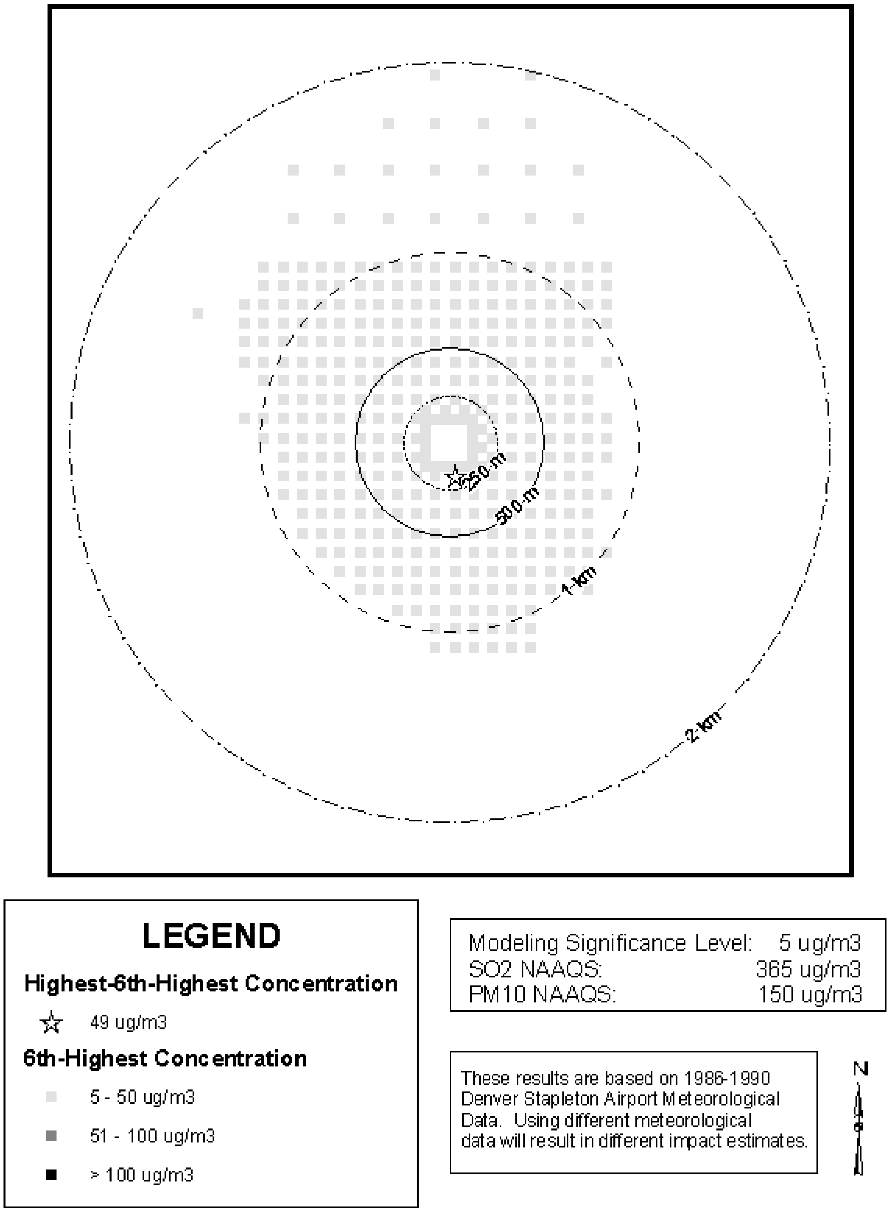
These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.



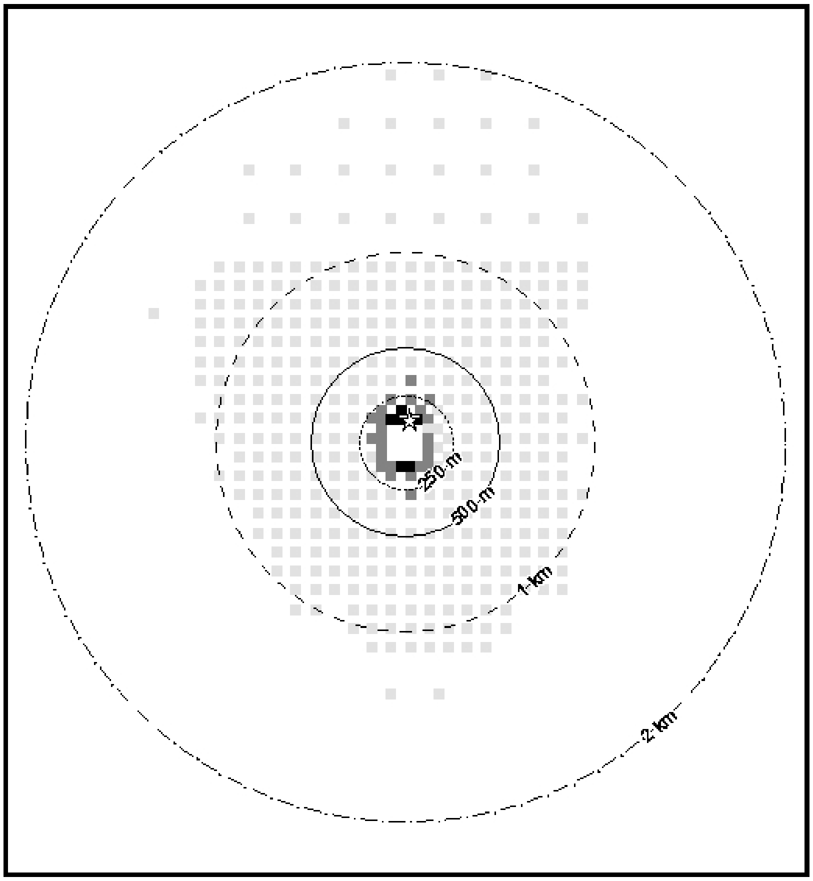
Magnitude and Location of Impacts from an Area Source 5 Square Acres and Release Height of 5 m at 15 tpy Emission Rate 24-hr Average Concentration (micrograms per cubic meter)



Magnitude and Location of Impacts from an Area Source 5 Square Acres and Release Height of 7.5 m at 15 tpy Emission Rate 24-hr Average Concentration (micrograms per cubic meter)



Magnitude and Location of Impacts from an Area Source 5 Square Acres, Release Height of 2 m, and Initial Vertical Dispersion of 3 m at 15 tpy Emission Rate Annual Average Concentration (micrograms per cubic meter)



LEGEND

Highest-6th-Highest Concentration

☆ 153 ug/m3

6th-Highest Concentration

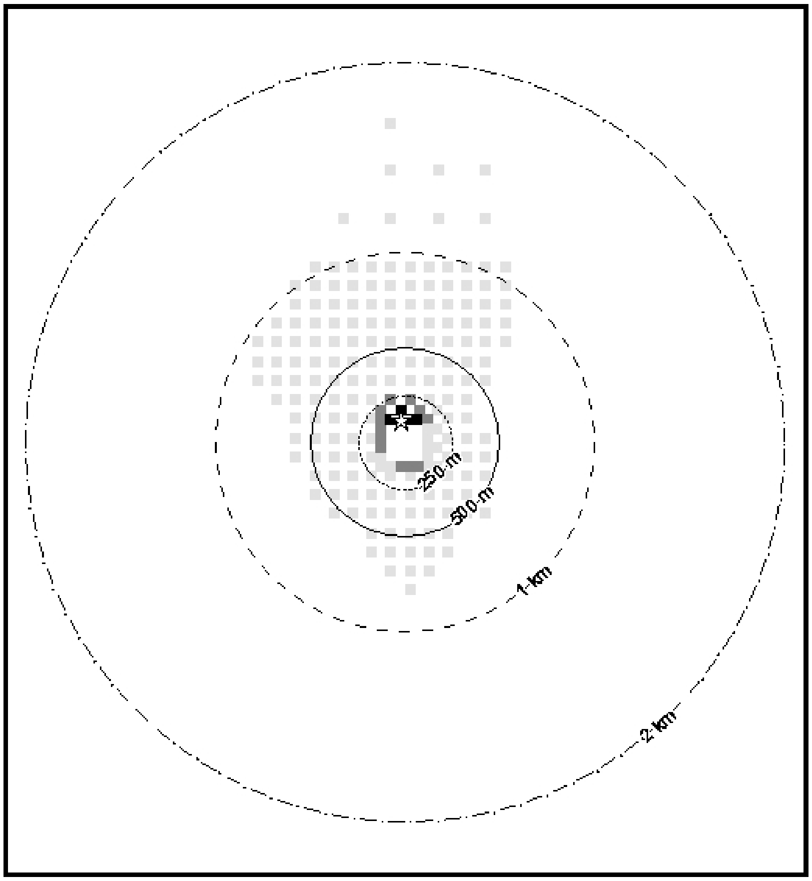
- 5 - 50 ug/m3
- 51 - 100 ug/m3
- > 100 ug/m3

Modeling Significance Level:	5 ug/m3
SO2 NAAQS:	365 ug/m3
PM10 NAAQS:	150 ug/m3

These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

N

Magnitude and Location of Impacts from an Area Source
5 Square Acres, Release Height of 2 m, and
Initial Vertical Dispersion of 3 m at 15 tpy Emission Rate
Annual Average Concentration
(micrograms per cubic meter)



LEGEND

Maximum Annual Concentration

☆ 52 ug/m3

Annual Concentration

- 1 - 15 ug/m3
- 16 - 30 ug/m3
- > 30 ug/m3

Modeling Significance Level:	1 ug/m3
NO2 NAAQS:	100 ug/m3
SO2 NAAQS:	80 ug/m3
PM10 NAAQS:	50 ug/m3

These results are based on 1986-1990 Denver Stapleton Airport Meteorological Data. Using different meteorological data will result in different impact estimates.

N