UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

March 2, 2012

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

MEMORANDUM

SUBJECT: Haul Road Workgroup Final Report Submission to EPA-OAQPS

FROM: Tyler Fox, Leader
Air Quality Modeling Group, C439-01

TO: Regional Office Modeling Contacts

The challenge of modeling the emissions and associated air quality impacts of haul roads has been a particularly vexing problem for the dispersion modeling community. There is a large degree of uncertainty in the magnitude of these fugitive dust emissions and subsequently in the modeled estimates at near-source receptor locations. At the 2009 Regional, State, and Local Modelers' Workshop, EPA held an interactive session on best modeling practices of haul roads that was chaired by Randy Robinson, USEPA Region 5, and Mick Daye, USEPA Region 7 to open up a constructive dialog throughout the regulatory dispersion modeling community on the challenges of characterizing and appropriately addressing the haul road fugitive emissions in a compliance demonstration project. Following this 2009 Workshop, the Haul Road Workgroup was formed with a collection of federal, state, and local government dispersion modelers. The goal of this Workgroup was to examine and better understand haul road characterization issues and recommend a modeling methodology back to the broader dispersion modeling community. The Workgroup decided to focus on the air quality modeling aspects and not address the fugitive dust emissions factor issues.

A report out of the Haul Road Workgroup was presented at the 2010 Regional, State, and Local Modelers' Workshop. Along with discussion amongst the regulatory dispersion modelers in attendance at the 2010 Workshop, feedback and comments were solicited and accepted on the recommendations of the Workgroup throughout 2010 and the first half of 2011. An update presentation on the Workgroup was given at the 2011 Regional, State, and Local Modelers' Workshop with the subsequent release of a draft version of the Haul Road Workgroup Final Report during the fall of 2011.

Attached to this letter is the Haul Road Workgroup Final Report that provides a "best practices guide" for modeling of haul road fugitive emissions in the AERMOD modeling system. This final report is being shared with the entire dispersion modeling community prior to the 10th Conference on Air Quality Models to promote broader consideration and facilitate further comment. Please send this report to your state, local and tribal agency modelers so that they can provide review and comment, as appropriate. The recommendations presented are not an endorsement by the USEPA as the definitive methodology for characterizing and addressing fugitive dust emissions from haul roads but should be considered a best practice approach based on the broad involvement of the co-regulating community in the development of this recommendation.

We would like to give special recognition to the initiative and labors of Randy Robinson and Mick Daye in spearheading this initiative in 2009, chairing the Haul Road Workgroup, and developing this final report. We would also like to thank all of the federal, state, and local government dispersion modelers that participated in the Workgroup and assisted in the drafting of the final report presented in the attachment.

Attachment: Robinson and Daye December 6, 2011 memorandum with Haul Roads Workgroup Final Report included as an attached document

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

DEC 6 2011

REPLY TO THE ATTENTION OF:

MEMORANDUM

SUBJECT: Haul Road Workgroup Final Report

FROM: Randy Robinson, EPA Region 5
Mick Daye, EPA Region 7

TO: Tyler Fox, Leader, Air Quality Modeling Group
George Bridgers, Clearinghouse Coordinator, Air Quality Modeling Group

The purpose of this memorandum is to transmit the attached haul road modeling final report to the Air Quality Modeling Group. The report represents the collective efforts of the Haul Road Workgroup, which was formed following the 2009 Regional/State/Local Modeling Workshop. The purpose of the workgroup was to identify and recommend a technically supportable approach for modeling haul road re-entrained dust.

The attached document contains a summary of the possible options for modeling fugitive road dust, a description of the sensitivity modeling conducted by the workgroup, and a tiered set of recommendations for modeling haul road fugitive emissions. The other attachment contains selected slides from the haul road presentation at the 2010 Regional/State/Local modeling workshop. The Workgroup requests Air Quality Modeling Group review and distribution of the recommendations document to the modeling community.

Thank you and please contact us if you have any questions or require additional information.

Haul Road Workgroup Recommendations
November 2011

Workgroup Charge -

The Haul Road Workgroup was formally established shortly after the May 2009 Regional/State/Local Workshop. The purpose of the workgroup is to identify and recommend a technically supportable approach for modeling haul road re-entrained dust. While emission factors are a critical part of any roadway modeling exercise, this workgroup felt that emissions were outside our scope and did not engage in a review or evaluation of available fugitive dust emission factors. Based on modeling work and field study/journal article review, the following represents a recommendation for an approach to characterizing haul road fugitive emissions in AERMOD.

Source Characterization - The model to be used for modeling haul road fugitive dust emissions is AERMOD. There are several ways haul road fugitive dust emissions can be characterized in AERMOD, including area source, volume source, and series of point sources. A line source algorithm is being developed but is not currently available. Each approach has advantages and disadvantages. The workgroup has considered each approach and a summary of the strengths and weaknesses is presented below.

Area source advantages:

- Can place receptors in ambient air contained within the area source
- Easy to replicate dimensions of roadway in X and Y coordinates
- Avoids the need to determine Sigma Y values (Sigma Z values are optional)
- Can utilize a Sigma Z value if desired, to reflect an initial, well-mixed plume
- Area sources explicitly simulate a uniform emission density across the roadway, which may be more realistic in some respects than other approaches.

Area source disadvantages:

- Area source in AERMOD does not have the meander algorithm
- Run times are generally longer than other approaches

Volume source advantages:

- Volume source in AERMOD contains meander algorithm
- Conceptually, a volume source mimics an initial, well-mixed plume
- Potentially faster run time than area source

Volume source disadvantages:

- Concentrations are not calculated in a volume source exclusion zone
  - Exclusion zone is the region ((2.15 x Sigma Y) + 1 meter)) from the center of the volume.

Point Source with downwash advantages:

- Precludes the need to establish Sigma values; handled internally by downwash
- Conceptually, consistent with well-mixed plume
- Can place receptors anywhere within roadway
- Can be used for buildings near roadways

Point source with downwash disadvantages:

- Downwash algorithm in AERMOD does not contain meander for receptors within the wake
- Technique would be new to modeling community
- Additional assumptions required, including building (truck) size, stack temp, velocity, height.
- Potential issues with BPIP used in this technique

Sensitivity analysis

Early in the process, the workgroup conducted an AERMOD sensitivity analysis to examine changes in haul road characterization inputs using volume and area source techniques. Limited, preliminary point source technique sensitivity runs were also conducted. Details of the sensitivity analyses are available at http://www.cleanairinfo.com/regionalstatelocalmodelingworkshop/archive/2010/Documents/Presentations/RSL2010_HaulRoads.pdf . The following summarizes the setup and general conclusions.

Analysis setup:

- Used AERMOD Version 09292
- 1 year of meteorological data (variety of locations)
- N-S and E-W crisscrossing road segments. Each 500m long, 10m wide.
- Flat Terrain
- Receptor Grids – Cartesian and Polar; beginning as near as possible to the volume sources. 1 meter from edge of area source. No receptors within source.
- Unit emission rate
- Evaluated range of values for top of plume height, Sigma Z, Sigma Y, and release height.
- Modeled using Adjacent Volume, Alternate Volume, and Area source representations.

- Calculated results for annual ave, peak 1-hr, 8th H 1-hr, peak 24-hr, 8th H 24-hr
- Point source modeling examined single vs multiple stacks and varying stack parameters.

General Conclusions:

- Increasing release height (and related Sigma Z) led to lower concentrations.
- Increasing Sigma Y for alternate and adjacent volume sources lowered concentrations.
- For area source – increasing X dimension lowered concentrations at lower release heights (i.e., 0m and 0.5m). It had little impact at higher release heights (i.e, 1.5m and 3m).
- For area source – adding a Sigma Z lowered concentrations for surface release heights, but generally increased concentrations at higher release heights
- For volume runs, adjacent gives higher concentrations than alternate.
- Point Source – limited, preliminary modeling shows some sensitivity to stack height and velocity
- On-site meteorological data model runs showed same trends as with National Weather Service data, although concentrations were higher with on-site data.

Model/Monitor Comparison

The workgroup was interested in locating field data to facilitate our review of haul road dispersion characteristics. Finding field data relevant to our task was difficult. While there are numerous field studies relevant to haul roads, the vast majority deal with monitoring designed to evaluate haul road emissions rather than dispersion characteristics. An evaluation conducted by OAQPS in 2006 examined haul road emissions from the Cordero Rojo Mine in Eastern Wyoming. The modeling looked at volume and area source configurations in AERMOD. The study, while limited, showed volume source characterizations performing slightly better than area source when compared to monitored PM10 data. The analysis was primarily designed to examine the impact of the meander algorithms. This is significant because the volume source approach incorporates meander while the area source approach does not. The difference in model performance was attributed to area source over-estimates due to lack of meander upwind dispersion. Details of the Cordero Rojo Mine evaluation results can be found at http://www.awma.org/events/confs/AQMODELS06/Session%204/4-Roger%20Brode.pdf .

Haul Road Recommendations

Definitions

During the workgroup discussions and sensitivity modeling work, the following definitions were used;

"VH" means vehicle height [~3m for typical haul trucks; ~10m for large mining trucks]
"VW" means vehicle width [~3m for typical haul trucks; ~10m for large mining trucks]
"VL" means vehicle length [~10m for typical haul trucks; ~20m for large mining trucks]

These definitions and associated dimensions were useful to the group as we discussed the various methods and developed the inputs to be used in the sensitivity modeling. They should not be treated as default values and/or used in place of site specific dimensions available for individual modeling demonstrations.

General Recommendation

The following represents a general recommendation for modeling of haul road emissions. The recommendation is not meant to be prescriptive; local conditions and specific information may lead to an alternative approach. However, the workgroup feels that the recommendation presented below is reasonable, can be technically supported, and provides a level of conservativeness given the large amount of uncertainty associated with characterizing and simulating dispersion of fugitive emissions resulting from haul road traffic. Concentrations must be calculated in areas that are considered ambient air.[1]

- **Volume Source – Recommend for all haul roads, except for cases where ambient air receptors are within the volume's exclusion zone (i.e.,** ((2.15 x Sigma Y) + 1 meter)) from the center of the volume.

Rationale:

Volume source contains the meander algorithm.
Conceptually fits the physical parameters associated with well-mixed plume.
Limited model/monitor comparison study information supports volume source

Recommended Volume Source Configuration:

- Adjacent Volume Source

[1] Ambient Air is defined at 40 CFR Part 50.1(e) and further clarified in a December 19, 1980 from Douglas Costle to Senator Jennings Randolph. See http://www.epa.gov/scram001/guidance/mch/ama4.txt

- Top of Plume Height[2] – 1.7 x VH
  - Volume Source Release Height – 0.5 x Top of Plume height
  - Width of Plume – VW + 6m for single lane roadways / Road Width + 6m for two lane roadways[3].
  - Initial Sigma Z – Top of Plume / 2.15 AERMOD User's Guide, Table 3-1 for use when modeling multiple volumes.
  - Initial Sigma Y – Width of Plume / 2.15 AERMOD User's Guide, Table 3-1
  - Emissions input as g/s

- The 1.7 factor in the Top of Plume Height equation above is supported by information in a 2005 Atmospheric Environment paper by Gillies, et. al, entitled Effect of Vehicle Characteristics on Unpaved Road Dust Emissions.
- The Width of Plume value is based on a conservative adaptation of monitor placement guidance from EPA's 1992 document, Guideline for Modeling Carbon Monoxide from Roadway Intersections. In that document, it is recommended that monitors not be placed nearer than 3 meters from the roadway edge to account for vehicle turbulence. Two-lane roadways are for cases with heavy two-way traffic where the combined plume needs to be approximated. Agencies may need to consider traffic counts, vehicle width, road width, and the amount of two-way traffic, in order to determine whether the roadway is best represented using single-lane or two-lane assumptions. While the workgroup's sensitivity analysis indicates increased volume source width leads to decreased concentrations, our group didn't specifically examine single-lane versus two-lane roadways. One option is to model two-lane roadways as two, single-lane volume sources.
- For cases where ambient air receptors fall within the volume source exclusion zone, a conservative volume source approach would be to reduce the width of plume dimensions enough so that the ambient air receptors are not inside the exclusion zone. Additionally, a mix of area sources and volume sources may adequately allow for consideration of all ambient air receptors.

Area Source – Recommended for haul roads where ambient air receptors are located within source dimensions.

Rationale:

Volume source doesn't allow placement of receptors within exclusion zone.
Area source can calculate concentrations at receptors within source.
Area source can simulate volume source with use of similar release height and Sigma Z parameters.

[2] Gillies, J.A., V. Etyemezian, H. Kuhns, D. Nikolic, D.A. Gillete, 2005. Effect of Vehicle Characteristics on Unpaved Road Dust Emissions. Atmospheric Environment, 39, 2341-2347
[3] EPA. 1992. Guideline for Modeling Carbon Monoxide From Roadway Intersections. EPA-454/R-92-005. http://www.epa.gov/scram001/guidance/guide/coguide.pdf

Recommended Area Source Configuration

- Length – length of roadway segment (Aspect ratio in AERMOD extended to 100:1 before warning is issued. See Model Change Bulletin #3, Miscellaneous item #10)
- Width – VW + 6m for single lane / Road Width + 6m for two-lane (same comment as for volume, two single-lanes is an option)
- Top of plume height – 1.7 x VH
- Release height – 0.5 x top of plume height
- Sigma Z – Top of Plume height / 2.15
- Emissions input as $g/s/m^2$

Point Source – The workgroup is not forwarding any point source recommendation at this time. There are potential benefits to this approach, however, more study is needed.

Future Efforts

The workgroup understands that efforts are underway on a line source algorithm to be included in AERMOD. The time frame for completion of this work may be within the next couple years. A new line source algorithm would likely supplant the need to model haul road fugitive dust emissions using either volume, area, or point sources.

Point source modeling of fugitive roadway emissions has some potential benefits, as noted earlier in this paper. One example is the ability to consider the influence of facility structures located near roadways when simulating the roadway fugitive dust in AERMOD. The Haul Road Workgroup supports further study of this approach.

More field studies examining initial plume dimensions are encouraged. The effects of vehicle speed on the initial plume dimensions is an area that should be investigated when, or if, more field studies are conducted.

References

Brode, R.W., Improved Algorithms for Modeling Impacts Near Roadways. MACTEC Federal Programs, Inc. A&WMA Specialty Conference, Denver, CO, April 2006

EPA. 1992. Guideline for Modeling Carbon Monoxide From Roadway Intersections. EPA-454/R-92-005. http://www.epa.gov/scram001/guidance/guide/coguide.pdf

EPA. 1994. Modeling Fugitive Dust Impacts from Surface Coal Mining Operations – Phase II. EPA-454/R-94-025

Eskridge, R. E., Thompson, R.S., 1982, Experimental and Theoretical Study of the Wake of a Block-Shaped Vehicle in a Shear-Free Boundary Flow. Atmospheric Environment, 16, 2821-2836

Fitz, D. R., 2001. Measurements of PM10 and PM2.5 Emission Factors from Paved Roads in California. Contract No. 98-723. California Air Resources Board, Monitoring and Laboratory Division

Gillies, J.A., V. Etyemezian, H. Kuhns, D. Nikolic, D.A. Gillete, 2005. Effect of Vehicle Characteristics on Unpaved Road Dust Emissions. Atmospheric Environment, 39, 2341-2347.

Guideline on Air Quality Models, US Environmental Protection Agency, 40 CFR Part 51, Appendix W, November 9, 2005.

Heinerikson, A., Goodman, A., Anderson, K., Analysis of Haul road Emission Test Data for Determining Dispersion Modeling Parameters. Trinity Consultants.

Reed, W. R., Performance Evaluation of a Dust-dispersion Model for Haul Trucks. National Institute for Occupational Safety and Health, Pittsburgh Research Lab.

User's Guide for the AMS/EPA Regulatory Model – AERMOD, US Environmental Protection Agency, EPA-454/B-03-001, September 2004.

Westbrook, J.A., Sullivan, P.S., Fugitive Dust Modeling with AERMOD for PM10 Emissions from a Municipal Waste Landfill.

Williams, D.S., Manoj, K.S., Ross, J., Particulate Matter Emission by a Vehicle Running on Unpaved Road. 2008. Atmospheric Environment, 42, 3899-3905.

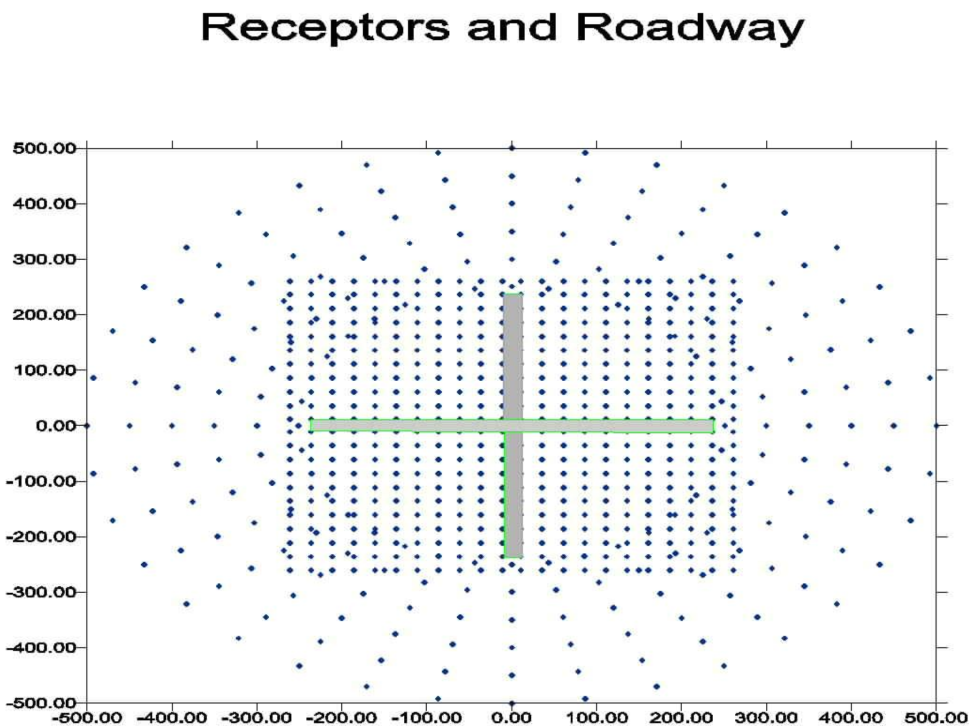
Select Slides from May 2010 Regional/State/Local Workshop Presentation

Sensitivity Analysis Work

- Used AERMOD Version 09292
- 1 year of meteorological data (variety of locations)
- N-S and E-W crisscrossing road segments. Each 500m long, 10m wide.
- Flat Terrain
- Receptor Grids – Cartesian and Polar; beginning as near as possible to the volume sources. 1 meter from edge of area source. No receptors within source.

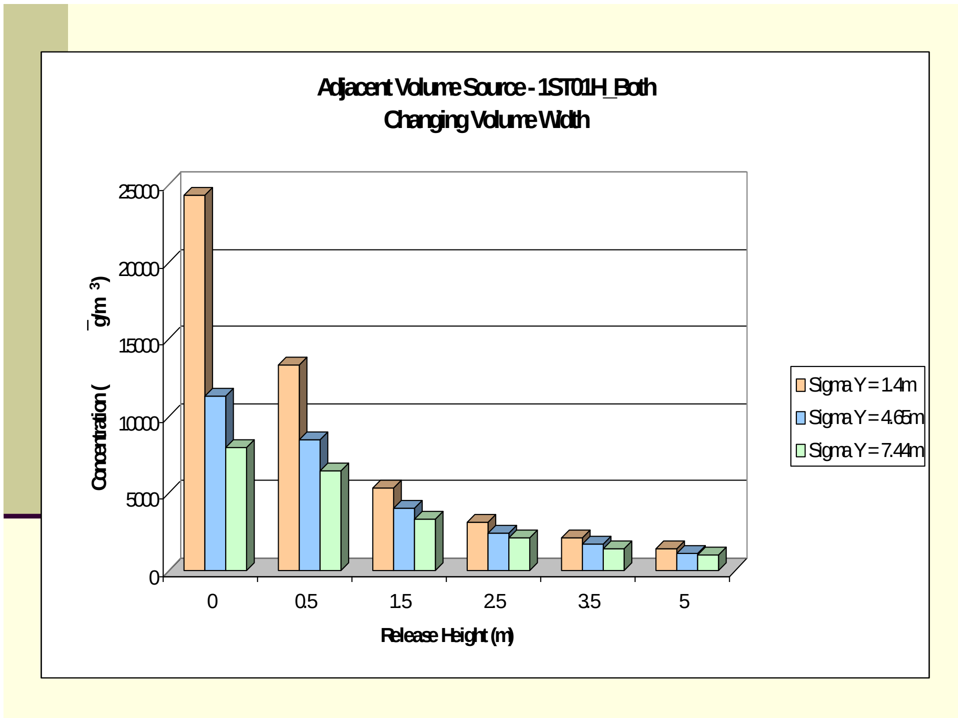
Cont.

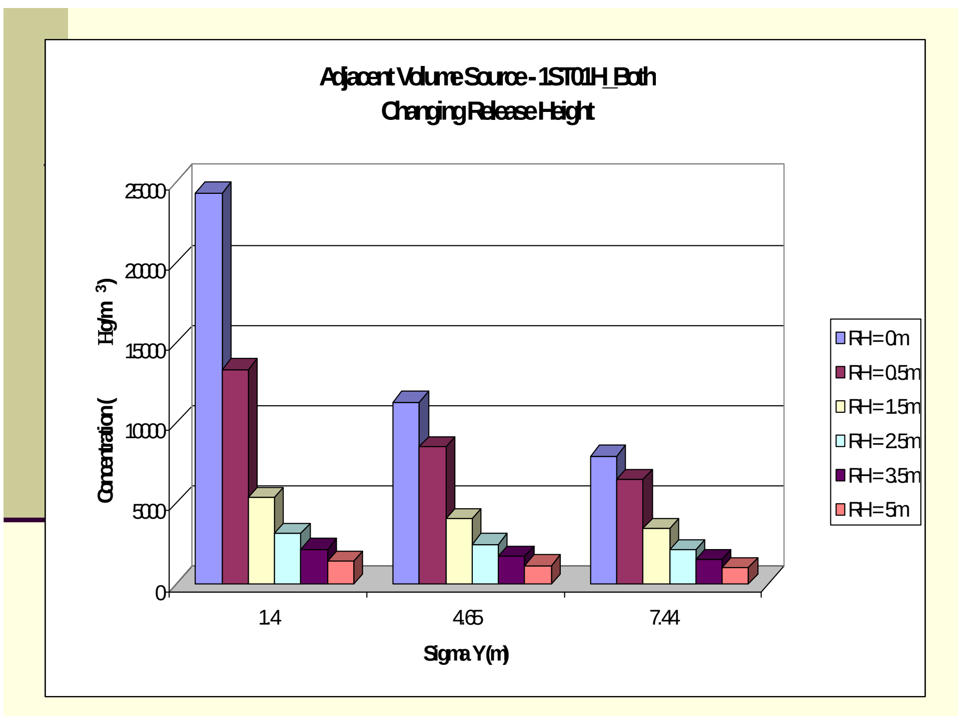
- Unit emission rate
- Evaluated range of values for top of plume height, Sigma Z, Sigma Y, and release height.
- Modeled using Adjacent Volume, Alternate Volume, and Area source representations.
- Calculated results for annual ave, peak 1hr, 8^{th} H 1hr, peak 24hr, 8^{th} H 24hr,

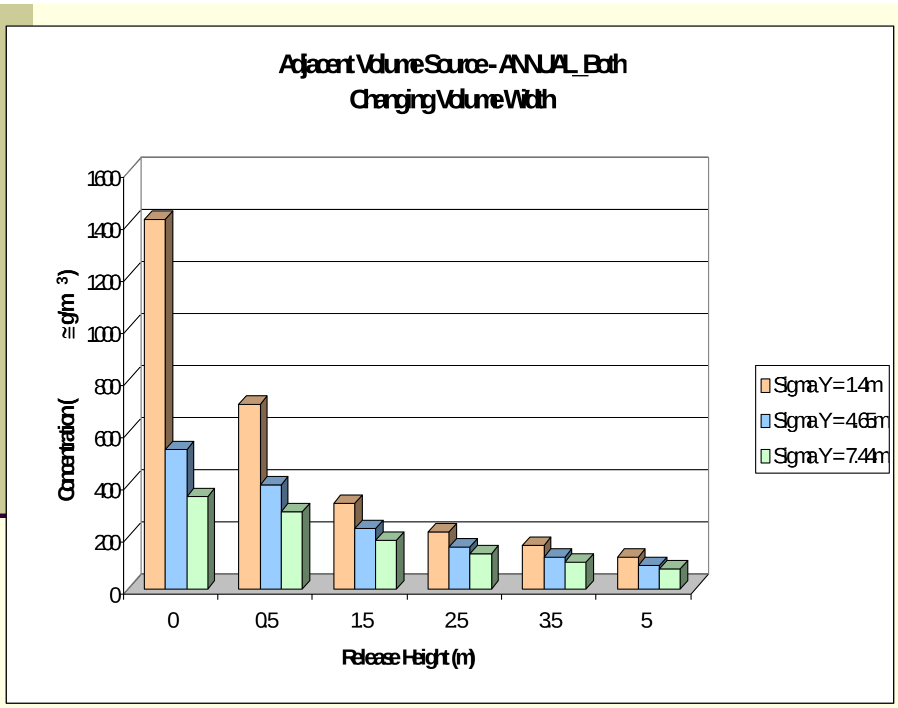


Matrix of Values for Analysis

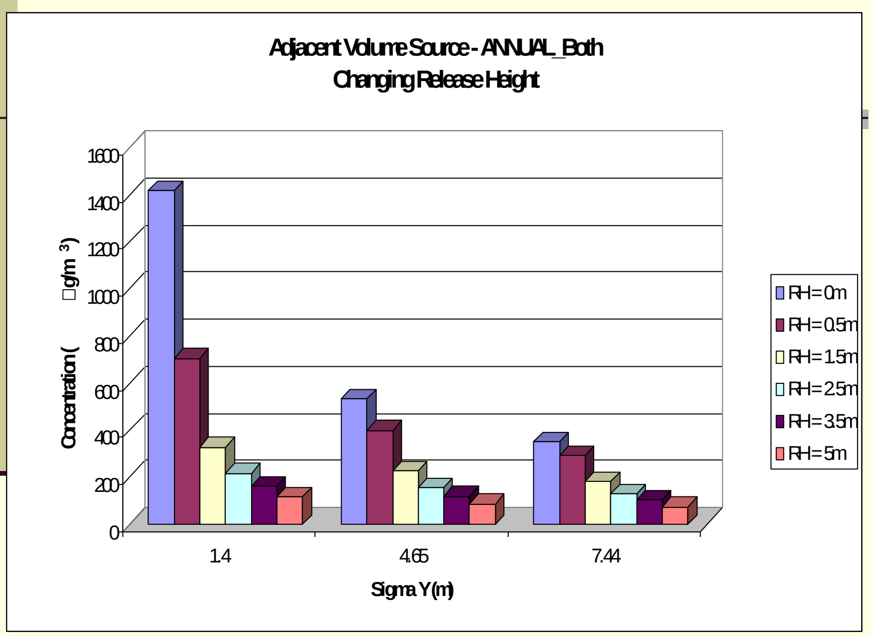
	Range of Values					
Top of Plume Ht	0m	1m	3m	5m	7m	10m
Sigma Z	Top of Plume Height / 2.15					
Sigma Y	3m / 2.15		10m / 2.15		16m / 2.15	
Release Height	Top of Plume Height / 2					


Adjacent Volume Source - 1ST01H_Both
Changing Volume Width
Concentration (μg/m³)
25000
20000
15000
10000
5000
0
0
0.5
1.5
2.5
3.5
5
Release Height (m)
Sigma Y = 1.4m
Sigma Y = 4.65m
Sigma Y = 7.44m

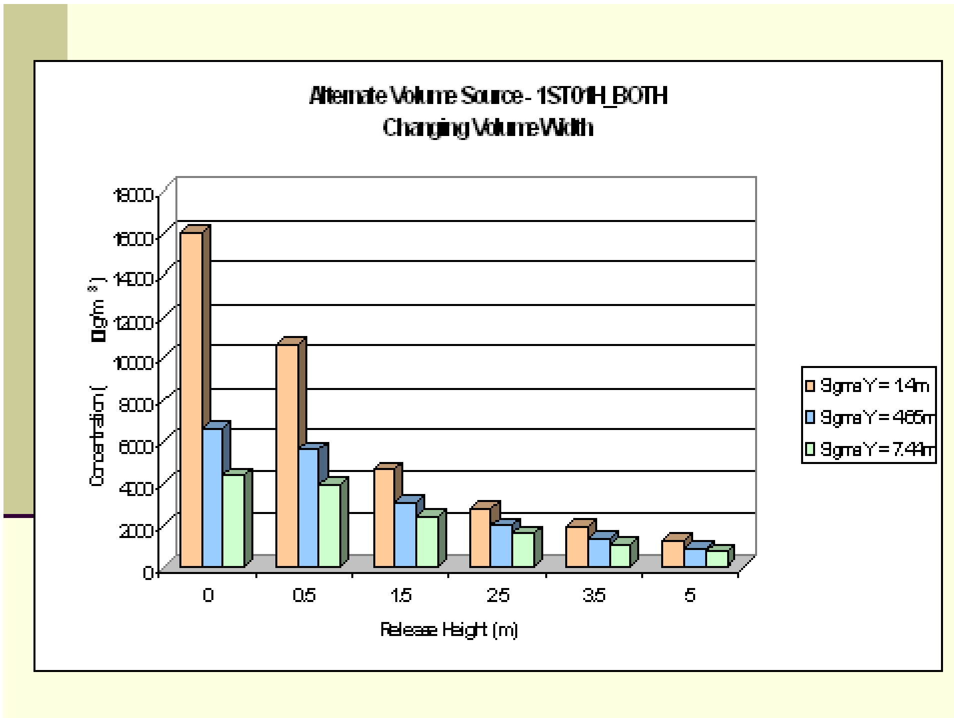

Adjacent Volume Source - 1ST01H_Both
Changing Release Height
Concentration (μg/m³)
25000
20000
15000
10000
5000
0
1.4
4.65
7.44
Sigma Y (m)
RH=0m
RH=0.5m
RH=1.5m
RH=2.5m
RH=3.5m
RH=5m

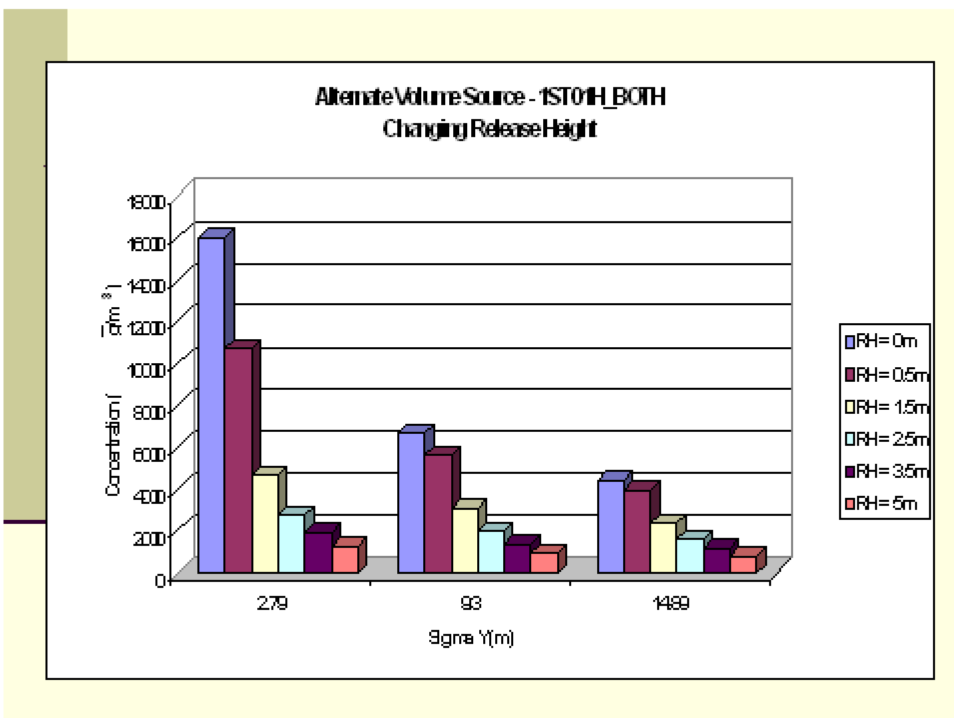


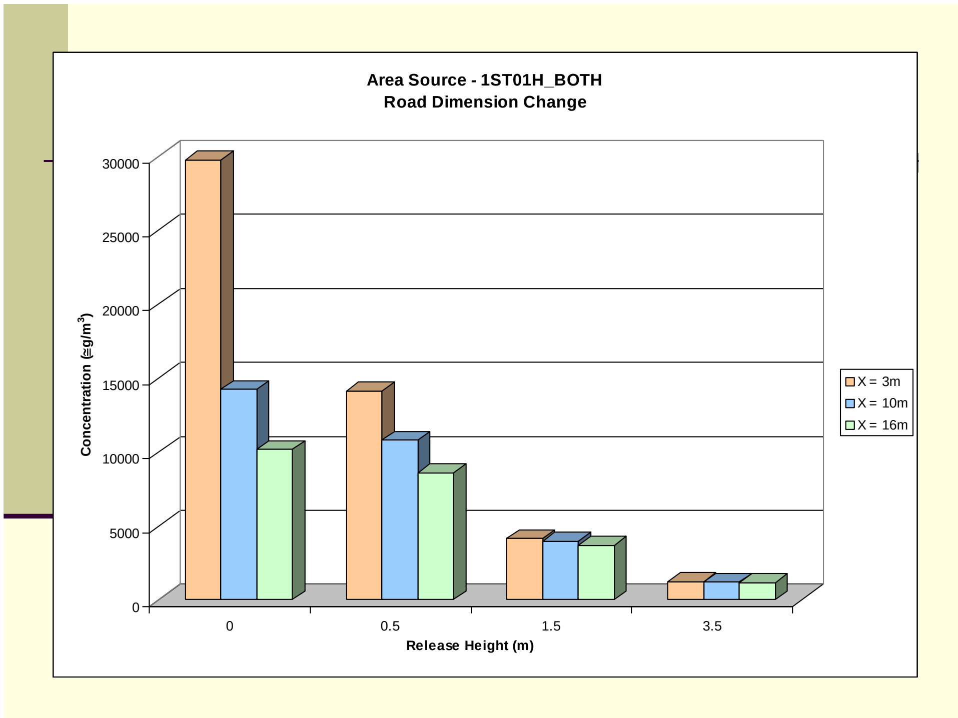
Adjacent Volume Source - ANNUAL_Both
Changing Volume Width
Concentration (≅g/m 3)
1600
1400
1200
1000
800
600
400
200
0
0
0.5
1.5
2.5
3.5
5
Release Height (m)
Sigma Y=1.4m
Sigma Y=4.65m
Sigma Y=7.44m

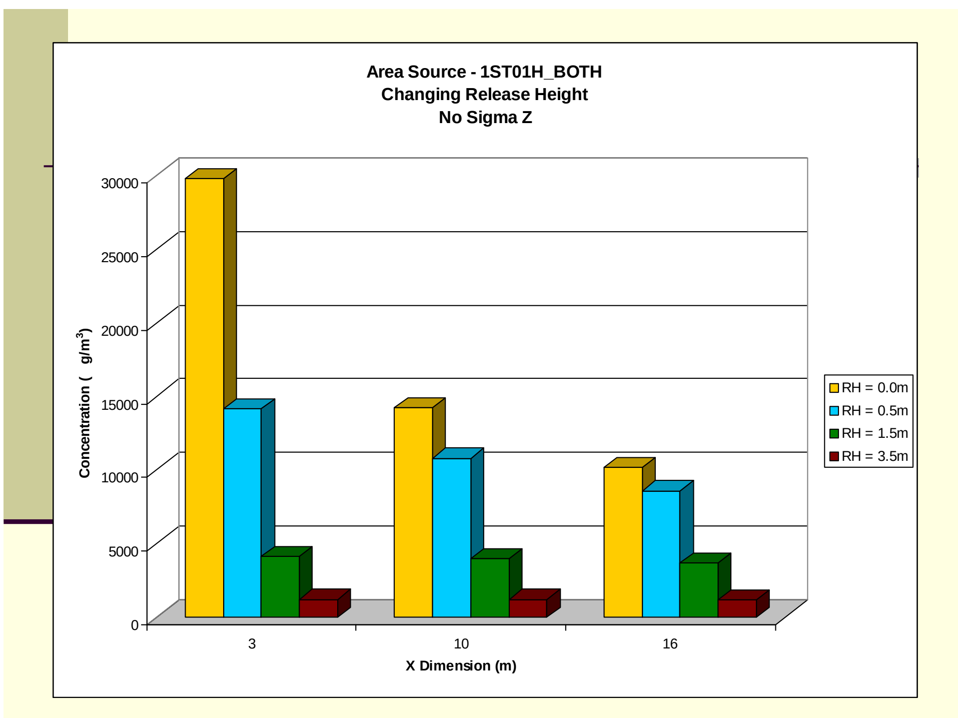


Adjacent Volume Source - ANNUAL_Both
Changing Release Height
Concentration (g/m 3)
1600
1400
1200
1000
800
600
400
200
0
1.4
4.65
7.44
Sigma Y (m)
RH=0m
RH=0.5m
RH=1.5m
RH=2.5m
RH=3.5m
RH=5m


Alternate Volume Source - 1ST01H_BOTH
Changing Volume Width
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Concentration (
Sigma Y = 1.4m
Sigma Y = 4.65m
Sigma Y = 7.44m
0
0.5
1.5
2.5
3.5
5
Release Height (m)


Alternate Volume Source - 1ST01H_BOTH
Changing Release Height
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Concentration (
RH = 0m
RH = 0.5m
RH = 1.5m
RH = 2.5m
RH = 3.5m
RH = 5m
2.79
9.3
14.89
Sigma Y(m)


Area Source - 1ST01H_BOTH
Road Dimension Change
Concentration (≤g/m3)
30000
25000
20000
15000
10000
5000
0
0
0.5
1.5
3.5
Release Height (m)
X = 3m
X = 10m
X = 16m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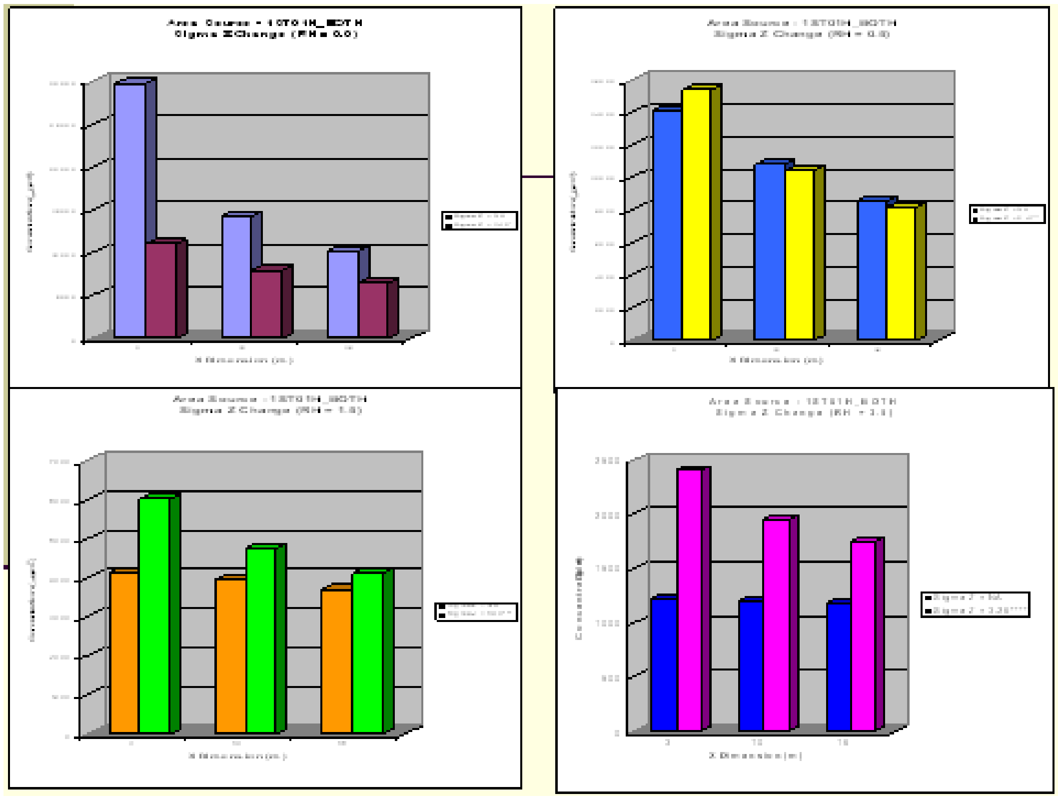
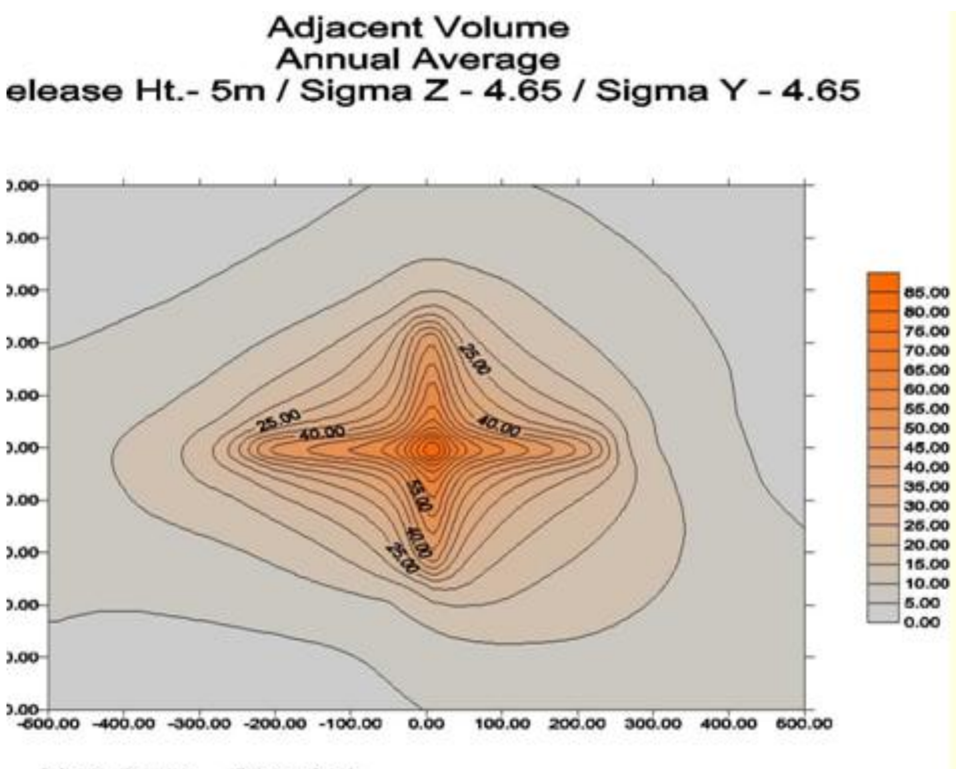
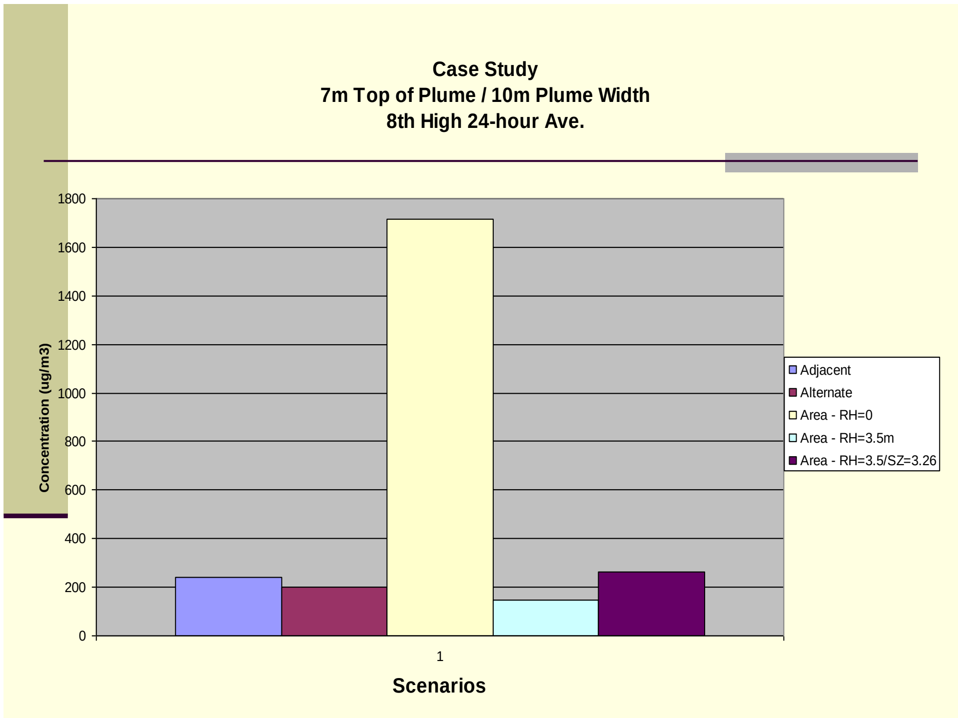
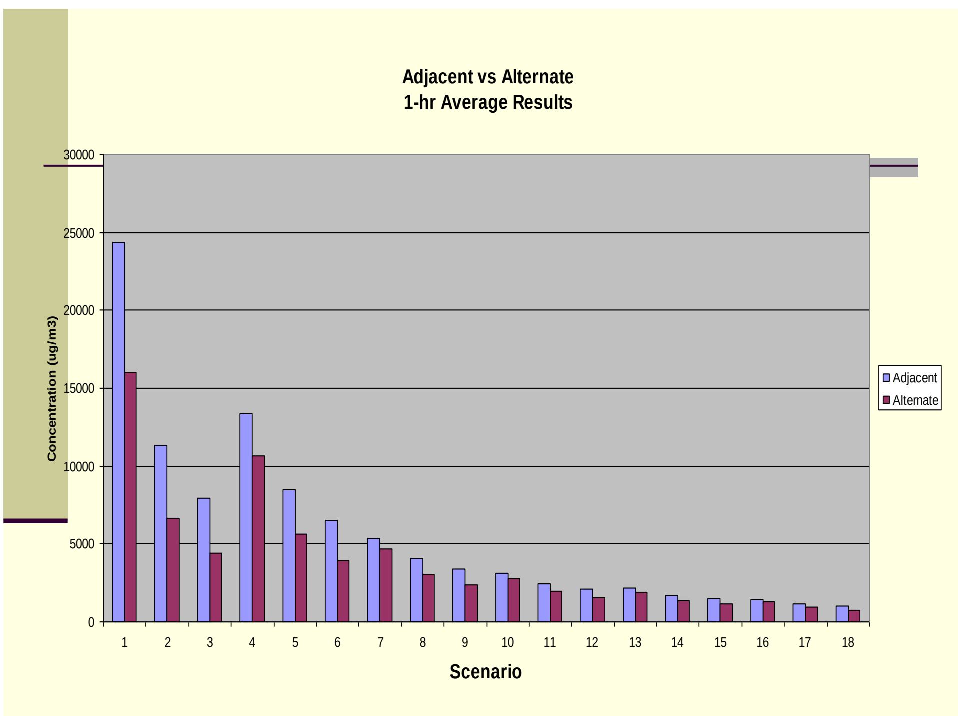
Changing Release Height
No Sigma Z
Concentration (g/m3)
30000
25000
20000
15000
10000
5000
0
3
10
16
X Dimension (m)
RH = 0.0m
RH = 0.5m
RH = 1.5m
RH = 3.5m

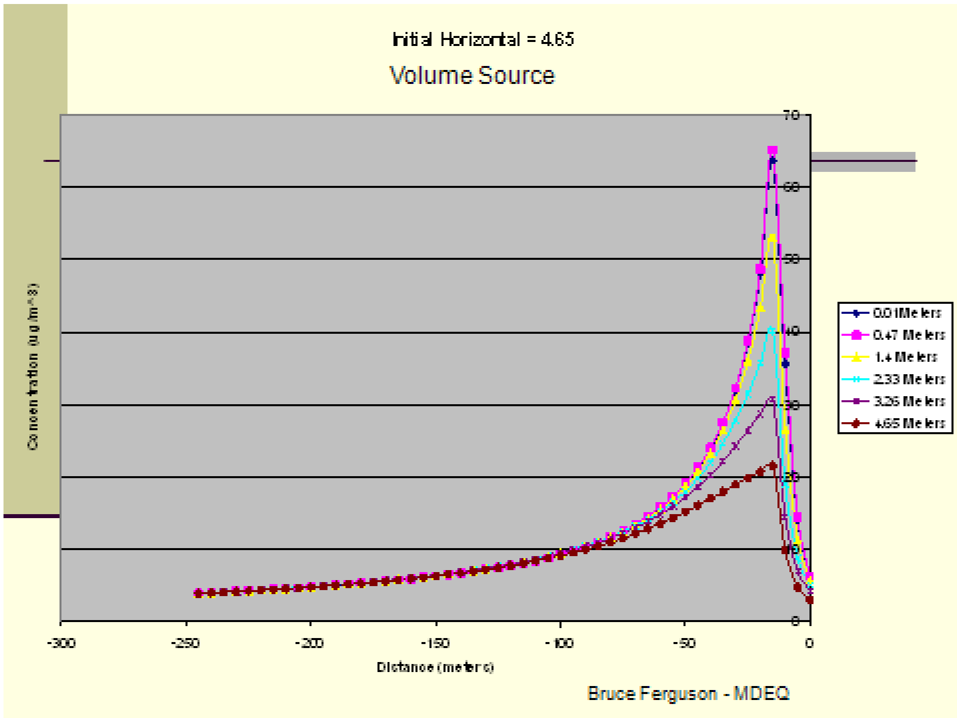


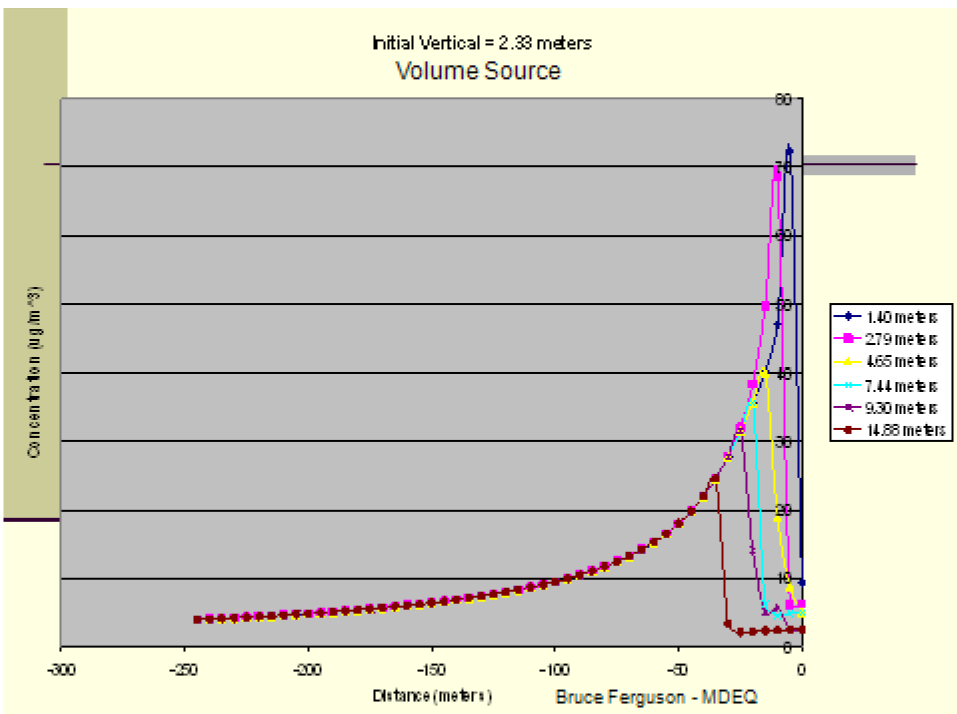


MAX. CONCENTRATION - 89 ug/m3


Case Study
7m Top of Plume / 10m Plume Width
8th High 24-hour Ave.
Concentration (ug/m3)
1800
1600
1400
1200
1000
800
600
400
200
0
1
Scenarios
Adjacent
Alternate
Area - RH=0
Area - RH=3.5m
Area - RH=3.5/SZ=3.26


Adjacent vs Alternate
1-hr Average Results
Concentration (ug/m3)
30000
25000
20000
15000
10000
5000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Scenario
Adjacent
Alternate


Initial Horizontal = 4.65
Volume Source
Concentration (ug/m^3)
Distance (meters)
0.01 Meters
0.47 Meters
1.4 Meters
2.33 Meters
3.26 Meters
4.65 Meters
Bruce Ferguson - MDEQ


Initial Vertical = 2.33 meters
Volume Source
Concentration (ug/m^3)
Distance (meters)
1.40 meters
2.79 meters
4.65 meters
7.44 meters
9.30 meters
14.88 meters
Bruce Ferguson - MDEQ

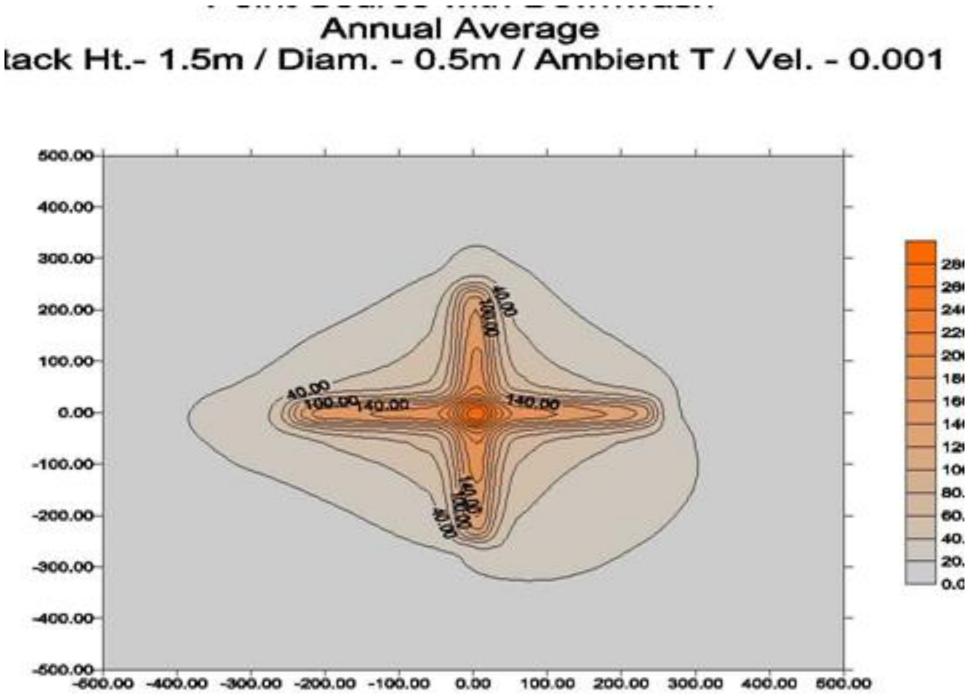
Haul Road as Point Sources

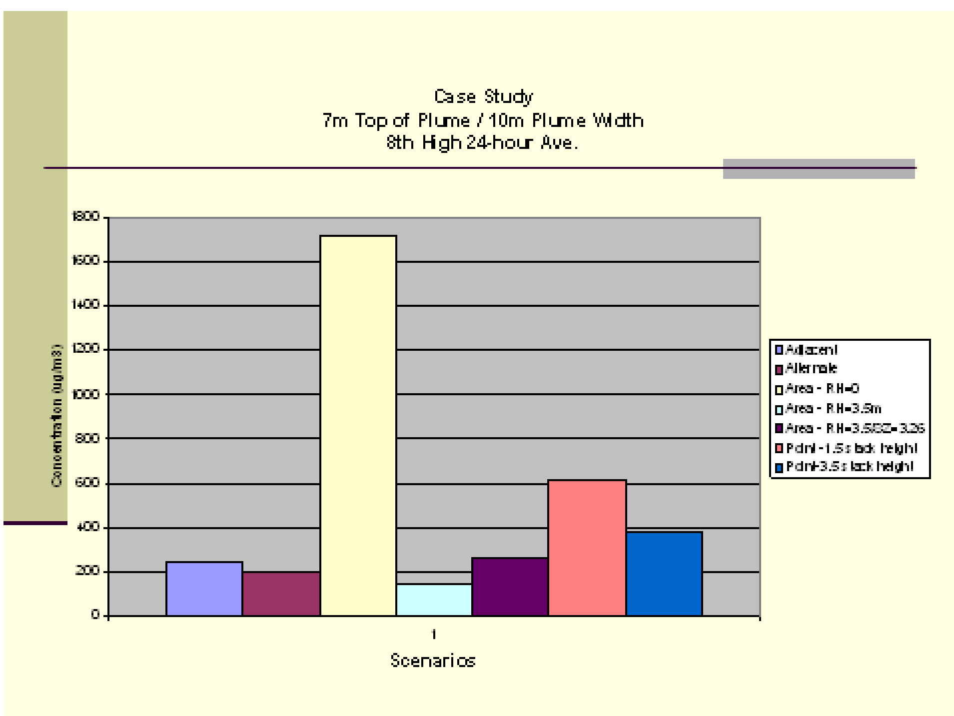
- Ran AERMOD using point sources to represent haul road
- Flat terrain
- Assume building with dimensions of 3m x 3m x 10m –oriented along roadway.
- Locate point at each corner of building - 384 total stacks.
- 1 g/s emissions distributed among stacks

Continued…

- Stack height = 1.5m and 3.5m
- Temperature = ambient
- Velocity = .001 m/s
- Diameter = 0.5m
- Receptors - cart. – start 11m from center of road at 25 m resolution plus 10 degree polar at 250m at 50 m resolution

POINT SOURCE WITH DOWNWASH





General Conclusions for Sensitivity Analysis Runs

- Increasing RH (release height) always led to lower concentrations.
- Increasing Sigma Y for alt. and adj. volume sources lowered concentrations.
- For area source – increasing X dimension lowered concentrations at 0 and 0.5 RH, at 1.5 and 3m RH, had little impact on concentrations.
- For area source – adding a sigma z lowered concentrations for 0 RHs, but usually increased concentrations at 1.5 and 3.5 RHs, mixed results for 0.5m RH.

Cont.

- For volume runs, adjacent gives higher concentrations than alternate.
- Point Source – limited modeling shows sensitivity to stack height; little sensitivity to stack diameter.
- On-site met data runs showed same trends as NWS, although concentrations higher with on-site.