COMPARISON OF REGULATORY DESIGN CONCENTRATIONS IN COMPLEX TERRAIN:

ADMS VERSUS AERMOD AND ISCST3

September 2000

Cambridge Environmental Research Consultants

Cambridge Environmental Research Consultants
3 Kings Parade, Cambridge, CB2 1SJ, UK
tel: 44 1223 357773, fax; 44 1223 357492
email: cerc@cerc.co.uk
web site: http://www.cerc.co.uk

TABLE OF CONTENTS

SUMMARY

This study is an extension of the comparisons presented in the report "Comparison of Regulatory Design Concentrations: AERMOD versus ISCST3 and CTDMPLUS". It presents a consequence analysis, to demonstrate how regulatory design concentration estimates for complex terrain scenarios from the dispersion model ADMS compare with those from AERMOD and ISCST3.

Different source locations and meteorological data have been used because the meteorological data in the AERMOD report were referenced as coming from an unnamed source. The two sets of terrain data used, Cinder Cone Butte and Mount St. Helens were used in the AERMOD report as were the two sources: "Source 4" and "Source 6". Table 1 describes the model input data. Results are presented as ratio charts for easy comparison with the earlier work.

A Brief Description of ADMS

The **ADMS** (**A**tmospheric **D**ispersion **M**odelling **S**ystem) model was developed by CERC (Cambridge Environmental Research Consultants) with the UK Meteorological Office, National Power plc and University of Surrey. The first version of ADMS was released in 1993. The current model is ADMS version 3 that was released in February 1999.

ADMS 3 is a state of the art dispersion model for passive and buoyant release to the atmosphere, that uses a parameterisation of the boundary layer in terms of boundary layer depth and Monin-Obukhov length rather than stability categories. It includes treatment of building effects, complex terrain, wet and dry deposition, puff (finite duration) releases and short time scale fluctuations in concentration. Plume rise is calculated from a Runge-Kutta solution of the conservation equations. Further details of the model can be found in the "ADMS 3 User Guide" and "ADMS 3 Technical Specification".

A Brief Description of AERMOD

AERMOD stands for the **AER**MIC Dispersion **Mod**el. AERMOD was designed by the **AERMIC** committee (the **A**merican Meteorological Society/ **E**nvironmental Protection Agency **R**egulatory **M**odel **I**mprovement **C**ommittee) to treat elevated and surface sources in terrain that is simple or complex. It is based on planetary boundary layer turbulence structure, scaling and concepts, like ADMS. More information can be found in the "AERMOD Description of Model Formulation".

A Brief Description of ISCST3

ISCST3 (**I**ndustrial **S**ource **C**omplex **S**hort **T**erm Dispersion Model) was designed especially to support the EPA's regulatory modelling programs. Unlike ADMS and AERMOD it does not use the ideas of boundary layer turbulence structure and scaling, but uses stability category ideas. It includes modelling of stack tip downwash, final plume rise, buildings downwash and complex terrain. More information can be found in the "User's Guide for the Industrial Source Complex (ISC3) Dispersion Models".

MODEL INPUT DATA

Two complex terrain scenarios were modelled as well as the corresponding flat terrain runs for those two sources, giving a total of four model scenarios. Table 1 lists the source data and output grids used. The sources are identical to two of those used in the AERMOD consequence analysis report (35m, slightly buoyant and 100m, buoyant)

This study used meteorological data from Pittsburgh (1964) and assumed parameters appropriate for rural conditions. The latitude of Pittsburgh is 40.5°.

Figures 1 and 2 illustrate the terrain data. The positions of the sources and output grids are marked.

Results presented are the maximum 2nd highest 1hour, 3 hour and 24 hour averages, and the maximum annual average. Results are presented as bar charts of the ADMS concentrations mormalised by the corresponding AERMOD and ISCST3 concentrations, and model results with complex terrain normalised by the model flat terrain concentrations.

Figure 3 shows the results for Source 4 modelled with Cinder Cone Butte. Figure 4 shows the complex terrain concentrations normalised by the flat terrain values, for each model. Figures 5-6 show the same results for Source 6, Mount St Helens.

Table 1: Source data

Name	**Source 4**	**Source 6**
Description	**medium height, slightly buoyant**	**high, buoyant**
height (m)	35	100
diameter (m)	2.4	4.6
exit velocity (m/s)	11.7	18.8
temperature (°C)	20	143
emission rate (g/s)	100	100
extent of output grid from source (m)	675	4500
output grid spacing (m)	45	300
Terrain	Cinder Cone Butte	Mount St. Helens
stack location (X,Y)(m)	(850, 600)	(564000, 114500)
roughness length (m)	0.15	0.15
surface albedo	0.25	0.25
Bowen ratio[1]	0.75	0.75
Priestly-Taylor parameter[2]	0.6	0.6

[1]Used in AERMOD & ISCST3
[2]Used in ADMS 3

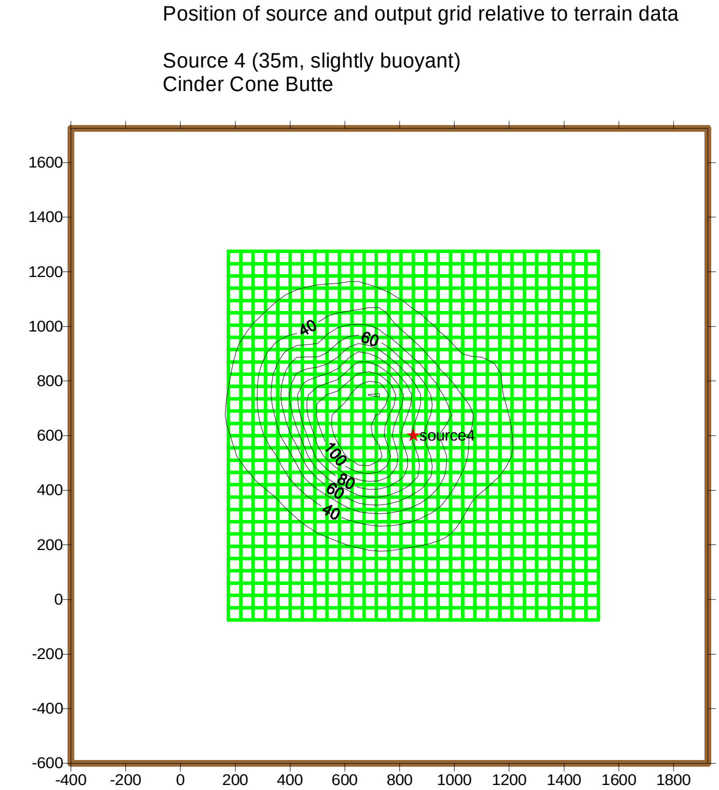

Figure 1 Cinder Cone Butte, Source 4

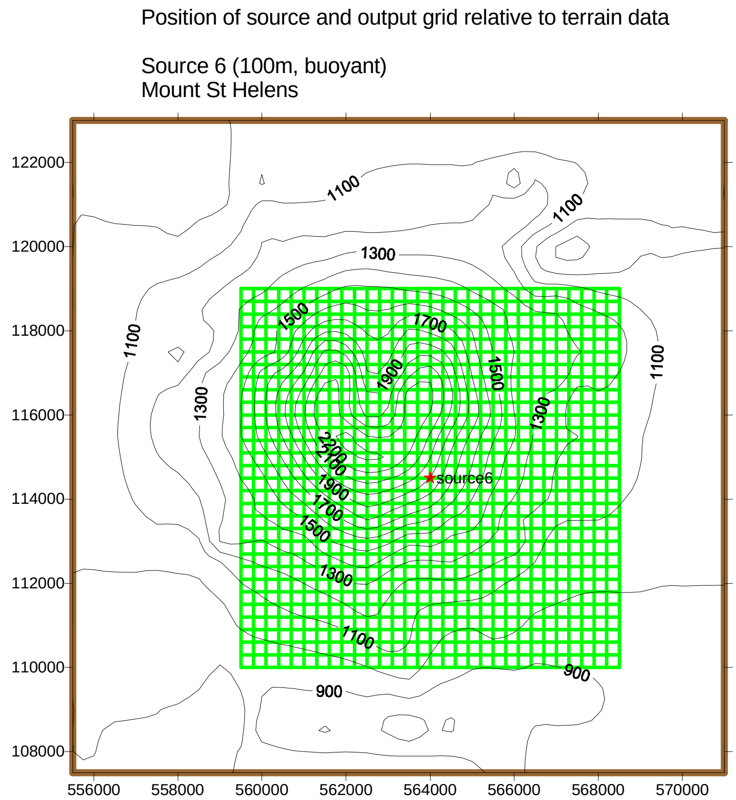

Figure 2 Mount St Helens, Source 6

DISCUSSION

ADMS 3 models the mean flow field and change in turbulent velocity around complex terrain and includes the impact of stable conditions on the flow pattern. This flow field is then used to calculate the plume trajectory and spread. The model contains algorithms for releases into regions of recirculating flow and plume impaction under stable meteorological conditions.

ISC terrain modelling takes account of the elevation of each receptor point but does not predict a change in plume direction or spread due to the terrain.

AERMOD treatment of complex terrain is a simplification of the procedure used in the CTDMPLUS model [Perry et al, 1989]. It uses the idea of a controlling hill elevation and point elevation at each receptor. The terrain preprocessor provides information for critical dividing streamline algorithms. The concentration is calculated by interpolation between solutions for concentration for neutral flow and for divided flows, although physically there is no smooth transition between the two regimes.

The first case modelled is a buoyant release from a 35m stack at a base elevation of 70m. The peak of Cinder Cone Butte is around 110m, approximately 300m from the stack. As the release is buoyant the release will not satisfy conditions for impaction onto the hill. Figure 3 shows that ADMS results in lower high-second-highest concentrations compared with both AERMOD and ISC. Figure 4 shows that the ADMS 3 predicted concentrations in complex terrain are up to 1.4 times the flat terrain concentrations. ISC predicts an increase of up to 17 times and AERMOD predicts concentrations would increase by up to 134 times!

In the second case, of a buoyant release from a 100m stack with a base elevation of 1900m, situated approximately 2km from the 2300m peak of Mount St. Helens. ADMS and ISC both predict higher complex terrain/flat terrain ratios for Mount St. Helens than for Cinder Cone Butte, but AERMOD predicts the opposite trend. Both AERMOD and ISC predict complex terrain/flat terrain ratios around 80 in the 1 hour value whereas AERMOD predicts ratios up to 5.3.

The long term average ratios should reflect the fact that the ground level concentration varies with meteorological conditions and wind direction. The wind direction does not always cause the plume to impact on the hill even when conditions are sufficiently stable for impaction to occur. It is therefore curious that the ISC annual average complex/flat ratios for both Cinder Cone Butte and Mount St. Helens are close to the 1 hour and 3 hour values.

References

Comparison of Regulatory Design Concentrations: AERMOD versus ISCST3 and CTDMPLUS: (April 1999) W. D. Peters, R. J. Paine, R. F. Lee, R. B. Wilson. A. J. Cimorelli, S. G. Perry, J. C. Weil and A. Venkatram

ADMS 3 User Guide: CERC Limited, 3 King's Parade, Cambridge, CB2 1SJ. February 1999

ADMS 3 Technical Specification: CERC Limited, 3 King's Parade, Cambridge, CB2 1SJ. April 2000

AERMOD Description of Model Formulation: AERMIC report for the US EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711. Version: 98314 (AERMOD & AERMET) 98022 (AERMAP) December 15, 1998

User's Guide for the Industrial Source Complex (ISC3) Dispersion Models/ Volume I – User Instructions: US EPA, Office of Air Quality Planning and Standards, Emissions Monitoring and Analysis Division, Research Triangle Park, NC 27711. Report number EPA-454/B-95-003a

Figure 3 Ratio of high-2nd-highest concentrations, Cinder Cone Butte, Source 4 (35m slightly buoyant)

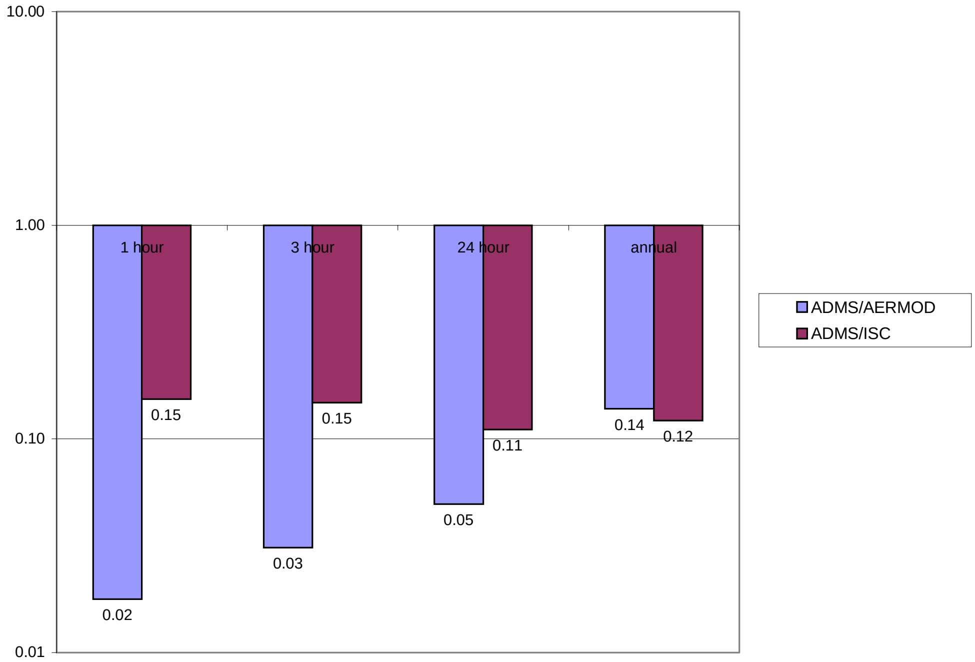

Figure 4 High-2nd-highest complex terrain concentrations normalised by flat terrain values, Cinder Cone Butte, source 4

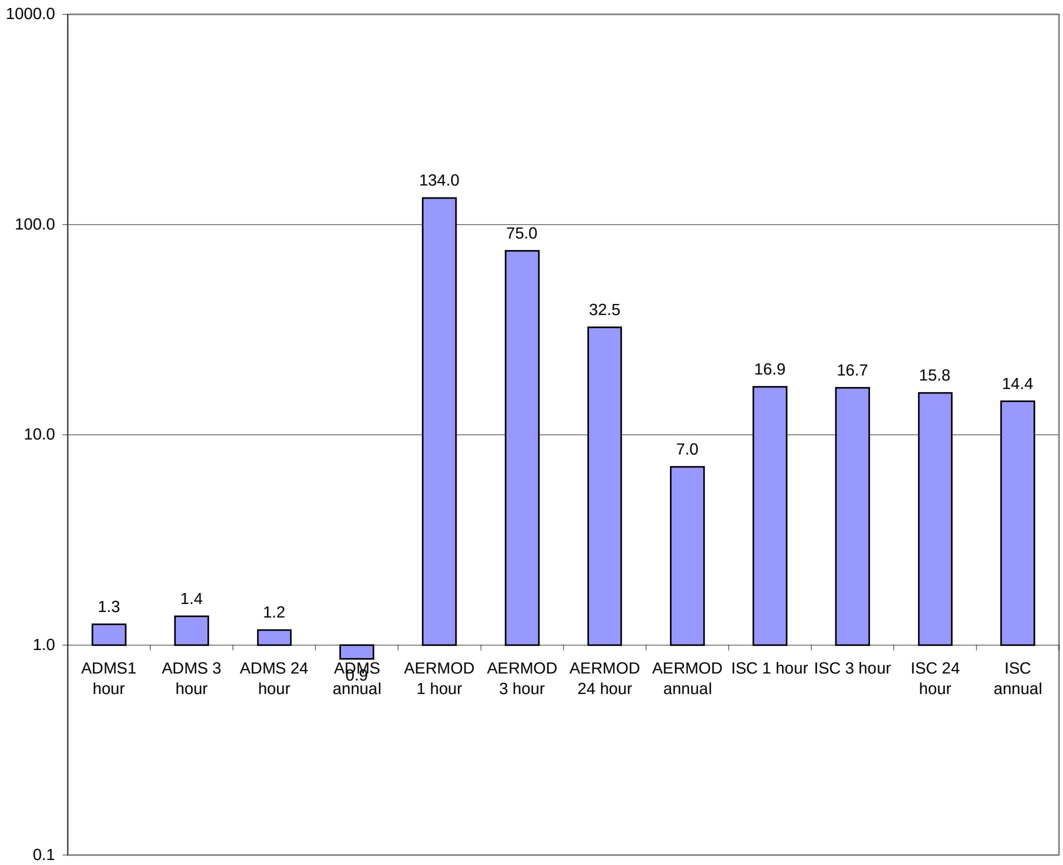

Figure 5 Ratio of high-2nd-highest concentrations, Mount St Helens, Source 6 (100m buoyant)

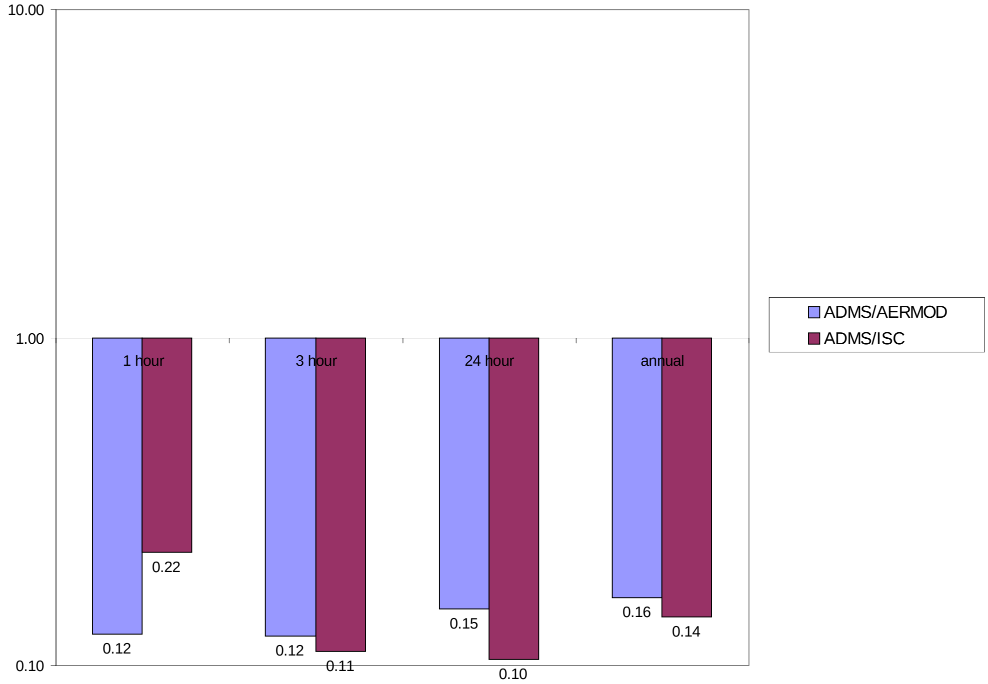

Figure 6 High-2nd-highest complex terrain concentrations normalised by flat terrain values, Mount St Helens, Source 6