Appendix F

United States Environmental Protection Agency Model for Estimating Asbestos Concentrations From Unpaved Roads

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GUIDANCE MANUAL ON THE ESTIMATION OF AIRBORNE ASBESTOS CONCENTRATIONS AS A FUNCTION OF DISTANCE FROM A CONTAMINATED ROADWAY FOR ROADWAY SCREENING

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PREFACE

California's state rock, serpentine, is commonly used in the surfacing and maintenance of unpaved roads. Serpentine is a natural source of asbestos fibers. Asbestos fibers are suspended into the air, along with road dust, by vehicle traffic along these roads and as a result pose a potential health risk to exposed populations.

Over the past few years, the U.S. Environmental Protection Agency's (EPA's) Emergency Response Section for Region 9 has had to perform three Superfund removal actions involving roads surfaced with serpentine rock. During the course of these investigations, it became apparent that many similar roads may exist.

The Exposure Assessment Group at EPA Headquarters has supported the development of the AACES-RS computer code, which has been developed as a tool to screen and rank roads in order of potential importance by providing estimates of downwind asbestos air concentrations. These air concentrations are not to be used for risk analyses, because a causal relationship between fiber morphology and health effects has not yet been established and accepted by the EPA.

ACKNOWLEDGMENTS

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1. INTRODUCTION

This Guidance Manual provides a quantitative approach for estimating, for the purpose of screening/ranking, the airborne concentrations of asbestos from roads surfaced with asbestos-bearing serpentine rock. This manual identifies the procedures necessary for estimating screening-level airborne concentrations of asbestos in disturbed soils associated with roadways whose surfacing material contains asbestos fibers. The manual is to be used in conjunction with the Airborne Asbestos Concentration Estimator System-Roadway Screening (AACES-RS) computer code, also provided in the form of computer disks in Appendix D. Step-by-step user instructions for the AACES-RS computer code are provided in Section 3.

1.1. BACKGROUND

On the earth's surface, where natural or artificial exposed surfaces containing asbestos fibers occur, there is a potential for human inhalation of these fibers. Exposure to airborne asbestos structures requires suspension of these fibers into the air and their subsequent transport in the atmosphere to a receptor. During the transport process, the concentrations of airborne asbestos fibers will be reduced by atmospheric dispersion and removal processes. As a specific example, considerable concern has been expressed over California's state rock, serpentine, which is a common material used in surfacing and maintaining unpaved roads in California. Serpentine is composed primarily of hydrous magnesium silicate and is therefore a source of naturally occurring asbestos fibers. The application of serpentine rock on a roadway allows asbestos fibers to be suspended in the air, along with road dust, by vehicle traffic along these roads. The suspended dust/asbestos structures pose a potential health risk to exposed populations.

Asbestos structures can also be suspended into the air by a number of other mechanisms. These mechanisms are normally divided into wind erosion and mechanical surface disturbance. The potential for wind erosion depends mainly on the local wind climatology and surface characteristics. Suspension by surface disturbances depends both on the frequency of disturbances and on surface characteristics.

1.2. PURPOSE

The purpose of this manual and the AACES-RS code is to provide a means of assessing and ranking potential airborne concentrations of asbestos resulting from the suspension of asbestos fibers from road surfaces. In the past few years, the U.S. Environmental Protection Agency (EPA) has investigated several asbestos-covered roads, some requiring removal actions. During the course of these investigations, it became apparent that there may be many similar roads and other contaminated surface areas across the nation. To assess potential impacts from asbestos on these road surfaces, EPA needed a method to estimate, from a screening/ranking perspective, the airborne concentrations of the asbestos fibers with respect to various distances from these contaminated road surfaces.

1.3. SCOPE

This manual and the companion AACES-RS computer code address the need to be able to produce screening-level estimates (i.e., rough estimates for comparative site evaluations and decision-making) of the airborne asbestos concentration deriving from these roadways. The AACES-RS code serves as a tool to make rough estimates of average airborne asbestos concentrations derived from unpaved roads containing serpentine rock or other asbestos-containing materials. The AACES-RS code requires that the user provide a minimum of two input parameters: 1) silt content and 2) asbestos content of the roadway surface. The default site and meteorological conditions can be modified for an analysis that is more specific to the roadway being evaluated. The AACES-RS code is a tool for evaluating conditions in the vicinity of the roadway, at distances between approximately 3 m (10 ft) and 150 m (500 ft).

The AACES-RS computer code uses menus for program control. The main menu is displayed in the upper left corner of the screen, with the light bar indicating which item is currently selected. The up and down arrow keys are used to move between items. Help can be obtained throughout an AACES-RS run either by moving the light bar to the help option or by pressing the F1 function key.

2. AIRBORNE ASBESTOS CONCENTRATION ESTIMATOR SYSTEM-ROADWAY SCREENING (AACES-RS) COMPUTER CODE

The AACES-RS computer code is designed to evaluate the average airborne asbestos concentrations derived from unpaved roadways whose surfaces are contaminated with asbestos. Such roadways include those where serpentine rock has been used as the gravel for the road surface. The AACES-RS code requires that the user provide a minimum of two input parameters: 1) silt content and 2) asbestos content of the roadway surface. However, a user who wants a screening analysis that is more specific to the situation being evaluated can modify other site specific inputs. Comparisons may be made for either a selected set of ambiant conditions or for average site conditions. The roadway model used in the AACES-RS code assumes that the wind direction always crosses the road surface toward the receptor. The AACES-RS code is applicable for evaluating conditions only in the vicinity of the roadway. Its range of applicability is for estimating concentrations at distances between approximately 3 m (10 ft) and 150 m (500 ft) from the roadway.

2.1. GENERAL STRUCTURE OF THE AACES-RS CODE

A flow diagram of the AACES-RS code, showing the general structure and most common flow path through the code, is provided in Figure 2-1.

2.2. AACES-RS OPERATIONAL METHODOLOGY

The AACES-RS code is designed to be user friendly. Operations are selected from the main menu and several submenus. Parameters are presented with explanatory text in a series of Help screens. The AACES-RS code allows the user considerable flexibility in choosing the route through a run. However, there is a default flow path, as shown in Figure 2-1, which will automatically lead users (unless they choose otherwise) through the various steps,

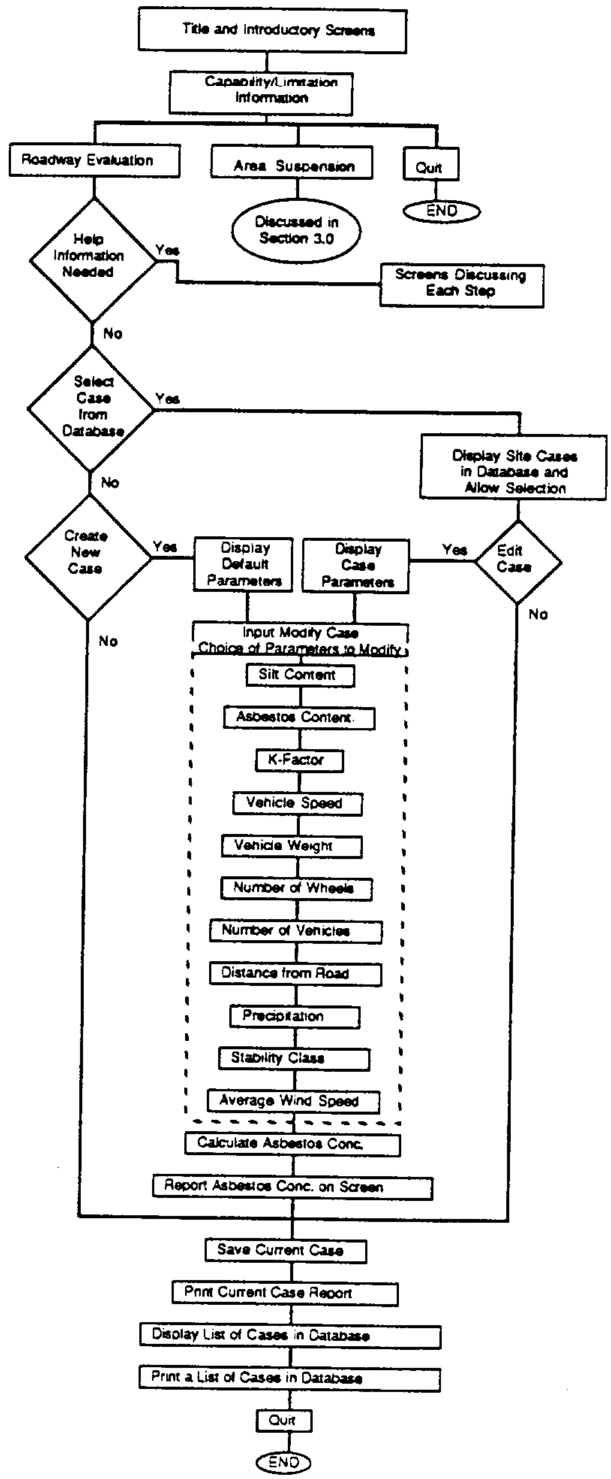

Figure 2-1. Flow chart illustrating the common flow path for the AACES-RS computer code.

store the input and output information in an internal database, and provide a printed report for each run (i.e., case).

The internal database allows the user to track runs by site name and case number. The site name should be kept the same for all runs made for a site, because the AACES-RS code will record all the information associated with an individual site under that common site name. The case number allows the tracking of separate runs that are made to examine different conditions and/or assumptions at an individual site.

In the development of the AACES-RS code, two candidate models for estimating asbestos suspension from unpaved roadways were identified. The two models considered were the Copeland Model (EPA, 1985) and the Cowherd Model (Cowherd et al., 1984). The Copeland and Cowherd models are very similar in their formulation; the primary difference is in the magnitude of exponents. The two models were compared to determine if one was clearly superior to the other, but they appeared to provide comparable predictive performance. For continuity with the California Environmental Asbestos Roads Study, the Copeland model was chosen as the base model to modify and use in the AACES-RS computer code.

Because a model was needed for predicting asbestos air concentrations at various distances from roads, an atmospheric dispersion and transport component enhancement was added to the Copeland Model. A workbook for making atmospheric dispersion and transport calculations has been developed by Turner (1969). Turner's dispersion parameters and formulation for a Gaussian line-source emission were used to derive an expanded air-concentration version of the Copeland Model. This new version of the Copeland Model includes wind speed and atmospheric stability as variables rather than as constants. This expanded version also resolves questions of unit consistency that had been raised regarding the

Copeland Model. The expanded version of the Copeland Model was developed for two reasons: First, it was felt that the unpaved-roadway asbestos model should be able to account for local climatological conditions and to provide concentration estimates for distances other than a single fixed distance from the roadway. A single fixed distance would not allow the evaluator to account for normal receptor distance from the roadway, which might be a critical factor in setting priorities and making decisions on actions among sites being evaluated. Second, consideration of wind speed and stability was needed to allow study of special cases. Wind speed and stability are also important for comparisons with measured values at various distances from the roadway.

The Expanded Copeland Model is presented in the following paragraphs by component development to show how it was developed for use in the AACES-RS code.

2.2.1. Copeland Emission Equation

The emission form of the Copeland Model has been given by EPA (1985, page 11.2.1-1) as

(2-1) $$E = 1.7\ k\ \frac{S}{12}\ \frac{V}{48}\ \left(\frac{W}{2.7}\right)^{0.7}\ \left(\frac{WH}{4}\right)^{0.5}\ \frac{(365-p)}{365}$$

where E = emission rate, kg/VKT (VKT=vehicle-km traveled)

k = aerodynamic particle-size multiplier (range of 0.8 to 0.095)

S = silt content of roadway (percent of road surface material passing through a 200-mesh screen)

V = vehicle speed, km/h

W = vehicle weight, Mg (Mg = megagrams = 10^6 g)

WH = number of wheels per vehicle

p = number of days with greater than 0.25 mm (0.01 in.) of precipitation.

To derive an expression for air concentrations, the first step is to relate the total distance traveled (on an arbitrary segment of the roadway) to traffic and roadway parameters using the equation

$$D = n\,L\,t \qquad (2\text{-}2)$$

where D = total distance traveled over the segment, VKT

n = vehicle frequency, #/s

L = length of roadway traveled by each vehicle, km

t = duration of emissions, s.

Next, the roadway emission rate is expressed as emissions per length of road per time

$$Q = \frac{E\,D}{L\,t} \qquad (2\text{-}3)$$

where Q is the emission rate, g/m per s. Combining Equations (2-1), (2-2), and (2-3) gives

$$Q = 1.7\;k\;n\;\frac{S}{12}\;\frac{V}{48}\left(\frac{W}{2.7}\right)^{0.7}\left(\frac{WH}{4}\right)^{0.5}\frac{(365-p)}{365} \qquad (2\text{-}4)$$

Equation (2-4) is an intermediate version of the Copeland Model that expresses emissions in a form appropriate for use in an atmospheric line-source transport and dispersion application.

2.2.2. Atmospheric Dispersion and Transport

Turner (1969) gives an equation for a line source that, for a ground-level release, reduces to

(2-5) $$C = \frac{2}{(2\pi)^{0.5}} \frac{Q}{\sigma_z U}$$

or

(2-6) $$\frac{C}{Q} = \frac{2}{(2\pi)^{0.5} \sigma_z U}$$

where C = the air concentration, g/m3

σ_z = the vertical dispersion parameter, m

U = the wind speed measured at about a 2-m height, m/s.

Along a roadway, two major factors determine the value of the vertical dispersion parameter for dust suspended by a passing vehicle. First, dispersion by the vehicle wake provides an initial dispersion for the suspended material. Second, ambient atmospheric turbulence will further dilute the plume as it is carried by wind.

A relatively simple wake model was selected for the climatological application of characterizing the initial wake of the vehicle and combining this initial dispersion with the ambient dispersion. The vertical dispersion parameter is computed from the relationship

(2-7) $$\sigma_z = (\sigma_z'^2 + H^2)^{0.5}$$

where σ_z' is the ambient vertical dispersion parameter (m) and H is the estimate of initial vertical dispersion of the vehicle wake (m).

The inclusion of the parameter for initial vertical dispersion of the vehicle wake is required for computations very near the roadway. At distances on the order of a few tens of feet, dispersion will normally be dominated by the vehicle wake. Use of the ambient vertical dispersion parameter formulations is normally recommended for applications no closer than a few hundred feet from the release. The use of the σ_z relationship at shorter distances represents an extrapolation to link the initial and ambient dispersion processes.

The value of H will mainly be a function of the characteristics (i.e., height, length, and speed) of the vehicles traveling over the roadway. As an approximation, H should be set equal to about 50% of the average vehicle height.

2.2.3. <u>Asbestos Concentrations from Roadway</u>

The air concentration of particulate matter (g/m^3) is converted to asbestos concentration (structures/m^3) using the equations

(2-8) $$A = \frac{C}{Q} \frac{AC}{100} Q \ CF$$

where A = asbestos concentration, structures/m^3

CF = conversion factor* = 3×10^{10}, structures/g

AC = asbestos content of road surface silt component, %

and

(2-9) $$A = \left(\frac{2}{(2\pi)^{0.5}}\right)\left(\frac{1}{\sigma_z U}\right) \frac{AC}{100} Q \ CF$$

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*The conversion factor of 3×10^{10} is an average value taken from the open literature. This average value is assumed to represent all fiber lengths, although it may only be accurate as an average for a specific size range of fibers (e.g., fibers >5 mm in length).

Finally, using Equation (2-4) the result is

$$A = 1.7\ k \left(\frac{2}{(2\ \pi)^{0.5}}\right) \frac{S}{12} \frac{V}{48} \left(\frac{W}{2.7}\right)^{0.7} \left(\frac{WH}{4}\right)^{0.5} \frac{AC}{100} \frac{n}{\sigma_z} \frac{CF}{U} \frac{365-p}{365} \qquad (2\text{-}10)$$

This equation comprises the Expanded Copeland Model.

The Expanded Copeland Model, as used by the AACES-RS code, is designed assuming that variables are expressed in metric units. However, because metric units are not the most common units used by the general public in the United States, the AACES-RS code requests the information in terms of common units and makes the appropriate conversion for each variable affected.

2.2.4. Default Values

Unless changed by the user, the AACES-RS code uses typical values as defaults. The initial run for each site (i.e., case 1) is automatically a run with site-specific input for only asbestos content and silt content and with all other parameters held at default values. This is done to provide a standard case situation from which to begin the comparison of the level of contamination at one site with the levels of contamination at other sites. The individual default parameters are discussed by parameter in the paragraphs that follow.

2.2.4.1. Particle-Size Multiplier (k-factor)--The default value used for the particle-size multiplier (k) is 0.36. In accordance with Section 11.2 of AP-42 (EPA, 1985), the particle-size multiplier varies with aerodynamic particle-size range, as shown in Table 2-1. The default value was set at 0.36 because this is the particle-size multiplier for a particle-size cutoff point of $\leq 10\ \mu m$, and the ≤ 10-μm particle-size range is commonly used when considering respirable particulate matter.

TABLE 2-1. AERODYNAMIC PARTICLE-SIZE MULTIPLIERS FOR UNPAVED ROADWAYS

Particle-size range, μm	Particle-size multiplier (k)
≤30	0.80
≤15	0.50
≤10	0.36
≤5	0.20
≤2.5	0.095

2.2.4.2. Vehicle Speed--The default value for the average vehicle speed is 48 km/h (30 mph). This value was established using information obtained from a fugitive dust study conducted by Cowherd and Guenther in the St. Louis area (Cowherd and Guenther, 1976). Based on driver interviews, they established that the average vehicle speed on unpaved roads in the St. Louis area is 48 km/h (30 mph).

2.2.4.3. Vehicle Weight--The default value for the average vehicle weight is 1.6 Mg (1.8 tons). This value was established assuming that the average weight of a full-sized car or pickup with a normal load of people and materials would be approximately 3,600 lb (1.8 tons).

2.2.4.4. Number of Wheels--The default value for the average number of wheels per vehicle is four. The assumption was made that the average vehicle using the unpaved roads being evaluated would be a regular passenger vehicle (i.e., automobile or pickup truck).

2.2.4.5. Vehicle Frequency (Number of Vehicles)--The default value for the average number of vehicles is 2×10^{-3} vehicles/second, which is approximately

76 vehicles per day averaged over a calandar day with an active period of 11 hours. This value of 76 vehicles per day (approximately 7 vehicles/hour on an active hourly basis) was established using information taken from a study conducted by Cowherd and Guenther (1976) in the state of Illinois. The data in the study showed an average annual daily traffic (ADT) of approximately 76 vehicles per day (based on an 11-hour day, from 6 am to 5 pm). The default vehicle frequency value of 76 vehicles per day (7 vehicles per hour) is environmentally conservative in that it is the number of vehicles averaged over only the active period of a day. It should be pointed out that this default vehicle frequency value is only a rough estimate established to provide baseline guidance from which to examine asbestos concentrations among sites. Although the actual number of vehicles per second or per hour may vary considerably at different hours of each day, the model requires input of the average frequency. The user should obtain traffic count data, generally available from most county and state highway departments, to more accurately account for the actual traffic pattern on the roadway being evaluated.

2.2.4.6. Vertical Dispersion Parameter (σ_Z)--Along a roadway, two major factors determine the value of the vertical dispersion parameter for dust suspended by a passing vehicle. First, dispersion by the vehicle wake provides an initial dispersion for the suspended material. Second, ambient atmospheric turbulence will further dilute the plume as it is carried by the wind. A relatively simple wake model was selected for the climatological application of characterizing the initial wake of the vehicle and combining this initial dispersion with the ambient dispersion. The vertical dispersion parameter is calculated using Equation (2-7). The ambient vertical dispersion parameter ($\sigma_{Z'}$) used in the AACES-RS code is taken from a series of equations developed by Martin and Tikvart (1968) that express $\sigma_{Z'}$ according to stability class and distance from the roadway. An H value of 1 m was selected as a first approximation to account for the dispersion caused by the vehicle wake. Comparisons with field data suggest a value for H between 0.5 m and 1.0 m for passenger vehicles. Equation (2-7) is used by the AACES-RS code to calculate σ_Z. The vertical dispersion parameter for passive atmospheric processes is computed using the equation

$$\sigma_z' = A\, d^B + C \qquad (2\text{-}11)$$

where A, B, and C are constants as defined in Table 2-2, and d is downwind distance. The break at 100 m in Table 2-2 is an arbitrary point chosen for curve-fitting and does not imply any special accuracy in these relationships.

TABLE 2-2. CONSTANTS FOR VERTICAL DISPERSION PARAMETER

Stability class	Distance ≤100 m A	B	C	Distance >100 m and <153 m A	B	C
A	0.192	0.936	0.0	0.00066	1.941	9.27
B	0.156	0.922	0.0	0.0382	1.149	3.3
C	0.116	0.905	0.0	0.113	0.911	0.0
D	0.079	0.881	0.0	0.222	0.725	-1.7
E	0.063	0.871	0.0	0.211	0.678	-1.3
F	0.053	0.814	0.0	0.086	0.74	-0.35

2.2.4.7. Distance from Road--The default value for the distance from the roadway being evaluated is 15 m (50 ft). This default value has been selected as a typical distance for the modeling system to address.

2.2.4.8. Precipitation Days--The default value for the number of precipitation days (p) is 60 days of precipitation per year. This default value was selected as a typical number of precipitation days for the area of California where roads with an asbestos problem typically occur.

2.2.4.9. Stability Class--The default entry is D atmospheric stability, representing average atmospheric conditions. Since the AACES-RS code is designed to provide an estimate of average exposures, any deviation from Class D stability should be based on an evaluation of local road usage. At most sites, the stability conditions will be a function of the time of day and of local traffic patterns, which may reflect a preferred set of stability conditions. Table 2-3 provides guidance on the variations of stability as a function of time of day, winds, and solar radiation.

2.2.4.10. Average Wind Speed--The average wind speed may either be a wind speed selected as a case-study, or be an average speed that is representative of the site. For the latter, the input wind speed should ideally be computed as average inverse wind speeds reflecting the use of inverse wind speed in the dispersion computation. For most purposes, the average wind speeds as reported in a Local Climatic Data (LCD) Summary for a location in the same region as the site will be sufficient. These LCD summaries are available for the entire United States. For the Central Valley of California, typical values are 2.8 m/s for Fresno; 3.7 m/s for Sacramento; and 3.9 m/s for Red Bluff (NOAA, 1978).

2.2.4.11. Vehicle Wake Vertical Dispersion--The vertical vehicle wake parameter (H) is an estimate of the initial vertical dispersion of material suspended by the vehicle wake. At distances on the order of a few tens of feet, dispersion is dominated by the vehicle wake. Therefore, the value of H will mainly be a function of the characteristics (i.e., height, length, and

TABLE 2-3. GENERAL STABILITY CLASS INFORMATION[a]

Stability class	Time	Wind condition	Wind, mph	Solar radiation
A	Day	Very light	<5	Strong
B	Day	Very light	<5	Moderate to light
B	Day	Light	5-7	Strong to moderate
C	Day	Light	5-7	Light
B	Day	Moderate	7-11	Strong
C	Day	Moderate	7-11	Moderate to light
C	Day	Windy	11-13	Strong
D	Day	Windy	11-13	Moderate to light
C	Day	Strong	<13	Strong
D	Day	Strong	>13	Moderate to light
E	Night	Light	5-7	50% cloud cover to overcast
F	Night	Light	5-7	<50% cloud cover
D	Night	Moderate	7-11	50% cloud cover to overcast
E	Night	Moderate	7-11	<50% cloud cover
D	Night	Windy to strong	>11	Any cloud cover condition

[a]Conditions are listed in order of ascending wind speed and decreasing solar radiation.

speed) of the vehicles traveling over the roadway. As an approximation, H should be set at approximately 50% of the average vehicle height. A default value of 1 m is provided for the user who has no means of determining the average vehicle height for computing the 50% value.

2.2.5. Modification of Default Values

As mentioned earlier, the initial run of the AACES-RS code for each site (i.e., case 1) is automatically run with site-specific input for only asbestos content and silt content and with other parameters set at the default values. This provides a standard case situation with which to begin the analysis. However, a user should use cases with site-specific input in place of default data values whenever possible to determine the need for action and to set priorities. The standard case (i.e., case 1) is created only to provide a common starting point from which to examine the modifications made in the other case runs, the differences among users applying the AACES-RS code to the sites, and the differences among sites at different locations.

A sensitivity analysis was conducted on the model used in the AACES-RS code to assist in determining which parameters are most sensitive (i.e., have the greatest impact on the results). The sensitivity analysis examined the response of the model when the parameters were at extremes. Two methods for sensitivity analysis were employed. In the first, the model outputs were compared for default and extreme data configurations. The results from this method provide an indication of the range of model predictions that can be obtained from various data configurations (i.e., this method addresses global change considerations). In the second method, the partial derivatives with respect to the input parameters were computed (i.e., this method addresses local change considerations). The partial derivatives can be used to put the input variables in order according to their influence on the model, considering a base set of variable conditions.

The series of curves shown in Figures 2-2 through 2-8 show the variability of the predicted asbestos concentration as it is related to the variability of the different evaluation parameters (i.e., evaluation parameters other than silt content, asbestos content, average wind speed, and distance from the roadway). The silt content and asbestos content are the two required site-specific inputs and should be determined as accurately as possible. The average wind speed is a significant parameter and should be obtained using the climatological data summary from a local weather station (e.g., at a local airport). The distance from the roadway is an input choice allowing the user to estimate concentrations at the point of exposure concern. The curves presented in Figures 2-2 through 2-8 are provided to allow the impact that each parameter has on the resulting asbestos concentration to be examined so that a more informed decision can be made regarding which parameters, if any, have the most effect in the range of interest.

The partial derivatives were used to put the evaluation parameters (i.e., variables) in order according to their influence on the model results, considering a base set of variable conditions. The partial derivatives are interpreted as representing the amount that the asbestos concentration results will change given a unit change in the evaluation parameter. Thus, variables with large-magnitude partial derivatives have more influence on the model than variables with partial derivatives having small magnitudes. A negative sign associated with the derivative means that the predicted asbestos concentration will decrease as the value of the parameter increases; a positive sign for the derivative means that the predicted asbestos concentration will increase as the parameter value increases. The default values and partial derivatives of the

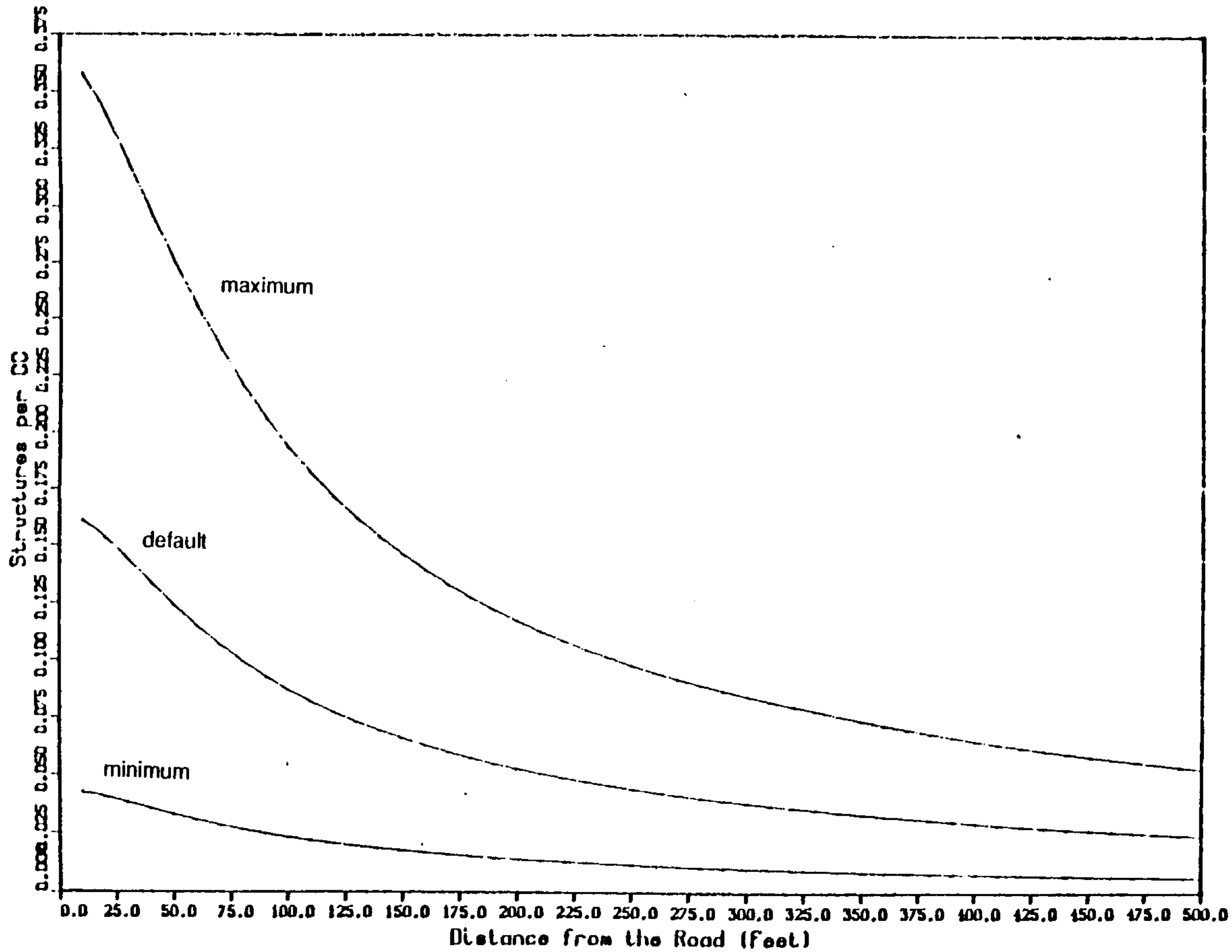

Figure 2-2. Graph showing asbestos air concentrations for extreme values of the k-factor (i.e., particle-size multiplier).

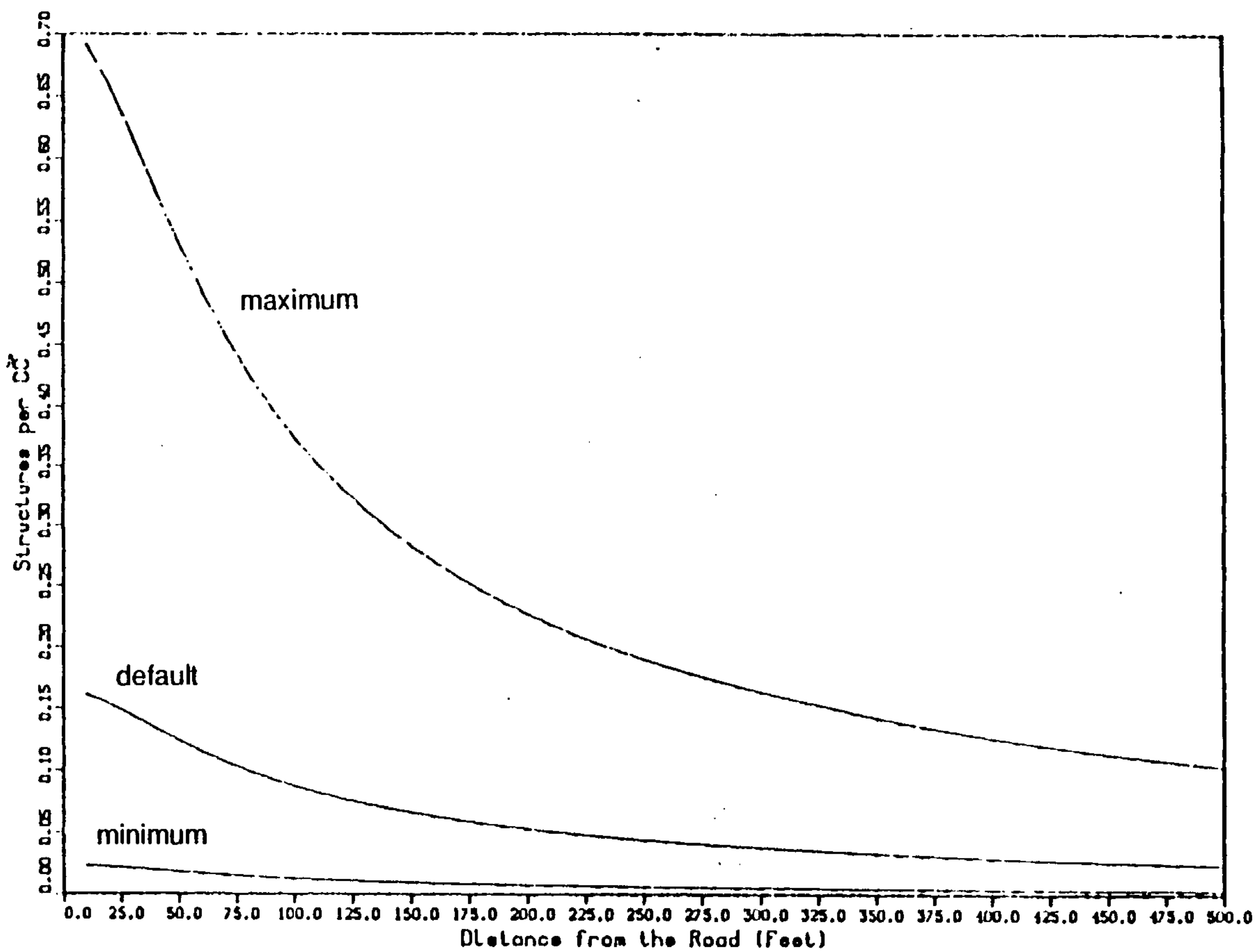

Figure 2-3. Graph showing asbestos air concentrations for extreme values of n (i.e., vehicle frequency).

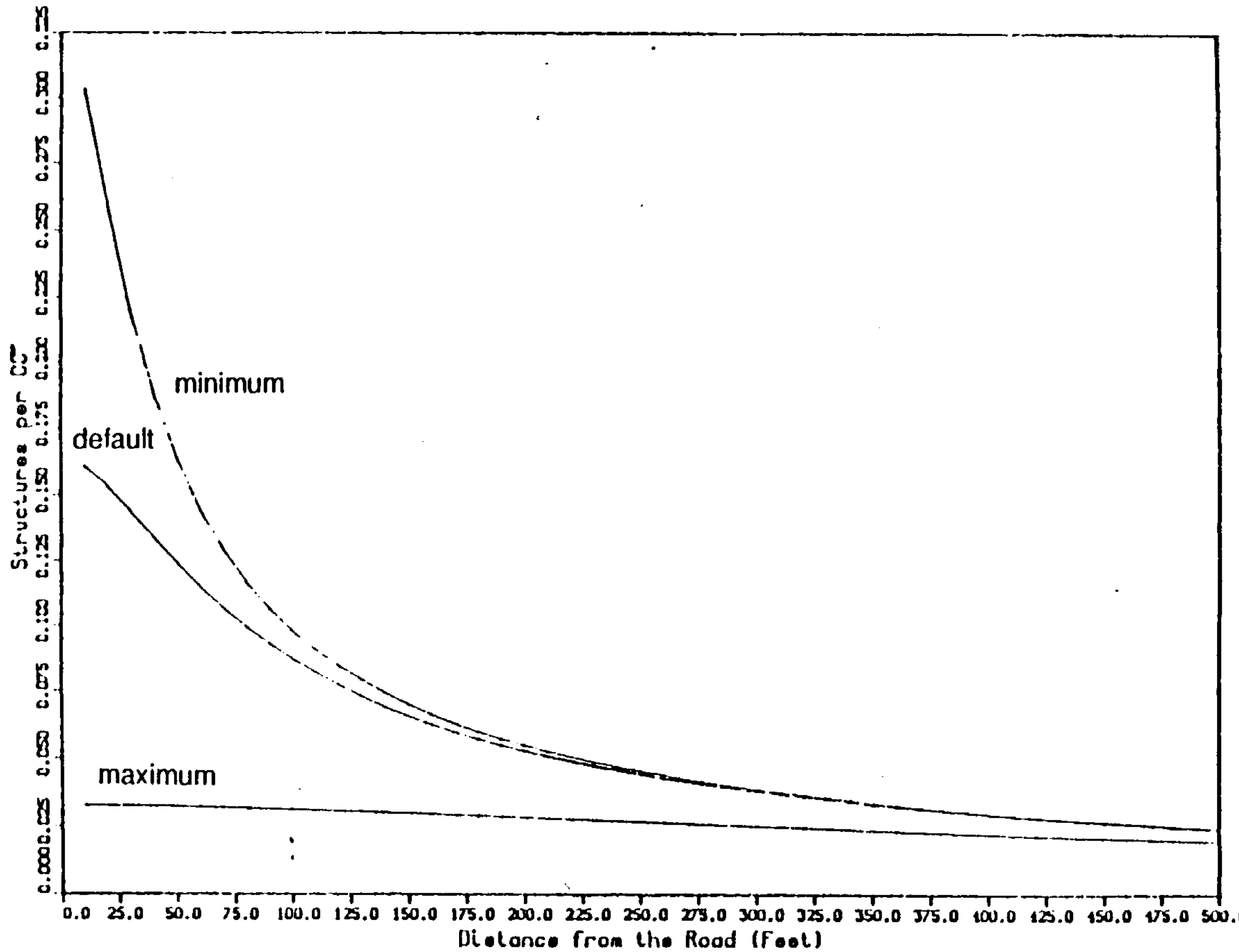

Figure 2-4. Graph showing asbestos air concentrations for extreme values of H (i.e., initial vertical dispersion of the vehicle wake).

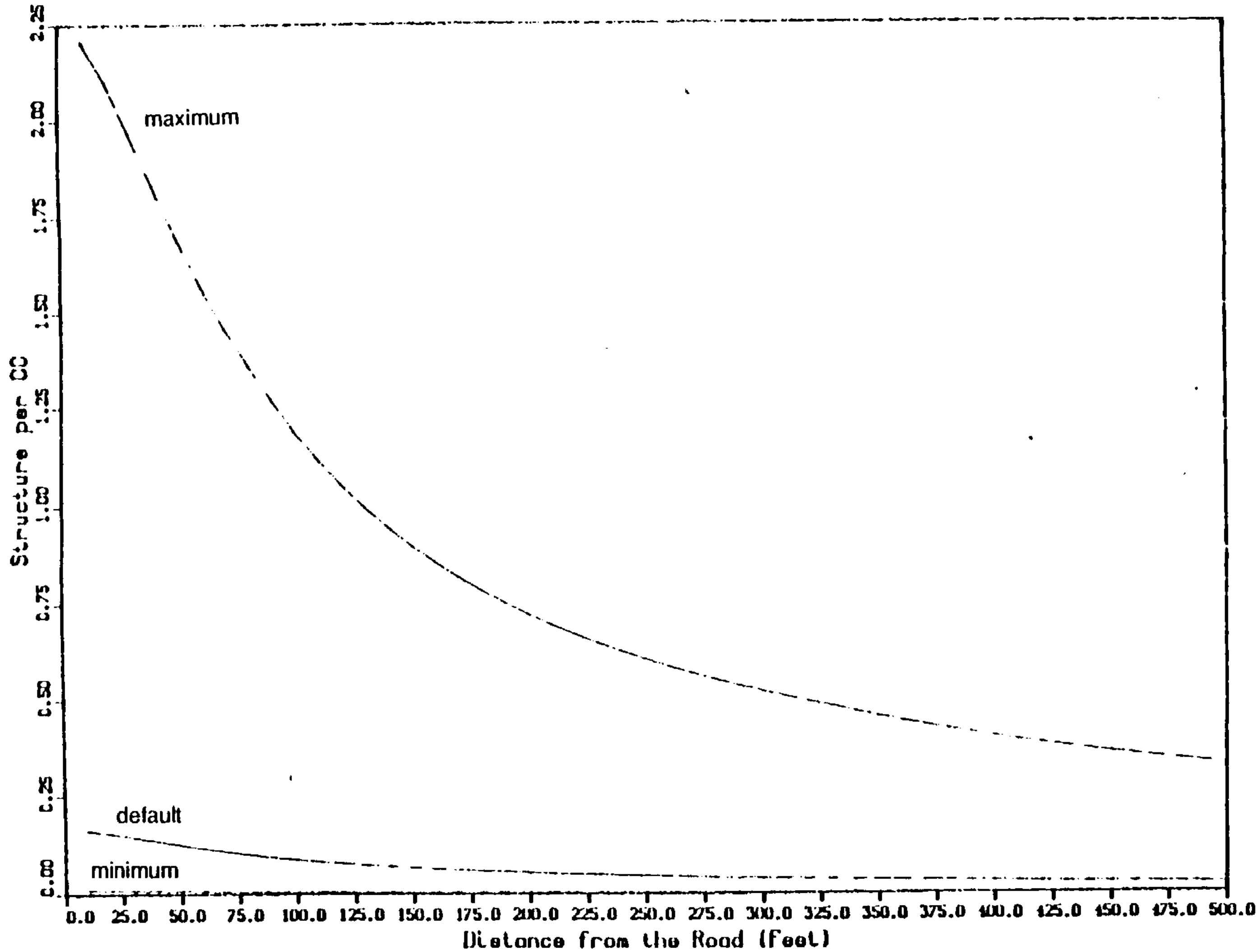

Figure 2-5. Graph showing asbestos concentrations for extreme values of vehicle weight and number of wheels.

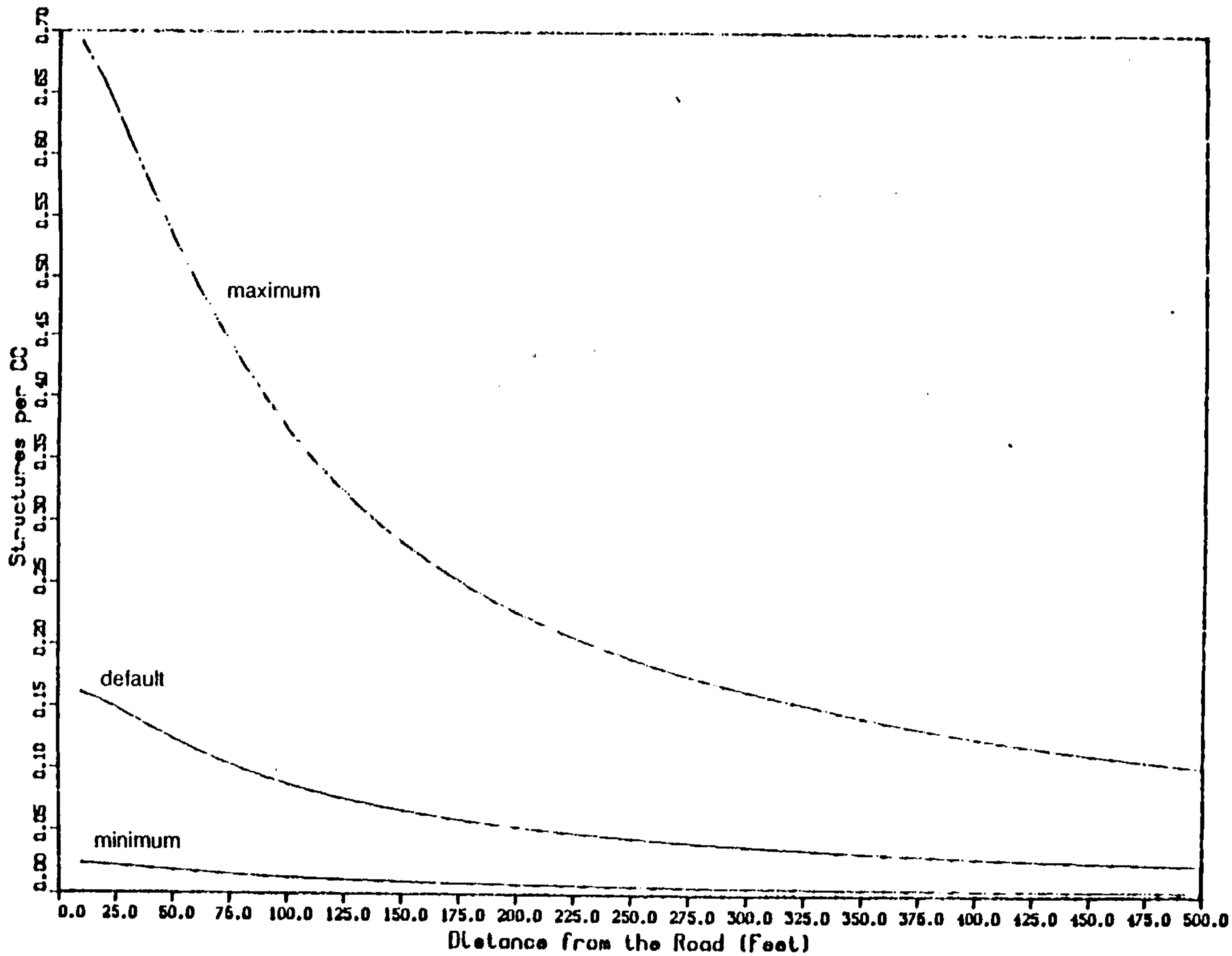

Figure 2-6. Graph showing asbestos air concentrations for extreme values of number of vehicles.

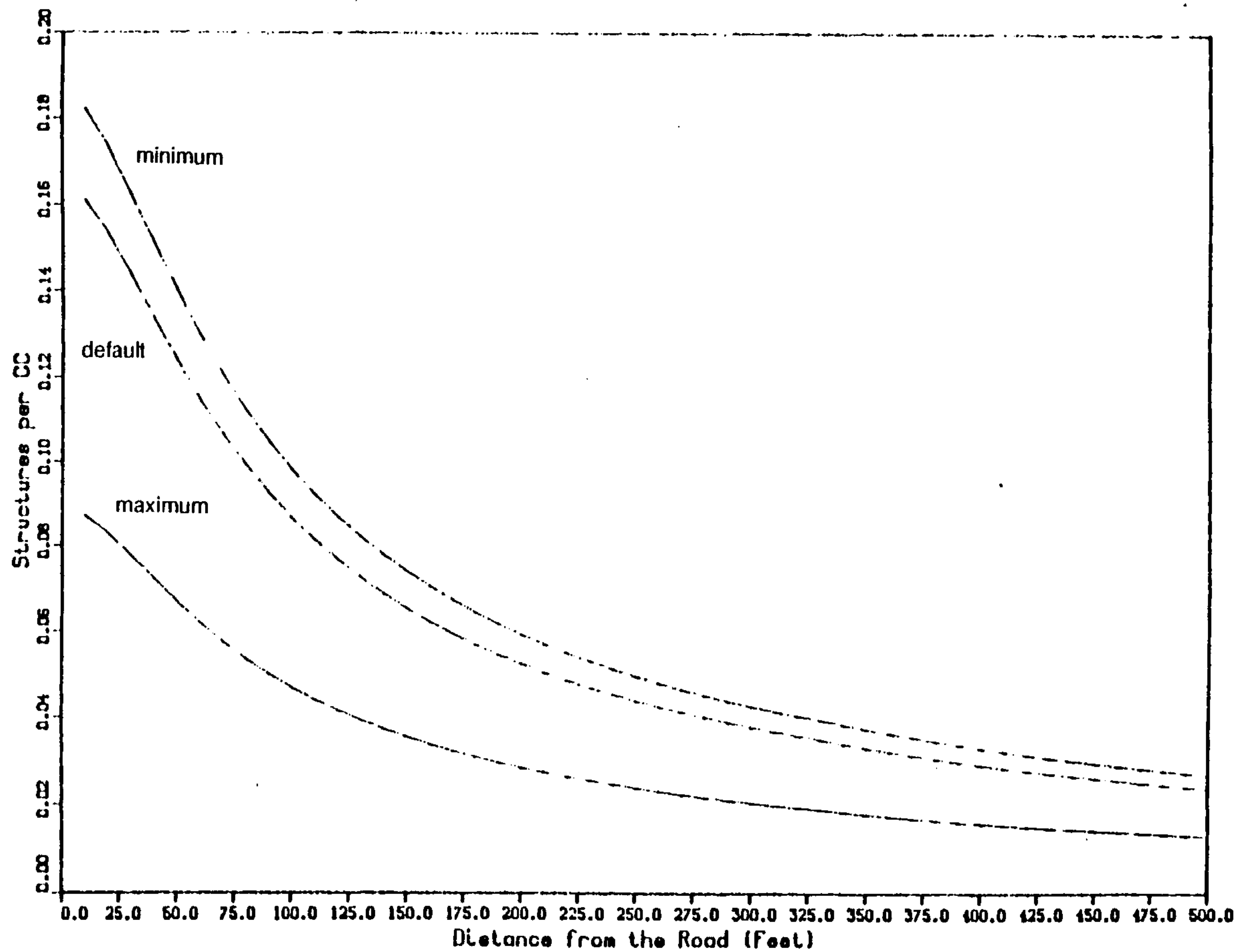

Figure 2-7. Graph showing asbestos air concentrations for extreme values of number of days with 0.254 mm (0.01 in.) of precipitation per year.

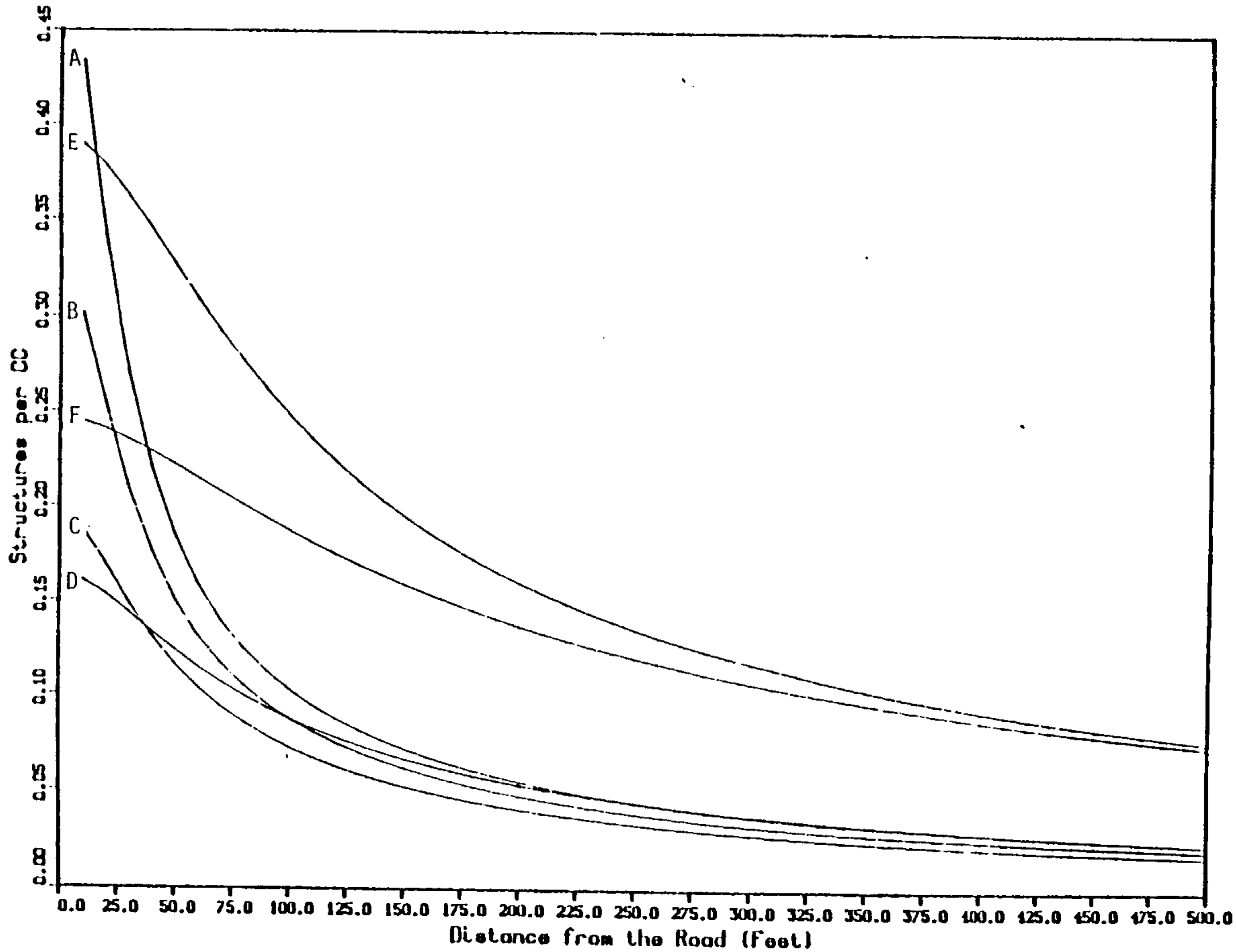

Figure 2-8. Graph showing asbestos concentrations for atmospheric stability classes.

evaluation parameters are shown in Table 2-4. The partial derivatives presented in Table 2-4 are provided to allow the impact that each parameter has on the resulting asbestos concentration to be examined, so that a more informed decision can be made regarding the data needed for input parameters (e.g., number of vehicles has most impact, then the k factor, and so on).

2.2.6. Calibration of AACES-RS Roadway Model

The AACES-RS code was calibrated to data that were collected as part of the California Environmental Asbestos Roads Study, as specifically requested by the EPA. Therefore the AACES-RS code was calibrated to the ≥5-μm data, as measured by Transmission Electron Microscopy (TEM) method, of the California Environmental Asbestos Roads Study.

TABLE 2-4. PARTIAL DERIVATIVES OF ROADWAY MODULE PARAMETERS

Parameter	Default value	Partial derivative
Number of vehicles	0.00194	6.40E+01
k-factor	0.36	3.59E-01
Vehicle weight	1.6	5.43E-02
Asbestos content	4	3.10E-02
Average wind speed	6	-2.07E-02
Number of wheels	4	1.55E-02
Silt content	18	6.90E-03
Vehicle speed	48	2.58E-03
Distance from road	50	-9.43E-04
Precipitation days	60	-4.07E-04

This roadway study was conducted for one special set of conditions in California. Comparing the model predictions with the field data provides a test of the model for this one set of conditions. In addition, values may be estimated from this test for certain of the model parameters.

The parameters that were fixed for each study period include 1) the vehicle weight, number of wheels, speed, and frequency of passage, 2) the wind direction (approximately perpendicular to the roadway), 3) meteorological dispersion conditions (daytime with low wind speeds), and 4) the roadway surface composition.

It was not possible to exactly define the stability for each study period, because specific atmospheric stability information was not collected. However, the conditions selected for study were clearly those typical for relatively rapid dispersion rates (i.e., unstable conditions). This was indicated by several things. First, data were all collected under low wind conditions during daytime hours. Second, the topography of the field site was such that the wind direction was normally perpendicular as a result of a local thermally driven upslope air flow, clearly indicating unstable atmospheric conditions. Hence, the assumption was made for the comparison that all tests were conducted under unstable atmospheric conditions.

Asbestos concentrations were computed using Equation 2-10 for comparison with the one-hour TEM analysis asbestos structures (PCM equivalent by size; TEM_TCO) data points. Measured data with a "<" designation were not used in the comparison. Tests indicated that the inclusion of these less certain data would not have changed the results of the comparison. The one-hour data points were taken at downwind distances of 10, 25, and 50 ft.

There was only one TEM_TCO eight-hour data point without the "<" designation, and the periods represented coincided with some of the one-hour data. Therefore, the eight-hour data values were not used in the comparison.

Most of the model input parameters were assumed to have fixed values. The average polarized light microscopy (PLM) analysis percent of asbestos by area (PLM_CAP) value of 2.3% for the percent asbestos in the roadway was used. A value of 13.4 was used for average silt content based on the analysis of the roadway surface material samples. The vehicle parameters used were a frequency of 4 per hour, a weight of 1.2 tons, an average of 4 tires, and a speed of 48.3 km/hr. A range of unstable atmospheric dispersion conditions, based on Pasquill categories of A, B, and C, was considered.

Given that the database contained information on wind direction and wind speed, case-specific values of these parameters were used to compute asbestos concentrations. Average wind speeds for the measurement period were used directly in the computation of asbestos air concentrations. The wind direction entered into the computation of the vertical dispersion parameter as a correction factor for the distances traveled by the plume between the roadway and the sampler locations.

(2-12) $$x' = x / \cos(DEV)$$

where x' = distance traveled by plume, m

x = distance of sampler from roadway, m

DEV = wind direction's deviation from perpendicular path, degree.

The AACES-RS model has two situation-specific parameters: the initial dispersion length (H) and the fraction of soil material suspended in the size range of interest (k). The initial dispersion length is a function of the turbulence generated by the vehicle. For soil suspension, the table in AP-42 (EPA, 1985) implies a value of 0.6 for the value of k for particles in the range of 5 μ to 30 μ. This value of k corresponds to the size range for TEM_TCO.

A combination of H and k values was selected that gave a good fit to both the absolute magnitude and the rate of concentration decrease with distance from the roadway. Stability category B was used as a basis of comparison.

Figure 2-9 shows a comparison of the average TEM_TCO concentrations with concentrations computed for stability classses A, B, and C. The match of slope and magnitude in this plot resulted from using k = 0.4 and H = 0.7. Figure 2-10 shows a comparison of the individual measured data points and those computed from B stability.

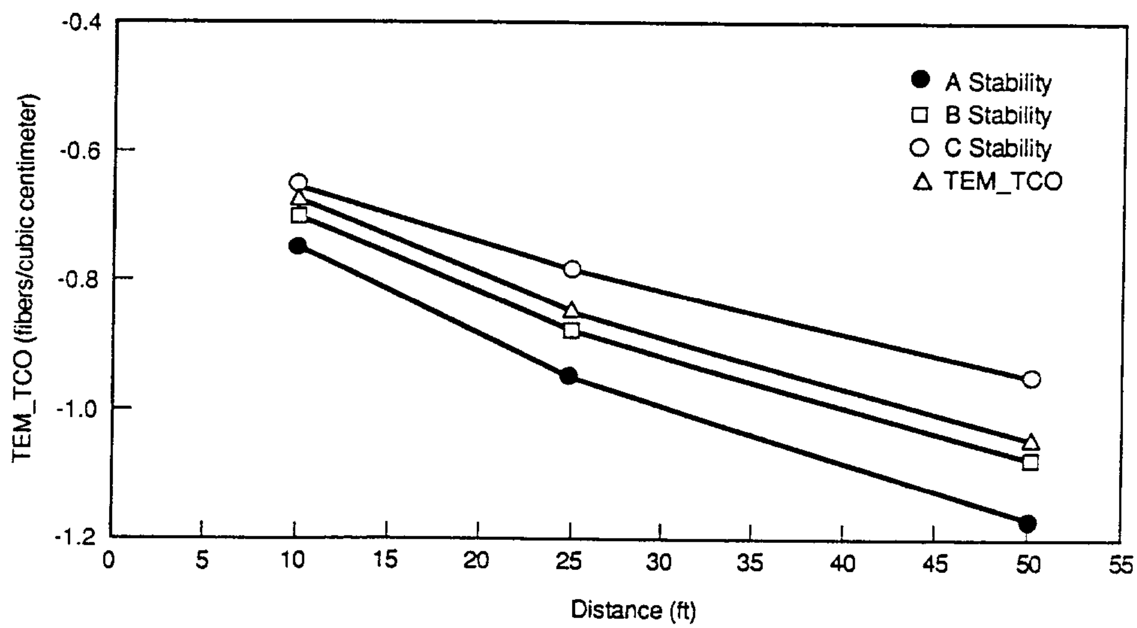

Figure 2-9. Comparison of average measured TEM_TCO with computed value.

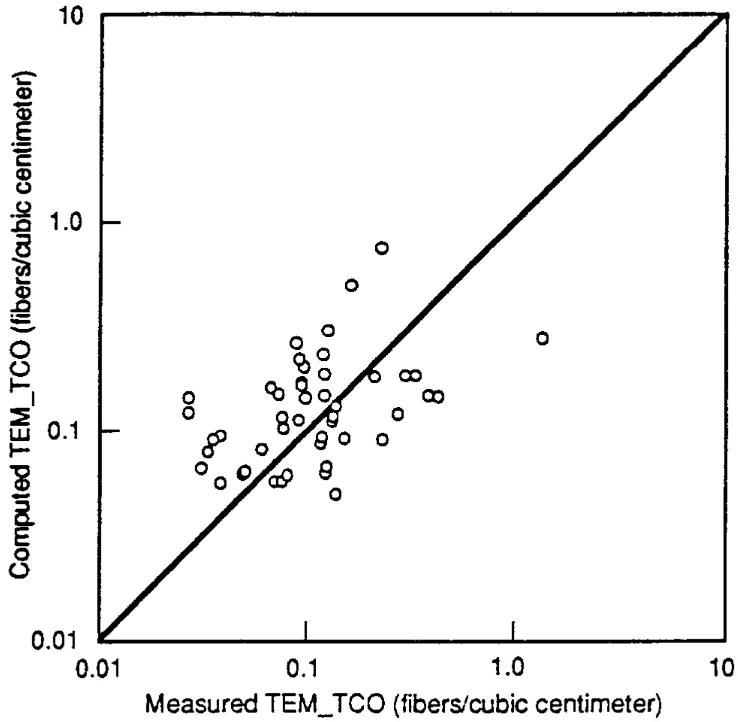

Figure 2-10. Comparison of measured TEM_TCO value with value computed for B stability category.

The narrow range of conditions covered by the field data limited the extent to which various portions of the model could be calibrated. Allowing for the scatter in the results, reasonable agreement between the computed and measured data could be obtained for H values in the range from 0.5 to 1.0 m and for k values between 0.2 and 0.8.

This calibration did not significantly improve the model. Even without calibration using the roadway data, the model will predict asbestos concentration to an order of magnitude. The fact that these values are within the range that would normally be selected for an application lends credibility to model formulation. The narrow range of study conditions and uncertainties in the stability conditions limit the opportunity for additional comparisons or calibrations. The model has been shown to perform well under the meteorological conditions and vehicular traffic patterns of the field study. It has not been evaluated, validated, or calibrated for a full range of meteorological, traffic, or roadbed conditions.

2.3. USE AND INTERPRETATION OF AACES-RS RESULTS

The AACES-RS code is primarily designed to provide a common means of estimating the localized airborne asbestos concentration associated with unpaved roads surfaced with serpentine rock. It is a tool designed to estimate such concentrations within a range of 3 to 150 m (10 to 500 ft) from a roadway.

The AACES-RS code is intended to provide a uniform and consistent basis from which to screen and prioritize the seriousness of airborne asbestos problems at roadway sites containing serpentine rock. The code is designed for the primary use of performing comparative evaluations between sites with serpentine-rock-associated airborne asbestos concentrations. Using the AACES-RS code in this manner will allow the screening and prioritizing of these sites. However, care should be taken in how the asbestos concentrations estimated by the AACES-RS are used. These concentrations are estimated from generalized site conditions. Point-in-time airborne asbestos concentrations at a site may vary considerably, depending on immediate site conditions, and the AACES-RS was not designed to evaluate such conditions (see Section 2.4 for a discussion of AACES-RS limitations).

The AACES-RS code should not be used in a public risk-assessment process, because it assumes average conditions and produces only average concentration results. It was purposely designed this way to limit the type and amount of input necessary to produce estimated concentrations for screening and ranking purposes.

2.4. AACES-RS CODE LIMITATIONS

The AACES-RS code is intended to serve only as an easy-to-use system that provides a rough screening estimate of the typical hourly airborne asbestos concentrations from a roadway contaminated with asbestos. The following limitations inherent in the code must be recognized:

- The estimates of downwind asbestos air concentrations calculated by AACES-RS are to serve as rough estimates for use in assessing site-specific risks, and are not to be used for specific risk analysis.
- The model assumes the wind direction is always across the road surface toward the receptor. This is not necessarily always the wind direction that will yield the maximum downwind concentration of asbestos. The most limiting case is that of a long straight roadway with winds nearly parallel to the roadway.
- The model assumes average conditions and produces typical asbestos concentration results.
- The model makes no allowances for particle deposition.
- Health impact and particle behavior issues regarding asbestos particle sizes are still unresolved. Once the issues have been resolved, adjustments for effective particle size should be made to the model.
- Issues regarding the state-of-the-art techniques for asbestos sampling and analysis are still unresolved. The model requires, as a primary input parameter, the asbestos content of the roadway in question.
- The model assumes that the roadway is straight and infinitely long and that its elevation is equal to that of the receptor.
- The predictive validity of the AACES-RS code may be overextended in cases where more time consuming and costly assessment measures are implicated.

REFERENCES FOR CHAPTER 2

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3. AACES-RS USER'S MANUAL

The AACES-RS code is designed to operate on IBM* or compatible microcomputers using a hard-disk storage system. If the AACES-RS code will be used to evaluate several sites, a hard-disk system will be more efficient, because the AACES-RS code maintains a database containing all the input parameters as well as results.

3.1. AACES CODE INSTALLATION

Section 3.1 discusses the elements necessary to install and set up the AACES-RS code.

3.1.1. Computer Implementation

The following subsections concern transfer package contents, minimum computer system requirements, and installation of the AACES-RS software package on a computer.

3.1.1.1. AACES-RS Transfer Package Contents--The AACES-RS software is distributed on a double-density 5.25-in. floppy disk formatted under DOS 3.1 for the IBM personal computer or compatible microcomputers.

3.1.1.2. Minimum Computer System Requirements--The current version of the AACES-RS software package was designed to execute on the IBM PC/XT/AT/PS2 computer operating under IBM DOS 3.1 (or a newer version of DOS). The computer must be configured with a minimum of 512 kilobytes of random access memory. The most efficient set-up would involve a hard-disk storage system with a printer. A math coprocessor is not necessary.

3.1.1.3. Installation of the AACES-RS Software Package on Computer--To install the AACES-RS Software Package on a hard disk, do the following:

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*IBM, IBM PC, IBM XT, IBM AT, and IBM PS/2 are trademarks of the International Business Machines Corporation, Boca Raton, Florida.

Step 1. Ensure that you are in the root directory of the hard disk on which you wish to install the AACES-RS code. Create a subdirectory for the AACES-RS code on your hard disk by typing:

MD \AACES-RS

and press **Enter** (or **Return**).

Step 2. Move to the newly created subdirectory by typing:

CD \AACES-RS

and press **Enter**.

Step 3. Insert the AACES-RS Distribution Disk in the A: floppy-disk drive.

Step 4. Type:

COPY A:*.*

and press **Enter**.

For the AACES-RS software to function properly, the following commands must be in the CONFIG.SYS file in the root directory of the disk drive used to boot the system:

```
FILES=20
BUFFERS=24
DEVICE=ANSI.SYS
```

Refer to the IBM DOS reference manual for details on installing these commands.

3.2. AACES-RS USER'S MANUAL

Section 3.2 discusses the step-by-step procedure for operating the AACES-RS code.

3.2.1. AACES-RS Description

An AACES-RS run is started by simply selecting "Create New Case" from the main menu of the AACES-RS code. The user then proceeds through the run by selecting options from the main menu and submenus. The AACES-RS program displays the computed results of a run at the bottom of the screen in a box labeled "Results." It will also store the results and input parameters for each site, and cases associated with each site, in an internal database and will provide a written report for each site, if these options are selected from the main menu. The AACES-RS code will display and print out a list of the sites and of the cases for each site that are stored in the internal database. The AACES-RS code also includes a series of help screens, which are available at any time during a run, to assist the user.

The AACES-RS code first leads the user through a reference run, which is a run using default parameters for all input variables except silt content and asbestos content. The reference run becomes the first or base-line case for a site. The purpose of the reference run is to provide a common case situation from which to begin the comparison of the contamination problem at one site with the contamination problems at other sites. However, when comparing sites to determine the need for corrective action and to set priorities, a user should not necessarily accept the results from the reference case run as the final results for a site. The reference case is only a basis from which to start the comparison. A user should try to obtain the most accurate site-specific values for the input variables possible for each site being evaluated. After the reference run has been completed, the user is free to make as many different case runs for a site as is desired.

The AACES-RS code was written and compiled in Microsoft QuickBASIC* language. It uses Finally[†] subroutine libraries to create pop-up screens for menus and operational assistance.

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*Microsoft is a registered trademark of the Microsoft Corporation. QuickBASIC is a trade name of the Microsoft Corporation.
[†]Finally is a trade name for Komputerwerk.

3.2.2. AACES-RS Operation

The following is a step-by-step description of how to operate the AACES-RS code. This is a tutorial approach that will logically lead a user through a run, permitting the user to change every input variable and option associated with a code run. However, the AACES-RS code is designed to be very flexible, and it allows a user to move among the input variables and options. Therefore, once a user becomes familiar with the AACES-RS code, it will not be necessary to follow this step-by-step procedure.

The tutorial step-by-step procedure is as follows:

Step 1. Call up the subdirectory containing the AACES-RS code.

Step 2. Type in **AACES-RS** and press **Enter** or **Return.** There will be a slight pause before the first screen appears while the computer loads the AACES-RS code. The first screen asks whether you have a color monitor. Press **Y** or **Enter** if you do; press **N** if you have a monochrome monitor. Then the AACES-RS title page will appear. The statement "Press Any Key to Continue (Q for Quick Entry)" will appear at the bottom of the title page. Press any key and the AACES-RS code will continue with a series of introductory screens. If **Q** is pressed, the AACES-RS code will skip over the introductory information screens.

Step 3. The AACES-RS code will proceed to display several information screens. It will pause at each screen to allow the user to read the screen. The statement "Press Any Key to Continue" will appear at the bottom of the screen. Press any key and the AACES-RS code will continue to the next information screen. While paging through the information screens, give special attention to the screen that discusses the "capabilities and limitations" of the AACES-RS code.

When all of the information screens have appeared, you will be asked if you have a printer attached to your computer. Press Y or **Enter** if you do; press **N** if you do not. If you do not have a printer, you will be unable to use some of the AACES-RS code's options.

Step 4. Next the main menu will appear. A number of options will be listed under "Roadway Suspension," and the Help option will be highlighted. If the Help option is selected, a series of eight Help screens will appear, describing how each option works. The Help option is selected by pressing **Enter** or **Return** when the help option is highlighted. Movement between the options is done by the arrow keys, as indicated on the screen.

Step 5. Press the down arrow key twice to move the highlighted area to the "Create New Case" option and press **Enter** or **Return**. This will bypass the "Select Dase from Database" option. (The "Select Case from Database" option will be discussed in Step 15.) A set of input parameters with default values will appear on the screen, along with a pop-down menu of "Input/Modify Case", which will have the "Silt Content" option highlighted.

Step 6. Press the **Enter** or **Return** key when "Silt Content" is highlighted. This will produce a pop-down Help screen that explains the "Silt Content" input variable. The cursor will be under the "0" value listed under "Current" in the small box on the right-hand side of the screen. Enter the correct silt content value and press **Enter** or **Return**. The AACES code will then accept this entry and move the highlighted area to the "Asbestos Content" option of the pop-down "Input/Modify Case" menu.

Step 7. Press the **Enter** or **Return** key when the "Asbestos Content" option is highlighted. This will produce a pop-down Help screen that explains the "Asbestos Content" input variable. The cursor will be under the "0" value listed under "Current" in the small box on the right-hand side of the screen. Enter the correct asbestos content value and press **Enter** or **Return**. The AACES-RS code will then perform the calculations and display the input parameters and results on the screen. The results will appear in the "Results" box at the bottom of the screen. The AACES-RS code is quick, so this will appear to happen instantaneously. The same value will appear for the "Asbestos Air Concentration (structures/cc)" and the "Reference Asbestos Air Concentration (structures/cc)" in the "Results" box. This matching occurs because the first case run for a site is the reference run (i.e., the run with default parameters, except for silt content and asbestos content). Subsequent case runs for a site will show different results under "Asbestos Air Concentration", which represent the result for the case currently being evaluated. Notice that this result will differ from that listed for the "Reference Asbestos Air Concentration." The message "Press Any Key to Continue" will appear at the bottom of the screen. After reading the results screen, press the **Enter** or **Return** key to continue. The message "Enter Site Name" will then appear.

Step 8. Type in the official name of the site (up to 20 characters are allowed for the site name). The site name should be unique for each site evaluated, because the AACES-RS code assigns and tracks case runs for a site based on that site name. After typing in the site name, press **Enter** or **Return**. The AACES-RS code will then assign a case number to the run and display it on the screen. After reading it, press any key to continue, which will return the system to the Roadway Suspension subroutine menu with the "Edit/Run Current Case" option highlighted. Press **Enter** or **Return** to select this option. If only the reference case is to be run and no changes to any of the other parameters are desired, use the arrow keys to move the highlighted bar to "Print Current Case" and proceed to Step 11.

Step 9. The screen will display the parameters and results of the run just completed with the "Input/Modify Case" pop-down menu shown. The highlight bar will be on "Silt Content." The user is now free to move the highlight bar up or down through the options to select the specific input parameters to be changed. The first run was the reference run (i.e., it was run using only default parameters). Now, the user has the option of modifying any parameters desired. Parameters are changed in the same manner that the silt content parameter was changed in Step 6. Immediately after each parameter value is changed, the result is calculated and displayed. Use the arrow keys to move to each parameter that is to be changed and repeat the process. When all the desired parameter changes have been made, use the left arrow key to move to the "Previous Menu" option and press **Enter** or **Return** to bring back up the main "Roadway Suspension" menu. The menu will have the "Save Current Case" option highlighted.

Step 10. Press **Enter** or **Return** with the "Save Current Case" option highlighted. This will result in a screen displaying the statement "Enter Site Name" with the name of the site displayed after it. If this is the correct site name, press **Enter** or **Return**. The AACES-RS code will then automatically record the run under that name with the next available successive case number, and will display the site name and case number on the screen. To continue, press any key.

Step 11. The main "Roadway Suspension" submenu is now displayed with the "Print Current Case" option highlighted. If a printer is hooked up to the computer system and a printed report of the run is desirable, press **Enter** or **Return**. The AACES-RS code will then display the site name and case number being printed and print out the report for the run. After the report is printed, the AACES-RS code will return to the main "Roadway Suspension" menu with the "Display List of Cases" option highlighted.

Step 12. If you wish to see a list of the sites/cases available in the database, press **Enter** or **Return**. The AACES-RS code will then display the list of sites/cases on the screen, with the "Return to Main Menu" option highlighted. After viewing the list of sites/cases, press **Enter** or **Return**.

Step 13. The main "Roadway Suspension" menu is displayed with the "Print List of Cases" option highlighted. If a printer is hooked up to the computer system and you wish to have a printed list of the sites/cases in the database, press **Enter** or **Return**. Once the list of sites/cases is printed out, the AACES-RS code will return to the main "Roadway Suspension" menu, and the Help option will be highlighted.

Step 14. This completes the operation of the Roadway Module. The user may choose either to evaluate another site, by starting the process over again, or to quit. To quit, use the arrow keys to move the highlight bar to "Quit". The "Quit" option will halt the run of the AACES-RS code and return the system to the DOS prompt. Before doing so, if the last case run was not saved, the AACES-RS code will provide an opportunity to save it.

Step 15. If the "Select Case from Database" option mentioned in Step 5 is desired, use the arrow keys to make sure the highlight bar is on "Select Case from Database" and press **Enter** or **Return**. This will bring up a list of the sites/cases in the database. Use the arrow keys to move the highlight bar to the desired site/case and press **Enter** or **Return**. The "Edit/Run Current Case" option will be highlighted. Press **Enter** or **Return** and the AACES-RS code will display the parameters and results for the chosen site/case and display the "Input/Modify Case" option. Repeat the steps starting with Step 9 to make any modification to the case run chosen and save it as an additional case run for that site.

APPENDIX A

SAMPLING AND ANALYSIS PROTOCOLS

Although the AACES-RS code provides default values for most parameters used in the calculation of asbestos air concentrations, two user inputs are required in all cases: 1) silt content of the roadway, and 2) asbestos content of the silt fraction. The following guidelines are suggested for obtaining these measurements.

A.1. SAMPLING AND ANALYSIS FOR SILT CONTENT

Representative samples of the surface material (ca. upper 0.5 in.) from the roadway should be collected and properly stored to avoid contamination and/or mechanical disruption. The silt fraction should be determined using the sieving technique reported in ASTM C136-84a, Standard Methods for Sieve Analysis of Fine and Coarse Aggregates (ASTM, 1984). The silt fraction is defined as the weight percent of the original dry sample material that passes through a No. 200 mesh screen (85 μm).

A.2. SAMPLING AND ANALYSIS FOR ASBESTOS CONTENT

The silt fraction described above should be homogenized and representative subsamples taken for asbestos analysis. There is currently no generally accepted methodology for the analysis of asbestos in soils. Polarized light microscopy (PLM) is an interim method for the analysis of asbestos in bulk insulation samples (EPA, 1982). This method can be adapted for analyzing soils. However, because of the mass conversion problems associated with its use in the AACES codes and problems with PLM in general regarding the structures and sizes it reports, additional research is being conducted to establish an accepted protocol for the sampling and analysis of asbestos in soils. A potentially more accurate method of determining asbestos content (with results reported as number of structures per unit mass) is Transmission Electron Microscopy (TEM). The TEM method offers several advantages over ordinary light-microscope techniques, including the ability to analyze the smaller (<5-μm) asbestos size fractions. Limitations to the use of TEM include its high cost (ca. $200-600 per sample; EPA, 1985) and its poor precision and accuracy for analyzing the smallest (<1-μm) fiber sizes (Steel and Small, 1985). There is as yet no standardized protocol for the analysis of soils by TEM. Suggested references for TEM analysis protocols include Yamate et al. (1984); 40 CFR Part 763, Subpart F, App. A; and NIOSH Method 7402.

REFERENCES FOR APPENDIX A

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Steel, E.B.; Small, J.A. (1985) Accuracy of transmission electron microscopy for the analysis of asbestos in ambient environments. Anal. Chem. 57:209-213.

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APPENDIX B

MISCELLANEOUS TECHNICAL ISSUES

This guidance manual covers the development and application of the AACES-RS computer code and is not intended to be a source of general information on asbestos. Information on a variety of asbestos-related topics, including the risk to public health, is available from a number of sources, and readers are urged to consult the technical literature for this material. However, for the convenience of the reader, a brief discussion of several important asbestos-related issues has been provided below.

B.1. CURRENT EXPOSURE STANDARDS

- The Occupational Safety and Health Administration (OSHA) has established a permissible airborne exposure limit for workers of 0.2 f/cc based on an 8-h time-weighted average (TWA) (29 CFR Part 1910.1001). OSHA's current action level for asbestos in the workplace is 0.1 f/cc (8-h TWA). These standards apply to asbestos fibers with a minimum length of at least 5 μm and an aspect ratio equal to or greater than 3:1.
- The current National Institute for Occupational Safety and Health (NIOSH) standard for chrysotile asbestos is 0.1 f/cc, based on an 8-h TWA. This standard also applies to fibers with an aspect ratio of $\geq$3:1. Both the OSHA and NIOSH standards are based on analysis by phase-contrast microscopy (PCM).
- The National Emission Standards for Hazardous Air Pollutants (NESHAP) regulate waste materials containing asbestos (40 CFR Parts 61.140-61.156). These standards apply to the handling of asbestos and emissions from waste-disposal operations. NESHAP prohibits the use of

tailings or asbestos-laden waste material as surfacing agents for roadways (except for temporary roadways or in areas with asbestos ore deposits), but it does not currently regulate commercial asbestos-bearing stone or gravel obtained from quarry operations.

B.2. RELATIONSHIP BETWEEN FIBER SIZE AND HAZARD POTENTIAL

The link between asbestos and a number of health disorders, including asbestosis and mesothelioma, has been well established (EPA, 1986). Although the disease-causing potential of asbestos is now widely accepted, a number of issues have generated considerable discussion in the health assessment and regulatory areas. For instance, the mechanism for carcinogenesis is largely unknown, and there is disagreement on the selection and use of risk and exposure assessment models. One area in particular that has generated controversy is the use of occupational health-effects data in risk assessments for non-occupational exposures (Levadie, 1984). Furthermore, there is considerable debate among experts regarding the relationship between health effects and asbestos fiber-size. Most investigators agree that asbestos toxicity is related to fiber length, diameter, and aspect ratio, but there is still a great deal of uncertainty about the potential health effects of short (<5-μm) fibers. While it is generally acknowledged that long, thin fibers are potentially the most toxic, experts caution that short fibers should not be ignored in health assessments. Part of the problem is that the current regulatory standards for asbestos size are based on methodological definitions, rather than on known health-effects relationships.

REFERENCES FOR APPENDIX B

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APPENDIX C

VALUES OF PARAMETERS FOR THE AACES-RS CODE

Appendix C contains data necessary for running the AACES-RS code.

MEAN NUMBER OF DAYS WITH 0.01 INCH OR MORE OF PRECIPITATION, ANNUAL

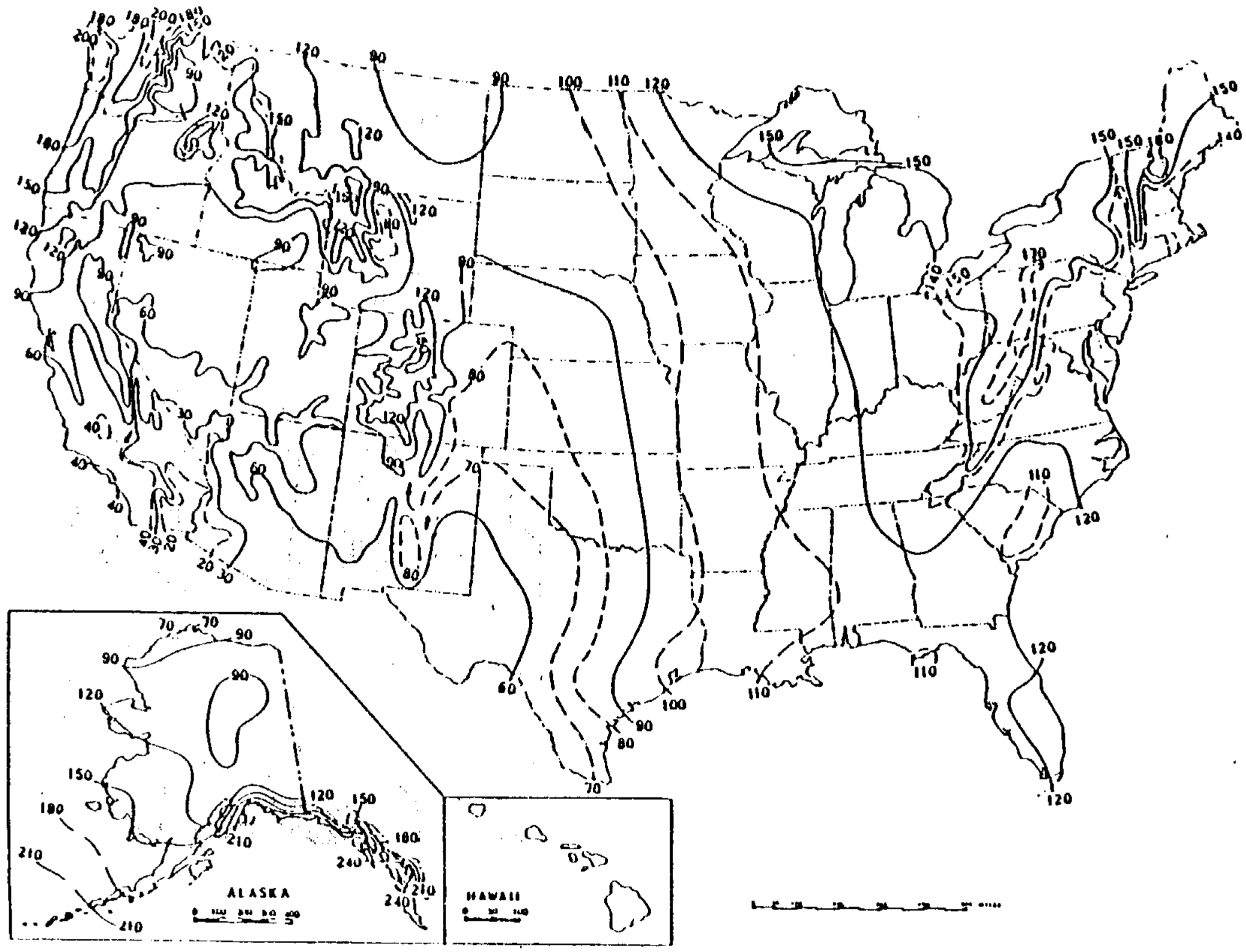

Figure C-1. Map of precipitation frequencies (number of days).