EPA-650/4-74-008

February 1975

Environmental Monitoring Series

USER'S GUIDE FOR HIWAY, A HIGHWAY AIR POLLUTION MODEL

U.S. Environmental Protection Agency
Office of Research and Development
National Environmental Research Center
Research Triangle Park, N.C. 27711

EPA-650/4-74-008

USER'S GUIDE FOR HIWAY, A HIGHWAY AIR POLLUTION MODEL

by

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and
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Program Element 1AA009

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, N.C. 27711

February 1975

During the period in which this document was prepared, John R. Zimmerman was assigned to the Environmental Protection Agency by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

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Publication No. EPA-650/4-74-008

ABSTRACT

A computer model, called HIWAY, that can be used for estimating the concentrations of nonreactive pollutants from highway traffic is described. This steady-state Gaussian model can be applied to determine air pollution concentrations at receptor locations downwind of "at-grade" and "cut-section" highways located in relatively uncomplicated terrain. For an at-grade highway, each lane of traffic is modeled as though it were a finite, uniformly emitting line source of pollution. For the cut section, the top of the cut is considered an area source. The area source is simulated by using ten line sources of equal source strength. The total source strength equals the total emissions from the lanes in the cut.

The air pollution concentration representative of hourly averaging times at a downwind receptor location is found by a numerical integration along the length of each lane and a summing of the contributions from each lane. With the exception of receptors directly on the highway or within the cut, the model is applicable for any wind direction, highway orientation, and receptor location. The model was developed for situations in which horizontal wind flow occurs. The model cannot consider complex terrain or large obstructions to the flow such as buildings or large trees.

An interactive version of the computer model is available on the Environmental Protection Agency's Users' Network for Applied Modeling of Air Pollution (UNAMAP).

PREFACE

HIWAY is one of the atmospheric dispersion models on both of the UNAMAP (Users' Network for Applied Modeling of Air Pollution) systems. One of these systems is restricted to Environmental Protection Agency users. The other system is available to non-EPA users. The systems are accessed through phone lines and time-share computer terminals. For information on accessing UNAMAP contact: Chief, Data Management, Meteorology Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, N. C. 27711.

Although attempts are made to thoroughly check out computer programs with a wide variety of input data, errors are found occasionally. In case there is a need to correct, revise, or update this model, revisions will be distributed in the same manner as this report. If your copy was obtained by purchase or special order, you may obtain revisions as they are issued by completing the mailing form on the following page. A user can be assured that the latest version of HIWAY is on the UNAMAP system.

Comments and suggestions regarding this document should be directed to Chief, Environmental Applications Branch, Meteorology Laboratory, EPA, Research Triangle Park, N. C. 27711.

ACKNOWLEDGMENTS

The authors greatly appreciate the assistance of Adrian Busse, Lea Prince, Susan Godfrey, and Karl Zeller.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

EPA	U.S. Environmental Protection Agency
g	grams
hr	hours
km	kilometers
m	meters
mi	miles
sec	seconds
UNAMAP	Users' Network for Applied Modeling of Air Pollution
veh	vehicles

SYMBOLS

A	end point of line source
a	virtual distance for initial σ_z, km
B	end point of line source
b	virtual distance for initial σ_y, km
$C(p)$	concentration at the perpendicular distance, p, g m^{-3}
c	term to determine Θ_p, dependent upon stability, degrees
d	factor to determine Θ_p, dependent upon stability, degrees
D	line source length, meters
EF	emission factor, g veh^{-1} mi^{-1}
f	point source dispersion function, m^{-2}
g	factor to determine σ_z (depends upon stability and distance range), meters
H	effective source height, meters
h	exponent to determine σ_z (depends upon stability and distance range), dimensionless
L	mixing height, meters
ℓ	distance from point A to point R,S, meters
p	perpendicular distance of receptor from line source, meters
q_ℓ	emission rate from line source, g m^{-1} sec^{-1}

R	east coordinate, meters
R_A	east coordinate of point A, meters
R_B	east coordinate of point B, meters
R_k	east coordinate of receptor k, meters
S	north coordinate, meters
S_A	north coordinate of point A, meters
S_B	north coordinate of point B, meters
S_k	north coordinate of receptor k, meters
TV	traffic volume, veh hr^{-1}
u	wind speed, m sec^{-1}
x	downwind distance, meters or km
x_o	normalizing distance, km
y	crosswind distance, meters or km
z	receptor height above ground, meters
β	direction, relative to north, of line from point A to point B, degrees
γ	angle between wind direction and a perpendicular to the line source, degrees
Θ	wind direction, relative to north, degrees
Θ_p	half angle of horizontal plume spreading, degrees
σ_y	standard deviation of the concentration distribution in the crosswind direction, meters
σ_{yo}	initial σ_y, meters
σ_z	standard deviation of the concentration distribution in the vertical direction, meters
σ_{zo}	initial σ_z, meters
χ	concentration, g m^{-3}

USER'S GUIDE FOR HIWAY, A HIGHWAY AIR POLLUTION MODEL

1. INTRODUCTION

The National Environmental Policy Act of 1969 requires any Federally funded highway construction project to be preceded by an impact statement analyzing the effect of the proposed roadway on air quality. This report describes a computer program, called HIWAY, for calculating air quality levels of nonreactive pollutants produced by highway automotive traffic at distances of tens to hundreds of meters downwind of the highway in relatively uncomplicated terrain.

In making estimates of pollution concentrations for an "at-grade" highway, highway emissions are considered to be equivalent to a series of finite line sources. Each lane of traffic is modeled as though it were a straight, continuous, finite line source with a uniform emission rate. Air pollution concentrations downwind from a line source are found by a numerical integration along the line source of a simple Gaussian point-source plume. Although most applications of this model will be for ground-level sources and receptors, and for receptors close to the source where mixing height will have almost no effect, the more general case of nonzero source and receptor heights and inclusion of the effects of mixing height can be considered by the model.

The HIWAY model is similar to the line-source equations (5.19 and 5.20) in the *Workbook of Atmospheric Dispersion Estimates* (Turner, 1970) but can also consider finite line sources at any angle to the wind.

An estimate may also be made of air pollution concentrations downwind of a "cut section." To do this, the top of the cut section is considered to be equivalent to an area source. This area source is simulated by using a series of ten equal line sources such that the total source strength is equal to the total pollution emissions of the highway.

No pollution emissions module is included in the batch (card input) version of the model. A value of the line-source strength, q_{ℓ} (g m^{-1} sec^{-1}), for each lane of traffic must be obtained from a separate computation (Beaton et al., 1972). Line-source strength is generally a function of traffic rate, average vehicle speed, and traffic mix (fraction of heavy-duty vehicles, fraction of late models with emission control devices, etc.). Data input for the HIWAY program can be accomplished in two ways: (1) through batch mode, with data cards that follow the program deck (see Section 4 for format) and (2) through continuous mode, that is, interactively on a time-share computer terminal. The term interactive refers to the information exchange between the user and the computer program in asking and answering questions.

In the interactive version of the model, to be discussed in Section 4 and Appendix A, the user can obtain a crude estimate of line-source emission rate for the pollutant carbon monoxide. If one does not enter emission rates interactively, an estimate of emission rate can be determined by entering a value for vehicle speed and traffic volume per hour for each lane of traffic. This emission rate is representative of that for 1969 model-year automobiles (Ludwig et al., 1970). According to *Compilation of Air Pollutant Emission Factors* (EPA, 1973), this emission factor of 58.7 g veh^{-1} mi^{-1} for a speed of 19.6 mi hr^{-1} is also representative of emissions for the vehicle model mix near the end of 1973. See Table 3.1.1-1 in EPA, 1973.

2. DESCRIPTION OF MODEL

AT-GRADE HIGHWAY

A view of an idealized four-lane at-grade highway is shown in Figure 1. Traffic pollution emissions from each lane are simulated in the computer model by a straight line source of finite length. As shown in Figure 1 for a four-lane highway, the location of the highway is specified by the coordinates at the centerline (from edge to edge) of the highway (points 1 and 2). The ordering of the lanes is from left to right when one looks from point 1 to point 2. One lane or any even number of lanes from 2 to 24 can be used in the model.

The width of the highway and its center strip must also be entered as input data. With this information, the computer program HIWAY will assign a finite uniform line source to each lane of traffic. These line sources are placed at the center of each traffic lane.

A uniform emission rate, q_ℓ, must be specified for each line source. This line-source emission rate can be found if the emission factor, *EF* (g veh^{-1} mi^{-1}), and the traffic volume, *TV* (veh hr^{-1}), are known:

$$q_\ell \,(\text{g sec}^{-1}\,\text{m}^{-1}) = \frac{EF\ (\text{g veh}^{-1}\,\text{mi}^{-1})\ TV\ (\text{veh hr}^{-1})}{1609.3\,(\text{m mi}^{-1})\ 3600\ (\text{sec hr}^{-1})} \tag{1}$$

$$= 1.726 \times 10^{-7}\,(EF)\,(TV)$$

A value of the emission factor for vehicles can be obtained from the most current issue of *Compilation of Air Pollutant Emission Factors* (EPA, 1973). It should be noted that for many pollutants the emission factor varies with vehicle speed.

Calculations

The calculation of concentration is made by a numerical integration of the Gaussian plume point-source equation over a finite length. The coordinates (meters) of the end points of a line source of length *D* (meters),

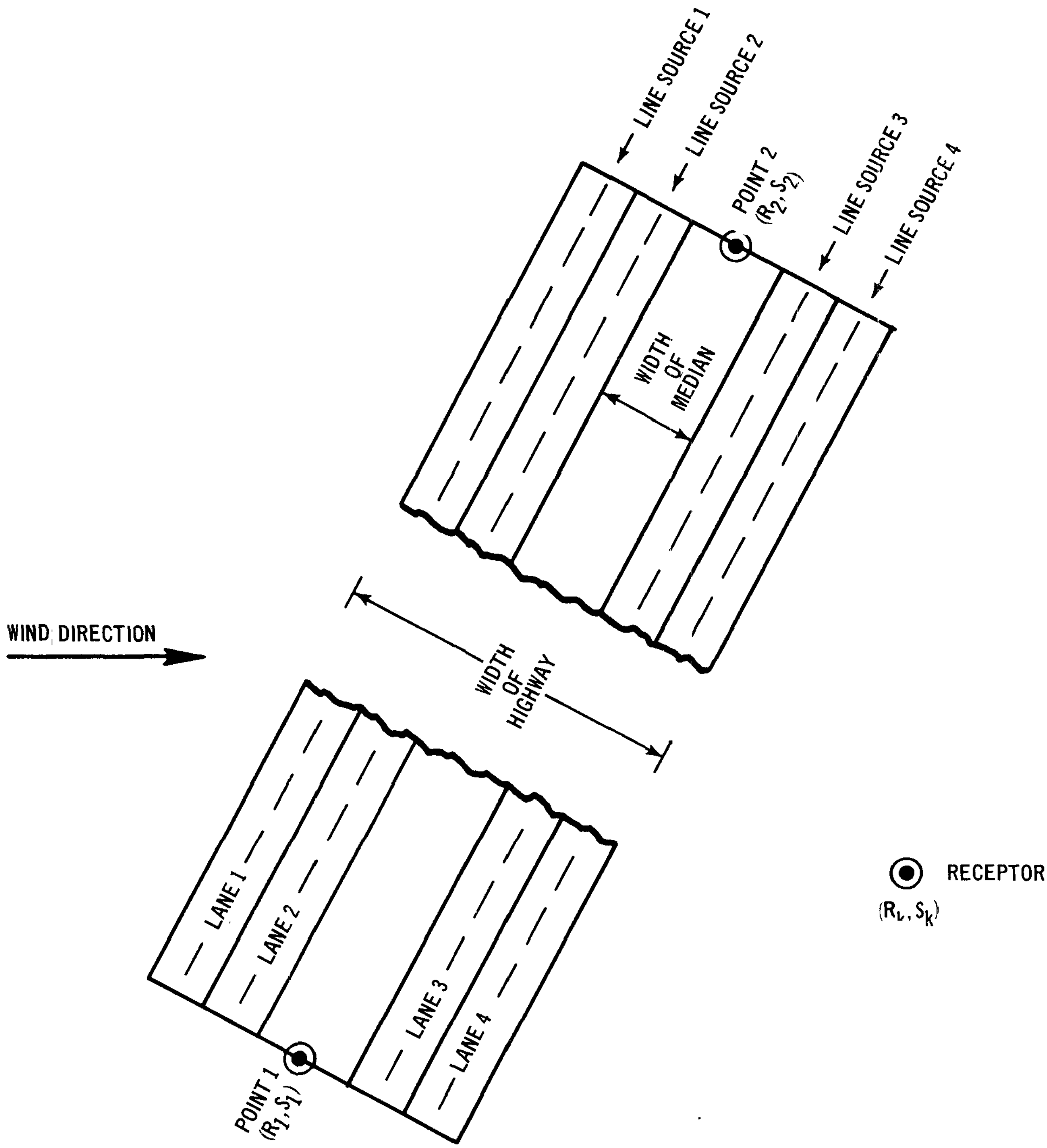

Figure 1. Overhead view of the geometry of at-grade highway as seen by the computer model. The endpoints of the highway are specified by the centerline coordinates, (R_1,S_1) and (R_2,S_2), while the receptor coordinates are given as (R_k,S_k). Line sources (four) are indicated by the dashed lines at the center of each lane of traffic.

representing a single lane extending from point A to point B (see Figure 2), are R_A, S_A and R_B, S_B. The direction of the line source from A to B is β (degrees). The coordinates, R,S, of any point along the line at an arbitrary distance, ℓ (meters), from point A are given by:

$$R = R_A + \ell \sin\beta \tag{2}$$

$$S = S_A + \ell \cos\beta \tag{3}$$

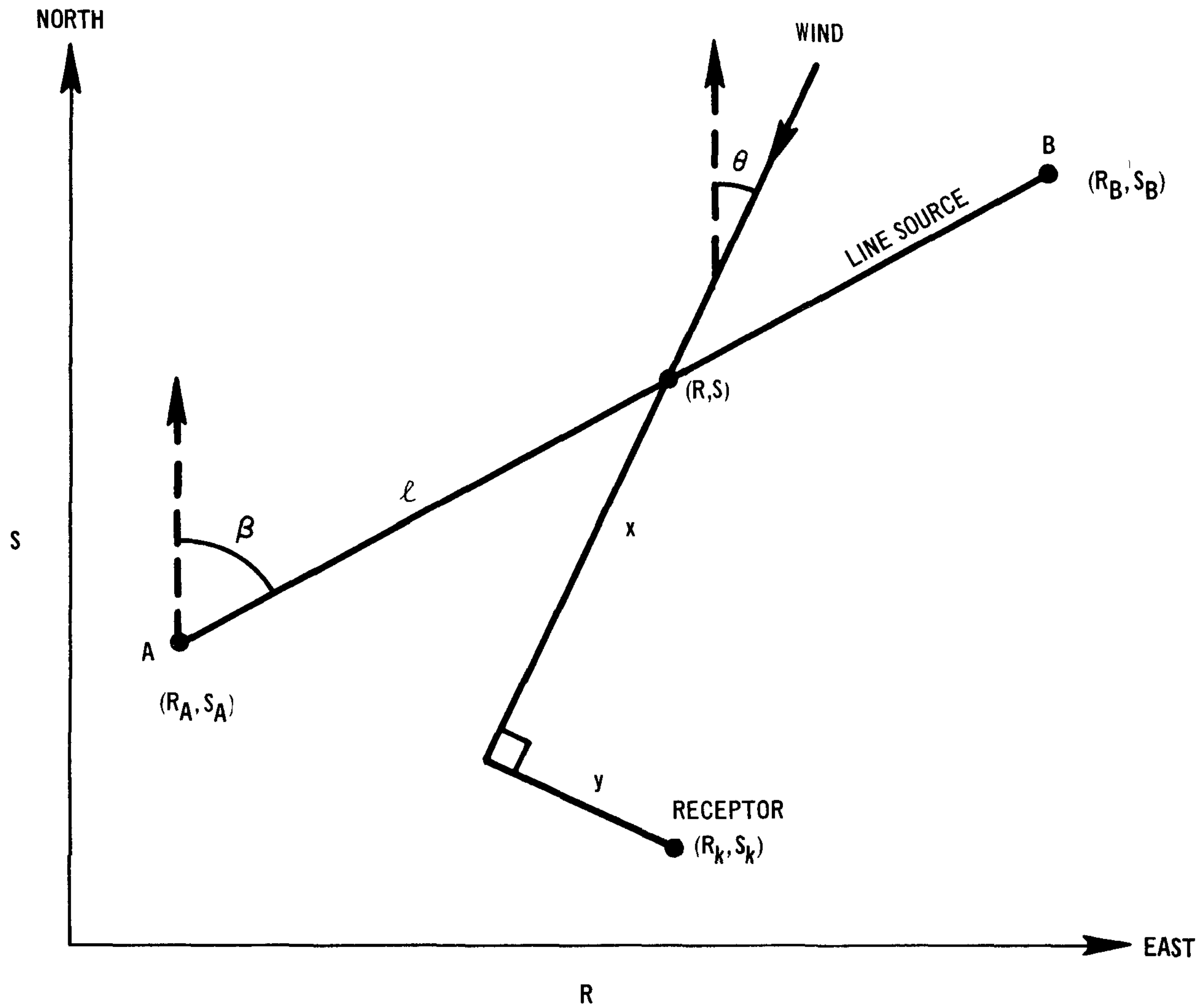

Figure 2. Line source and receptor relationships.

Given a receptor at R_k, S_k, the downwind distance, x (meters), and the crosswind distance, y (meters), of the receptor from the point R,S for any wind direction, θ (degrees), is given by:

$$x = (S - S_k)\cos\theta + (R - R_k)\sin\theta \quad (4)$$

$$y = (S - S_k)\sin\theta - (R - R_k)\cos\theta \quad (5)$$

Since R and S are functions of ℓ, x and y are also functions of ℓ. The concentration, χ (g m^{-3}), from the line source is then given by:

$$\chi = \frac{q_\ell}{u}\int_0^D f\, d_\ell \quad (6)$$

where:

u = wind speed, m sec^{-1}

D = line source length, meters

f = point source dispersion function (Equations 7 to 9), m^{-2}

For application of this model to a highway segment in relatively open terrain, an approximate estimate of the wind speed, u, at 2 meters height above ground is suitable.

For stable conditions or if the mixing height is $\geq$ 5000 meters,

$$f = \frac{1}{2\pi\sigma_y\sigma_z}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \quad (7)$$

where:

σ_y = standard deviation of the concentration distribution in the crosswind direction, meters

σ_z = standard deviation of the concentration distribution in the vertical direction, meters

z = receptor height above ground, meters

H = effective source height, meters

In unstable or neutral conditions, if σ_z is greater than 1.6 times the mixing height, L (meters), the distribution below the mixing height is uniform with height regardless of source or receptor height, provided both are less than the mixing height:

$$f = \frac{1}{\sqrt{2\pi}\sigma_y L} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \tag{8}$$

In all other unstable or neutral conditions:

$$f = \frac{1}{2\pi\sigma_y\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]\right.$$

$$+ \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right] + \sum_{N=1}^{N=\infty}\left[\exp -\frac{1}{2}\left(\frac{z-H-2NL}{\sigma_z}\right)^2\right.$$

$$+ \exp -\frac{1}{2}\left(\frac{z+H+2NL}{\sigma_z}\right)^2 + \exp -\frac{1}{2}\left(\frac{z-H+2NL}{\sigma_z}\right)^2$$

$$\left.\left. + \exp -\frac{1}{2}\left(\frac{z+H+2NL}{\sigma_z}\right)^2\right]\right\} \tag{9}$$

The infinite series in Equation 9 converges rapidly, and more than four or five sums of the four terms are seldom required.

In each of the three above equations, σ_y and σ_z are evaluated for the given stability class and the distances $x + b$ for σ_y and $x + a$ for σ_z. The virtual distances, a and b (km), are required to produce the initial σ_z and σ_y (σ_{zo} and σ_{yo}), respectively.

If z, H, or both are zero, the resulting simpler forms of Equations 7, 8, and 9 are used by the computer program.

The value of the integral in Equation 6 is approximated by use of the trapezoidal rule. Let $\Delta \ell = D/N$. Then the trapezoidal approximation gives:

$$\chi = \frac{q_\ell \, \Delta \ell}{u} \left[\frac{1}{2} (f_0 + f_N) + \sum_{i=1}^{N-1} f_i \right] \tag{10}$$

where f_i is evaluated, as appropriate, from Equation 7, 8, or 9 for $\ell = i\Delta \ell$. The distances x and y are, of course, functions of ℓ.

For a given initial choice of the interval length, $\Delta \ell$, the calculation is then successively repeated with twice the number of intervals, that is, with $\Delta \ell/2$, $\Delta \ell/4$ ..., until the concentration estimates converge to within 2 percent of the previous estimate. This value is then used as the value of the integral.

The above evaluation of the integral is repeated for each lane of traffic, and the resulting concentrations are summed to represent the total concentration from the highway segment.

Computer Model

The FORTRAN computer program consists of a main program, three subroutines, and two functions. The main program handles input and sets up a separate line source for each lane of traffic. Subroutine DBTLNE does the integration and output of results. This subroutine calls DBTRCX, which evaluates Equations 7, 8, or 9, or simplifications of these equations if H or z is zero. Evaluation of σ_y and σ_z are done by subroutine DBTSIG, which is called from DBTRCX. Functions XVY and XVZ determine virtual distances for a given stability class corresponding to the initial σ_y and initial σ_z, respectively.

An east-north coordinate system is used in the computer model. The width of the highway and of its center strip, the coordinates of the centerline of the highway, and the coordinates of the receptor(s) are input parameters.

It should be noted that in Equations 4 and 5, x and y refer to a coordinate system aligned along the wind vector (x the downwind direction, and y the crosswind direction). That system is distinct from the coordinate system used for locating sources and receptors in the model.

In the basic equations given earlier (Equations 2 to 5), units of the coordinate system have been specified as meters for dimensional balance. However, units of the computer coordinate system, for practicality, are in kilometers. The user may use any convenient highway map unit if he enters an appropriate scaling factor to convert those units to kilometers. For example, if it is desired to use the units of meters for highway coordinates, the scale factor should be entered as 0.001. Section 4 contains a list of the input variables, including a brief description of each of the units by which the input parameters must be expressed. An example of input data, as well as the output of a run made with the example input data, is given in Appendix A.

CUT SECTION

Estimates of air pollution concentrations at locations downwind of a depressed highway (cut section) can be determined by considering the top of the cut section to be an area source of pollution (Figure 3). In the model, this area source is approximated by using ten line sources located at the top of the cut section. The total emission rate for the highway is first found by adding together the emission rates for each individual lane of traffic. Then this emission rate is distributed equally over each of the ten line sources used to simulate the area source at the top of the cut section.

Once this has been done, the procedure used to determine pollutant concentrations downwind of the cut section is entirely similar to the procedure used to determine the concentrations for an at-grade highway. It should be emphasized that these estimates of air pollution concentrations should be made for receptors downwind of the cut section and not for locations inside the cut section itself.

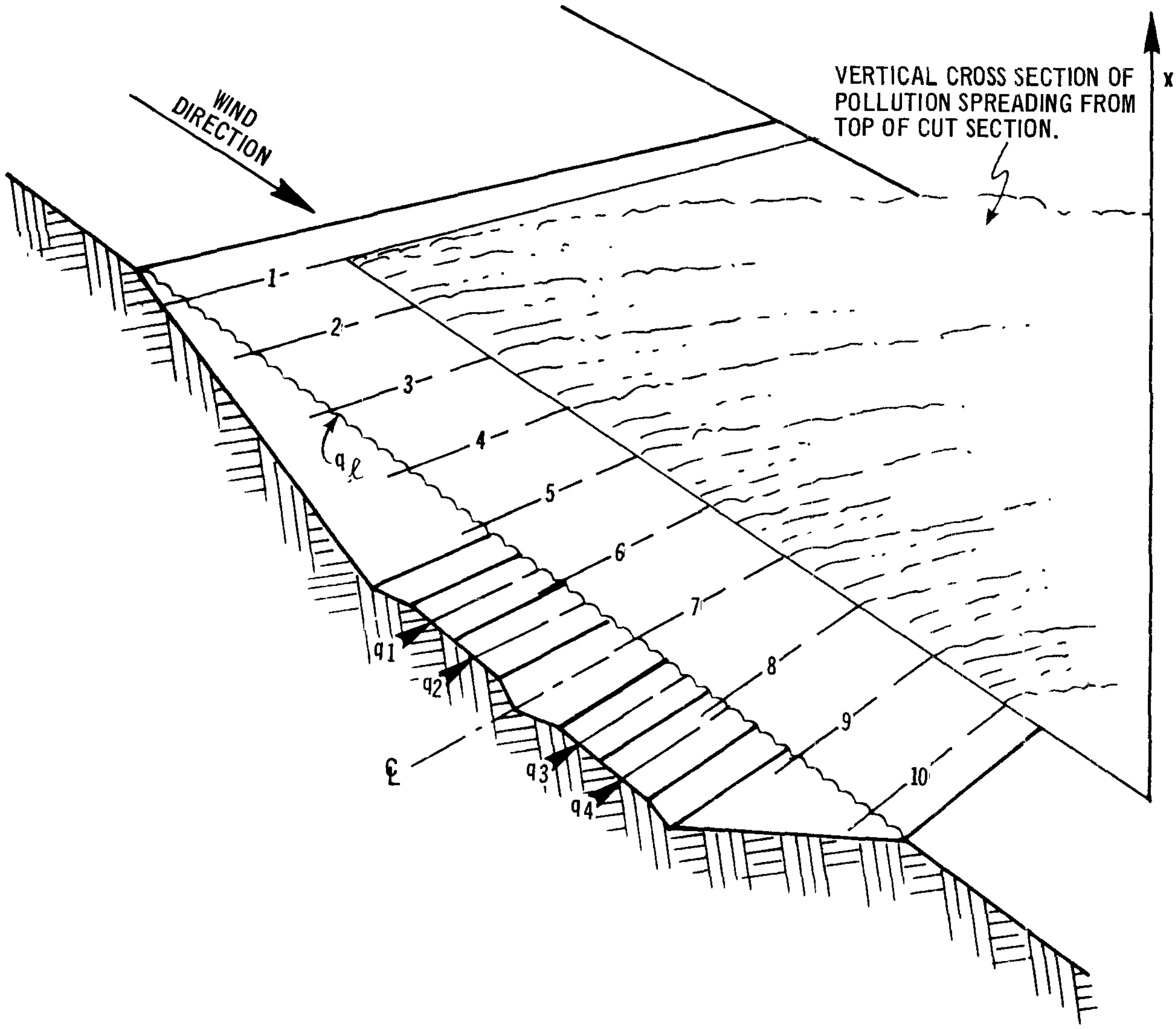

Figure 3. Method of simulating dispersion from a cut section. In this illustration, there are four lanes of traffic in a cut section with pollution emission rates q_1, q_2, q_3, and q_4. These emission rates are summed up and distributed equally over ten line sources placed at the top of the cut section, i.e., $q_\ell = (q_1 + q_2 + q_3 + q_4)/(10)$.

3. DISPERSION FUNCTIONS σ_y AND σ_z

The dispersion functions σ_y and σ_z (meters) indicate the amount the pollutant plume has spread (dispersed) after leaving its source. The values for these functions are those of Pasquill (if the virtual distance is taken as zero) as given in graphical form in Turner (1970). Pasquill stability classes are given in Table 1.

Table 1. PASQUILL STABILITY CLASSES

Stability class[a]	Description
A (1)	Very unstable
B (2)	Moderately unstable
C (3)	Slightly unstable
D (4)	Neutral
E (5)	Slightly stable
F (6)	Moderately stable

[a]The stability classes are commonly referred to by letter. For input to the computer program, the numbers in parentheses are used.

The horizontal dispersion parameter value is given by

$$\sigma_y = 465.1\,(x + b)\tan\theta_p \qquad (11)$$

where:

- x = downwind distance from source to receptor, km
- b = virtual distance for lateral σ_y, km
- θ_p = half angle of horizontal plume spreading, degrees

The factor 465.1 is 1000 m km^{-1} divided by [illegible], the number of standard deviations of a Gaussian distribution from the centerline to the point where the distribution falls to 10 percent of the centerline value. The angle θ_p is given by:

$$\theta_p = c - d \ln\left([illegible] \right) \qquad (12)$$

[illegible]

where c and d (degrees) are functions of Pasquill stability class and the normalizing distance, x_o, is 1 km. Values of the parameters c and d are given in Table 2.

Table 2. VALUES OF c AND d USED TO CALCULATE θ_p

Stability class	Value, degrees	
	c	d
A (1)	24.167	2.5334
B (2)	18.333	1.8096
C (3)	12.5	1.0857
D (4)	8.333	0.72382
E (5)	6.25	0.54287
F (6)	4.167	0.36191

The vertical dispersion parameter value, σ_z (meters), is given by equations of the form:

$$\sigma_z = g \left(\frac{x + a}{x_o} \right)^h \tag{13}$$

where a is the virtual distance (km) to give the initial σ_z (meters), and g (meters) and h (dimensionless) are functions of stability class and also various ranges of the distance x. When a is zero, the values are the same as those in Figure 3-3 of Turner (1970). Since the values of σ_z for x less than 0.1 km are not given in that figure, the values of the parameters g and h for x less than 0.1 km are given in Table 3. The values corresponding to g and h for x at other distances can be determined by examining the program listing for subroutine DBTSIG (Appendix B).

Turbulence of the air produced by the motion of automobiles results in a rapid mixing of the pollutants near the highway. This is modeled by assuming that an initial spreading of the pollutant plume occurs over the highway. To determine an acceptable initial vertical plume spread, data taken near at-grade sections from various highways were used. When the

Table 3. VALUES OF g AND h USED TO DETERMINE σ_z FOR DOWNWIND DISTANCES LESS THAN 0.1 km

Stability class	Value	
	g, meters	h, dimensionless
A (1)	122.8	0.9447
B (2)	90.673	0.93198
C (3)	61.141	0.91465
D (4)	34.459	0.86974
E (5)	24.26	0.8366
F (6)	15.209	0.81558

wind direction is less than 75 degrees from the perpendicular to the highway, it has been shown that an approximate expression can be used to determine pollutant concentrations from an infinite line source (Calder, 1973). Solving this expression for σ_z yields:

$$\sigma_z(x) = \sqrt{\frac{2}{\pi}} \quad \frac{q_\ell}{C(p)\ u \cos\gamma} \tag{14}$$

where:

$\sigma_z(x)$ = the vertical standard deviation of plume distribution at the downwind distance, x, from the source

$C(p)$ = the measured concentrations at the perpendicular distance, p (meters), from the highway $\left(x = \frac{p}{\cos\gamma}\right)$, g m^{-3}

γ = the angle between the wind direction and a perpendicular to the highway, degrees

By making estimates of the line-source emission rate, q_ℓ, and obtaining observed data for air pollution concentrations, a plot of σ_z versus distance was determined (Figure 4). From this analysis, it is seen that an initial σ_z (σ_{zo}) equal to 1.5 meters is a conservative approximation of the vertical

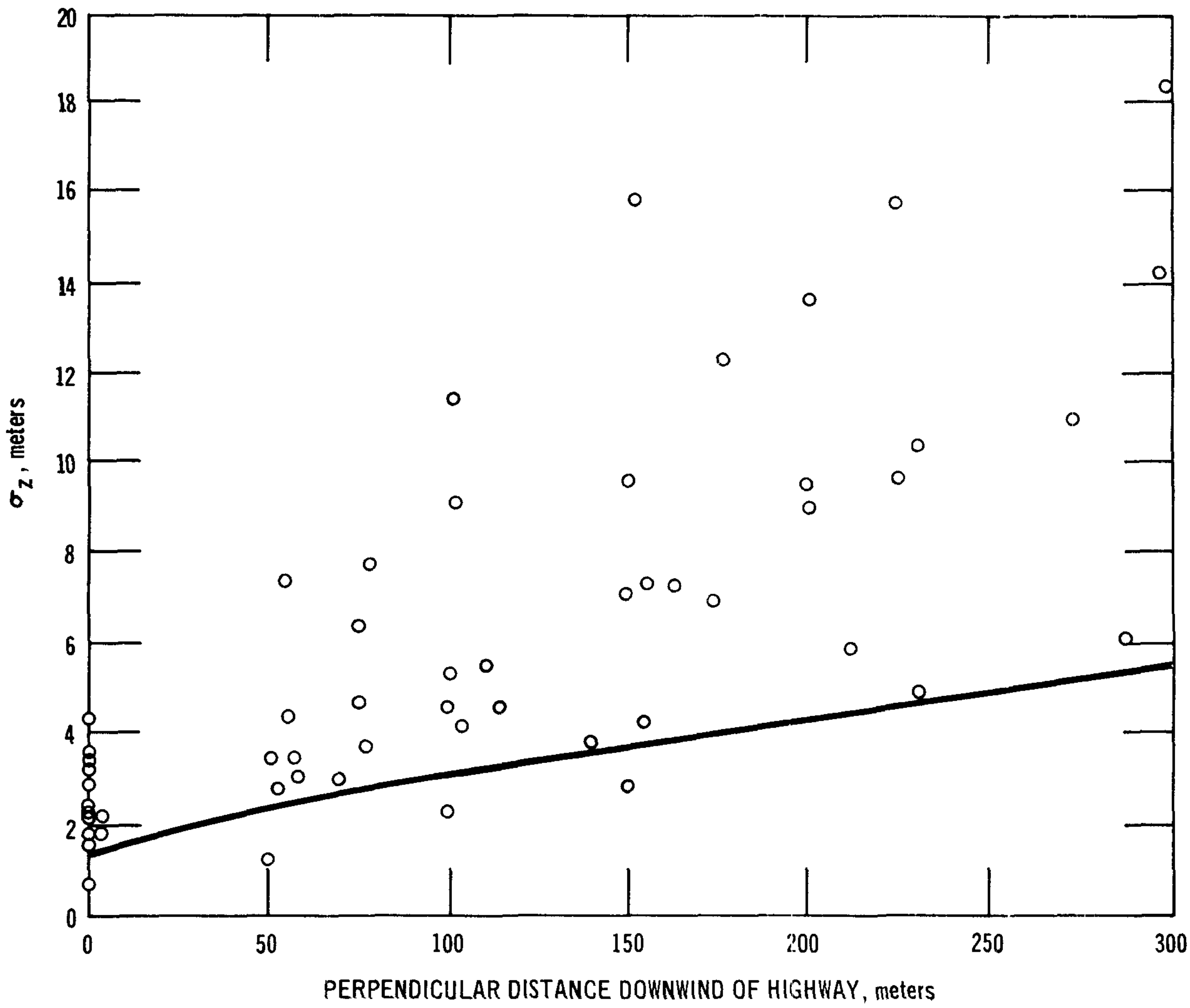

Figure 4. Data points used to determine an estimate of initial σ_z. Also plotted is the $\sigma_z(x)$ curve for neutral stability. The line is the approximate lower bound of the data.

standard deviation of the plume at the downwind edge of the at-grade highway. This is only a tentative value based on a limited amount of data and may be revised as more data become available. This empirical value of σ_{zo} is applied in the operation of the model to each of the line sources placed along each lane of traffic.

For at-grade pollution dispersion, an arbitrary value for initial σ_y (σ_{yo}) of 3 meters (approximately one-half the length of a car) was selected. The value given to σ_{yo} has little effect on the computation of air pollution concentrations when the wind direction has a component perpendicular to the highway. The use of an initial σ_y is to account for a reasonable amount of cross-highway spreading caused by vehicle-generated turbulence when the wind direction is parallel or nearly parallel to the highway.

The virtual distances, *a*, corresponding to an initial σ_z of 1.5 meters and the virtual distances, *b*, corresponding to an initial σ_y of 3.0 meters for each stability class are given in Table 4.

Table 4. VIRTUAL DISTANCES *a* AND *b* CORRESPONDING TO INITIAL σ_z OF 1.5 METERS AND INITIAL σ_y OF 3.0 METERS, RESPECTIVELY

Stability class	Distance, km	
	a	*b*
A (1)	0.00944	0.00863
B (2)	0.01226	0.0132
C (3)	0.01736	0.0210
D (4)	0.02722	0.0348
E (5)	0.03590	0.0471
F (6)	0.05842	0.0733

There are very few published measurements of air quality downwind of a cut section. Nevertheless, the available data indicate that the cut-section configuration tends to increase the dispersion of the air pollution originating from the cut section. This is particularly true when wind speeds are light, for then the release of heat from combustion, the long travel time of the pollutant to the receptor, and mechanical turbulence produced by the cut-section highway aid the dispersion. Thus, for the cut-section case, based upon very limited data, the initial σ's for wind speeds less than 1 m sec^{-1} were set at 10 meters for σ_y and 5 meters for σ_z. It was assumed that for wind speeds greater than 3 m sec^{-1} the cut section did not enhance the initial dispersion and that it was the same as for the at-grade highway: 3 meters for σ_y and 1.5 meters for σ_z. For speeds between 1 and 3 m sec^{-1}, the initial sigmas are linearly interpolated. These initial σ's are assumed for each of the ten lanes used to represent the cut. The initial values of σ_y and σ_z (meters) are found from:

$$\left.\begin{aligned} \sigma_{yo} &= 3 \\ \sigma_{zo} &= 1.5 \end{aligned}\right\} \quad \text{for } u > 3 \text{ m sec}^{-1} \tag{15}$$

$$\left.\begin{aligned} \sigma_{yo} &= 10 - 7\left(\frac{u-1}{2}\right) \\ \sigma_{zo} &= 5 - 3.5\left(\frac{u-1}{2}\right) \end{aligned}\right\} \quad \text{for } 1 < u < 3 \text{ m sec}^{-1} \tag{16}$$

and

$$\left.\begin{aligned} \sigma_{yo} &= 10 \\ \sigma_{zo} &= 5 \end{aligned}\right\} \quad \text{for } u < 1 \text{ m sec}^{-1} \tag{17}$$

4. PREPARATION OF INPUT DATA

CARD INPUT SEQUENCE

The arrangement of data on the input cards for the batch mode of operation is given in Table 5. The coordinates of the roadway are in the center of the highway (from edge to edge). The ordering of the lanes is from left to right when looking from point 1 to point 2.

INTERACTIVE OPERATION

The HIWAY model has been placed on the Environmental Protection Agency's (EPA) Users' Network for Applied Modeling of Air Pollution (UNAMAP) computer system and is accessible to EPA users. The model is also on the UNAMAP system available to all users. For information on this system contact: Chief, Data Management, Meteorology Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, N. C. 27711.

The self-explanatory listing produced by the model on a remote computer terminal is shown in Appendix A to illustrate the operation of the model in an interactive mode. The computer communicates to the user in upper case letters, while the user replies in lower case letters. To initiate the program, the user issues the command, *hiway*.

Operation of the model in an interactive mode is similar to batch mode operation. To determine emission rates for the pollutant carbon monoxide, however, the user can elect the option to use the internally generated emission rates for carbon monoxide that are representative of the emissions for the vehicle model mix near the end of 1973. This applies a correction factor for vehicle speed.

Table 5. INPUT DATA CARDS

Name	Columns	Format	Form	Variable	Units
Card type 1 (1 card)					
Head	1-80	20A4	AAAA	Alphanumeric data for heading	-
Card type 2 (1 card)					
REP1	1-10	F10.0	XXXX.XXX	East coordinate, point 1	Map units
SEP1	11-20	F10.0	XXXX.XXX	North coordinate, point 1	Map units
REP2	21-30	F10.0	XXXX.XXX	East coordinate, point 2	Map units
SEP2	31-40	F10.0	XXXX.XXX	North coordinate, point 2	Map units
H	41-50	F10.0	XX.X	Height of line source	Meters
WIDTH	51-60	F10.0	XX.	Total width of highway	Meters
CNTR	61-70	F10.0	XX.	Width of center strip	Meters
XNL	71-80	F10.0	X.	Number of traffic lanes	-
Card type 3 (up to 3 cards)					
QLS	1-80	F10.0	.XXXXXXXXX	Emission rate for each lane	g $sec^{-1}m^{-1}$
Card type 4 (1 card; can be blank for at grade)					
CUT	1-10	F10.0	X.	1, if cut; 0, if at grade	-
WIDTC	11-20	F10.0	XX.	Width of top of cut section	Meters
Card type 5 (1 card)					
THETA	1-10	F10.0	XXX.	Wind direction	Degrees
U	11-20	F10.0	XX.X	Wind speed	m sec^{-1}
HL	21-30	F10.0	XXXX.	Height of mixing layer	Meters
XKST	31-40	F10.0	X.	Pasquill stability class	-
Card type 6 (1 card)					
GS	1-10	F10.0	X.	Scale factor[a]	-
Card type 7 (any number of cards)					
XXRR	1-10	F10.0	XXXX.XXX	East coordinate of receptor[b]	Map units
XXSR	11-20	F10.0	XXXX.XXX	North coordinate of receptor	Map units
Z	21-30	F10.0	XX.	Height (above ground) of receptor	Meters

[a]The scale factor converts map units to kilometers.
If map units in kilometers, scale factor = 1.0
If map units in meters, scale factor = 0.001
If map units in feet, scale factor = 0.000305
If map units in miles, scale factor = 1.61

[b]To begin again with another set of data, a value of 9999. is punched for XXRR (card type 7) following the last receptor card.

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GLOSSARY

Several frequently used terms have become part of the jargon used by air quality dispersion modelers, and these terms are defined briefly in this section. For a more complete discussion of the concepts implied by these terms, the reader should consult the references cited.

Stability class: Atmospheric stability ranked according to classes, which are given in indexes *A* through *F* (or 1 through 6), as shown in Table 1 (Pasquill, 1961). Class *A* is very unstable and is found when skies are clear and sunny, while class *F* is moderately stable and occurs under calm conditions on clear nights.

Mixing height: The height to which pollutants are actively mixed. The air close to the earth's surface generally becomes unstable after sunrise, resulting in a zone of vigorous atmospheric mixing in the layer of air at ground level. The height of this layer increases after sunrise and reaches a maximum about 4:00 p.m. (Holzworth, 1972). For most locations close to the pollution source, the mixing height will have very little influence on the calculation of pollution concentration. When the receptor is located at a great distance from the pollution source and the travel time of the pollutant from source to receptor location is long, the mixing height will be the limiting height to which pollution will spread vertically.

Receptor: A location for which it is desired to predict pollutant concentrations. When a model is being validated, it is necessary to obtain model predictions at the receptor locations for which air quality data are measured.

Emission rate of a line source: An estimate of the amount of pollution being generated by a line source (e.g., lane of automobile traffic). To determine this value, two pieces of information are required: (1) the volume of traffic and (2) the emission factor, which is dependent on vehicle speed. The emission rate can then be determined by

$$q_{\ell} = (CV)\ (EF)\ (TV)$$

where:

q_ℓ = line source emission rate, g sec^{-1} m^{-1}

EF = emission factor, g veh^{-1} mi^{-1}

TV = traffic volume, veh hr^{-1}

CV = conversion constant = 1.726×10^{-7}, mi hr m^{-1} sec^{-1}

σ_y *and* σ_z: The standard deviation of concentration distribution in the horizontal and vertical planes, respectively. The values of σ_y and σ_z will increase with downwind distance from the source of pollution as the dimensions of the pollution plume increase. This increase in pollution plume dimension is caused by atmospheric turbulence. The intensity of atmospheric turbulence is in turn related to atmospheric stability. The plume growth will be greatest in an unstable atmosphere (more turbulence) and least when the atmosphere is stable.

APPENDIX A. EXAMPLE PROBLEM

INTRODUCTION

In order to clarify the procedure for using both the batch and interactive (continuous) versions of the HIWAY model, the following test problem is solved using both versions.

Given: Length of highway - 5 km.

Orientation - east-west.

Number of lanes - four.

Road width (edge to edge) - 46 meters.

Median width - 30 meters.

Emission rate in each lane from south to north - 0.0112, 0.0103, 0.0106, and 0.0156 g sec^{-1} m^{-1}.

Wind direction - 42 degrees.

Wind speed - 3.7 m sec^{-1}.

Stability class - 3.

Find: The expected concentration at receptors along a line perpendicular to the center of the highway segment at distances 1, 5, 10, 30, and 50 meters from the downwind edge of the roadway (1) if the road is an at-grade section, and (2) if the road is a cut section with the top of the cut being 50 meters in width.

SOLUTION USING THE INTERACTIVE VERSION

Assuming that you have already logged on the computer, etc., type in the name *hiway* as indicated in Table A-1. You are then given the choice of receiving a description of the model. Following that, enter the input parameters as the model calls for them. Most of them are self-explanatory; however, a few comments are in order:

1. When entering the mixing height never use the value 0.

2. If you do not want the effect of a limit to vertical mixing in your calculation, use a large enough mixing height so that there is no chance of its influencing your results, such as 5000 meters.

3. When entering the receptor coordinates, remember that this program is valid only downwind of the line source. A receptor location defined on the line source will not give a valid answer. If you are interested in the concentration at the edge of the highway, use a downwind distance greater than 0.1 meter from the edge of the highway and the result will be valid.

4. The coordinates for the ends of the roadway segment are assumed to be in the center of the road (from edge to edge).

5. The ordering of emission rates is for lanes in order from left to right when looking from point 1 to point 2.

The results for the at-grade section are given following the entry of receptor coordinates. For convenience, the center of the roadway has been placed 0.023 km north of the origin in this example so that the edge of the road is on the axis and the y coordinate of the receptor is the distance from the edge of the road. The roadway and receptors could have been placed at any location.

The option to run the model for a new receptor location (LOC), change the road type (TYPE), or to end the program (END) is given after the results.

In the second part of the problem, the road type (cut), the width (50 meters), and the location of the road (to again place the edge of the road at a y coordinate value of zero) are changed. The results for the cut section are shown following the entry of data. Note that the concentrations are in micrograms per cubic meter (UGM/M**3). The part per million (PPM) column is a conversion from micrograms per cubic meter for the pollutant carbon monoxide. The part per million column would be incorrect for any other pollutant.

If you decide to continue and change the receptor locations (LOC), remember that the receptors must remain downwind from the downwind edge of the roadway.

SOLUTION USING THE BATCH VERSION

The batch version requires at least seven input cards. Depending upon the number of receptor points and number of problems to be run, there may be more. The format for each card is given in Table 5. Table A-2 lists the input for the example problem; Table A-3 lists the results. Note that for the cut section the sixth and seventh fields (columns 51 to 70) in card type 2 were left blank. Also note that the card with 9999. for the variable XXRR is only used if more than one set of input data are used. A card like this does *not* follow the last set of input data. As in the interactive version, the parts per million column is only valid if carbon monoxide is the pollutant being modeled.

Table A-1. EXAMPLE OF INTERACTIVE VERSION OF HIWAY

```
hiway

DO YOU WANT A DESCRIPTION OF THE EPA "HIWAY" MODEL
BEFORE APPLYING IT?(YES OR NO)

yes

1.THE EPA "HIWAY" MODEL COMPUTES INERT POLLUTANT CONCENTRATIONS IN THE
  VICINITY OF A ROADWAY ON A SHORT TERM BASIS (HOURLY AVERAGES) USING
  THE GAUSSIAN PLUME FORMULATION. IF MORE THAN ONE ROADWAY IS PRESENT,
  SUPERPOSITION APPLIES. THE MODEL CAN BE USED FOR AT GRADE AND CUT
  SECTIONS FOR RECEPTOR DISTANCES OF TENS TO HUNDREDS OF METERS DOWNWIND
  OF THE LINE SOURCE IN RELATIVELY UNCOMPLICATED TERRAIN.
2.THE COORDINATE SYSTEM IS ARRANGED SUCH THAT THE X-AXIS INCREASES FROM
  WEST TO EAST WHILE THE Y-AXIS INCREASES FROM SOUTH TO NORTH.THE UNITS
  RELATED TO HIGHWAY MEASUREMENTS ARE INDICATED BY A SCALE FACTOR OF
  USER UNITS TO KILOMETERS. THE MOST FREQUENTLY USED FACTORS ARE:
            UNITS          SCALE FACTOR
           KILOMETERS       1.0
           METERS           0.001
           FEET             0.000305
           MILES            1.61
  SCALE FACTOR UNITS APPLY EXCEPT WHEN OTHER UNITS ARE SPECIFICALLY
  REQUESTED.
3.THE EMISSION DATA IS DEPENDENT ON VEHICLE SPEED,TYPES AND NUMBER OF
  VEHICLES,AND EMISSION CONTROL DEVICES.THE PROGRAM WILL GENERATE AN
  EMISSION RATE BASED ON AN ESTIMATE OF AVERAGE ROADWAY SPEED AND
  VOLUME OF TRAFFIC.ALTERNATIVELY,THE USER CAN ELECT TO SPECIFY HIS
  OWN EMISSION RATES IN GRAMS PER SECOND-METER.THE LATTER APPROACH IS
  HIGHLY PREFERABLE SINCE THE INTERNALLY GENERATED RATE IS BASED UPON
  A SPECIFIC AUTOMOBILE MIX (END OF 1973) WHICH DOES NOT APPLY ACCURATELY
  IN MOST CASES. EMISSIONS (GM/SEC*M) ARE ENTERED IN ORDER FROM LEFT
  TO RIGHT WHEN LOOKING FROM ROAD END PT 1 TO END PT 2.
4.ROAD COORDINATES ARE THE ENDPOINTS OF THE HIGHWAY CENTER LINE.
  WIND DIRECTION IS DERIVED BY MEASURING CLOCKWISE(EAST) FROM
  DUE NORTH.(E.G.,WIND FROM NORTH IS 0 DEGREES;EASTERLY WIND IS 90.)
5.THE PROGRAM CONTAINS THE OPTION TO EVALUATE ANY NUMBER OF
  RECEPTOR LOCATIONS AND/OR TYPES OF ROADS.
6.YOU MUST SEPARATE MULTIPLE INPUTS WITH COMMAS.
7.FOR MOST APPLICATIONS,THE HEIGHTS OF THE RECEPTOR AND
  SOURCES ARE ASSUMED TO BE THE SAME.
```

Table A-1 (continued). EXAMPLE OF INTERACTIVE VERSION OF HIWAY

```
 DO YOU WANT A DESCRIPTION OF THIS VERSION OF "HIWAY"?(YES OR NO)
no
 ENTER SCALE FACTOR (USER UNITS/KILOMETER).
1
 ENTER LINE(ROAD) ENDPOINTS.(ORDERED PAIRS:X1,Y1,X2,Y2)
2.5,.023,-2.5,.023
 ENTER EMISSION HEIGHT. (METERS)
0
 ENTER WIND DIRECTION (DEG).  NORTH IS ZERO.
42
 ENTER WIND SPEED (METERS/SEC).
3.7
 ENTER MIXING HEIGHT (METERS).
1000
 ENTER PASQUILL-TURNER STABILITY CLASS (1-6).
3
 ENTER THE NUMBER OF LANES.
4
 DO YOU WISH TO ENTER YOUR OWN EMISSION RATES?(YES OR NO)
yes
 ENTER LINE SOURCE STRENGTH VECTOR.(A VALUE FOR EACH LANE)
.0112,.0103,.0106,.0156
 IS THIS A CUT SECTION?  (YES OR NO)
no
 ENTER HIWAY WIDTH (METERS).
46
 ENTER WIDTH OF CENTER STRIP (METERS).
30
 ENTER NUMBER OF RECEPTOR LOCATIONS DESIRED.(MAXIMUM OF 25)
5
 ENTER RECEPTOR COORDINATE SETS.(X&Y IN SCALE FACTOR UNITS;Z IN METERS)
0,-.001,0,0,-.005,0,0,-.010,0
0,-.030,0,0,-.050,0
```

Table A-1 (continued). EXAMPLE OF INTERACTIVE VERSION OF HIWAY

```
HIWAY VERSION: 74250
ENDPOINTS OF THE LINE SOURCE
   2.500,      .023  AND   -2.500,      .023
EMISSION HEIGHT IS    0.000 METERS
EMISSION RATE (GRAMS/SECOND*METER) OF   4 LANE(S)
   .112-01     .103-01     .106-01     .156-01
WIDTH OF AT-GRADE HIGHWAY IS    46.000 METERS
WIDTH OF CENTER STRIP IS    30.000 METERS
WIND DIRECTION IS    42.  DEGREES
WIND SPEED IS    3.7 METERS/SEC
STABILITY CLASS IS    3
HEIGHT OF LIMITING LID IS  1000.0 METERS
THE SCALE FACTOR IS     1.0000 USER UNITS/KM.
```

RECEPTOR LOCATION X	Y	HEIGHT Z (M)	CONCENTRATION UGM/M**3	PPM*
.0000	-.0010	.0000	4449.	3.871
.0000	-.0050	.0000	3831.	3.333
.0000	-.0100	.0000	3294.	2.866
.0000	-.0300	.0000	2184.	1.900
.0000	-.0500	.0000	1669.	1.452

* PPM CONCENTRATIONS CORRECT FOR CARBON MONOXIDE ONLY.

Table A-1 (continued). EXAMPLE OF INTERACTIVE VERSION OF HIWAY

```
 YOU HAVE THE OPTION TO RUN THE MODEL FOR A NEW RECEPTOR LOCATION
 (LOC),OR TO CHANGE THE ROADWAY TYPE,OR TO END THE PROGRAM.
 ENTER LOC, OR TYPE, OR END.
type
 ENTER LINE(ROAD) ENDPOINTS.(ORDERED PAIRS:X1,Y1,X2,Y2)
2.5,.025,-2.5,.025
 ENTER EMISSION HEIGHT. (METERS)
0
 ENTER WIND DIRECTION (DEG).  NORTH IS ZERO.
42
 ENTER WIND SPEED (METERS/SEC).
3.7
 ENTER MIXING HEIGHT (METERS).
1000
 ENTER PASQUILL-TURNER STABILITY CLASS (1-6).
3
 ENTER THE NUMBER OF LANES.
4
 DO YOU WISH TO ENTER YOUR OWN EMISSION RATES?(YES OR NO)
yes
 ENTER LINE SOURCE STRENGTH VECTOR.(A VALUE FOR EACH LANE)
.0112,.0103,.0106,.0156
 IS THIS A CUT SECTION?  (YES OR NO)
yes
 ENTER WIDTH OF TOP OF CUT. (METERS)
50
 ENTER NUMBER OF RECEPTOR LOCATIONS DESIRED.(MAXIMUM OF 25)
5
 ENTER RECEPTOR COORDINATE SETS.(X&Y IN SCALE FACTOR UNITS;Z IN METERS)
0,-.001,0,0,-.005,0
0,-.010,0,0,-.030,0
0,-.050,0
```

Table A-1 (continued). EXAMPLE OF INTERACTIVE VERSION OF HIWAY

```
HIWAY VERSION: 74250
ENDPOINTS OF THE LINE SOURCE
    2.500,      .025  AND   -2.500,      .025
EMISSION HEIGHT IS     .000 METERS
EMISSION RATE (GRAMS/SECOND*METER) OF    4 LANE(S)
    .112-01     .103-01      .106-01      .156-01
WIDTH OF TOP OF CUT SECTION IS    50.000 METERS
WIND DIRECTION IS     42.  DEGREES
WIND SPEED IS    3.7 METERS/SEC
STABILITY CLASS IS     3
HEIGHT OF LIMITING LID IS  1000.0 METERS
THE SCALE FACTOR IS     1.0000 USER UNITS/KM.


     RECEPTOR LOCATION        HEIGHT             CONCENTRATION
      X            Y          Z (M)     UGM/M**3       PPM*
     .0000      -.0010        .0000       3894.        3.388
     .0000      -.0050        .0000       3452.        3.003
     .0000      -.0100        .0000       3040.        2.645
     .0000      -.0300        .0000       2107.        1.833
     .0000      -.0500        .0000       1636.        1.423

* PPM CONCENTRATIONS CORRECT FOR CARBON MONOXIDE ONLY.



ENTER LOC, OR TYPE, OR END.
end
```

Table A-2. CARD INPUT FOR EXAMPLE PROBLEM

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
--------------------------------------------------------------------------------
    AT-GRADE SECTION     EXAMPLE FOR HIWAY USERS MANUEL
       2.5      .023      -2.5      .023        .0      46.0      30.0         4
    .0112      .0103     .0106     .0156
         0
        42       3.7      1000         3
         1
        .0     -.001        .0
        .0     -.005        .0
        .0     -.010        .0
        .0     -.030        .0
        .0     -.050        .0
     9999.
    CUT-SECTION          EXAMPLE FOR HIWAY USERS MANUEL
       2.5      .025      -2.5      .025        .0                             4
    .0112      .0103     .0106     .0156
         1        50
        42       3.7      1000         3
         1
        .0     -.001        .0
        .0     -.005        .0
        .0     -.010        .0
        .0     -.030        .0
        .0     -.050        .0
--------------------------------------------------------------------------------
12345678901234567890123456789012345678901234567890123456789012345678901234567890
         1         2         3         4         5         6         7         8
```

Table A-3. EXAMPLE OF BATCH VERSION OF HIGHWAY

```
@XQT HIWAYBATCH.KZ

    AT-GRADE SECTION     EXAMPLE FOR HIWAY USERS MANUEL

   HIWAY VERSION: 74250
 ENDPOINTS OF THE LINE SOURCE
    2.500,     .023 AND   -2.500,     .023
 EMISSION HEIGHT IS    .000 METERS
 EMISSION RATE (GRAMS/SECOND*METER) OF    4 LANE(S)
     .112-01     .103-01     .106-01     .156-01
 WIDTH OF AT-GRADE HIGHWAY IS      46.0 M
 WIDTH OF CENTER STRIP IS      30.0 M
 WIND DIRECTION IS     42.  DEGREES
 WIND SPEED IS     3.7 METERS/SEC
 STABILITY CLASS IS    3
 HEIGHT OF LIMITING LID IS  1000.0 METERS
 THE SCALE OF THE COORDINATE AXES IS     1.0000 USER UNITS/KM.


   RECEPTOR LOCATION        HEIGHT     CONCENTRATION
      X          Y            Z(M)     UGM/METER**3      PPM *
     .0000      -.0010       .0000         4449.       3.871
     .0000      -.0050       .0000         3831.       3.333
     .0000      -.0100       .0000         3294.       2.866
     .0000      -.0300       .0000         2184.       1.900
     .0000      -.0500       .0000         1669.       1.452

 *  PPM CONCENTRATIONS CORRECT FOR CARBON MONOXIDE ONLY.
```

Table A-3 (continued). EXAMPLE OF BATCH VERSION OF HIGHWAY

```
   CUT-SECTION          EXAMPLE FOR HIWAY USERS MANUEL


  HIWAY VERSION: 74250
ENDPOINTS OF THE LINE SOURCE
   2.500,     .025 AND   -2.500,     .025
EMISSION HEIGHT IS     .000 METERS
EMISSION RATE (GRAMS/SECOND*METER) OF    4 LANE(S)
    .112-01     .103-01     .106-01     .156-01
WIDTH OF TOP OF CUT SECTION IS    50.000 M
WIND DIRECTION IS    42.  DEGREES
WIND SPEED IS    3.7 METERS/SEC
STABILITY CLASS IS    3
HEIGHT OF LIMITING LID IS  1000.0 METERS


THE SCALE OF THE COORDINATE AXES IS     1.0000 USER UNITS/KM.


  RECEPTOR LOCATION       HEIGHT     CONCENTRATION
     X          Y           Z(M)     UGM/METER**3      PPM *
   .0000      -.0010       .0000        3894.        3.388
   .0000      -.0050       .0000        3452.        3.003
   .0000      -.0100       .0000        3040.        2.645
   .0000      -.0300       .0000        2107.        1.833
   .0000      -.0500       .0000        1636.        1.423

*  PPM CONCENTRATIONS CORRECT FOR CARBON MONOXIDE ONLY.
```

APPENDIX B. FORTRAN SOURCE PROGRAM LISTING FOR BATCH VERSION OF HIWAY

```
C        HIWAY - NEW VERSION - JUNE 1974
C        THIS PROGRAM CALCULATES THE CONCENTRATION FROM A LINE SOURCE
      COMMON /SOL/ QLN(25),HLN(25), RAQ(25),SAQ(25),RBQ(25),SBQ(25),
     *SYON,SZON,CON(50)
      COMMON /REC/ RR(51),SR(51),ZR(51)
      COMMON /WEA/ THETA,U,KST,HL
      COMMON /PUT/ XXRR(51),XXSR(51),QLS(25),HEAD(20),IWRI
      DIMENSION Z(51)
      IVERS=74250
      IRD=5
      IWRI = 6
C        READ HEADER CARD
10    READ(IRD,500,END=190)HEAD
500   FORMAT(20A4)
      WRITE(IWRI,510)HEAD
510   FORMAT('C',/,20A4,/)
      WRITE(IWRI,520)IVERS
520   FORMAT('0  HIWAY VERSION:',I6)
      READ(IRD,540,END=190) REP1,SEP1,REP2,SEP2,H,WIDTH,CNTR,XNL
540   FORMAT(8F10.0)
C        REP1,SEP1 ARE THE COORDINATES OF AN END POINT OF THE LINE
C         SOURCE IN SOURCE COORDINATES.
C        REP2,SEP2 ARE THE COORDINATES OF THE OTHER END POINT OF THE
C         LINE SOURCE IN SOURCE COORDINATES.
C        H IS THE EFFECTIVE EMISSION HEIGHT OF THE SOURCE IN METERS.
C        WIDTH IS THE HIGHWAY WIDTH (M) FOR AT GRADE
C        CNTR IS THE WIDTH OF THE CENTER STRIP (M)
C        XNL IS THE NUMBER OF LANES FOR THE AT-GRADE HIGHWAY.
      WRITE(IWRI,550)REP1,SEP1,REP2,SEP2
550   FORMAT(' ENDPOINTS OF THE LINE SOURCE',/,
     *F9.3,',',F9.3,' AND',F9.3,',',F9.3)
      NL=XNL
      WRITE(IWRI,560)H
560   FORMAT (' EMISSION HEIGHT IS',F8.3,' METERS')
      WRITE(IWRI,570)NL
570   FORMAT(' EMISSION RATE (GRAMS/SECOND*METER) OF',I4,' LANE(S)')
      READ(IRD,540)(QLS(I),I=1,NL)
```

```
C          QLS IS THE LINE SURCE STRENGTH (GRAMS/SECOND*METER)                 HIWAY 38
        WRITE(IWRI,580)(QLS(I),I=1,NL)                                     25 HIWAY 39
580     FORMAT(8E12.3)                                                      26 HIWAY 40
        READ(IRD,540)CUT,WIDTC                                              27 HIWAY 41
C           CUT SECTION.                                                       HIWAY 42
C           WIDTC IS THE WIDTH OF THE TOP OF THE CUT SECTION (M)               HIWAY 43
        IF(CUT.EQ.0.)GOTO40                                                 28 HIWAY 44
C          DQLS IS THE CUT SECTION SOURCE STRENGTH                             HIWAY 45
        DQLS=0.                                                             29 HIWAY 46
        DO 20 I=1,NL                                                        30 HIWAY 47
20      DQLS=DQLS+QLS(I)                                                    31 HIWAY 48
        XNDL=10.                                                            32 HIWAY 49
        NL=XNDL                                                             33 HIWAY 50
        DQLS=DQLS/XNDL                                                      34 HIWAY 51
        WRITE(IWRI,590)WIDTC                                                35 HIWAY 52
590     FORMAT(' WIDTH OF TOP OF CUT SECTION IS',F10.3,' M')                36 HIWAY 53
        DO 30 I=1,NL                                                        37 HIWAY 54
30      QLS(I)=DQLS                                                         38 HIWAY 55
        WIDTH=WIDTC                                                         39 HIWAY 56
        XNL=XNDL                                                            40 HIWAY 57
        CNTR=0.                                                             41 HIWAY 58
        GO TO 50                                                            42 HIWAY 59
40      WRITE(IWRI,600)WIDTH,CNTR                                           43 HIWAY 60
600     FORMAT(' WIDTH OF AT-GRADE HIGHWAY IS',F10.1,' M',/,               44 HIWAY 61
       *' WIDTH OF CENTER STRIP IS',F10.1,' M')                                HIWAY 62
50      READ(IRD,540) THETA,U,HL,XKST                                       45 HIWAY 63
        KST=XKST                                                            46 HIWAY 64
C          THETA IS THE WIND DIRECTION IN DEGREES.                             HIWAY 65
C          U IS THE WIND SPEED IN METERS PER SECOND.                           HIWAY 66
C          KST IS THE STABILITY CLASS                                          HIWAY 67
C          HL IS THE HEIGHT OF THE LIMITING LID                                HIWAY 68
60      WRITE (IWRI,610) THETA,U,KST,HL                                     47 HIWAY 69
610     FORMAT (' WIND DIRECTION IS',F7.0,'  DEGREES',/,' WIND SPEED IS',   48 HIWAY 70
       *F7.1,' METERS/SEC'/' STABILITY CLASS IS',I5,/,' HEIGHT OF LIMITING     HIWAY 71
       * LID IS',F8.1,' METERS')                                               HIWAY 72
        READ(IRD,540)GS                                                     49 HIWAY 73
C          GS IS THE MEASURE BETWEEN COORDINATES (KM).                         HIWAY 74
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```
      WRITE(IWRI,620)GS                                                  50 HIWAY 75
620   FORMAT(' THE SCALE OF THE COORDINATE AXES IS ',F10.4,' USER UNITS/ 51 HIWAY 76
     *KM.'//)                                                               HIWAY 77
      WRITE(IWRI,630)                                                    52 HIWAY 78
630   FORMAT(1H0,'  RECEPTOR LOCATION        HEIGHT      CONCENTRATION',/, 53 HIWAY 79
     * '        X',10X,'Y              Z(M)     UGM/METER**3      PPM  ')   HIWAY 80
      RA=REP1*GS                                                         54 HIWAY 81
      RB=REP2*GS                                                         55 HIWAY 82
      SA=SEP1*GS                                                         56 HIWAY 83
      SB=SEP2*GS                                                         57 HIWAY 84
      WL= (WIDTH-CNTR)/XNL                                               58 HIWAY 85
      IF(CUT.GT.0.) GO TO 80                                             59 HIWAY 86
70    SYON=3.                                                            60 HIWAY 87
      SZON=1.5                                                           61 HIWAY 88
      GO TO 100                                                          62 HIWAY 89
80    IF(U.GT.3.)GO TO 70                                                63 HIWAY 90
      IF(U.LT.1.) GO TO 90                                               64 HIWAY 91
      DUM=(U-1.)/2.                                                      65 HIWAY 92
      SYON=10.-7.*DUM                                                    66 HIWAY 93
      SZON=5.-3.5*DUM                                                    67 HIWAY 94
      GO TO 100                                                          68 HIWAY 95
90    SYON=10.                                                           69 HIWAY 96
      SZON=5.                                                            70 HIWAY 97
100   CONTINUE                                                           71 HIWAY 98
      DELR=RB-RA                                                         72 HIWAY 99
      DELS=SB-SA                                                         73 HIWAY100
      DIST=SQRT(DELS*DELS+DELR*DELR)                                     74 HIWAY101
      NLIM=NL/2                                                          75 HIWAY102
      ALIM=NLIM                                                          76 HIWAY103
      DO 110 ID=1,NLIM                                                   77 HIWAY104
      A=ID                                                               78 HIWAY105
      DL=(-0.5)*CNTR+((-1)*ALIM-0.5+A)*WL                                79 HIWAY106
      DUM=DL*0.001/DIST                                                  80 HIWAY107
      RAQ(ID)=RA+DELS*DUM                                                81 HIWAY108
      RBQ(ID)=RB+DELS*DUM                                                82 HIWAY109
      SAQ(ID)=SA-DELR*DUM                                                83 HIWAY110
      SBQ(ID)=SB-DELR*DUM                                                84 HIWAY111
```

```
      QLN(ID)=QLS(ID)                                                    85 HIWAY112
      HLN(ID)=H                                                          86 HIWAY113
  110 CONTINUE                                                           87 HIWAY114
      NS=NLIM+1                                                          88 HIWAY115
      AS=NS                                                              89 HIWAY116
      DO 120 ID=NS,NL                                                    90 HIWAY117
      A=ID                                                               91 HIWAY118
      DL=0.5*CNTR+(0.5+A-AS)*WL                                          92 HIWAY119
      DUM=DL*0.001/DIST                                                  93 HIWAY120
      RAQ(ID)=RA+DELS*DUM                                                94 HIWAY121
      RBQ(ID)=RB+DELS*DUM                                                95 HIWAY122
      SAQ(ID)=SA-DELR*DUM                                                96 HIWAY123
      SBQ(ID)=SB-DELR*DUM                                                97 HIWAY124
      QLN(ID)=QLS(ID)                                                    98 HIWAY125
      HLN(ID)=H                                                          99 HIWAY126
  120 CONTINUE                                                          100 HIWAY127
      K=NL                                                              101 HIWAY128
      ICHK=1                                                            102 HIWAY129
      N=1                                                               103 HIWAY130
  130 READ(IRD,540,END=150)XXRR(N),XXSR(N),Z(N)                         104 HIWAY131
      IF(XXRR(N).GE.9999.)GO TO 170                                     105 HIWAY132
      IF(N-51) 160,140,140                                              106 HIWAY133
  140 WRITE(IWRI,640)                                                   107 HIWAY134
  640 FORMAT(1H0,'THE NUMBER OF RECEPTORS IS LIMITED TO 50. YOU HAVE AT 108 HIWAY135
     *TEMPTED TO READ THE 51ST. COMPUTATIONS WILL BE MADE FOR 50.')         HIWAY136
  150 ICHK=2                                                            109 HIWAY137
      GO TO 170                                                         110 HIWAY138
  160 RR(N)=XXRR(N)*GS                                                  111 HIWAY139
      SR(N)=XXSR(N)*GS                                                  112 HIWAY140
      ZR(N)=Z(N)                                                        113 HIWAY141
      N=N+1                                                             114 HIWAY142
      GO TO 130                                                         115 HIWAY143
  170 N=N-1                                                             116 HIWAY144
      DO 180 IDUM=1,N                                                   117 HIWAY145
  180 CON(IDUM)=0.                                                      118 HIWAY146
C     K IS NUMBER OF LINE SOURCES                                           HIWAY147
C     N IS NUMBER OF RECEPTORS                                              HIWAY148
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```
      CALL DBTLNE(K,N)                                                   119 HIWAY149
      WRITE(IWRI,650)                                                    120 HIWAY150
650   FORMAT(1HO,'*  PPM CONCENTRATIONS CORRECT FOR CARBON MONOXIDE ONLY121 HIWAY151
     *.')                                                                    HIWAY152
      GO TO (10,190),ICHK                                                122 HIWAY153
190   CALL EXIT                                                          123 HIWAY154
      END                                                                124 HIWAY155

 22  COMMENT CARDS          9   CONTINUATION CARDS        34 NUMBERED STATEMENTS
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```
      SUBROUTINE DBTLNE(NQ,NR)                                          HIWAY156
      COMMON /SOL/ QLN(25),HLN(25),RAQ(25),SAQ(25),RBQ(25),SBQ(25),     HIWAY157
     *SYON,SZON,CON(50)                                                 HIWAY158
      COMMON /REC/ RR(51),SR(51),ZR(51)                                 HIWAY159
      COMMON /WEA/ THETA,U,KST,HL                                       HIWAY160
      COMMON /PUT/ XXRR(51),XXSR(51),QLS(25),HEAD(20),IWRI              HIWAY161
      DIMENSION XST(11),YST(11)                                         HIWAY162
      X(R,S) = (R-RREC)*SINT + (S-SREC)*COST                            HIWAY163
C        X IS UPWIND DISTANCE OF R,S FROM RREC,SREC                     HIWAY164
      Y(R,S) = (S-SREC)*SINT - (R-RREC)*COST                            HIWAY165
C        Y IS CROSSWIND DISTANCE OF R,S FROM RREC,SREC                  HIWAY166
      TR = THETA/57.2958                                                HIWAY167
      SINT = SIN(TR)                                                    HIWAY168
      COST = COS(TR)                                                    HIWAY169
      PIN=0.02                                                          HIWAY170
      UZ=U                                                              HIWAY171
      XVYL=XVY(SYON,KST)                                                HIWAY172
      XVZL=XVZ(SZON,KST)                                                HIWAY173
      DO 465 NC=1,NR                                                    HIWAY174
      RREC=RR(NC)                                                       HIWAY175
      SREC=SR(NC)                                                       HIWAY176
      Z=ZR(NC)                                                          HIWAY177
      DO 470 NS=1,NQ                                                    HIWAY178
      R1 = RAQ(NS)                                                      HIWAY179
      S1 = SAQ(NS)                                                      HIWAY180
      R2 = RBQ(NS)                                                      HIWAY181
      S2 = SBQ(NS)                                                      HIWAY182
      QL = QLN(NS)                                                      HIWAY183
      H = HLN(NS)                                                       HIWAY184
      X1 = X(R1,S1)                                                     HIWAY185
      X2 = X(R2,S2)                                                     HIWAY186
      IF (X1) 35,45,45                                                  HIWAY187
35    IF (X2) 40,45,45                                                  HIWAY188
40    RC = 0.                                                           HIWAY189
      GO TO 470                                                         HIWAY190
   45 IF (X1-100.)46,46,47                                              HIWAY191
   46 IF (X2-100.)49,49,47                                              HIWAY192
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   47 WRITE(IWRI,48)                                                           35 HIWAY193
   48 FORMAT(1H0,'THIS RECEPTOR IS 100KM OR MORE FROM SOURCE')                 36 HIWAY194
      GO TO 465                                                                37 HIWAY195
   49 DELR=R2-R1                                                               38 HIWAY196
      DELS = S2 - S1                                                           39 HIWAY197
      Y1 = Y(R1,S1)                                                            40 HIWAY198
      Y2 = Y(R2,S2)                                                            41 HIWAY199
      IF(Y1-Y2) 100,255,100                                                    42 HIWAY200
C        IF Y1 = Y2, LINE SOURCE IS PARALLEL TO UPWIND AZIMUTH FROM RECE          HIWAY201
[illegible] IF(COST + 0.0001)135,105,165                                       43 HIWAY202
[illegible] COST - 0.0001)110,110,135                                          44 HIWAY203
[illegible] DELR + 0.0001)125,115,115                                          45 HIWAY204
[illegible]                                                                    46 HIWAY205
[illegible]                                                                    47 HIWAY206
[illegible]                                                                    48 HIWAY207
[illegible] 200                                                                49 HIWAY208
[illegible] DELS                                                               50 HIWAY209
[illegible] 5,130                                                              51 HIWAY210
[illegible]                                                                    52 HIWAY211
[illegible] (SLOC - S1)/SLP + R1                                               53 HIWAY212
[illegible] 200                                                                54 HIWAY213
[illegible] (SINT + 0.0001)160,140,140                                         55 HIWAY214
[illegible] SINT - 0.0001)145,145,160                                          56 HIWAY215
      IF(DELR + 0.0001)155,150,150                                             57 HIWAY216
      IF(DELR - 0.0001)255,255,155                                             58 HIWAY217
  155 SLP = DELS/DELR                                                          59 HIWAY218
      RLOC = RREC                                                              60 HIWAY219
      SLOC = SLP * (RLOC - R1) + S1                                            61 HIWAY220
      GO TO 200                                                                62 HIWAY221
  160 IF(DELR + 0.0001)175,165,165                                             63 HIWAY222
  165 IF(DELR - 0.0001)170,170,175                                             64 HIWAY223
  170 RLOC = R1                                                                65 HIWAY224
      SLOC = (RLOC - RREC) * COST/SINT + SREC                                  66 HIWAY225
      GO TO 200                                                                67 HIWAY226
  175 IF(DELS + 0.0001)190,180,180                                             68 HIWAY227
  180 IF(DELS - 0.0001)185,190,190                                             69 HIWAY228
  185 SLOC = S1                                                                70 HIWAY229
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      RLOC = (SLOC - SREC) * SINT/COST + RREC                             71 HIWAY230
      GO TO 200                                                           72 HIWAY231
190   TATH = SINT/COST                                                    73 HIWAY232
C        TATH IS TANGENT (THETA)                                             HIWAY233
      SLP = DELS/DELR                                                     74 HIWAY234
C        SLP IS SLOPE OF LINE SOURCE.                                        HIWAY235
      RLOC = (RREC/TATH + S1 - SLP*R1 - SREC)/ (1./TATH - SLP)           75 HIWAY236
      SLOC = (RLOC - RREC)/TATH + SREC                                   76 HIWAY237
C        RLOC, SLOC IS LOCUS OF UPWIND VECTOR FROM RECEPTOR AND LINEAR      HIWAY238
C            EXTENSION OF LINE SOURCE.                                       HIWAY239
200   XLOC = X(RLOC,SLOC)                                                 77 HIWAY240
      IF (XLOC)255,255,205                                                78 HIWAY241
C        XLOC IS POSITIVE IF LOCUS IS UPWIND.                                HIWAY242
205   IF(S2-S1)210,210,215                                                79 HIWAY243
210   SMAX = S1                                                           80 HIWAY244
      SMIN = S2                                                           81 HIWAY245
      GO TO 220                                                           82 HIWAY246
215   SMAX = S2                                                           83 HIWAY247
      SMIN = S1                                                           84 HIWAY248
220   IF(R2-R1)225,225,230                                                85 HIWAY249
225   RMAX = R1                                                           86 HIWAY250
      RMIN = R2                                                           87 HIWAY251
      GO TO 235                                                           88 HIWAY252
230   RMAX = R2                                                           89 HIWAY253
      RMIN = R1                                                           90 HIWAY254
C        SEE IF UPWIND LOCUS IS ON LINE SOURCE.                              HIWAY255
235   IF(RLOC-RMIN)255,240,240                                            91 HIWAY256
240   IF(RMAX-RLOC)255,245,245                                            92 HIWAY257
245   IF(SLOC-SMIN)255,250,250                                            93 HIWAY258
250   IF(SMAX-SLOC)255,260,260                                            94 HIWAY259
255   INDIC = 1                                                           95 HIWAY260
C        INDIC =1 FOR NO LOCUS ON LINE SOURCE.                               HIWAY261
      XA = X1                                                             96 HIWAY262
      YA = Y1                                                             97 HIWAY263
      XB = X2                                                             98 HIWAY264
      YB = Y2                                                             99 HIWAY265
      GO TO 300                                                          100 HIWAY266
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260   INDIC = 2                                                  101 HIWAY267
C        INDIC =2 FOR LOCUS ON LINE SOURCE.                           HIWAY268
      XA = X1                                                    102 HIWAY269
      YA = Y1                                                    103 HIWAY270
      XB = XLOC                                                  104 HIWAY271
      YB = 0.                                                    105 HIWAY272
300   DISX = XB - XA                                             106 HIWAY273
      DISY = YB - YA                                             107 HIWAY274
      DISI = SQRT (DISX*DISX + DISY*DISY)                        108 HIWAY275
C        DISI IS LENGTH(KM) OF LINE CONSIDERED.                       HIWAY276
      IF(DISI)310,305,310                                        109 HIWAY277
305   CURR = 0.                                                  110 HIWAY278
      GO TO 435                                                  111 HIWAY279
310   DDI = DISI*1000./20.                                       112 HIWAY280
C        ONE-HALF IS INCLUDED IN THE 20.                              HIWAY281
C        DDI IS ONE-HALF TIMES 1/10 OF DISI (M).                      HIWAY282
      DX = DISX/10.                                              113 HIWAY283
      DY = DISY/10.                                              114 HIWAY284
      PREV =0.                                                   115 HIWAY285
      KNTRL = 1                                                  116 HIWAY286
      XI = XA                                                    117 HIWAY287
      YI = YA                                                    118 HIWAY288
      KNT = 0                                                    119 HIWAY289
      DO 355 I = 1,11                                            120 HIWAY290
C        STORE EACH XI,YI.                                            HIWAY291
      XST(I) = XI                                                121 HIWAY292
      YST(I) = YI                                                122 HIWAY293
      XZ = XI + XVZL                                             123 HIWAY294
      XY = XI + XVYL                                             124 HIWAY295
      CALL DBTRCX(UZ,Z,H,HL,XZ,XY,YI,KST,AN,M,SY,SZ,RC)          125 HIWAY296
      GO TO(315,335),KNTRL                                       126 HIWAY297
C        IF RC IS ZERO, CONTINUE UNTIL RC IS POSITIVE.                HIWAY298
315   IF(RC)350,350,320                                          127 HIWAY299
320   IF(I-1)325,325,330                                         128 HIWAY300
325   KNTRL = 2                                                  129 HIWAY301
      GO TO 345                                                  130 HIWAY302
C        RESET POINT A TO LAST ONE PREVIOUS.                          HIWAY303
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330   XA = XST(I-1)                                                   131 HIWAY304
      YA = YST(I-1)                                                   132 HIWAY305
      KNTRL = 2                                                       133 HIWAY306
      GO TO 345                                                       134 HIWAY307
335   IF(RC) 340,340,345                                              135 HIWAY308
C        RESET POINT B IF REACH ZERO CONCENTRATION.                       HIWAY309
340   XB = XI                                                         136 HIWAY310
      YB = YI                                                         137 HIWAY311
      GO TO 360                                                       138 HIWAY312
345   KNT = KNT + 1                                                   139 HIWAY313
350   XI = XI + DX                                                    140 HIWAY314
      YI = YI + DY                                                    141 HIWAY315
355   CONTINUE                                                        142 HIWAY316
360   IF(KNT)370,370,365                                              143 HIWAY317
365   IF(KNT-6)300,300,390                                            144 HIWAY318
C        IF GET TO 370, CONC. FROM THIS SEGMENT IS 0.                     HIWAY319
370   GO TO (375,380,385),INDIC                                       145 HIWAY320
375   RC = 0.                                                         146 HIWAY321
      GO TO 465                                                       147 HIWAY322
380   FIRST = 0.                                                      148 HIWAY323
      GO TO 450                                                       149 HIWAY324
385   RC = FIRST                                                      150 HIWAY325
      GO TO 460                                                       151 HIWAY326
390   CONTINUE                                                        152 HIWAY327
C        DO A TRAPEZOIDAL INTEGRATION FROM A TO B IN TEN STEPS.           HIWAY328
C        IT IS LIKELY THAT A OR B HAVE BEEN REDEFINED.                    HIWAY329
400   DISX = XB-XA                                                    153 HIWAY330
      DISY = YB-YA                                                    154 HIWAY331
      DISI = SQRT(DISX*DISX + DISY*DISY)                              155 HIWAY332
C        DISI IS DISTANCE(KM) FROM A TO B                                 HIWAY333
      DELD = DISI*100.                                                156 HIWAY334
C        DELD IS 1/10 DISI IN METERS.                                     HIWAY335
      DX = DISX/10.                                                   157 HIWAY336
      DY = DISY/10.                                                   158 HIWAY337
      SUM = 0.                                                        159 HIWAY338
      XDUM = XA                                                       160 HIWAY339
      YDUM = YA                                                       161 HIWAY340
```

```
      XZ = XDUM + XVZL
      XY = XDUM + XVYL
      CALL DBTRCX(UZ,Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
      SUM = SUM + RC/2.
      DO 405 I = 1,9
      XDUM = XDUM + DX
      YDUM = YDUM + DY
      XZ = XDUM + XVZL
      XY = XDUM + XVYL
      CALL DBTRCX(UZ,Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
  405 SUM = SUM + RC
      XDUM = XDUM + DX
      YDUM = YDUM + DY
      XZ = XDUM + XVZL
      XY = XDUM + XVYL
      CALL DBTRCX(UZ,Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
      SUM = SUM + RC/2.
C        INTEGRATED VALUE IS CURR.
      CURR = SUM * DELD
      ILIM = 10
C     FIRST ESTIMATE COMPLETED HERE.
  410 PREV = CURR
C        EVALUATE FOR POINTS IN BETWEEN THOSE ALREADY EVALUATED.
      DELD = DELD/2.
      XDUM = XA + DX/2.
      YDUM = YA + DY/2.
      DO 415 I = 1,ILIM
      XZ = XDUM + XVZL
      XY = XDUM + XVYL
      CALL DBTRCX(UZ,Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
C        NOTE ADD THESE TO RC'S FOUND ABOVE.
      SUM = SUM + RC
      XDUM = XDUM + DX
  415 YDUM = YDUM + DY
      CURR = SUM * DELD
C    SECOND ESTIMATE COMPLETED HERE. ALSO FOURTH,SIXTH,ETC.
      TEST = ABS((CURR-PREV)/CURR)
```

```
C        IF WITHIN PIN OF LAST VALUE (PREV), CONSIDER THIS AS FINAL VALU
      IF(TEST-PIN)435,420,420
420   ILIM = ILIM * 2
      PREV = CURR
C        EVALUATE POINTS IN BETWEEN.
      DELD = DELD/2.
      DX = DX/2.
      DY = DY/2.
      XDUM = XA + DX/2.
      YDUM = YA + DY/2.
      DO 425 I = 1,ILIM
      XZ = XDUM + XVZL
      XY = XDUM + XVYL
      CALL DBTRCX(UZ,Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
      SUM = SUM + RC
      XDUM = XDUM +DX
425   YDUM = YDUM +DY
      CURR = SUM * DELD
C        THIRD ESTIMATE COMPLETED HERE. ALSO FIFTH,SEVENTH, ETC.
      TEST = ABS((CURR-PREV)/CURR)
      IF (TEST-PIN)435,430,430
430   ILIM = ILIM * 2
      DX = DX/2.
      DY = DY/2.
      GO TO 410
C        AT 435 HAVE FINAL VALUE OF INTEGRATION IN CURR.
435   GO TO (440,445,455),INDIC
440   RC = CURR
      GO TO 460
445   FIRST = CURR
450   INDIC = 3
      XA = XLOC
      YA = 0.
      XB = X2
      YB = Y2
      GO TO 300
455   RC = FIRST + CURR
```

```
 460    CON(NC)=CON(NC)+RC*QL                                              227 HIWAY415
 470    CONTINUE                                                           228 HIWAY416
        CON(NC)=1.0E+6*CON(NC)                                             229 HIWAY417
        CLSS=0.0087*CON(NC)                                                230 HIWAY418
        WRITE(IWRI,660)XXRR(NC),XXSR(NC),ZR(NC),CON(NC),CLSS               231 HIWAY419
 660    FORMAT(1H ,3(F10.4,2X),F10.0,F10.3)                                232 HIWAY420
 465    CONTINUE                                                           233 HIWAY421
        RETURN                                                             234 HIWAY422
        END                                                                235 HIWAY423

  32  COMMENT CARDS          1   CONTINUATION CARDS         74 NUMBERED STATEMENTS
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      SUBROUTINE DBTRCX (U,Z,H,HL,X,XY,Y,KST,AN,M,SY,SZ,RC)              1 HIWAY424
C        THIS IS THE 1972 VERSION OF DBTRCX.                               HIWAY425
C        SUBROUTINE DBTRCX CALCULATES CHI/Q CONCENTRATION VALUES, DBTRCX   HIWAY426
C         CALLS UPON SUBROUTINE DBTSIG TO OBTAIN STANDARD DEVIATIONS.      HIWAY427
C        THE INPUT VARIABLES ARE....                                       HIWAY428
C         U    WIND SPEED (M/SEC)                                          HIWAY429
C         Z    RECEPTOR HEIGHT (M)                                         HIWAY430
C         H    EFFECTIVE STACK HEIGHT (M)                                  HIWAY431
C         HL=L HEIGHT OF LIMITING LID (M)                                  HIWAY432
C         X    DISTANCE RECEPTOR IS DOWNWIND OF SOURCE (KM)                HIWAY433
C         XY   X+VIRTUAL DISTANCE USED FOR AREA SOURCE APPROX. (KM)        HIWAY434
C         Y    DISTANCE RECEPTOR IS CROSSWIND FROM SOURCE (KM)             HIWAY435
C         KST  STABILITY CLASS                                             HIWAY436
C        THE OUTPUT VARIABLES ARE....                                      HIWAY437
C         AN   THE NUMBER OF TIMES THE SUMMATION TERM IS EVALUATED         HIWAY438
C                AND ADDED IN.                                             HIWAY439
C         RC   RELATIVE CONCENTRATION (SEC/M**3)                           HIWAY440
C        IWRI IS CONTROL CODE FOR OUTPUT                                   HIWAY441
      IWRI = 6                                                           2 HIWAY442
C        THE FOLLOWING EQUATION IS SOLVED --                               HIWAY443
C          RC = (1/(2*PI*U*SIGMA Y*SIGMA Z))* (EXP(-0.5*(Y/SIGMA Y)**2))   HIWAY444
C            (EXP(-0.5*((Z-H)/SIGMA Z)**2) + EXP(-0.5*((Z+H)/SIGMA Z)**2)  HIWAY445
C              PLUS THE SUM OF THE FOLLOWING 4 TERMS K TIMES (N=1,K) --    HIWAY446
C               TERM 1- EXP(-0.5*((Z-H-2NL)/SIGMA Z)**2)                   HIWAY447
C               TERM 2- EXP(-0.5*((Z+H-2NL)/SIGMA Z)**2)                   HIWAY448
C               TERM 3- EXP(-0.5*((Z-H+2NL)/SIGMA Z)**2)                   HIWAY449
C               TERM 4- EXP(-0.5*((Z+H+2NL)/SIGMA Z)**2)                   HIWAY450
C        THE ABOVE EQUATION IS SIMILAR TO EQUATION (5.8) P 36 IN           HIWAY451
C         WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES WITH THE ADDITION   HIWAY452
C         OF THE EXPONENTIAL INVOLVING Y.                                  HIWAY453
C        IF THE SOURCE IS ABOVE THE LID, SET RC = 0., AND RETURN.          HIWAY454
      IF (H-HL)302,302,304                                               3 HIWAY455
302   IF (Z-HL)300,300,30                                                4 HIWAY456
304   IF (Z-HL)30,306,306                                                5 HIWAY457
306   WRITE(IWRI, 307)                                                   6 HIWAY458
307   FORMAT (1H0,'BOTH H AND Z ARE ABOVE THE MIXING HEIGHT SO A RELIABL 7 HIWAY459
     *E COMPUTATION CAN NOT BE MADE.')                                     HIWAY460
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 30     RC=0.                                                                 8 HIWAY461
        RETURN                                                                9 HIWAY462
 C        IF X IS LESS THAN 1 METER, SET RC=0. AND RETURN.  THIS AVOIDS         HIWAY463
 C          PROBLEMS OF INCORRECT VALUES NEAR THE SOURCE.                       HIWAY464
 300    IF (X-0.001)30,310,310                                               10 HIWAY465
 C        CALL DBTSIG TO OBTAIN VALUES FOR SY AND SZ                            HIWAY466
 310    CALL DBTSIG (X,XY,KST,SY,SZ)                                         11 HIWAY467
 C          SY = SIGMA Y, THE STANDARD DEVIATION OF CONCENTRATION IN THE        HIWAY468
 C          Y-DIRECTION (M)                                                     HIWAY469
 C          SZ = SIGMA Z, THE STANDARD DEVIATION OF CONCENTRATION IN THE        HIWAY470
 C          Z-DIRECTION (M)                                                     HIWAY471
        C1 = 1.                                                              12 HIWAY472
        IF (Y)5,400,5                                                        13 HIWAY473
 5      YD = 1000. * Y                                                       14 HIWAY474
 C        YD IS CROSSWIND DISTANCE IN METERS.                                   HIWAY475
 C                                                                              HIWAY476
        DUM = YD/SY                                                          15 HIWAY477
        TEMP = 0.5*DUM*DUM                                                   16 HIWAY478
        IF (TEMP-50.)6,30,30                                                 17 HIWAY479
 6      C1 = EXP(TEMP)                                                       18 HIWAY480
 400    IF (KST-4)401,401,403                                                19 HIWAY481
 401    IF (HL-5000.)7,403,403                                               20 HIWAY482
 C        IF STABLE CONDITION OR UNLIMITED MIXING HEIGHT,                       HIWAY483
 C          USE EQUATION 3.2 IF Z = 0, OR EQ 3.1 FOR NON-ZERO Z.                HIWAY484
 403    C2 = 2.*SZ*SZ                                                        21 HIWAY485
        IF (Z)30,404,406                                                     22 HIWAY486
 404    C3 = H*H/C2                                                          23 HIWAY487
        IF (C3-50.)405,30,30                                                 24 HIWAY488
 405    A2= 1./EXP(C3)                                                       25 HIWAY489
 C        WADE EQUATION 3.2.                                                    HIWAY490
        RC = A2/(3.14159*U*SY*SZ*C1)                                         26 HIWAY491
        M = 1                                                                27 HIWAY492
        RETURN                                                               28 HIWAY493
 406    A2 = 0.                                                              29 HIWAY494
        A3 = 0.                                                              30 HIWAY495
        CA = Z-H                                                             31 HIWAY496
        CB = Z+H                                                             32 HIWAY497
```

```
      C3 = CA*CA/C2                                                     33 HIWAY498
      C4 = CB*CB/C2                                                     34 HIWAY499
      IF(C3-50.)407,408,408                                             35 HIWAY500
407   A2 = 1./EXP(C3)                                                   36 HIWAY501
408   IF(C4-50.)409,411,411                                             37 HIWAY502
409   A3 = 1./EXP(C4)                                                   38 HIWAY503
C        WADE EQUATION 3.1.                                                HIWAY504
411   RC = (A2 + A3)/(6.28318*U*SY*SZ*C1)                               39 HIWAY505
      M = 2                                                             40 HIWAY506
      RETURN                                                            41 HIWAY507
C        IF SIGMA-Z IS GREATER THAN 1.6 TIMES THE MIXING HEIGHT,           HIWAY508
C          THE DISTRIBUTION BELOW THE MIXING HEIGHT IS UNIFORM WITH        HIWAY509
C          HEIGHT REGARDLESS OF SOURCE HEIGHT.                             HIWAY510
7     IF(SZ/HL - 1.6)9,9,8                                              42 HIWAY511
C        WADE EQUATION 3.5.                                                HIWAY512
8     RC = 1./(2.5066*U*SY*HL*C1)                                       43 HIWAY513
      M = 3                                                             44 HIWAY514
      RETURN                                                            45 HIWAY515
C        INITIAL VALUE OF AN SET = 0.                                      HIWAY516
9     AN = 0.                                                           46 HIWAY517
      IF (Z) 30,340,40                                                  47 HIWAY518
C        STATEMENTS 40 TO [illegible] CALCULATE [illegible] RELATIVE CONCENTRATION,  HIWAY519
C          USING THE EQUATION DISCUSSED ABOVE. SEVERAL INTERMEDIATE        HIWAY520
C          VARIABLES ARE USED TO AVOID [illegible] CALCULATIONS.           HIWAY521
C          CHECKS ARE MADE TO BE SURE THAT THE ARGUMENT OF THE             HIWAY522
C          EXPONENTIAL FUNCTION IS NEVER GREATER THAN 50 (OR LESS THAN     HIWAY523
C          -50). IF 'AN' BECOMES GREATER THAN 45, A LINE OF OUTPUT IS      HIWAY524
C          PRINTED INFORMING OF THIS.                                      HIWAY525
C        CALCULATE MULTIPLE EDDY REFLECTIONS FOR RECEPTOR HEIGHT Z.        HIWAY526
40    A1 = 1./(6.28318*U*SY*SZ*C1)                                      48 HIWAY527
      C2 =2.*SZ*SZ                                                      49 HIWAY528
      A2 = 0.                                                           50 HIWAY529
      A3 = 0.                                                           51 HIWAY530
      CA = Z-H                                                          52 HIWAY531
      CB = Z+H                                                          53 HIWAY532
      C3 = CA*CA/C2                                                     54 HIWAY533
      C4 = CB*CB/C2                                                     55 HIWAY534
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      IF ( C3 -50. )60,80,80                                            56 HIWAY535
60    A2 =1./EXP( C3 )                                                  57 HIWAY536
80    IF (C4- 50.) 90,110,110                                           58 HIWAY537
90    A3 =1./EXP( C4 )                                                  59 HIWAY538
110   SUM= 0.                                                           60 HIWAY539
      THL = 2. * HL                                                     61 HIWAY540
120   AN =AN+ 1.                                                        62 HIWAY541
      A4 = 0.                                                           63 HIWAY542
      A5 = 0.                                                           64 HIWAY543
      A6 = 0.                                                           65 HIWAY544
      A7 = 0.                                                           66 HIWAY545
      C5 = AN* THL                                                      67 HIWAY546
      CC = CA- C5                                                       68 HIWAY547
      CD = CB- C5                                                       69 HIWAY548
      CE = CA+ C5                                                       70 HIWAY549
      CF = CB+ C5                                                       71 HIWAY550
      C6 = CC* CC /C2                                                   72 HIWAY551
      C7 = CD* CD /C2                                                   73 HIWAY552
      C8 = CE* CE /C2                                                   74 HIWAY553
      C9 = CF* CF /C2                                                   75 HIWAY554
      IF (C6- 50.) 130,150,150                                          76 HIWAY555
130   A4 =1./EXP( C6 )                                                  77 HIWAY556
150   IF (C7- 50.) 160,180,180                                          78 HIWAY557
160   A5 =1./EXP( C7 )                                                  79 HIWAY558
180   IF (C8- 50.) 190,210,210                                          80 HIWAY559
190   A6 =1./EXP( C8 )                                                  81 HIWAY560
210   IF (C9- 50.) 220,240,240                                          82 HIWAY561
220   A7 =1./EXP( C9 )                                                  83 HIWAY562
240   T= A4 +A5+ A6 +A7                                                 84 HIWAY563
      SUM= SUM+ T                                                       85 HIWAY564
      IF ( T- 0.01 )250,120,120                                         86 HIWAY565
250   RC =A1* (A2+ A3+SUM)                                              87 HIWAY566
      M = 5                                                             88 HIWAY567
      RETURN                                                            89 HIWAY568
C        CALCULATE MULTIPLE EDDY REFLECTIONS FOR GROUND LEVEL RECEPTOR H     HIWAY569
340   A1 = 1./(6.28318*U*SY*SZ*C1)                                      90 HIWAY570
      A2 = 0.                                                           91 HIWAY571
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      C2 = 2.*SZ*SZ                                              HIWAY572
      C3 = H*H/C2                                                HIWAY573
      IF(C3-50.)360,410,410                                      HIWAY574
360   A2 = 2./EXP(C3)                                            HIWAY575
410   SUM = 0.                                                   HIWAY576
      THL = 2. * HL                                              HIWAY577
420   AN = AN + 1.                                               HIWAY578
      A4 = 0.                                                    HIWAY579
      A6 = 0.                                                    HIWAY580
      C5 = AN*THL                                                HIWAY581
      CC = H-C5                                                  HIWAY582
      CE = H + C5                                                HIWAY583
      C6 = CC*CC/C2                                              HIWAY584
      C8 = CE*CE/C2                                              HIWAY585
      IF(C6-50.)430,480,480                                      HIWAY586
430   A4 = 2./EXP(C6)                                            HIWAY587
480   IF(C8-50.)490,540,540                                      HIWAY588
490   A6 = 2./EXP(C8)                                            HIWAY589
540   T = A4 + A6                                                HIWAY590
      SUM = SUM + T                                              HIWAY591
      IF(T-0.01)550,420,420                                      HIWAY592
550   RC = A1 * (A2 + SUM)                                       HIWAY593
      M = 4                                                      HIWAY594
      RETURN                                                     HIWAY595
      END                                                        HIWAY596

 56 COMMENT CARDS        1 CONTINUATION CARDS        41 NUMBERED STATEMENTS
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      SUBROUTINE DBTSIG (X,XY,KST,SY,SZ)                                  HIWAY597
      DIMENSION XA(7),XB(2),XD(5),XE(8),XF(9),AA(8),BA(8),AB(3),BB(3),    HIWAY598
     * AD(6),BD(6),AE(9),BE(9),AF(10),BF(10)                              HIWAY599
      DATA XA/.5,.4,.3,.25,.2,.15,.1/                                     HIWAY600
      DATA XB/.4,.2/                                                      HIWAY601
      DATA XD /30.,10.,3.,1.,.3/                                          HIWAY602
      DATA XE /40.,20.,10.,4.,2.,1.,.3,.1/                                HIWAY603
      DATA XF /60.,30.,15.,7.,3.,2.,1.,.7,.2/                             HIWAY604
      DATA AA /453.85,346.75,258.89,217.41,179.52,170.22,158.08,122.8/    HIWAY605
      DATA BA /2.1166,1.7283,1.4094,1.2644,1.1262,1.0932,1.0542,.9447/    HIWAY606
      DATA AB /109.30,98.483,90.673/                                      HIWAY607
      DATA BB /1.0971,0.98332,0.93198/                                    HIWAY608
      DATA AD /44.053,36.650,33.504,32.093,32.093,34.459/                 HIWAY609
      DATA BD /0.51179,0.56589,0.60486,0.64403,0.81066,0.86974/           HIWAY610
      DATA AE /47.618,35.420,26.970,24.703,22.534,21.628,21.628,23.331,   HIWAY611
     * 24.26/                                                             HIWAY612
      DATA BE /0.29592,0.37615,0.46713,0.50527,0.57154,0.63077,0.75660,   HIWAY613
     * 0.81956,0.8366/                                                    HIWAY614
      DATA AF /34.219,27.074,22.651,17.836,16.187,14.823,13.953,13.953,   HIWAY615
     * 14.457,15.209/                                                     HIWAY616
      DATA BF /0.21716,0.27436,0.32681,0.41507,0.46490,0.54503,0.63227,   HIWAY617
     * 0.68465,0.78407,0.81558/                                           HIWAY618
      GO TO (10,20,30,40,50,60),KST                                       HIWAY619
C        STABILITY A (10)                                                 HIWAY620
   10 TH = (24.167 - 2.5334*ALOG(XY))/57.2958                             HIWAY621
      IF (X.GT.3.11) GO TO 69                                             HIWAY622
      DO 11 ID = 1,7                                                      HIWAY623
      IF(X.GE.XA(ID)) GO TO 12                                            HIWAY624
   11 CONTINUE                                                            HIWAY625
      ID = 8                                                              HIWAY626
   12 SZ = AA(ID) * X ** BA(ID)                                           HIWAY627
      GO TO 71                                                            HIWAY628
C        STABILITY B (20)                                                 HIWAY629
   20 TH = (18.333 - 1.8096*ALOG(XY))/57.2958                             HIWAY630
      IF(X.GT.35.) GO TO 69                                               HIWAY631
      DO 21 ID = 1,2                                                      HIWAY632
      IF (X.GE.XB(ID)) GO TO 22                                           HIWAY633
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21      CONTINUE                                                31 HIWAY634
        ID = 3                                                  32 HIWAY635
22      SZ = AB(ID) * X ** BB(ID)                               33 HIWAY636
        GO TO 70                                                34 HIWAY637
C          STABILITY C (30)                                        HIWAY638
30      TH = (12.5 - 1.0857*ALOG(XY))/57.2958                   35 HIWAY639
        SZ = 61.141 *X ** 0.91465                               36 HIWAY640
        GO TO 70                                                37 HIWAY641
C          STABILITY D (40)                                        HIWAY642
40      TH = (8.3333-0.72382*ALOG(XY))/57.2958                  38 HIWAY643
        DO 41 ID = 1,5                                          39 HIWAY644
        IF (X.GE.XD(ID)) GO TO 42                               40 HIWAY645
41      CONTINUE                                                41 HIWAY646
        ID = 6                                                  42 HIWAY647
42      SZ = AD(ID) * X ** BD(ID)                               43 HIWAY648
        GO TO 70                                                44 HIWAY649
C          STABILITY E (50)                                        HIWAY650
50      TH = (6.25 - 0.54287*ALOG(XY))/57.2958                  45 HIWAY651
        DO 51 ID = 1,8                                          46 HIWAY652
        IF (X.GE.XE(ID)) GO TO 52                               47 HIWAY653
51      CONTINUE                                                48 HIWAY654
        ID = 9                                                  49 HIWAY655
52      SZ = AE(ID) * X ** BE(ID)                               50 HIWAY656
        GO TO 70                                                51 HIWAY657
C          STABILITY F (60)                                        HIWAY658
60      TH = (4.1667 - 0.36191*ALOG(XY))/57.2958                52 HIWAY659
        DO 61 ID = 1,9                                          53 HIWAY660
        IF (X.GE.XF(ID)) GO TO 62                               54 HIWAY661
61      CONTINUE                                                55 HIWAY662
        ID = 10                                                 56 HIWAY663
62      SZ = AF(ID) * X ** BF(ID)                               57 HIWAY664
        GO TO 70                                                58 HIWAY665
69      SZ = 5000.                                              59 HIWAY666
        GO TO 71                                                60 HIWAY667
70      IF (SZ.GT.5000.) SZ = 5000.                             61 HIWAY668
71      SY = 1000. * XY * SIN(TH)/(2.15 * COS(TH))              62 HIWAY669
        RETURN                                                  63 HIWAY670
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      END                                                                     64 HIWAY671

    6  COMMENT CARDS        5  CONTINUATION CARDS        19 NUMBERED STATEMENTS



      FUNCTION XVY (SYO,KST)                                                   1 HIWAY672
      GO TO (1,2,3,4,5,6),KST                                                  2 HIWAY673
 1    XVY = (SYO/213.)**1.1148                                                 3 HIWAY674
      RETURN                                                                   4 HIWAY675
 2    XVY = (SYO/155.)**1.097                                                  5 HIWAY676
      RETURN                                                                   6 HIWAY677
 3    XVY = (SYO/103.)**1.092                                                  7 HIWAY678
      RETURN                                                                   8 HIWAY679
 4    XVY = (SYO/68.)**1.076                                                   9 HIWAY680
      RETURN                                                                  10 HIWAY681
 5    XVY = (SYO/50.)**1.086                                                  11 HIWAY682
      RETURN                                                                  12 HIWAY683
 6    XVY = (SYO/33.5)**1.083                                                 13 HIWAY684
      RETURN                                                                  14 HIWAY685
      END                                                                     15 HIWAY686

    0  COMMENT CARDS        0  CONTINUATION CARDS         6 NUMBERED STATEMENTS
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      FUNCTION XVZ (SZO,KST)                                                   1 HIWAY687
      DIMENSION SA(7),SB(2),SD(5),SE(8),SF(9),AA(8),AB(3),AD(6),AE(9),        2 HIWAY688
     * AF(10),CA(8),CB(3),CD(6),CE(9),CF(10)                                     HIWAY689
      DATA SA /13.95,21.40,29.3,37.67,47.44,71.16,104.65/                      3 HIWAY690
      DATA SB /20.23,40./                                                      4 HIWAY691
      DATA SD /12.09,32.09,65.12,134.9,251.2/                                  5 HIWAY692
      DATA SE /3.534,8.698,21.628,33.489,49.767,79.07,109.3,141.86 /           6 HIWAY693
      DATA SF /4.093,10.93,13.953,21.627,26.976,40.,54.89,68.84,83.25/         7 HIWAY694
      DATA AA /122.8,158.08,170.22,179.52,217.41,258.89,346.75,453.85/         8 HIWAY695
      DATA AB /90.673,98.483,109.3/                                            9 HIWAY696
      DATA AD /34.459,32.093,32.093,33.504,36.650,44.053/                     10 HIWAY697
      DATA AE /24.26,23.331,21.628,21.628,22.534,24.703,26.97,35.42,         11 HIWAY698
     * 47.618/                                                                   HIWAY699
      DATA AF /15.209,14.457,13.953,13.953,14.823,16.187,17.836,22.651,      12 HIWAY700
     * 27.074,34.219/                                                            HIWAY701
      DATA CA /1.0585,.9486,.9147,.8879,.7909,.7095,.5786,.4725/              13 HIWAY702
      DATA CB /1.073,1.017,.9115/                                             14 HIWAY703
      DATA CD /1.1498,1.2336,1.5527,1.6533,1.7671,1.9539/                     15 HIWAY704
      DATA CE /1.1953,1.2202,1.3217,1.5854,1.7497,1.9791,2.1407,2.6585,      16 HIWAY705
     * 3.3793/                                                                   HIWAY706
      DATA CF /1.2261,1.2754,1.4606,1.5816,1.8348,2.151,2.4092,3.0599,       17 HIWAY707
     * 3.6448,4.6049/                                                            HIWAY708
      GO TO (10,20,30,40,50,60),KST                                           18 HIWAY709
C        STABILITY A(10)                                                         HIWAY710
10    DO 11 ID = 1,7                                                          19 HIWAY711
      IF(SZO.LE.SA(ID)) GO TO 12                                              20 HIWAY712
11    CONTINUE                                                                21 HIWAY713
      ID = 8                                                                  22 HIWAY714
12    XVZ =(SZO/AA(ID))**CA(ID)                                               23 HIWAY715
      RETURN                                                                  24 HIWAY716
C        STABILITY B (20)                                                        HIWAY717
20    DO 21 ID = 1,2                                                          25 HIWAY718
      IF (SZO.LE.SB(ID)) GO TO 22                                             26 HIWAY719
21    CONTINUE                                                                27 HIWAY720
      ID = 3                                                                  28 HIWAY721
22    XVZ = (SZO/AB(ID))**CB(ID)                                              29 HIWAY722
      RETURN                                                                  30 HIWAY723
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C          STABILITY C (30)                                      HIWAY724
30      XVZ = (SZO/61.141)**1.0933                            31 HIWAY725
        RETURN                                                32 HIWAY726
C          STABILITY D (40)                                      HIWAY727
40      DO 41 ID = 1,5                                        33 HIWAY728
        IF(SZO.LE.SD(ID)) GO TO 42                            34 HIWAY729
41      CONTINUE                                              35 HIWAY730
        ID = 5                                                36 HIWAY731
42      XVZ = (SZO/AD(ID))**CD(ID)                            37 HIWAY732
        RETURN                                                38 HIWAY733
C          STABILITY E (50)                                      HIWAY734
50      DO 51 ID = 1,8                                        39 HIWAY735
        IF (SZO.LE.SE(ID)) GO TO 52                           40 HIWAY736
51      CONTINUE                                              41 HIWAY737
        ID = 9                                                42 HIWAY738
52      XVZ = (SZO/AE(ID))**CE(ID)                            43 HIWAY739
        RETURN                                                44 HIWAY740
C          STABILITY F(60)                                       HIWAY741
60      DO 61 ID = 1,9                                        45 HIWAY742
        IF(SZO.LE.SF(ID)) GO TO 62                            46 HIWAY743
61      CONTINUE                                              47 HIWAY744
        ID = 10                                               48 HIWAY745
62      XVZ = (SZO/AF(ID))**CF(ID)                            49 HIWAY746
        RETURN                                                50 HIWAY747
        END                                                   51 HIWAY748

    6  COMMENT CARDS          5  CONTINUATION CARDS         16 NUMBERED STATEMENTS
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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-650/4-74-008	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE USER'S GUIDE FOR HIWAY: A HIGHWAY AIR POLLUTION MODEL		5. REPORT DATE February 1975 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) John R. Zimmerman,* and Roger S. Thompson		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Environmental Research Center Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, N.C. 27711		10. PROGRAM ELEMENT NO. 1AA009 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS		13. TYPE OF REPORT AND PERIOD COVERED Final report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

*On assignment from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce

16. ABSTRACT

A computer model, called HIWAY, that can be used for estimating the concentrations of nonreactive pollutants from highway traffic is described. This steady-state Gaussian model can be applied to determine air pollution concentrations at receptor locations downwind of "at-grade" and "cut-section" highways located in relatively uncomplicated terrain. For an at-grade highway, each lane of traffic is modeled as though it were a finite, uniformly emitting line source of pollution. For the cut section, the top of the cut is considered an area source. The area source is simulated by using ten line sources of equal source strength. The total source strength equals the total emissions from the lanes in the cut. The air pollution concentration representative of hourly averaging times at a downwind receptor location is found by a numerical integration along the length of each lane and a summing of the contributions from each lane. With the exception of receptors directly on the highway or within the cut, the model is applicable for any wind direction, highway orientation, and receptor location. The model was developed for situations in which horizontal wind flow occurs. The model cannot consider complex terrain or large obstructions to the flow such as buildings or large trees. An interactive version of the computer model is available on Environmental Protection Agency's Users' Network for Applied *Modeling of Air Pollution* (UNAMAP).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution Turbulent diffusion Highway transportation Meteorology Mathematical models Computer models	Dispersion Air quality simulation model	

18. DISTRIBUTION STATEMENT Release unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 74
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

U.S. GOVERNMENT PRINTING OFFICE: 1975 - 640-880/648 - Region 4

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