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APPLICATION OF THE HIWAY MODEL FOR INDIRECT SOURCE ANALYSIS - USER'S MANUAL

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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by

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Prepared for

U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
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PREPARED FOR THE
U.S. ENVIRONMENTAL PROTECTION AGENCY
UNDER ORDER NO. 5-02-3670A

BY
KENNETH AXETELL, JR.

JULY 23, 1975

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1. INTRODUCTION

This document describes a detailed methodology for employing EPA's HIWAY model for microscale analysis of proposed indirect sources. The recommended methodology may be used to obtain a more accurate estimate of maximum carbon monoxide (CO) concentrations in cases where the screening procedure in the Guidelines for the Review of Indirect Sources[1] indicates that the National Ambient Air Quality Standards (NAAQS) would possibly be exceeded, or it may be used initially in complex analyses that are not readily handled by the screening procedure. It is applicable for all types of indirect sources, but was developed particularly for those indirect sources with emissions from both access streets and parking areas.

The methodology relies on emission estimates for specific types of indirect sources calculated by the procedures presented in Appendices A through G of the Guidelines, and draws upon other procedures included in the Guidelines and its appendices (e.g., selection of receptors and estimation of background concentrations).

Use of the HIWAY model in the analysis does require access to EPA's UNAMAP system or installation of the HIWAY program on the user's computer. However, once the program is on line, very little knowledge of computer operations is necessary to use the HIWAY model for indirect source analysis. Simple instructions on the preparation of input data and interpretation of output are provided in this document. The User's Guide for HIWAY[2] is a reference for additional information on the model.

For indirect sources with pollutant contributions from access streets, entrance/exit queues and parking areas, computer analysis greatly reduces the calculation effort for the several different alternatives that may need to be considered. For example, peak traffic on the access street may occur at a different time of day than peak traffic movement in the parking areas, or the most adverse meteorological conditions may never occur during periods of the day with peak traffic. In either of these cases, more than one time period must be analyzed. Also, with the additive effect of pollutant contributions from several sources, different wind directions should be investigated to determine the direction resulting in maximum concentrations at each receptor site.

In addition to its efficient handling of multiple line sources and of different alternatives, the HIWAY model has several analytical advantages over the screening procedure:

- complicated source configurations can be simulated;
- meteorological and traffic data specifically applicable to the site can be input;
- use of the same dispersion equation for all sources is assured.

The HIWAY model accepts only line source emissions, so a procedure for allocating parking lot emissions to the major traffic lanes within the parking lot has been developed. It is explained and demonstrated in Chapter 3. Chapter 2 outlines the individual steps in the indirect source analysis; Chapter 4 explains how to compile the required input data; Chapter 5 describes formatting procedures for the HIWAY model; Chapter 6 describes the output of the HIWAY model; and Chapter 7 discusses approaches for estimating 8-hour CO concentrations.

2.0 PROCEDURE FOR ANALYSIS USING THE HIWAY MODEL

The steps involved in using the HIWAY model for indirect source analysis are shown in the flow diagram of Figure 1. This flow diagram may be used as a checklist while performing the analysis.

Specific information on how to perform each step is explained in subsequent chapters. Page numbers are shown in Figure 1 to assist in locating the appropriate instructions for each step.

As shown in Figure 1, the types of input data that must be generated are source-receptor distance measurements, CO emission rates, and meteorological data. Most of the steps are associated with development of these input data, but the final steps relate to handling and interpretation of the HIWAY model output.

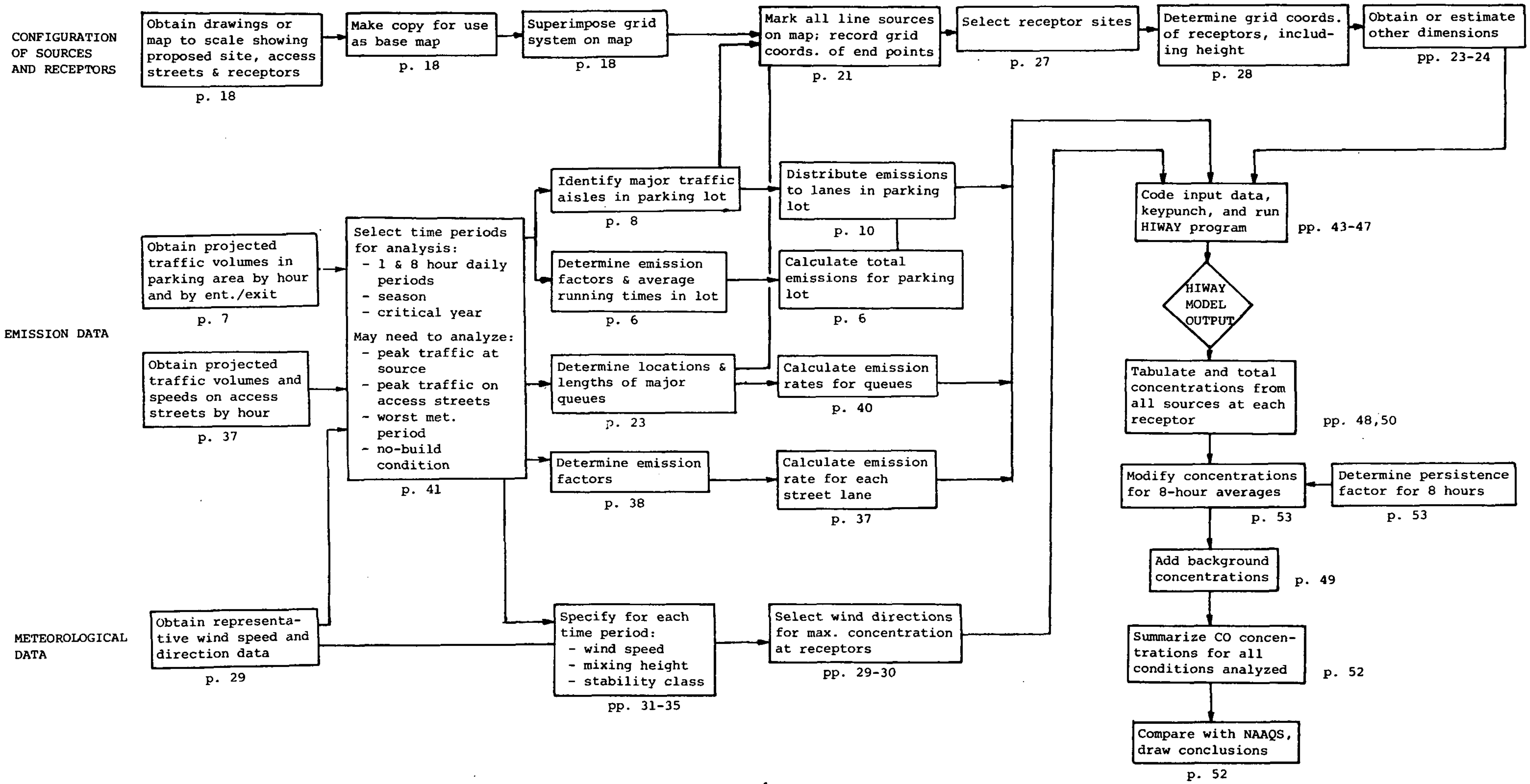

Figure 1. Flow diagram for indirect source analysis using HIWAY model

3.0 SIMULATION OF PARKING LOT EMISSIONS AS LINE SOURCES

3.1 Rationale for Simulation as Line Sources

The detailed procedures for estimating emissions in parking lots described in Appendices B through G of the Guidelines indicate that only a small percentage of the total automotive running times in the lots are associated with parking and unparking the vehicles at the parking spaces. Most of the running time and emissions are associated with movement along the entrance/exit lanes to the parking areas, movement on the main traffic aisles within the parking areas, and stop-and-start travel in queues on these aisles (each with one or more traffic lanes). Therefore, a procedure which assigns parking lot emissions to a series of line sources representing these major traffic aisles generally should more accurately simulate the distribution of emissions than an assumption of uniform emission density throughout the parking lot. This is particularly true when a structure such as a shopping center or stadium occupies a large portion of the area within the parking lot.

In order to utilize the HIWAY model for parking lot analysis and to more accurately simulate the actual distribution of emissions within parking lots, a methodology has been developed to distribute the estimated emissions among several line sources representing the major traffic aisles. It should be emphasized that this methodology is strictly for distribution of emissions, and that the emissions are still to be calculated by the procedures described in Appendices B through G of the Guidelines.

The steps in estimating emissions from the parking areas vary with each specific type of indirect source, but all are based on the same principle--that total carbon monoxide emissions from motor vehicles, exclusive of emissions from major queues, can be calculated by multiplying the number of vehicles moving in the lot during any period by the average running time per vehicle, times an appropriate emission factor for CO emitted per vehicle-minute of operation:

$$Q = \frac{(EF)(V)(RT)}{216{,}000}$$

Q = emissions from mobile sources, gm/sec

EF = emission factor, gm/min-veh*

V = traffic demand, veh/hr

RT = typical vehicle running time, sec

$\frac{1}{216{,}000}$ = conversion factor from $\frac{\text{gm-sec}}{\text{min-hr}}$ to gm/sec

The average running time is estimated as the sum of a base running time required for driving between the access street and the parking spaces under congestion-free conditions and an incremental running time resulting from traffic congestion.

Running times in major queues (RT_q) at entrances/exits and intersections within the parking lot should not be included in the estimated running time described above. Instead, the major queues are to be considered as separate line sources, with emission rates calculated by the procedure described in Section 4.4.3 of this document. The parts of the traffic aisles on which the queues occur are still identified as line sources receiving an apportionment of parking lot emissions (Q) because there are also cruising vehicles using these parts of the aisles. The emission rates for the additional line sources simulating queues only account for the excess emissions (or running times) occurring

*See Figure 8, page 39 for appropriate emission factor values.

over the queue lengths as a result of acceleration/deceleration and idling.

In most cases the parking lots being analyzed have not yet been built, so the process of apportioning emissions to traffic aisles within the parking lot is just an extension of the estimating procedure used to predict average running times in the lots. Both processes require that assumptions of preferred parking areas and travel paths within the parking lot be made. Also, detailed plans of the parking lot, including locations of traffic lanes and entrances/exits, are necessary in both cases. Comparatively, more latitude may be exercised in predicting vehicle movement within parking lots for purposes of emission distribution, since any rational traffic assignment should result in an improvement over the assumption of vehicles being uniformly distributed throughout the lots.

Thus, the traffic assignments can be made from a knowledge of the entry points and destinations of vehicles within the parking area by subjectively determining preferred travel routes. The methodology for apportioning emissions is outlined in detail in Section 3.2.

3.2 Methodology for Allocating Parking Lot Emissions to Traffic Lanes

1. Obtain estimates of the number of vehicles entering and exiting at each entrance/exit to the parking area during the time period of concern.

2. Identify the desired ultimate destination points within the development and the number or percent of trips bound for each identified destination point (based on building entrances, tenant mix, ticket booth locations, walking distances from parking area, etc.).

3. Using a drawing or map to scale of the development and its parking area, mark the major movement routes of vehicles to parking spaces nearest the destination points. Some of the traffic aisles may be used on routes from more than one entrance. Do not show the individual parking aisles unless traffic other than that parking along the aisle would normally use it in traveling through the parking lot.

4. Mark nodes on the drawing at points where the traffic movement splits or where there should be a significant change in traffic volume as some of the cars park. Number the resulting traffic links between each pair of nodes.

5. Starting at one entrance, estimate the distribution of vehicles at each node (intersection) by assigning percentages of the traffic reaching the node to each link (aisle) leading away from that node. The traffic volume leaving the node will not equal 100 percent if some vehicles park in the vicinity of that node. Continue splitting the traffic coming from the entrance onto subsequent links until it is all distributed to parking areas. Repeat this procedure for the other entrances. (There is no need to consider links carrying less than two percent of the total traffic in the parking lot, as this would increase the number of line sources in the HIWAY model without greatly increasing the accuracy of emission distribution.) This step is shown schematically in Figure 2.

6. If aisles are two-way and motorists would normally use the same aisles to exit as they did to enter, no separate distribution for exiting vehicles need be performed. However, if the aisles are designed for one-way traffic or if entrances and exits are located at different points on the periphery of the parking lot, the procedure described

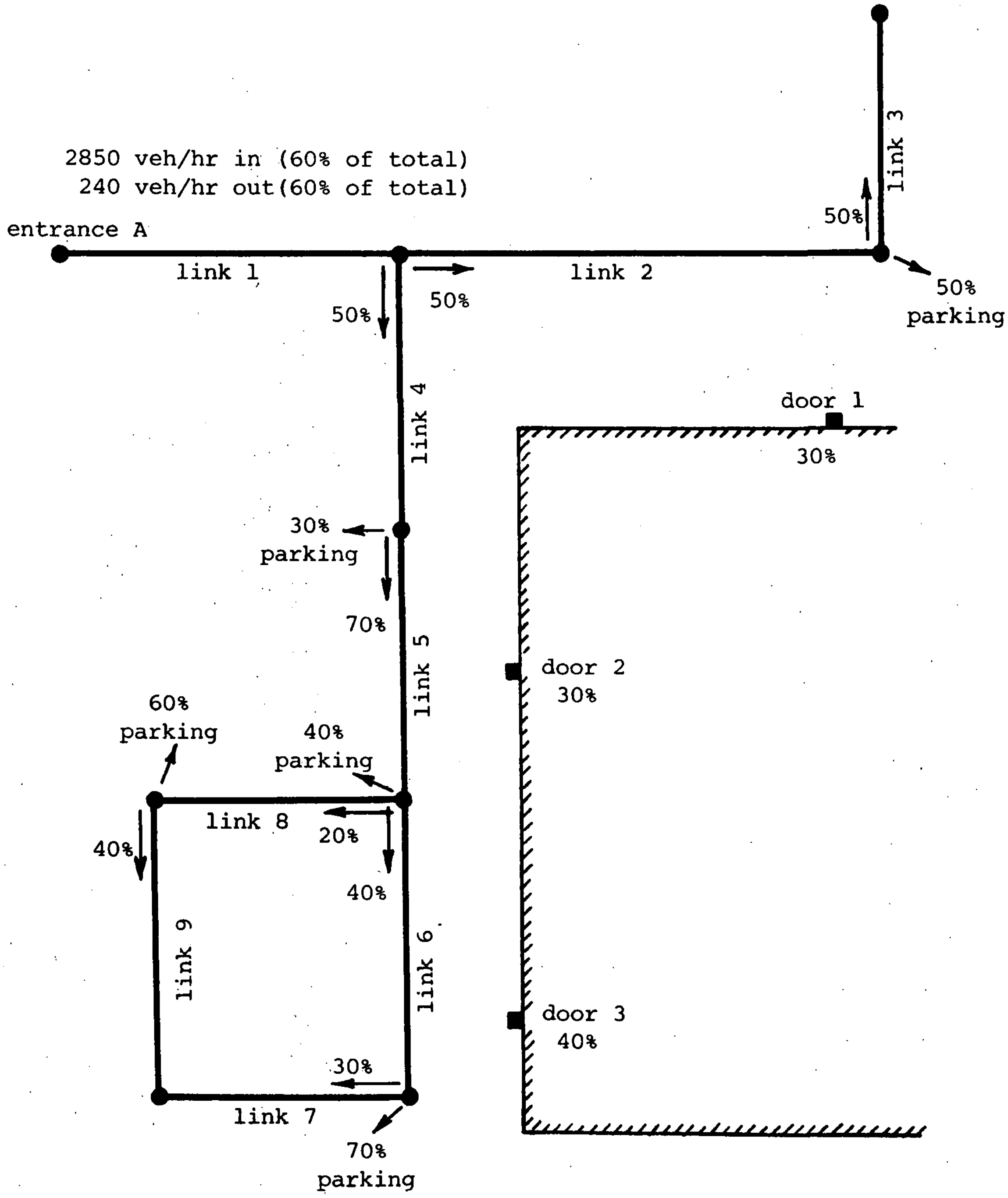

Figure 2. Example distribution of vehicles from one entrance to parking spaces

in step 5 should also be conducted for traffic exiting during the corresponding time period. The starting points with exiting traffic are the parking lot exits; otherwise, the procedure is completely analogous to that described above.

7. Measure the length of each link carrying two or more percent of the traffic and record these values in the tabular format shown in Table 1.

8. Determine a weighting factor for each link by multiplying its length by the fraction of total traffic traveling in the aisle. Total the weighting factors, then determine the constant (c) for calculating line source emission rates for the HIWAY model by dividing the estimated parking lot emissions by the total of the weighting factors:

$$c = \frac{Q}{\sum_{1}^{i} P_i L_i} \text{, where}$$

Q = parking lot emissions, gm/sec

P_i = fraction of running vehicles using traffic link i

L_i = length of link i, any consistent units

If separate analyses are performed for entering and exiting traffic, then subtotals for emissions due to entering vehicles (Q_{in}) and exiting vehicles (Q_{out}) must be used to calculate separate weighting factors for the two analyses.

9. Calculate the line source strength of each link (in gm/sec-m):

$$q_i = cP_i/z \text{, where}$$

z = factor to convert units of length to meters

These calculations should be recorded in the same table as used in steps 7 and 8.

Table 1. ALLOCATION OF PARKING LOT EMISSIONS TO TRAFFIC LINKS

Traffic link	Length	Fraction of entering or exiting vehicles using this link	Weighting factor	Line source strength, gm/sec-m

10. Divide the total line source strength for each link into emission rates per lane. The relative emission rates for traffic in each direction on two-way aisles are estimated to be the same as the ratio of entering to exiting vehicles at the entrance/exit serving this traffic aisle. If separate distributions are performed for entering and exiting traffic (see step 6 above), the traffic volumes in each direction on the aisle can be calculated. Unless specific information to the contrary is available, the emissions from travel in each direction should be divided uniformly among the lanes in that direction.

11. Indicate the locations of major queues in the parking area that were segregated to be input as separate line sources. The line source strength and upstream length of each queue should be calculated per the instructions in Section 4.4.3 and 4.1, respectively.

EXAMPLE

Problem. The convention/exposition hall design shown in Figure 3 has two parking lot entrances/exits. During the peak hour, traffic through the main entrance is estimated to be 2,850 in and 240 out. Traffic through the other gate would be 1,900 in and 160 out. All internal traffic aisles have two lanes and are designed for two-way traffic.

The developer estimates that approximately 60 percent of the persons entering the hall will enter through doors 1 and 2 (30 percent each) while 40 percent will enter through door 3. Average vehicle running times (in or out) during the peak hour are estimated to be 175 seconds, and parking lot emissions (Q) are calculated to be 79.3 gm/sec. Distribute the emissions to line sources within the parking lot and estimate line source strengths for input to HIWAY.

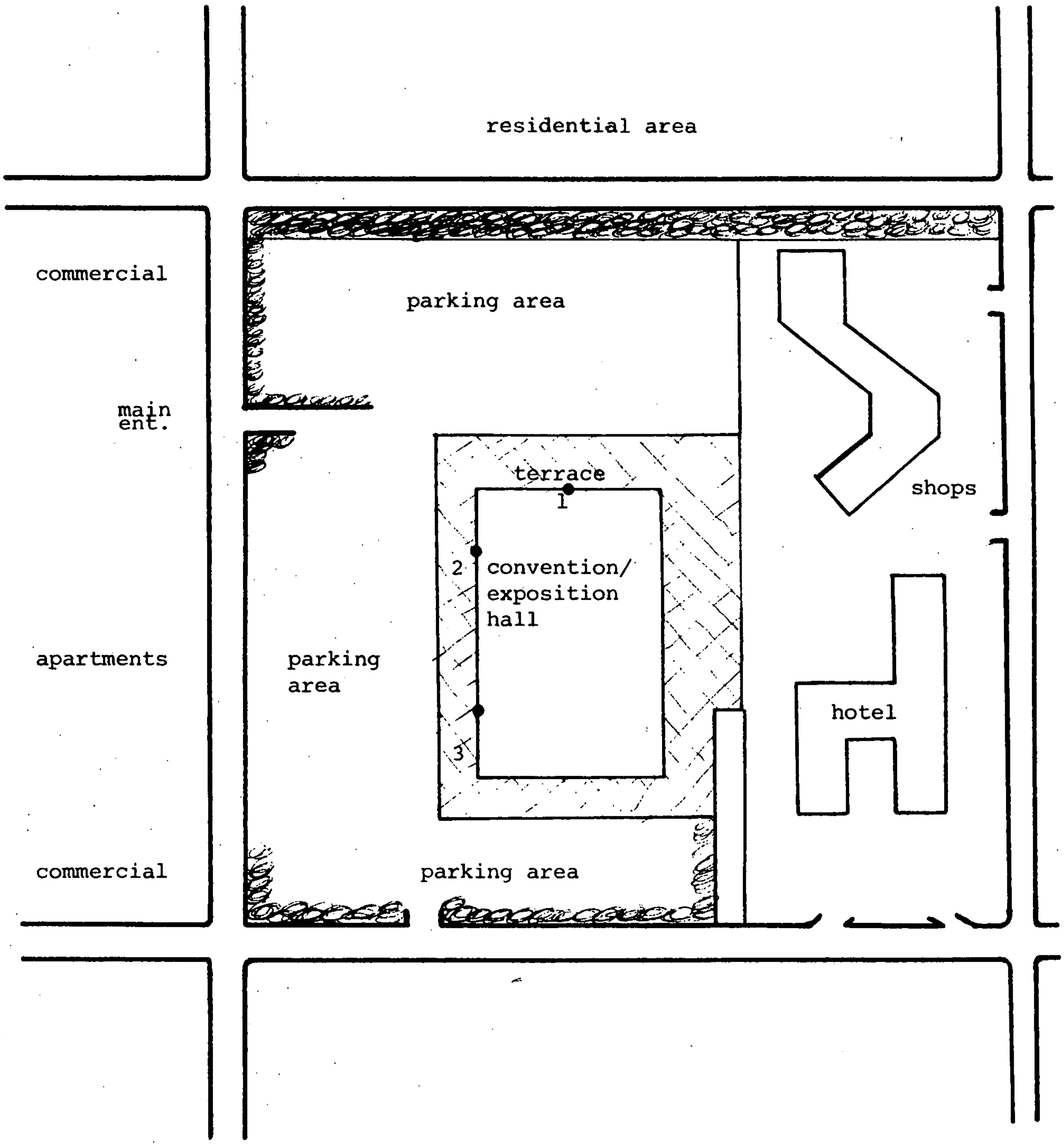

Figure 3. Convention/exposition hall

Solution.

a. Traffic volumes and destination points are given. From this information and the map showing locations of traffic lanes and parking spaces, major movement routes can be identified and traffic links can be identified and marked. This is shown separately for each of the entrances in Figures 2 and 4.

b. The distribution of vehicles at each intersection is determined subjectively. The vehicles from Entrance A (Figure 2) account for 60 percent of the total and are nearest doors 1 and 2, which likewise account for about 60 percent of the attraction points. Since there is adequate parking approximately equidistant from the two doors, the traffic would probably split in half at the first intersection. Traffic on link 2 would park as near to door 1 as possible, with those vehicles unable to find a parking space (50 percent) continuing on to link 3. A similar process would occur with vehicles on links 4 and 5, except that some might continue on this traffic lane attempting to find a parking space near door 3. However, they would be competing for these spaces with vehicles from Entrance B.

In summary, the estimates of traffic splits and vehicles parking are based on available parking spaces and proximity to the convention hall entrances. The values for vehicle distribution presented in this example are for illustrative purposes and should not be applied directly in other analyses.

c. Distribution of vehicles from Entrance B (Figure 4) is based primarily on attraction to door 3, although some vehicles (16 percent in this example) would undoubtedly continue along the main traffic lane to park nearer to door 2.

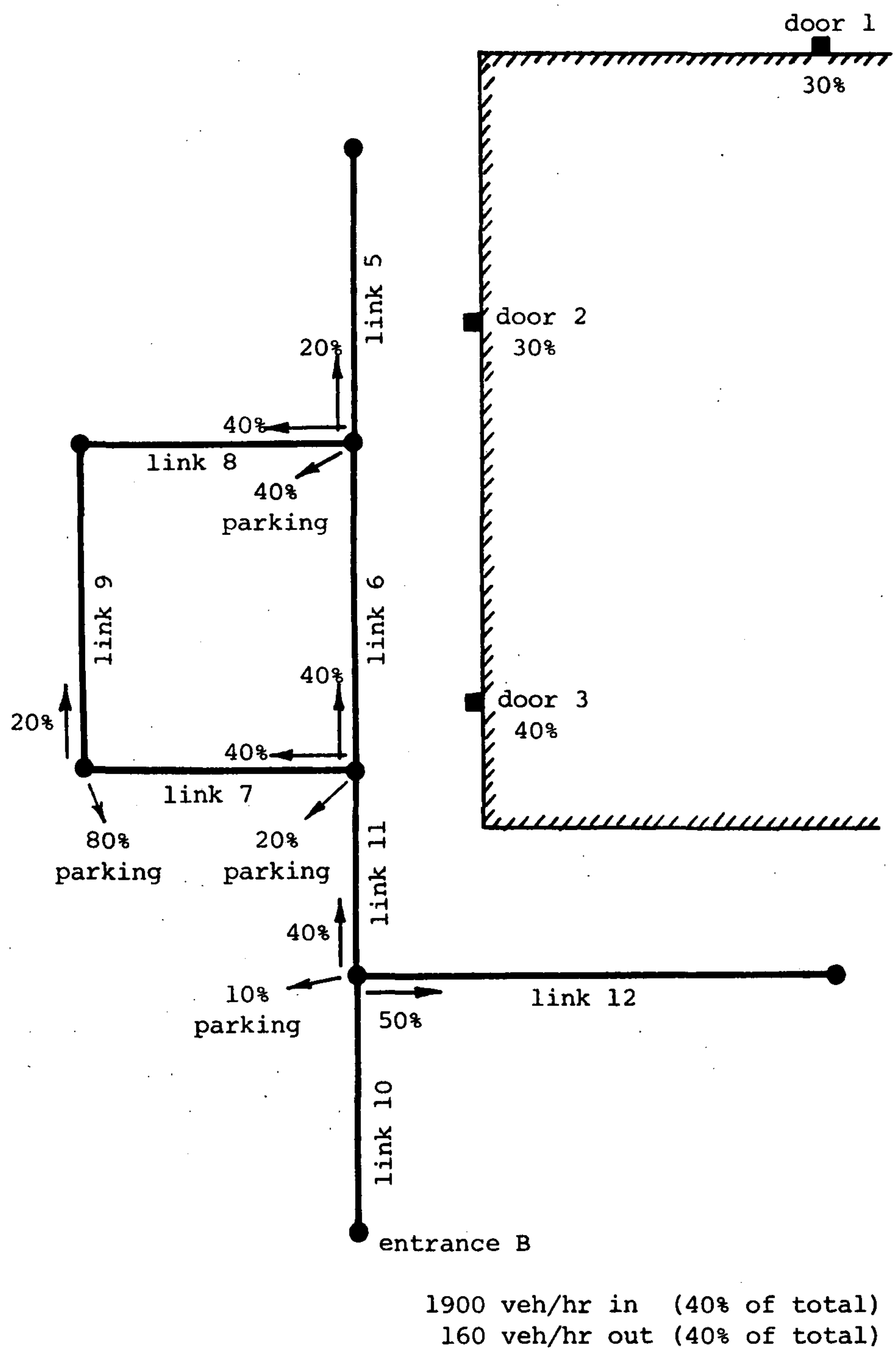

Figure 4. Distribution of vehicles from entrance B to parking spaces

d. The length of each link is scaled from the map and recorded in Table 2.

e. The fraction of total incoming vehicles using each link is then calculated as shown in Table 2, and a weighting factor determined for each link.

f. The constant for calculating line source strengths is determined to be .0643 by dividing parking lot emissions (79.3) by the sum of the weighting factors (1,234).

g. The line source strengths for each link are then calculated using the equation $q_i = cP_i/z$. The conversion factor (z) from feet to meters is 0.305. Resulting values are recorded in Table 2.

h. The ratio of entering to exiting vehicles is the same at both entrances/exits, 11.83 to 1. The emission rates for each lane are calculated from this ratio, with the emission estimates for links 5, 6 and 9 also requiring data on the percentage of traffic from each entrance. The emission data for input to HIWAY are summarized in Table 2.

Table 2. EXAMPLE ALLOCATION OF PARKING LOT EMISSIONS TO TRAFFIC LINKS

Traffic link	Length feet	Fraction of entering or exiting vehicles using this link (p)	Weighting factor	Line source strength, g/m-s	Emission rate by lane, gm/sec-m	
					S or E lane	N or W lane
1	500	(.6) = .60	300	0.1264	0.1166	0.0098
2	720	(.6)(.5) = .30	216	0.0632	0.0583	0.0049
3	350	(.6)(.5)(.5) = .15	52	0.0315	0.0291	0.0024
4	400	(.6)(.5) = .30	120	0.0632	0.0049	0.0583
5	400	(.6)(.5)(.7) + (.4)(.4)(.4)(.2) = .22	88	0.0464	0.0059	0.0405
6	450	(.6)(.5)(.7)(.4) + (.4)(.4)(.4) = .15	68	0.0315	0.0139	0.0176
7	380	(.6)(.5)(.7)(.4)(.3) + (.4)(.4)(.4) = .09	34	0.0190	0.0015	0.0175
8	380	(.6)(.5)(.7)(.2) + (.4)(.4)(.4)(.4) = .07	27	0.0147	0.0011	0.0136
9	450	(.6)(.5)(.7)(.2)(.4) + (.4)(.4)(.4)(.2) = .03	14	0.0063	0.0028	0.0035
10	350	(.4) = .40	140	0.0843	0.0778	0.0065
11	280	(.4)(.4) = .16	45	0.0337	0.0311	0.0026
12	650	(.4)(.5) = .20	130	0.0421	0.0388	0.0033
			1,234			

4.0 COMPILATION OF INPUT DATA

The data that must be compiled in order to run the HIWAY model are shown in Table 3. These data may be classified into four general categories: source configuration (measurements of the site and surrounding area), receptor location, meteorological data, and emission data. The steps to be followed in obtaining or generating all of these data are explained in this chapter. The final section of this chapter describes the selection of specific combinations of emission data and meteorological data for input to the model to simulate CO concentrations during different time periods.

4.1 Source Configuration

The distance between sources and receptors must be accurately defined in the analysis. This is normally accomplished by obtaining an engineering drawing or site plan of the proposed development plus a large enough surrounding area to include all potential receptor sites. A copy of the drawing or plan should be made so that notations and additional markings can be written on it. A base map should then be prepared from this copy by placing a coordinate system on the map and marking each access street and parking lot traffic link as a straight line (along the centerline of the street or lane) with well-defined end points.

Any convenient units can be used for the coordinate system; probably those of the base map would be easiest to apply. If the arbitrary origin of the coordinate system is placed to the south and west of all line source end points and receptor locations, the (x,y) coordinates

Table 3. INPUT DATA REQUIREMENTS FOR HIWAY

Source Configuration

- Coordinates (x,y) of line source end points
- Source height
- Total width of highway
- Width of center strip
- Number of traffic lanes
- Cut section or at-grade highway
- Width of cut section
- Factor to convert site measurements to kilometers

Receptor Location

- Coordinates (x,y) of receptor
- Receptor height

Meteorological Data

- Wind direction
- Wind speed
- Mixing height
- Stability class

Emission Data

- Line source emission rate for each traffic lane

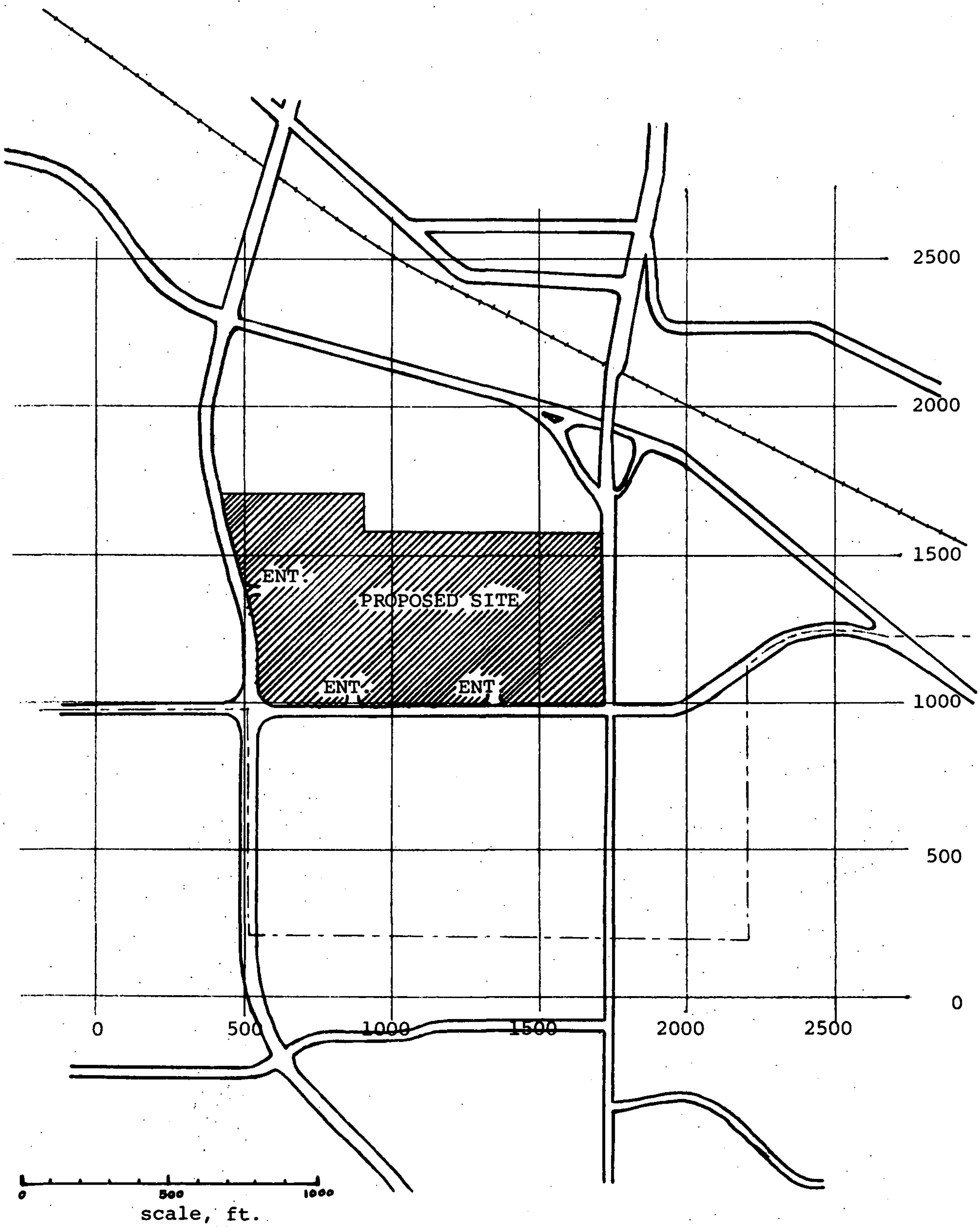

Figure 5. Example base map with coordinate system superimposed

will all be positive. However, the model will accept negative coordinates. An example base map with a coordinate grid superimposed is shown in Figure 5.

The locations of the line sources are input to the HIWAY model by the grid coordinates of the two end points of each link. Distances between line sources and receptors are calculated in the model from their respective coordinates. Because of the importance of the source-receptor configuration to the accuracy of the analysis, it is recommended that coordinates used in the model be checked by calculating distances between key points trigonometrically and comparing these values with measurements between the corresponding points scaled directly from the base map. For crucial dimensions, such as the distance of a public sidewalk from the edge of an access street or parking lot entrance, field measurements of these small distances (if facilities are already in existence, this is preferable to scaling from the base map) should be used in conjunction with coordinates for the line source to calculate the exact grid coordinates of the receptor. (Receptor location is also discussed in Section 4.4.) Calculation of receptor coordinates relative to line source end points is demonstrated in the example at the end of this section.

Non-linear streets or lanes must be represented in the HIWAY model by straight-line segments. Generally, this may be done more accurately by keeping the line on the base map over some part of the street rather than by connecting points on the centerline of the curving street. The correct procedure is shown in Figure 6. Attention to this procedure is important only when receptors are to be specified in the model near the non-linear street's edge.

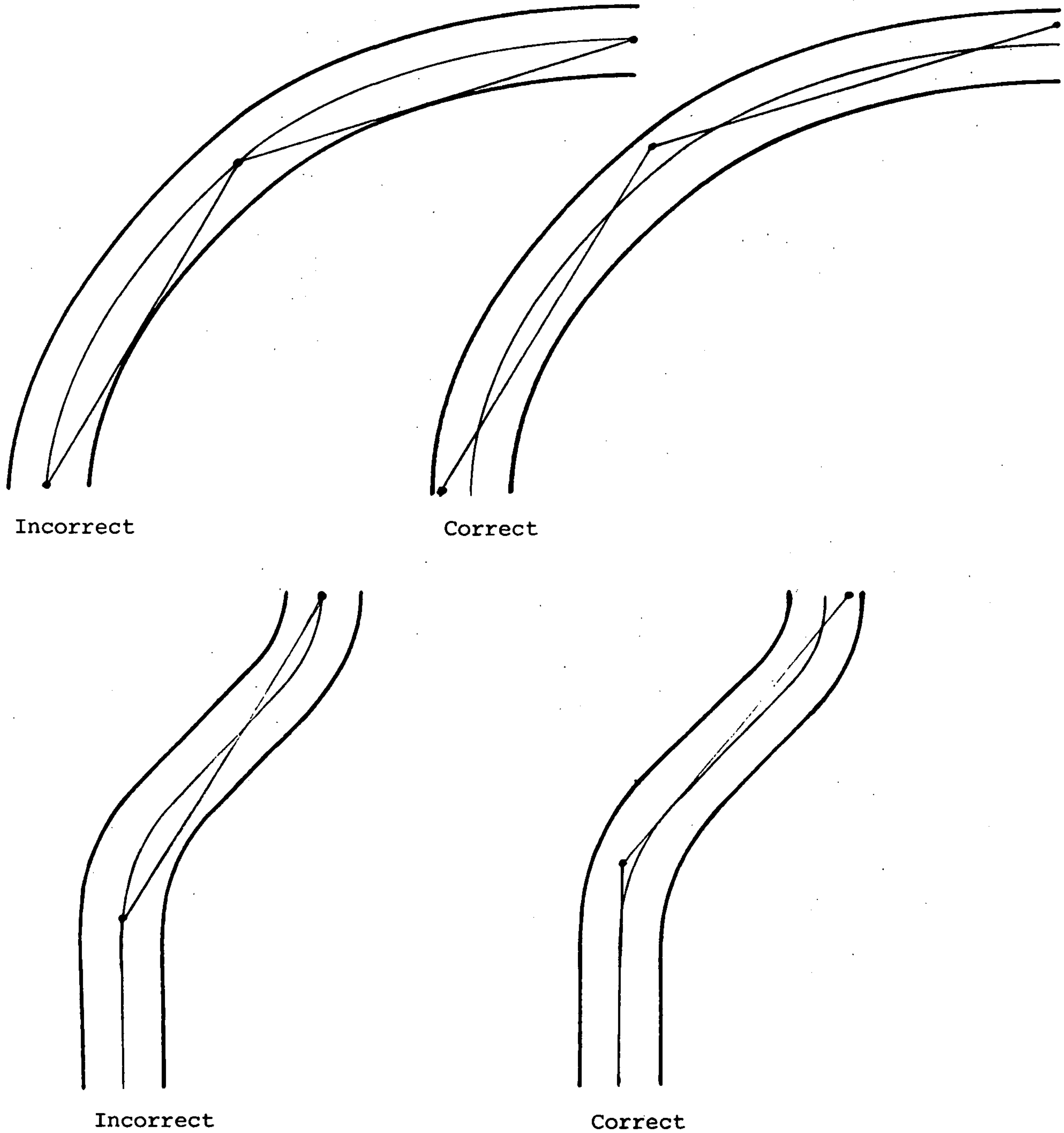

Figure 6. Simulation of Curving Streets with Straight Line Segments

If emission rates change substantially along a street due to different traffic volumes or speeds, the street should be split into separate line sources at the points where the emission rates change. For an access street on which emission rates remain fairly constant over the length of the street, end points of the line source should be extended sufficiently so that any portion of the length that would impact on a downwind receptor (with a wind direction specified in the analysis) is included.

No distinction is made in the model among any of the three types of line sources that are included--access streets, major traffic aisles in parking areas, and major queues on either the access streets or the parking areas.

The sources representing queues have a finite length. This length is calculated from equations presented in the Guidelines:

At signalized intersections

$$L = \frac{V(1-G/Cy)D}{CPH}$$

where L = queue length, meters

V = traffic demand, veh/hr

G/Cy = green time to signal cycle ration, dimensionless

D = spacing between successive vehicle tailpipes in the queue, assumed to be 8 m/veh

CPH = number of signal cycles per hour

At non-signalized intersections

$$L = \left[\frac{V^2}{C(C-V)}\right]D$$

where C = capacity, veh/hr, and other symbols are as defined above

One end point for the queue is the intersection. The other end point can be calculated after the length of the queue is determined. If the queue length is less than 25 meters (about three vehicles), it should not be included in the model as a separate line source.

Several other dimensions and data values must be provided to fully define the source configuration. The additional dimensions are: (1) height of the line source above ground level, (2) total width of the street, (3) width of the median strip (if present), and (4) width of cut section at its top (if the street is in a cut section). All of these dimensions must be input in units of meters rather than the units used for the coordinate system. Three other pieces of information must be specified: (1) the number of lanes in the street, (2) whether the street is in a cut section, and (3) the scale factor for converting the coordinate system units to kilometers. Scale factors for the most common units are shown below:

Map units	Scale factor
feet	0.0003048
miles	1.6093
meter	0.001
kilometers	1.

The HIWAY model is only applicable to relatively flat terrain. For at-grade streets, the height of the line source may be estimated as 0.0 rather than tailpipe height (0.5 meter) without any loss of accuracy because an initial vertical dispersion of 1.5 meters is included in the model.

The width of the street or highway should include the width of any center median present, but not the highway shoulders. If the width is not specified in the material submitted and cannot be accurately measured from the drawing, an estimate of 12 feet (3.66 meters) per lane may be made for modern main streets and highways.[3] If the right-of-way width is obviously limited by existing development, an estimate of 10 feet (3.05 meters) per lane may be more appropriate.

EXAMPLE

<u>Problem</u>. A receptor site located on the centerline of a sidewalk is 6 feet from the edge of the curb of a major access street to a shopping center, as shown in Figure 7. The street, including curbs, is 52 feet wide. The coordinates (in feet) specified for its end points are (165, 300) and (366, 416). If the receptor is 80 feet (measured along the street) from the intersection denoted by the coordinates (165, 300), what are the coordinates of the receptor site?

<u>Solution</u>.

a. Distance (d) of the receptor from the centerline of the street is:

$$d = \frac{52}{2} + 6$$
$$= 32 \text{ feet}$$

b. The angle (a) formed by the street and the x-axis is calculated as follows:

$$a = \arctan \frac{416 - 300}{366 - 165}$$
$$= \arctan 0.557$$
$$= 30.0^{\circ}$$

c. The coordinates of the receptor can then be calculated trigonometrically:

$$x_R = 165 + 80 \cos a + 32 \sin a$$
$$= 250$$
$$y_R = 300 + 80 \sin a - 32 \cos a$$
$$= 312$$

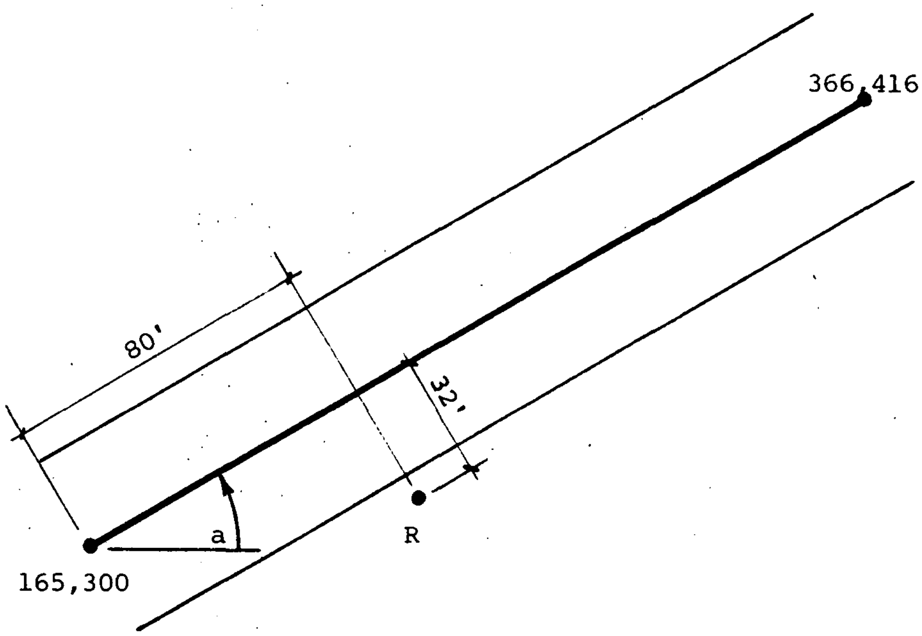

Figure 7. Location of receptor relative to line source end points

4.2 Receptor Location

Critical receptor sites are usually the nearest "reasonable" locations to streets or traffic lanes with the highest line source strength and locations immediately downwind of a group of line sources. For an indirect source with emissions from both access streets and a parking area, these locations are usually near an intersection of access streets or near an entrance/exit to the parking area. By using the HIWAY model, all potential points of maximum CO concentration can be evaluated simultaneously. Up to 50 receptor sites can be specified in the HIWAY run.

The Guidelines recommend that receptor site selection be through joint review of maps and plans of the area by the reviewing agency and the applicant. Several examples of locations that would generally be regarded as reasonable and unreasonable receptor sites are presented in the Guidelines and are repeated herein:

Examples of Reasonable Receptor Sites

1. All sidewalks where the general public has access on a more or less continuous basis for 1- or 8-hour periods.

2. A vacant lot in which a neighboring facility is planned and in whose vicinity the general public (including employees if the neighboring facility is not being built for the prime purpose of traffic control) would have access continuously for 1- and 8-hour periods.

3. Portions of a parking lot to which pedestrians have access continuously for 1- and 8-hour periods.

4. The vicinity of a parking lot's entrances and exits, providing there is an area nearby, such as a public sidewalk, residences, or structures (e.g., an auto service center at a shopping center), where

the general public is likely to have continuous access for 1 or 8 hours.

5. The property lines of all residences, hospitals, rest homes, schools, playgrounds, and the entrances and air intakes to all other buildings.

Examples of Unreasonable Receptor Sites

1. Median strips on roadways.
2. Locations within the right-of-way on limited access highways.
3. Within intersections or on crosswalks at intersections.
4. Tunnel approaches.
5. Within tollbooths.
6. Portions of parking lots where the general public is not likely to have access for 1- or 8-hour periods.

Some other receptor sites may be of special interest, even though they are not anticipated to be points of maximum CO concentration in the area, because sensitive members of the population are likely to be exposed there. These special receptors might include schools, playgrounds, day care centers, hospitals, sanitariums, nursing homes, and parks.

The x and y coordinates of all receptor sites must be specified in the same units as the line source end points. It is important that the receptors' grid coordinates be determined from the same base map used to fix the location of the line sources so that possible errors in defining the source-receptor relationship are minimized.

The heights of all receptor sites must be specified in meters. Normally, receptor height would be about two meters above ground level, at nose height.

4.3 Meteorological Data

Meteorological input data for the analysis should be specified to: (1) result in the maximum CO concentrations that may occur at receptor sites and (2) be consistent with observed meteorological conditions that are representative of the site for the time periods of concern. Four different meteorological inputs are required for the HIWAY model:

- wind direction
- wind speed
- mixing height
- stability class

To provide assurance that the specified data are consistent with actual meteorological conditions, a full year's records from a nearby meteorological station should be obtained and reviewed. Joint frequency distribution for wind direction, wind speed, and stability class (e.g., the STAR program output available from the National Climatic Center) will indicate whether certain critical combinations of these three variables occur with sufficient frequency to be considered in the analysis. However, these frequency distributions are not normally generated for a specific hour of the day, so the raw data still must be scanned to determine whether the critical combinations of wind direction, wind speed, and stability class ever occur during the hour(s) with highest emission rates. If not, it is also important to determine the hours in which these adverse meteorological conditions do occur.

4.3.1 Wind Direction

The wind directions to be investigated should be selected based on the locations of receptors relative to sources, with the receptors falling downwind of major line sources. Obviously, this may require the analysis of several wind directions if receptors have been specified in different directions from the proposed development site. Since there is no simple procedure for isolating the wind direction or receptor site that will result in the highest CO concentrations, each wind direction must be modeled separately. A major advantage of the HIWAY model compared to the screening procedure is its ability to analyze several receptors and alternative sets of meteorological input data efficiently.

The base map showing locations of sources and receptors provides an excellent aid in establishing the wind directions for use in the model.

Several general guidelines are applicable to the selection of wind directions for the model:

1. For receptors near a large number of short line source segments, as in a parking lot or adjacent to intersection approaches, a wind direction that places the maximum number of these sources directly upwind should be used.

2. For receptors near (within about 10 meters) access street line sources which extend for a long distance (more than 100 meters) beyond the receptor location, a wind direction parallel or nearly parallel to the line source should be considered in estimating maximum 1-hour concentrations. Parallel winds are not appropriate for estimating 8-hour concentrations because winds would not persist parallel to the street for such an extended period.

3. For receptors more distant from sources, the wind direction should place the receptor directly upwind of the nearest access street intersection or parking lot entrance/exit.

4. The wind direction most frequently associated with D or E stability classes and low wind speeds should be considered.

4.3.2 Wind Speed

This is the most sensitive input in the estimation of CO concentrations because the diffusion equation in the model calculates ambient concentrations as being inversely proportional to wind speeds. For example, a change in wind speed from 2.0 to 1.0 m/sec in the model doubles the predicted CO concentration.

With this inverse relationship, predicted concentrations approach infinity as the average wind speed approaches zero. Therefore, the model is not appropriate for wind speeds less than 0.5 m/sec and usually overpredicts for wind speeds less than 1.0 m/sec. A 1.0 m/sec minimum should be observed in indirect source analyses.

The number of annual occurrences of a 1.0 m/sec wind speed in conjunction with a D or E stability class and the selected wind direction during the time period of concern should be determined from raw meteorological data, if available, or National Weather Service monthly climatological summaries before the 1.0 value is used in the model. If this combination of adverse meteorological conditions has not occurred during the year, the minimum wind speed recorded for the time period with the assumed stability class and wind direction should be input instead. Alternately, a different wind direction or stability class for which a 1.0 m/sec wind speed has been recorded may be considered.

The wind speed data should be representative of the winds at the height of the plume from the line source. For at-grade highways and nearby receptors, the most appropriate height is two meters above ground level. Surface wind measurements taken at the more common height of 10 meters may be used directly, but measurements from greater heights should be adjusted to corresponding speeds at 10 meters height. Wind profiles (variations in wind speed with height) which can be used to estimate the ratio of the wind speeds at the two heights are shown in the Workbook of Atmospheric Dispersion Estimates,[5] Figures 1-1 and 1-2.

4.3.3 Mixing Height

In contrast to wind speed, mixing height is not a critical input for indirect source analysis. The distances between sources and receptors, generally less than 100 meters, are so small that the ceiling on vertical dispersion imposed by the mixing height has no effect on predicted concentrations at the receptors.

Sufficiently accurate values for use in the model can be obtained from the EPA publication Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States,[4] Figures 1 through 10. This compilation of mixing height data provides a selection of values specific for the time of day, season, and national location being analyzed. Mean annual early morning (mimimum for the day) mixing heights shown in this publication are 300 to 700 meters for most parts of the country. Afternoon (maximum for the day) mixing heights range from 1,000 to 2,600 meters.

Morning and afternoon mixing height values for specific dates (e.g., to compare model results with CO sampling data) can be readily calculated from vertical temperature profiles and surface temperature readings available from the National Climatic Center, Asheville, North Carolina, for any of the 62 national locations at which upper-air measurements are routinely made. The 62 cities are listed in Table 4 and the method for calculating mixing height from the vertical temperature profile is explained in the publication cited above.[4] This more detailed estimation of mixing height is not warranted for predicting future CO concentrations in the indirect source analysis.

4.3.4 Stability Class

Pasquill stability classes A (very unstable) through F (moderately stable) are used in the HIWAY model to indicate the rate of atmospheric mixing. For the source-receptor configurations in indirect source analysis, higher CO concentrations are generally predicted with increasing atmospheric stability. In order to determine the most stable potential stability class for a particular analysis, the time of day and urban/rural location of the development site must be known.

In a relatively flat and open area, stability is primarily a function of wind speed and incoming solar radiation (during the day) or cloud cover (during the night). The relationship is shown in Table 5. Note that neither E nor F stability normally occurs during the daytime. Therefore, D stability should be used to estimate the highest CO concentrations for all daytime hours.

Day is defined as the period from one hour after sunrise until one hour before sunset.[5] National Weather Service stations record the local times of sunrise and sunset each day, or the official times for any date and U.S. city can be obtained from the Naval Observatory, Washington, D.C.

Guidelines for estimating stability classes for open land or rural areas are presented in Table 5. In urban areas, the atmosphere is likely to be less stable as a result of the mechanical turbulence

Table 4. NATIONAL WEATHER SERVICE UPPER-AIR OBSERVING STATIONS

Location	NWS Abbr.	Location	NWS Abbr.
Albany, New York	ALB	Little Rock, Arkansas	LIT
Albuquerque, New Mexico	ABQ	Medford, Oregon	MFR
Amarillo, Texas	AMA	Miami, Florida	MIA
Athens, Georgia	AHN	Midland, Texas	MAF
Bismarck, North Dakota	BIS	Montgomery, Alabama	MGM
Boise, Idaho	BOI	Nantucket, Massachusetts	ACK
Brownsville, Texas	BRO	Nashville, Tennessee	BNA
Buffalo, New York	BUF	New York, New York	JFK
Burwood, Louisiana	BRJ	North Platte, Nebraska	LBF
Cape Hatteras, N. C.	HAT	Oakland, California	OAK
Caribou, Maine	CAR	Oklahoma City, Okl.	OKC
Charleston, S. C.	CHS	Peoria, Illinois	PIA
Columbia, Missouri	CBI	Pittsburgh, Penn.	PIT
Dayton, Ohio	DAY	Portland, Maine	PWM
Denver, Colorado	DEN	Rapid City, S. D.	RAP
Dodge City, Kansas	DDC	St. Cloud, Minnesota	STC
El Paso, Texas	ELP	Salem, Oregon	SLE
Ely, Nevada	ELY	Salt Lake City, Utah	SLC
Flint, Michigan	FNT	San Antonio, Texas	SAT
Glasgow, Montana	GGW	San Diego, California	SAN
Grand Junction, Colo.	GJT	Santa Monica, Calif.	SMO
Great Falls, Montana	GTF	Sault Ste. Marie, Mich.	SSM
Green Bay, Wisconsin	GRB	Seattle, Washington	SEA
Greensboro, N. C.	GSO	Shreveport, Louisiana	SHV
Huntington, W. Va.	HTS	Spokane, Washington	GEG
International Falls, Minn.	INL	Tampa, Florida	TPA
Jackson, Mississippi	JAN	Topeka, Kansas	TOP
Jacksonville, Florida	JAX	Tucson, Arizona	TUS
Lake Charles, Louisiana	LCH	Washington, D. C.	DIA
Lander, Wyoming	LND	Winnemucca, Nevada	WMC
Las Vegas, Nevada	LAS	Winslow, Arizona	INW

Source: Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the United States. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. 1972. Table A-1.

Table 5. ESTIMATION OF PASQUILL STABILITY CLASSES

Surface wind speed (at 10 m), m/sec	Day			Night	
	Incoming solar radiation				
	Strong	Moderate	Slight	Thinly overcast or ≥4/8 low cloud	≤3/8 cloud
< 2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night.

Source: Workbook of Atmospheric Dispersion Estimates. U.S. Department of Health, Education, and Welfare, Public Health Service. Cincinnati, Ohio. 1970. Table 3-1.

created by vehicles, aerodynamic effects of buildings, and heat island effects in highly paved areas. This increased atmospheric mixing would preclude E and F stability classes from occurring, except in special situations, in urban areas. Therefore, D stability should be used to estimate the highest CO concentrations for urban locations, even for nighttime periods. For open suburban sites, E stability may be used to stimulate night stability.

4.4 Emission Data

The only emission data required by the HIWAY model are the line source emission rates (q) in gm/sec-m for each lane of traffic in the study area. Point or area source CO emissions cannot be input. There is no upper limit to the number of line sources that can be considered in a single run. One lane or any even number of lanes from 2 to 24 can be specified for each line source. The emission rates for multiple-lane sources should be listed in order from left to right as the line source is viewed from end point 1 to end point 2.

4.4.1 Emission Rates for Parking Area Traffic Lanes

The emission rates for traffic lanes in parking lots are calculated by first estimating the total emissions per hour in the parking area and then apportioning this total to the individual traffic lanes by the procedure described in Chapter 3. This procedure produces emission rates in gm/sec-m for direct input to the HIWAY model.

The emissions attributable to major queues at entrances/exits and intersections within the parking lot are not included in the emission rates calculated for these traffic lanes. The queue emissions, like those from queues occurring along access streets, are considered as separate line sources. Calculation of emission rates from queues is explained in Section 4.4.3 below.

4.4.2. Emission Rates for Access Streets

Emission rates for access streets are calculated by a procedure described in detail in Appendix A of the Guidelines, "Methods for Estimating Emissions from Highways." The equation used in that procedure is presented here, but it is recommended that the detailed description be followed in the calculations.

This equation estimates the uniform emission intensity for each lane of freely flowing traffic on the street or highway. The excess emissions that occur as a result of queues at intersections are estimated by additional calculations described in the next section and are handled as separate line sources. It should be noted that the emission rate calculated for the free flowing segments of the access street also extends over the length of the queue; the additional line source representing the queue only simulates the extra emissions due to acceleration/deceleration and idling.

The equation for estimating emission rates by lane is:

$$q_{ij} = (1.036 \times 10^{-5})\ (EF)_{ij}\ (V_{ij}/S_{ij})$$

where q_{ij} = line source emission rate in lane j for road segment i, resulting from free flowing traffic, gm/sec-m

V_{ij} = traffic volume demand, veh/hr

S_{ij} = average vehicle operating speed, mph

$(EF)_{ij}$ = speed corrected emission factor, gm/min-veh

(1.036×10^{-5}) = conversion factor from gm/min-mi to gm/sec-m

Volume demands for some time period(s) on all access streets should be provided by the applicant. If average daily traffic (ADT) volume is provided, the volume demand for the 1-hour periods of concern can be estimated as a fraction of ADT by using data on local diurnal traffic patterns. Traffic volumes during particular seasons may be estimated by applying seasonal adjustment factors. Traffic volumes are usually given separately for travel in each direction on a street, but not by lane. Therefore, the total one-way volume must be apportioned to the lanes in that direction.

The average operating speed on a highway link is a function of the volume-to-capacity ratio of the link and its design speed. Estimated speeds during specific hours may also be provided by the applicant. If not, operating speeds may be estimated from Figures A2 through A5 in Appendix A of the Guidelines.

The CO emission factors, a function of operating speed, are presented for the year 1975 in Figure 8. These values in units of gm/min-veh were derived from data in EPA publication AP-42, Supplement Number 5.[6] For years other than 1975, the appropriate emission factor may be estimated as follows:

$$(EF)_{yr} = (EF)_{75}\ (ef/55)$$

where $(EF)_{yr}$ = emission factor for year of concern

$(EF)_{75}$ = emission factor obtained from Figure 8

ef = emission factor in gm/mi for the year of concern:

Calendar year	ef for CO
1972	70.6
1973	65.6
1974	61.6
1975	55.0
1976	48.2
1977	41.5
1978	35.0
1979	29.1
1980	23.2

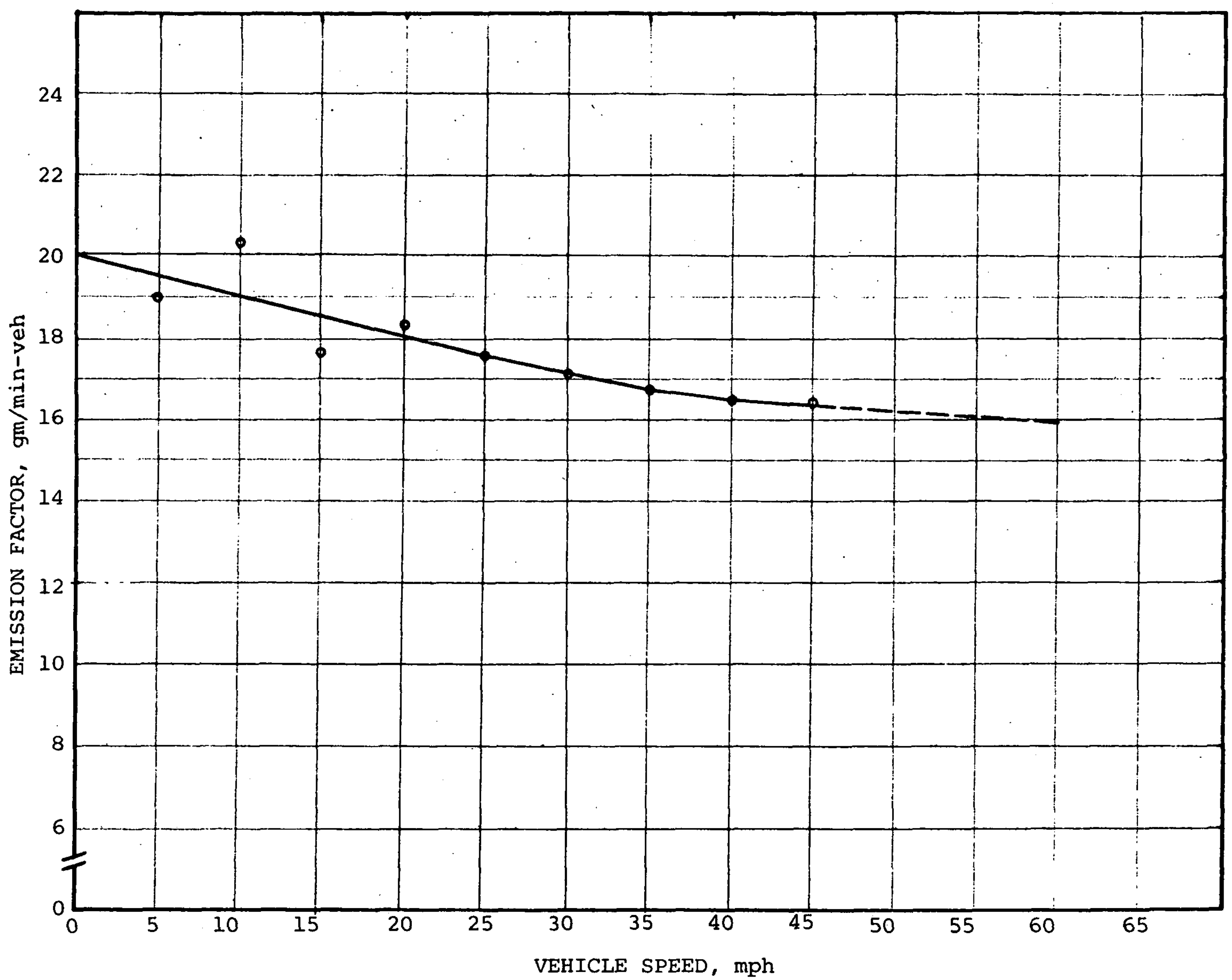

Figure 8. Composite emission factors for carbon monoxide for calendar year 1975

Several assumptions were made in the derivation of data in Figure 8:

- a national average mix of vehicles by model year
- 88 percent of VMT by light-duty vehicles, 12 percent of VMT by light-duty trucks
- 20 percent of vehicles operating from a cold start
- ambient temperature in range of 68° F to 86° F
- a low altitude location outside California

If any of these assumptions are not applicable, correction factors should be obtained from the Guidelines (Tables 1 and 2) or from AP-42, Supplement Number 5.

4.4.3 Emission Rates for Queues

The emission rate for a queue on either an access street or in a parking area is calculated from equations presented in Appendix A of the Guidelines. Two different types of queue formation are considered--at signalized intersections and at non-signalized intersections. The average emission rate over the finite length (as determined by the method described in Section 4.1, page 23) of a queue at signalized and non-signalized intersections may be estimated as follows:

At Signalized Intersections

$$q_{ij} = \frac{\overline{(EF)}_{ij} + 0.5\ (EF)'_{ij}\ (1 - G/Cy)}{60\ D}$$

where q_{ij} = excess line source emission intensity to be applied over the finite queue length L_{ij} in lane j at intersection approach i, gm/sec-m

$\overline{(EF)}_{ij}$ = average emission factor for accelerating and decelerating vehicles over the estimated queue length, gm/min-veh

$(EF)'_{ij}$ = emission factor for idling vehicles in the queue, gm/min-veh

G/Cy = green time to signal cycle ratio at approach i, dimensionless

D = spacing between successive vehicle tailpipes in the queue, assumed to be 8 m/veh

The emission factors used for $\overline{(EF)}_{ij}$ and $(EF)'_{ij}$ are not presented in Appendix A, but can be derived from Supplement 5 to AP-42[6] and the U.S. EPA Modal Emission Analysis Model. Summary tables of source intensity (q) in Appendix A of the Guidelines indicate that $\overline{EF}_{ij}$ and $(EF)'_{ij}$ are a function of both signal cycle length and traffic volume. Values for q_{ij} should be obtained from Tables A8 to A12 of Appendix A.

<u>At Non-signalized Intersections</u>

$$q_{ij} = (EF)_{ij}/60D$$

where $(EF)_{ij}$ = average emission factor for vehicle speeds about 0 mph, gm/min-veh, and other symbols are as defined above

The emission factor $(EF)_{ij}$ is the same as described in Section 4.4.2, so the value of 20 gm/min-veh for 1975 (from Figure 8) and the calculation procedure for estimating the factor for years other than 1975 are applicable.

4.5 Selection of Alternatives for Modeling

The objective of the indirect source microanalysis is to determine the highest 1- and 8-hour CO concentrations likely to occur at a reasonable receptor site in the vicinity of a proposed development. In making this determination, several different alternatives that possibly require separate modeling analyses should be evaluated:

- different wind directions must be input to produce maximum CO concentrations at different receptors;

- 1-hour and 8-hour periods have different source emission rates and meteorological conditions;

- peak traffic periods and most adverse meteorological conditions may occur at different times of day.
- peak traffic volumes on access streets may not coincide with peak traffic movement periods in the parking area;
- CO concentrations at receptor sites without the impact of the proposed development (no-build alternative) may be of concern.

Each of the above situations should be considered in preparing a list of alternatives to be modeled for a specific indirect source analysis. Some of the potential alternatives may drop out without performing a modeling analysis. For example, if emission rates are 15 percent higher during the peak traffic period than during the hour with worst meteorology and wind speed is twice as high in the peak traffic period, then it should be clear that the hour with worst meteorology would produce the higher predicted CO concentrations, because the concentration is inversely proportional to wind speed.

In some cases, there are no means of readily determining which alternative will produce the highest predicted concentration without running the alternatives in the HIWAY model. The only input data that are variables after the source-receptor configuration of the site has been established are line source emission rates and meteorological data. These data are input on only a few punch cards, so it may be advantageous to make two or more runs with changes in a few data cards rather than to include all alternatives in one run. Another benefit of this procedure is that it provides an opportunity for an interim review of results.

Analyses of 8-hour periods should be accomplished with relatively high priority, since the 8-hour NAAQS of 10 mg/m^3 (9 ppm) for CO is exceeded more often than the 1-hour NAAQS of 40 mg/m^3 (35 ppm). If the first run shows that the 8-hour standard is threatened but not the 1-hour standard, further analysis of alternatives could focus exclusively on 8-hour periods. Methods of estimating maximum 8-hour CO concentrations with the HIWAY model are discussed in Chapter 7.

5.0 INPUT DATA FORMAT FOR THE HIWAY MODEL

This chapter describes how the data generated per the instructions in the previous chapter are transformed into an input data card deck for the HIWAY program. The discussion concentrates on batch (card deck) rather than interactive (computer terminal keyboard) operation because the amount of data generally necessary for the indirect source analysis would be too time-consuming to input with the interactive mode.

A minimum of seven data cards are required for each line source in the analysis. Table 6 shows the sequence and format for these seven types of input data cards.

Note that all data except the heading (card type 1) are in floating point format with 10-space field widths. It is crucial that a decimal point be placed in each field. Otherwise, the data will be misread and results will be incorrect. It is recommended that the data be left-oriented in the fields, as shown in the columns titled "Forms," to facilitate keypunching and verification.

For indirect source analysis, many line sources (e.g., 10 to 50) will probably be input as a single data set representing one time period. Also, more than one of these data sets of several sources may be included in a computer run of the model. Before the seven types of data cards for another line source are placed in the deck, a card with the value 9999. in columns 1 through 5 should be used to separate this input data from the previous line source's data. The same card should be used between data sets for different alternatives. The card with 9999. should not be used after the final set of line source input data.

Data on card types 5, 6 and 7 are the same for all line sources in a data set representing one time period. Therefore, these cards can be

Table 6. INPUT DATA FORMAT

Card/input name	Columns	Format	Form	Description	Units	Value limits
Type 1 (1 card)						
Heading	1-80	20A4	AAAA	Alphanumeric description of line source segment & other information (e.g., time pd.)	-	-
Type 2 (1 card)						
REP1	1-10	F10.0	XXXX.XXX	East coordinate, pt. 1	Map units	-
SEP1	11-20	F10.0	XXXX.XXX	North coord., point 1	Map units	-
REP2	21-30	F10.0	XXXX.XXX	East coord., point 2	Map units	-
SEP2	31-40	F10.0	XXXX.XXX	North coord., point 2 (end points of the line source are at centerline of road)	Map units	-
H	41-50	F10.0	XX.X	Height of source	Meters	0. or +
WIDTH	51-60	F10.0	XX.	Total width of road incl. center strip (not input for cut section)	Meters	-
CNTR	61-70	F10.0	XX.	Width of center strip (not input for cut section)	Meters	$<$ width
XNL	71-80	F10.0	X.	Number of traffic lanes	-	1. or even integer 2. to 24.
Type 3 (up to 3 cards)						
QLS	1-80	F10.0	.XXXXXXXX	Emission rate for each lane (in order from left to right viewed from pt. 1)	Gm/sec-m	-
Type 4 (1 card; may be blank for at-grade)						
CUT	1-10	F10.0	X.	0. if at-grade 1. if cut section	-	0. or 1.
WIDTC	11-20	F10.0	XX.	Width of top of cut section	Meters	-

Table 6. INPUT DATA FORMAT (continued)

Card/input name	Columns	Format	Form	Description	Units	Value limits
Type 5 (1 card)						
THETA	1-10	F10.0	XXX.	Wind direction, degrees from north	Degrees	0.-360.
U	11-20	F10.0	XX.X	Wind speed	M/sec	1.0 or greater
HL	21-30	F10.0	XXXX.	Height of mixing layer	Meters	>100
XKST	31-40	F10.0	X.	Pasquill stability class: A = 1. D = 4. B = 2. E = 5. C = 3. F = 6.	-	1. to 6.
Type 6 (1 card) GS	1-10	F10.0	X.XXXXXXX	Scale factor for map units: kilometers = 1.0 meters = 0.001 feet = 0.0003048 miles = 1.6093	-	-
Type 7 (up to 50 cards)						
XXRR	1-10	F10.0	XXXX.XXX	East coordinate of receptor*	Map units	-
XXSR	11-20	F10.0	XXXX.XXX	North coordinate of receptor	Map units	-
Z	21-30	F10.0	XX.	Height of receptor	Meters	0. or +

*A value of 9999. is entered in this field following the last receptor card if another set of data is to follow.

duplicated to produce the appropriate number of copies for compilation of the data deck.

The data cards for a run are placed behind the HIWAY program deck as shown in Figure 9. Job control cards for the specific computer system are located at the front of the deck, between the HIWAY program and input data decks, and at the end of the input data. The program can be run on computers that read FORTRAN IV.

The computer CPU time required to run the program is a function of many factors, including the number of sources and receptors. On an IBM 370 computer, about 17 seconds are required to compile the program plus about 0.2 seconds running time for every source-receptor combination. For example, an analysis with 20 sources and 12 receptor sites would take about 65 seconds CPU time (17 + 20 x 12 x 0.2) on this computer. Depending on the number of sources and receptors, either a 3- or 5-minute upper limit should be specified for an IBM 370 in case of an error in the input data.

To simulate a different alternative, only the emission rates (card type 3) and/or meteorological conditions (card type 5) will change. Type 3 and type 5 cards containing data for the second alternative can be manually inserted in the deck, replacing the corresponding cards from the first run. The revised deck is then ready to be run again, although the printout from the first run should be reviewed for errors or unexpected results before the deck is resubmitted.

If the interactive operation of HIWAY through the UNAMAP system is used for an uncomplicated analysis, the same input data must be available. After the computer is accessed, the HIWAY program is initiated by typing the command "hiway." All communication by the user is in lower

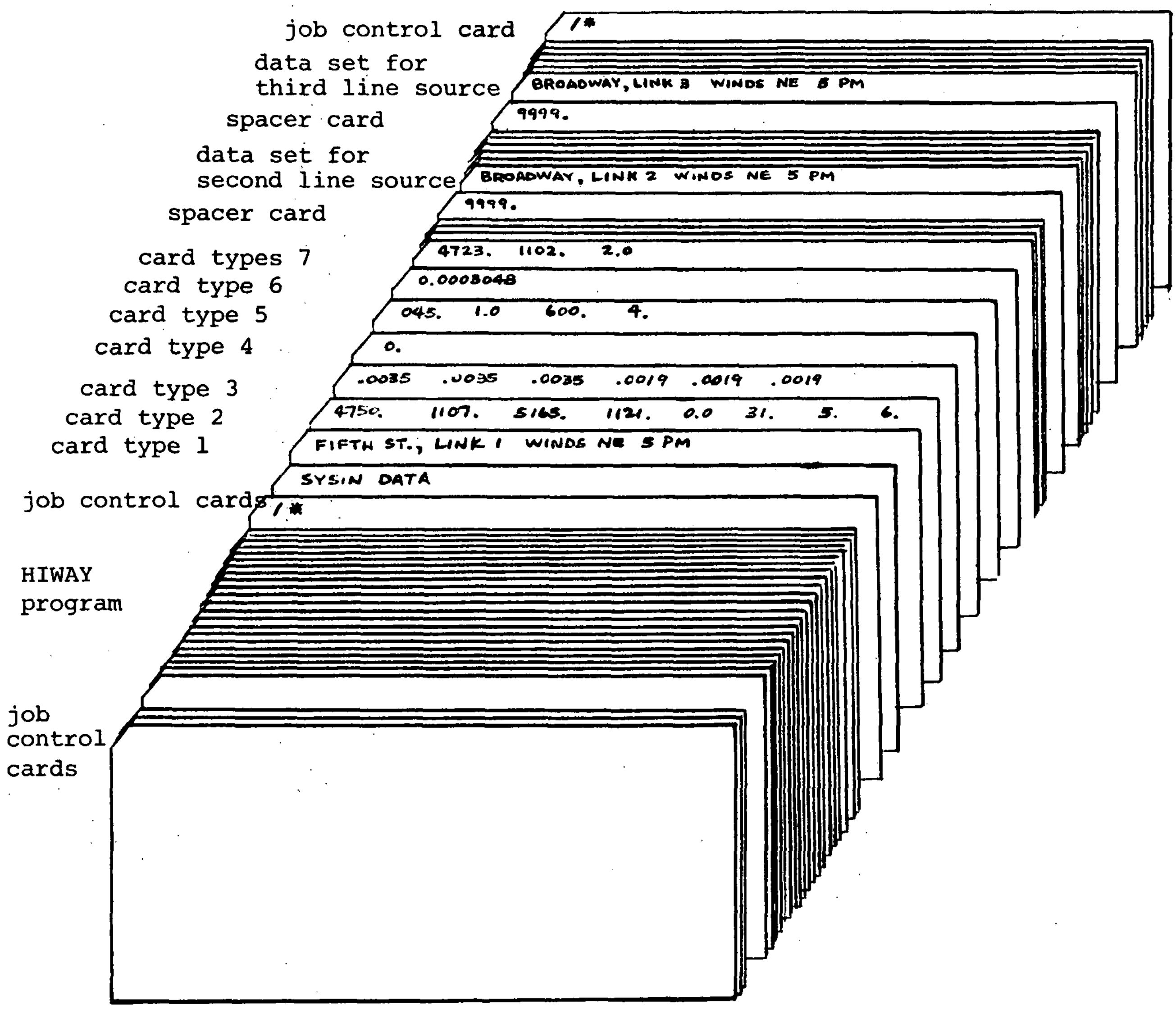

Figure 9. Assembly of HIWAY card deck

case letters. Input data are entered as the computer calls for them. Results are output after the data for each line source have been entered. After the results are printed, options are available to run the model for new receptor locations or a new road segment (line source), or to end the program.

6.0 OUTPUT DATA AND ITS PRESENTATION

The model-calculated CO concentrations, in ug/m^3 and ppm, at all specified receptor locations resulting from the traffic lanes of a single line source are output in the format shown in Figure 10. Notice that the name assigned to the line source on input card 1 is printed as the heading for the output for that data set, and that all other input data are summarized above the tabular presentation of CO concentrations.

The combined impact on any receptor site of all line sources in the vicinity of the proposed development is determined by adding the concentrations contributed by each line source. The same meteorological input data must be used with every source in a data set representing the combined effect of all sources. A convenient tabular format for calculating total predicted CO concentrations at each receptor is shown in Table 7.

The impact of the nearby traffic considered in the model is usually predominant at the specified receptor locations. However, the total CO concentration at any receptor would also have some contribution from other, more distant traffic, commonly referred to as the urban background component. As indicated in Table 7, a value representing the CO background should be added to the model-predicted concentrations at each receptor site before these estimated total concentrations are compared with the National Ambient Air Quality Standards (NAAQS).

Several approaches for estimating background concentrations, depending on what data are available, are described in Section 4.3 of the Guidelines and in Appendix H of the Guidelines. The approaches are summarized below, but it is recommended that the full descriptions from the original references be reviewed before calculating background concentrations.

```
18H4

HIWAY VERSION: 74333
ENDPOINTS OF THE LINE SOURCE
    .415,      .220 AND      .415,      .100
EMISSION HEIGHT IS      .000 METERS
EMISSION RATE (GRAMS/SECOND*METER) OF    1 LANE(S)
    .300-02
WIDTH OF AT-GRADE HIGHWAY IS        5.0 M
WIDTH OF CENTER STRIP IS        .0 M
WIND DIRECTION IS     10.   DEGREES
WIND SPEED IS     1.0 METERS/SEC
STABILITY CLASS IS     4
HEIGHT OF LIMITING LID IS  3000.0 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 *
.2050	-.0075	2.0000	0.	.000
.3350	-.0075	2.0000	27.	.024
.3850	-.0075	2.0000	833.	.725
.4200	-.0075	2.0000	59.	.052
.4650	-.0075	2.0000	0.	.000
.5650	-.0075	2.0000	0.	.000
.6650	-.0075	2.0000	0.	.000
.3975	-.0125	2.0000	612.	.532
.2000	-.0125	2.0000	0.	.000
.2000	.2200	2.0000	0.	.000
.9000	-.0125	2.0000	0.	.000

* PPM CONCENTRATIONS CORRECT FOR CARBON MONOXIDE ONLY.

Figure 10. Example HIWAY output

Table 7. CALCULATION OF TOTAL CO CONCENTRATIONS AT RECEPTOR SITES

Hour of Day ______________

Season ____________________

Wind Direction __________________

Wind Speed, m/sec ______________

Mixing Height, m ________________

Stability Class ________________

Receptor No.					
Receptor Coordinates					
Line Source	CO Concentration, ppm				
Subtotal, ppm					
Estimated Background, ppm					
Total Concentration, ppm					

Approaches for Estimating Background Concentrations

1. Note the second highest 1- and 8-hour concentrations observed at a continuous monitoring station near the site of the proposed source over the past year during the time period of concern. These values should be adjusted to account for the effect that the Federal Motor Vehicle Emission Control Program will have by the first year of the proposed source's operation.

2. Use results of a calibrated mesoscale diffusion model such as APRAC-1A to estimate the highest representative 1- and 8-hour concentrations likely to occur during the time period of concern.

3. If ambient sampling data for a limited period (assumed to be 14 days) at the proposed site plus a full year's data by hour for another site in the urban area (located at least 100 meters from major traffic lanes) are available, the background (x_b) may be calculated as follows:

$$x_b = \frac{\left[\begin{array}{l}\text{Max. observed 1-hr/8-hr conc.}\\ \text{at proposed site during oper-}\\ \text{ating hours}\end{array}\right]\left[\begin{array}{l}\text{Max. observed 1-hr/8-hr conc.}\\ \text{at historical site during}\\ \text{source operating hours in}\\ \text{past year}\end{array}\right]}{\left[\begin{array}{l}\text{Max. observed 1-hr/8-hr conc.}\\ \text{at historical site during}\\ \text{source operating hours during}\\ \text{the limited sampling period}\end{array}\right]}$$

4. If ambient sampling data for a limited period at the proposed site plus maximum observed concentrations at another site in the urban area are available, the background may be calculated as follows:

$$x_b = \frac{\begin{bmatrix}\text{Max. observed 1-hr/8-hr conc.} \\ \text{at proposed site during oper-} \\ \text{ating hours}\end{bmatrix} \begin{bmatrix}\text{Max. observed 1-hr/8-hr conc.} \\ \text{at historical site during} \\ \text{past year}\end{bmatrix}}{\begin{bmatrix}\text{Max. observed 1-hr/8-hr conc.} \\ \text{at historical site during} \\ \text{the limited sampling period}\end{bmatrix}}$$

5. If only ambient sampling data for a limited period at the proposed site are available, the background may be calculated as follows:

$$x_b = \frac{\begin{bmatrix}\text{Max. observed 1-hr/8-hr conc.} \\ \text{at proposed site during oper-} \\ \text{ating hours}\end{bmatrix} \begin{bmatrix}\text{Max. } \bar{X}/\bar{Q} \text{ in site's locale} \\ \text{for any season from Figures} \\ \text{42 - 45 of AP-101}\end{bmatrix}}{\begin{bmatrix}\bar{X}/\bar{Q} \text{ in site's locale from Figures} \\ \text{42 - 45 of AP-101 during time of} \\ \text{year in which sampling is performed}\end{bmatrix}}$$

6. If the source is to be located in a rural area, a natural background of 1 ppm may be assumed.

For each time period and set of meteorological conditions simulated, a different CO concentration is predicted at any given receptor site. The maximum concentration, including background, predicted at a receptor site under any alternative is compared with the 1-hour NAAQS of 40 mg/m^3 (35 ppm) or 8-hour NAAQS of 10 mg/m^3 (9 ppm) as the final step in the indirect source analysis. If one or more of the predicted concentrations exceed the NAAQS, the proposed source's application may not be approved until its traffic handling facilities have been redesigned so that NAAQS can be met.

7.0 ESTIMATION OF MAXIMUM 8-HOUR CO CONCENTRATIONS

In most instances, peak 8-hour CO concentrations are more likely to exceed the NAAQS than are peak 1-hour concentrations. However, there is presently no completely satisfactory procedure for estimating peak 8-hour concentrations, since the HIWAY model is designed to accept input data for 1-hour averaging periods.

The procedure described in Section 4.2 of the Guidelines for estimating peak 8-hour concentrations is to manually modify predicted 1-hour concentrations by applying a persistence factor. The persistence factor, which is always less than 1.0, accounts for variations in meteorology (primarily in wind direction) occurring over an 8-hour period as opposed to a 1-hour period.

The other modification necessary to predict peak 8-hour concentrations by the persistence factor procedure is to input emission rates consistent with the mean hourly traffic volume during the 8-hour period of concern rather than peak 1-hour emission rates. The mean traffic volume for the 8-hour period is always less than peak 1-hour volume.

A method for calculating an appropriate meteorological persistence factor from concurrent wind data, CO sampling data, and traffic data at a site "similar" to the proposed one is also presented in Section 4.2 of the Guidelines.

The persistence factor is calculated as follows:

a. Select an existing indirect source similar to the proposed one.

b. Concurrently monitor hourly traffic volume, wind speed, wind direction, and CO concentrations.

c. Note the highest 1-hour CO concentrations (with wind speed <2 m/sec) and traffic volume during that hour for each day.

d. Note the highest 8-hour average CO concentration and average hourly traffic volume during that period for each day.

e. Calculate a persistence factor, p, for each day:

$$p = \frac{(\text{Max. 8-hr av. CO})}{(\text{Max. 1-hr. CO with } u < 2 \text{ m/sec})} \frac{V_1}{V_8}$$

f. Select the highest observed daily persistence factor for estimating maximum 8-hr CO concentrations.

The steps involved in estimating peak 8-hour concentrations are summarized below:

1. Determine the mean hourly traffic volumes and emission rates on each traffic lane for the 8-hour period of interest.

2. Determine the meteorological input data for the peak 1-hour emission period during the 8 hours according to the instructions outlined in Section 4.3 of this document.

3. Run the HIWAY model with the emission and meteorological input data obtained in steps 1 and 2.

4. Multiply predicted concentrations at each receptor site by the calculated persistence factor to account for lack of persistence in the adverse meteorological conditions.

5. Add a background concentration for the 8-hour period, calculated by one of the approaches described in Chapter 6, to the predicted concentrations to determine the estimated peak 8-hour concentrations for comparison with the NAAQS of 9 ppm.

In addition to the procedure based on a persistence factor relating 1-hour and 8-hour concentrations, several other procedures for estimating peak 8-hour concentrations at proposed developments are discussed in Appendix H of the Guidelines. All of the procedures are empirical in that they require analysis and application of wind data and/or air quality data from the proposed development site or a similar location.

Two of these alternate procedures are:

1. Using predicted maximum hourly traffic volumes for an 8-hour period and observed adverse meteorological data on an hourly basis for that same time period, run the HIWAY model eight times to simulate the successive 1-hour concentrations. Peak 8-hour concentrations can then be obtained by averaging these eight values.

2. Using wind speed and direction observations for the peak 8-hour emission period, construct conditional hourly wind direction change frequency distributions[8] for those periods with low wind speeds. These wind direction change frequency distributions can then be input to a simulation of the proposed site in which receptors are strategically placed, and the simulation repeated with several sets of wind direction change data. To estimate peak 8-hour concentrations for comparison with NAAQS, the highest ratio between estimated 1-hour and 8-hour concentrations at each receptor should be used.

It should be emphasized that these procedures do require collection of wind speed and direction data at a location that is determined to be representative of the proposed site. Any of these three procedures for estimating peak 8-hour concentrations can be used if the necessary data are available and if applied appropriately.

REFERENCES

[1] U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards; "Guidelines for the Review of the Impact of Indirect Sources on Ambient Air Quality"; EPA-450/4-74-010; (January 1975); Research Triangle Park, N. C. 27711.

[2] Zimmerman, J. R. and R. S. Thompson; "User's Guide for HIWAY: A Highway Air Pollution Model"; Environmental Monitoring Series EPA-650/4-008; (February 1975); National Environmental Research Center, U.S. Environmental Protection Agency, Research Triangle Park, N. C. 27711.

[3] American Association of State Highway Officials; "A Policy on Geometric Design of Highways in Urban Areas"; (1957); Washington, D. C.

[4] U.S. Environmental Protection Agency, Office of Air Programs; "Mixing Heights, Wind Speeds and Potential for Urban Air Pollution Throughout the Contiguous United States"; Office of Air Programs Publication Number AP-101; (January 1972); Office of Technical Information and Publications, Research Triangle Park, N. C. 27711.

[5] Turner, D. B.; "Workbook of Atmospheric Dispersion Estimates"; PHS Publication No. 999-AP-26; (1969); U.S. Environmental Protection Agency, Research Triangle Park, N. C. 27711.

[6] U.S. Environmental Protection Agency; "Compilation of Air Pollutant Emission Factors"; Publication Number AP-42; Supplement No. 5 to the Second Edition; (April 1975); Office of Technical Information and Publications, Research Triangle Park, N. C. 27711.

[7] Kunselman, P., H. T. McAdams, C. J. Domke and M. Williams; Automobile Exhaust Emission Modal Analysis Model; (January 1974); U.S. Environmental Protection Agency, Ann Arbor, Michigan.

[8] Meyer, E. L., Jr., and J. E. Quon; "A Method for Simulating Wind Conditions During Atmospheric Stagnation Periods"; J. Appl. Met. 11; (August 1972).

APPENDIX. EXAMPLE ANALYSIS

Problem. A regional shopping center of 780,000 square feet leasable floor space and 3800 parking spaces is to be built in a Southeastern metropolitan area. Completion is expected by January 1978. A plan of the proposed shopping center and surrounding area is shown in Figure A 1.

Traffic volumes on access streets and at entrances/exits to the parking lot for a peak shopping period have been projected by the developer with input from the Highway Department. Estimated traffic demand by hour for each access street and entrance/exit is shown in Table A 1. Average speeds by hour on the access streets are shown in Table A 2. During the peak seasonal shopping period, it is estimated that ambient temperature would be approximately 50° F and that about 30 percent of the vehicles in the parking lot (20 percent on the access streets) would be operating from a cold start. Traffic in the parking area and on 68th and Mill Streets will be about 88 percent light-duty vehicles, 12 percent light-duty trucks. On other streets and highways, the split will be about 80 percent LDV, 12 percent LDT, and 8 percent heavy-duty truck (assume negligible diesel-powered trucks). Extensive queuing is anticipated at two signalized intersections--Florida Boulevard at Irving Boulevard and at Mill Street. Queuing will probably also occur at the non-signalized intersection at 68th Street and Irving Boulevard. The approximate signal times for the signalized intersections and approach capacities for the non-signalized intersection are summarized in Table A 3.

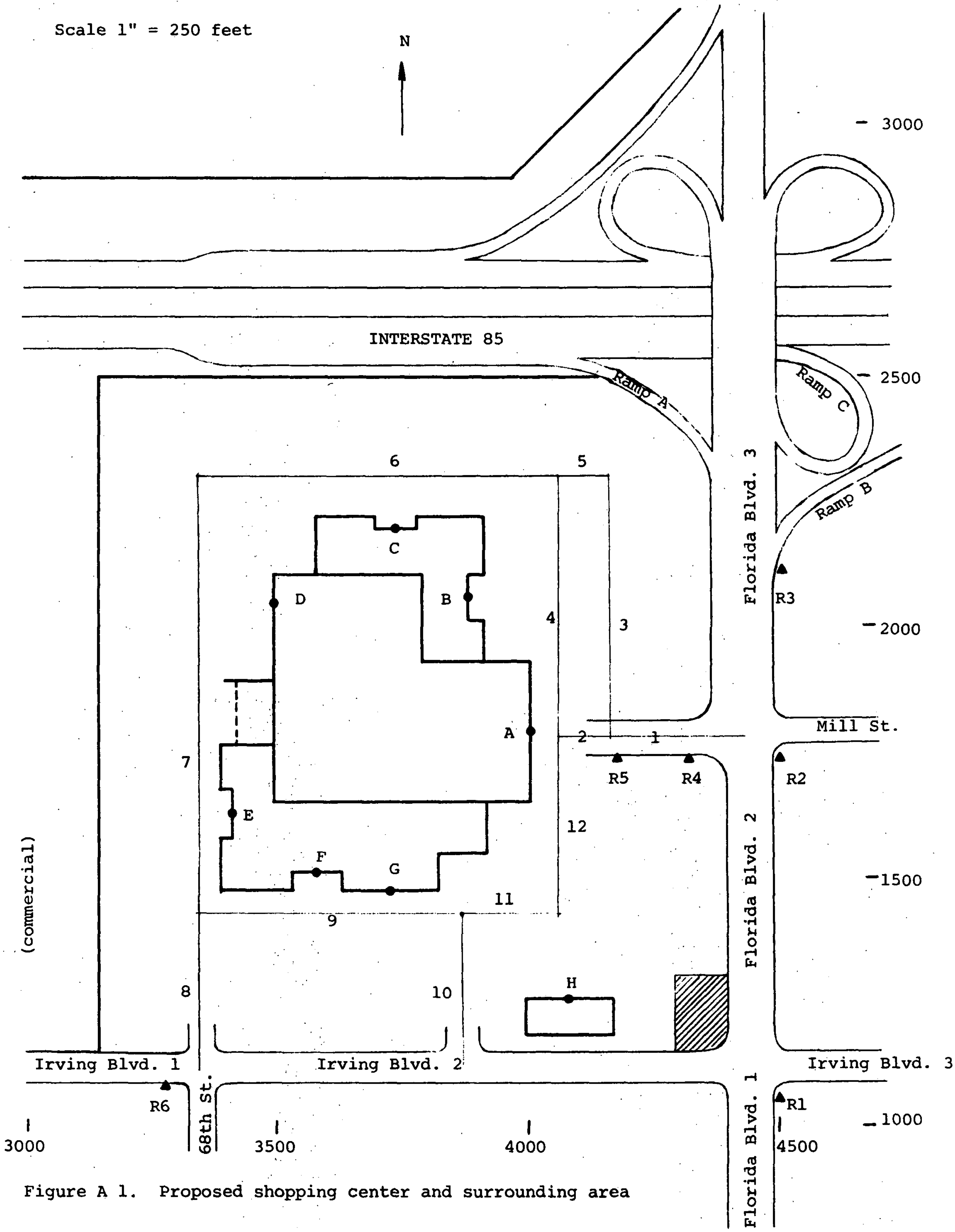

Figure A 1. Proposed shopping center and surrounding area

Table A 1. TRAFFIC DEMAND BY HOUR ON PEAK TRAFFIC DAYS

Hour Beginning	Traffic demand, vehicles/hour													
	Irving 1, E*	Irving 1, W	Irving 2, E	Irving 2, W	Irving 3, E	Irving 3, W	68th, N	68th, S	Florida 1, N	Florida 1, S	Florida 2, N	Florida 2, S	Florida 3, N	Florida 3, S
7 a.m.	460	1170	450	1140	260	850	170	150	1920	1540	1920	1640	2040	1640
8	520	1220	500	1180	300	870	180	150	2120	1600	2140	1730	2470	1940
9	370	540	210	560	140	400	100	140	1460	1100	1510	1240	1420	1340
10	420	380	290	390	210	290	60	130	1290	940	1370	1040	1140	920
11	510	430	380	450	280	310	70	120	1650	1050	1710	1150	1460	1060
12 noon	620	440	620	450	420	320	210	190	1770	1650	1810	1620	1700	1550
1 p.m.	400	610	380	480	300	350	100	90	1190	1320	1200	1380	1240	1220
2	360	350	380	340	260	250	50	50	1080	1020	1200	1110	1230	1070
3	480	430	400	370	290	250	80	60	1210	1520	1290	1610	1200	1590
4	1250	480	1190	480	780	340	90	120	1750	2270	1980	2230	1880	2280
5	1310	470	1200	490	850	340	140	200	1820	2350	2010	2340	1920	2500
6	940	440	820	500	580	380	180	220	1430	1620	1580	1650	1380	1710
7	890	410	800	420	600	310	220	190	1280	1270	1410	1310	1150	1270
8	360	750	350	580	340	420	50	60	860	1120	880	1290	1070	1200
9	320	730	320	500	310	410	40	50	740	1050	720	1110	980	960
10	230	390	270	250	260	200	30	50	510	800	520	850	660	660

*E = eastbound
W = westbound
N = northbound
S = southbound

Table A 1 (continued). TRAFFIC DEMAND BY HOUR ON PEAK TRAFFIC DAYS

Hour Beginning	Traffic demand, vehicles/hour												
	Mill, E	Mill, W	I-85, E	I-85, W	Ramp A, E	Ramp B, E	Ramp C,	East ent.	East exit	South ent.	South exit	S.W. ent.	S.W. exit
7 a.m.	40	160	3410	3850	130	60	80	0	0	0	0	0	0
8	60	200	2600	4220	100	90	120	20	0	0	0	10	0
9	60	130	2520	3160	90	40	100	450	190	130	60	240	100
10	50	70	2250	2100	80	30	50	260	130	70	40	140	70
11	30	60	2280	2350	90	30	40	450	260	130	70	240	140
12 noon	80	110	2770	2920	120	30	40	710	640	210	190	370	340
1 p.m.	90	90	2590	2480	110	50	80	510	710	150	210	270	370
2	70	70	2600	2740	100	40	100	320	390	90	110	170	200
3	80	80	3180	2660	150	30	160	260	190	70	60	140	100
4	140	60	4350	3390	210	100	240	390	320	110	90	200	170
5	200	80	4600	2700	280	80	250	580	450	170	130	310	240
6	180	180	2160	1690	120	100	90	770	510	220	150	410	270
7	160	200	1880	1950	80	70	90	840	580	240	170	440	310
8	100	60	1470	1520	50	110	50	450	770	130	220	240	410
9	90	50	1750	1300	60	80	40	320	770	90	220	170	410
10	80	30	1210	980	40	20	30	130	510	40	150	70	270

E = eastbound
W = westbound
N = northbound
S = southbound

Table A 2. AVERAGE SPEEDS ON ACCESS STREETS

Street	Lanes	Time period	Average speed, mph
Irving Boulevard, all sections	4	All hours	25
68th Street	2	All hours	20
Mill Street	2	All hours	20
Ramps A, B, and C	1	All hours	35
I-85, eastbound	3	All hours except those listed	50
		7-8 a.m.	42
		3-4 p.m.	43
		4-5 p.m.	34
		5-6 p.m.	27
I-85, westbound	3	All hours except those listed	50
		7-8 a.m.	39
		8-9 a.m.	36
		9-10 a.m.	43
		4-5 p.m.	42
Florida Boulevard, sections 1 and 2	4	All hours except those listed	30
		7-8 a.m.	27
		8-9 a.m.	26
		12-1 p.m.	28
		4-5 p.m.	24
		5-6 p.m.	24
Florida Boulevard, section 3	4	All hours except those listed	30
		8-9 a.m.	27
		5-6 p.m.	27

Table A 3. DATA ON INTERSECTION DESIGNS

Intersection	Approach	Green time to signal cycle ratio	Cycles per hr	Capacity, veh/hr
Florida and Irving Boulevards	northbound	0.67	40	
	southbound	0.67		
	eastbound	0.33		
	westbound	0.33		
Florida Boulevard and Mill Street	northbound	0.67	40	
	southbound	0.67		
	eastbound	0.33		
	westbound	0.15		
Irving Boulevard and 68th Street	northbound			600*
	southbound			900
	eastbound			1400
	westbound			1400

*Estimated at half of lane capacities assuming traffic in each direction has right of way half the time.

Based on tenant location, the developer predicts that the building entrances will attract the following percentages of the center's customers:

Building entrance	Percent of customers entering
A	20
B	16
C	12
D	11
E	14
F	6
G	20
H	1

Meteorological data recorded at a nearby airport representative of the shopping center location indicated that the average wind speed was 2.0 m/sec or less in 380 of the hours between 9 a.m. and 11 p.m. during the past year. In the same time periods, wind speed was 1.0 m/sec or less in 131 hours. Wind directions and stability classes corresponding to the hours with wind speed - 1.0 m/sec are shown in Tables A 4 and A 5, respectively.

Ambient CO sampling has been conducted for a two week period on the proposed site (near the coordinates 3600, 1800). The maximum observed CO concentration during that time was 2.5 ppm, from 6 to 7 p.m. on Friday. The maximum 8-hour concentration during source operating hours was 1.8 ppm, from 3 to 11 p.m. on Friday. CO sampling data are also available for another suburban shopping center site in the same city. The maximum 1- and 8-hour values recorded at that similar site on several days throughout the past year are summarized in Table A 6.

Table A 4. WIND DIRECTIONS DURING HOURS WITH WIND SPEED OF 1.0 M/SEC OR LESS

Wind direction, degrees from north	Number of annual occurrences, hours
0	2
10	4
20	0
30	0
40	0
50	3
60	1
70	1
80	0
90	1
100	2
110	4
120	3
130	3
140	0
150	0
160	3
170	7
180	9
190	7
200	14
210	5
220	4
230	4
240	4
250	3
260	3
270	4
280	7
290	12
300	8
310	5
320	2
330	4
340	1
350	1
Total	131

Table A 5. NUMBER OF ANNUAL OCCURRENCES OF WIND SPEED $\leq$ 1 M/SEC BY HOUR OF DAY AND CONCURRENT STABILITY CLASS

Hour Beginning	Stability Class*						Total
	A	B	C	D	E	F	
9 a.m.		2		4			6
10		1		5			6
11	1	1		4			6
12 noon		2		2			4
1 p.m.	2	1		4			7
2	2			3			5
3	1	1		3			5
4	2	3		4			9
5		3		9			12
6		3		10			13
7				12	1		13
8				10	3		13
9				13	2		15
10				14	3		17
Total	8	17	0	97	9	0	131

*Daytime stability classes estimated from Table 5, p. 35. Nighttime stability estimated to be D if sky cover $\geq$ ½, and E if < ½ because of suburban location.

Table A 6. MAXIMUM 1- AND 8-HOUR CO CONCENTRATIONS AT AN EXISTING SUBURBAN SHOPPING CENTER

Date	Max. 1-hour CO, ppm*	Time period	Max. 8-hour CO, ppm	Time period
Jan. 19	18.0	1600-1700	8.8	1300-2100
Jan. 23	15.5	1900-2000	7.0	1500-2300
Feb. 1	12.1	1600-1700	7.3	1300-2100
Feb. 23	14.6	1100-1200	6.5	1000-1800
Feb. 26	15.8	1700-1800	9.3	1400-2200
Apr. 19	20.1	1700-1800	12.0	1500-2300
Jun. 7	10.9	2000-2100	6.5	1500-2300
Jun. 8	14.5	1200-1300	8.5	1100-1900
Jun. 12	15.1	1600-1700	9.1	1500-2300
Sep. 14	16.0	1600-1700	9.0	1000-1800
Sep. 20	15.5	1700-1800	8.1	1500-2300
Sep. 30	12.8	1700-1800	7.7	1400-2200
Oct. 5	16.5	1100-1200	8.5	1100-1900
Nov. 6	16.5	1700-1800	9.9	1500-2300
Nov. 22	11.7	1800-1900	6.8	1400-2200
Nov. 23	19.0	1600-1700	11.1	1200-2000
Dec. 6	16.5	1900-2000	7.2	1300-2100
Dec. 7	16.1	1200-1300	9.4	1200-2000
Dec. 14	21.3	1400-1500	10.7	1300-2100
Dec. 17	26.6	1600-1700	12.8	1500-2300
Dec. 20	23.2	1700-1800	13.0	1400-2200
Dec. 21	27.7	1700-1800	12.9	1400-2200

*Wind speeds during these hours were ≤ 2 m/sec.

Determine whether the traffic associated with the proposed shopping center will cause either CO standard to be exceeded and, if so, where the expected violations will occur.

Solution. The steps in this solution follow those outlined in Figure 1. Many of the initial steps shown in Figure 1 have already been completed as part of the problem description.

1. Select time periods and alternatives for analysis. By reviewing the traffic volume and speed data, it can be determined that the highest emission rates in the vicinity of the shopping center will probably occur between 5 and 6 p.m., as a result of heavy commuter traffic on access streets. The meteorological data in Table A 5 indicate that the most adverse conditions for dispersion (E stability) are likely to occur from 8 to 11 p.m. Therefore, both the 5 to 6 p.m. and 8 to 9 p.m. periods should be analyzed as possible peak 1-hour periods.

Depending on which of those two hours shows the highest CO concentrations, either the 12 noon to 8 p.m. or 3 p.m. to 11 p.m. 8-hour period will be used to calculate the maximum 8-hour concentration. The noon to 8 p.m. period has the highest traffic volumes and the 3 to 11 p.m. period has the most hours of E stability.

The peak traffic season for which the traffic data are applicable is December, which coincides with the time of year with highest probability for low wind speeds and stable atmospheric conditions. Therefore, no other seasonal conditions need to be analyzed. The year to be simulated in the analysis should be 1978, the first year that the shopping center will be open.

2. Determine emission factors. The emission factor for movement in the parking lot can be calculated by adjusting the value obtained from Figure 8 for year, ambient temperature, and percent of vehicles operating from a cold start. An average speed of 10 mph is assumed in the parking lot.

$$(EF)_{78} = (EF)_{75} \text{ (ef/55) (factor for } 50^{\circ} \text{ F, 30\% cold start)}$$
$$= (19.0)\ (35/55)\ (1.6)$$
$$= 19.3 \text{ gm/min-veh}$$

The correction factor of 1.6 is obtained from Table 1 of the Guidelines.

Additional calculations are required to determine emission factors for access streets because of the different speeds for each link and the heavy-duty vehicles present. These factors are summarized in Table A 7. The HDV emission rate, 56.4 gm/min at 18 mph, must be calculated from Supplement No. 5 of AP-42.[6]

3. Calculate total emissions for parking lot. Emissions are estimated from the equation:

$$Q = \frac{(EF)\ (V)\ (RT)}{216{,}000}$$

The emission factor, EF, was determined in step 2 above. Traffic volume, V, is the sum of all vehicles either entering or leaving the parking lot during the time period. According to the data in Table A 1, the values for V in veh/hr are:

5 to 6 p.m. - 1880

8 to 9 p.m. - 2220

12 to 8 p.m. - 1856

3 to 11 p.m. - 1782

Base running time for movement into and out of a parking space has been

Table A 7. EMISSION FACTORS FOR ACCESS STREETS

Average speed, mph	Street section	Emission factor, with 8% HDV, gm/min-veh
50	(I-85 E and W, 8-9 p.m. I-85 W, 5-6 p.m. and 12-8 p.m.)	17.2
44	(I-85 E, 12-8 p.m.)	17.4
35	(Ramps A, B, and C)	18.2
30	(Florida Boulevard 1, 2, and 3, 8-9 p.m.)	18.9
28	(Florida Boulevard 1 and 2, 12-8 p.m.)	19.3
27	(Florida Boulevard 3 and I-85 E, 5-6 p.m.)	19.5
25	(Irving Boulevard)	19.9
24	(Florida Boulevard 1 and 2, 5-6 p.m.)	20.0
20	(68th Street, Mill Street)	15.0 (0% HDV)

The above factors are based on 50° F temperature and 20 percent of vehicles operating from a cold start in 1978.

estimated at 130 seconds. There should be no extra running time due to congestion during the 5 to 6 p.m. period because the parking lot is only about 25 percent (960/3800) full at the beginning of the hour. Accumulation in the parking lot is also less than the 80 percent full level at which running times start increasing appreciably at 8 p.m. Therefore, the base running time can be used for all time periods of interest, and emissions are estimated as follows:

5 to 6 p.m. - 21.8 gm/sec

8 to 9 p.m. - 25.8

12 to 8 p.m. - 21.6

3 to 11 p.m. - 20.7

4. Distribute emissions to lanes in parking lot. Using the procedure presented in Section 3, the parking lot emissions can be allocated to the 12 major traffic links identified in Figure A 1. The calculations for this distribution and the resulting line source emission rates for the 5 to 6 p.m. period are summarized in Table A 8. For other time periods, emission rates by link are proportioned to total parking lot emission rate for the period compared to the 5 to 6 p.m. period.

5. Calculate emission rates for access streets. Emissions rates can be determined directly by use of the equation presented in Section 4.4.2, page 37. In order to obtain the emission rates per lane, the calculated value must be divided by the number of lanes carrying traffic in the given direction on the street. The emission rates are shown in Table A 9.

6. Calculate lengths and emission rates for queues. Using the two equations on page 23 and data from Table A 3, queue lengths during

Table A 8. ALLOCATION OF PARKING LOT EMISSIONS TO TRAFFIC LINKS

Traffic link	Length, feet	Fraction of entering or exiting vehicles using this link		Weighting factor	Line source strength, g/S-m	Emission rate by lane, gm/sec-m	
						5-6 p.m., south or east lane	5-6 p.m., north or west lane
1	250	(.55)	.55	137	.0359	.0078	.0101
2	110	(.55)(.6)	.33	36	.0215	.0094	.0121
3	520	(.55)(.3)	.16	83	.0104	.0059	.0045
4	520	(.55)(.6)(.6)+(.16)(.4)(.8)(.7)+ (.29)(.6)(.5)(.8)(.7)+(.29)(.3)(.6)(.2)	.29	151	.0189	.0106	.0083
5	110	(.55)(.6)(.6)(.2)+(.55)(.3)(.3)+(.16)(.4)(.8)(.7)(.1)+ (.29)(.6)(.5)(.8)(.7)(.2)	.10	11	.0065	.0033	.0032
6	720	(.55)(.6)(.6)(.4)+(.55)(.3)(.3)(.8)+(.29)(.3)(.6)+ (.16)(.4)(.8)(.7)(.3)+(.29)(.6)(.5)(.8)(.7)(.3)	.20	144	.0131	.0061	.0070
7	880	(.55)(.6)(.6)(.4)(.3)+(.55)(.3)(.3)(.8)(.3)+ (.29)(.3)+(.16)(.3)(.4)+(.55)(.6)(.4)(.4)(.9)(.3)	.16	141	.0104	.0055	.0049
8	280	(.29)	.29	81	.0189	.0106	.0083
9	520	(.55)(.6)(.4)(.4)(.9)+(.29)(.6)+(.16)(.3)	.27	140	.0176	.0091	.0085
10	280	(.16)	.16	45	.0104	.0059	.0045
11	190	(.55)(.6)(.4)(.4)+(.29)(.6)(.5)+(.16)(.4)	.20	38	.0131	.0069	.0062
12	350	(.55)(.6)(.4)+(.29)(.6)(.5)(.8)+(.16)(.4)(.8)	.25	88	.0163	.0082	.0081
				1095			

Table A 9. EMISSION RATES BY LANE FOR ACCESS STREETS

Street	Direction	Emission rate for each lane, gm/sec-m 5-6 p.m.	8-9 p.m.	12-8 p.m.	3-11 p.m.
Irving 1	eastbound	.0054	.0015	.0032	.0030
	westbound	.0019	.0031	.0019	.0021
Irving 2	eastbound	.0049	.0014	.0030	.0028
	westbound	.0020	.0024	.0018	.0019
Irving 3	eastbound	.0035	.0014	.0021	.0010
	westbound	.0014	.0017	.0013	.0014
68th Street	northbound	.0011	.0004	.0010	.0008
	southbound	.0016	.0005	.0011	.0009
Florida 1	northbound	.0079	.0028	.0055	.0043
	southbound	.0101	.0037	.0058	.0054
Florida 2	northbound	.0087	.0029	.0056	.0046
	southbound	.0101	.0042	.0059	.0055
Florda 3	northbound	.0048	.0023	.0032	.0028
	southbound	.0063	.0026	.0036	.0033
Mill Street	eastbound	.0016	.0008	.0010	.0010
	westbound	.0006	.0005	.0008	.0007
I-85	eastbound	.0115	.0017	.0041	.0035
	westbound	.0032	.0018	.0030	.0024
Ramp A	eastbound	.0015	.0003	.0008	.0007
Ramp B	eastbound	.0004	.0006	.0003	.0004
Ramp C	SE-bound	.0013	.0003	.0007	.0006
	NW-bound	.0013	.0003	.0007	.0006

peak traffic hours can be estimated. For signalized intersections, traffic volume (V) should be per lane. For the significant queues (greater than 25 meters in length), emission rates over the queue length are then estimated with the equations in Section 4.4.3. These calculations are summarized in Table A 10.

7. List all line sources, record the grid coordinates of their end points, and obtain other dimensions. As indicated in the previous steps of this analysis, there will be 12 access street links, 12 major traffic aisle links in the parking lot, and eight queues. End point coordinates are scaled from Figure A 1 and other dimensions should be obtained from the developer and/or a site visit. These data are presented in Table A 11.

8. Select receptor sites. Receptor sites should be specified at locations near the highest line source emission rates, in directions that are normally downwind of these sources during the periods with adverse meteorology, and at points where the general public is likely to have access for 1- or 8-hour periods. With these criteria, receptors on the east side of Florida Boulevard are likely to have the highest CO concentrations in the vicinity of the shopping center. Due to the right-of-way areas on both sides of I-85, no potential receptor sites can be found near this highway even though it has high emission rates.

For this shopping center, the traffic aisles in the lot are shown to have approximately the same emission rates as the access streets. Therefore, receptor sites should be specified at reasonable locations in or adjacent to the lot. One receptor should be established near the main (east) gate of the shopping center because of the potential queues

Table A 10. QUEUE LENGTHS AND EMISSION RATES

Intersection	Approach	Queue length, meters		Emission rate, gm/sec-m	
		5-6 p.m.	8-9 p.m.	5-6 p.m.	8-9 p.m.
Florida and Irving Boulevards	northbound	60	29	.0084	.0068
	southbound	77	43	.0085	.0078
	eastbound	80	24	.0149	.0136
	westbound	23	28	.0136	.0136
Florida Boulevard and Mill Street	northbound	67	29	.0085	.0068
	southbound	82	40	.0085	.0078
	eastbound	30	52	.0136	.0142
	westbound	14	10	--	--
Irving Boulevard and 68th Street	northbound	1	0	--	--
	southbound	1	3	--	--
	eastbound	109	30	.0425	.0425
	westbound	2	2	--	--

Table A 11. CONFIGURATION OF LINE SOURCES

Line source	End point coordinates, ft. x_1	y_1	x_2	y_2	Width of road, m	Width of median, m	Number of lanes
Access streets							
Irving 1	2500	1119	3358	1119	16.5	0	4
Irving 2	3358	1119	4444	1119	16.5	0	4
Irving 3	4444	1119	5000	1119	15.9	0	4
68th Street	3358	700	3358	1119	7.2	0	2
Florida 1	4444	700	4444	1119	18.9	3.0	4
Florida 2	4444	1119	4444	1782	18.9	3.0	4
Florida 3	4444	1782	4439	3200	27.4	3.0	6
Mill Street	4444	1782	5000	1782	7.1	0	2
I-85	2500	2650	5000	2650	45.7	17.7	6
Ramp A	4018	2557	4340	2443	4.2	0	1
Ramp B	4505	2217	5125	2565	4.2	0	1
Ramp C	4500	2548	4668	2338	8.4	0	2
Parking lot aisles							
1	4174	1776	4444	1776	15.3	0.7	4
2	4067	1776	4174	1776	7.2	0	2
3	4174	1776	4174	2302	7.2	0	2
4	4067	1776	4067	2302	7.2	0	2
5	4067	2302	4174	2302	7.2	0	2
6	3358	2302	4067	2302	7.2	0	2
7	3358	1425	3358	2302	7.2	0	2
8	3358	1119	3358	1425	7.2	0	2
9	3358	1425	3877	1425	7.2	0	2
10	3877	1119	3877	1425	7.2	0	2
11	3877	1425	4067	1425	7.2	0	2
12	4067	1425	4067	1776	7.2	0	2
Queues							
Florida/Irving-							
northbound	4462	1092	4462	895*	4.0	0	2
southbound	4426	1147	4426	1400*	4.0	0	2
eastbound	4413	1105	4151*	1105	4.1	0	2
westbound	4475	1133	4550*	1133	4.1	0	2
Florida/Mill-							
northbound	4462	1751	4462	1531*	4.0	0	2
southbound	4426	1801	4426	2070*	4.0	0	2
eastbound	4399	1763	4300*	1763	3.7	0	2
Irving/68th-							
eastbound	3343	1105	2985*	1105	4.1	0	2

*For 5 to 6 p.m. period; queue length and end point are different for other hours.

at this exit. The highest queue emission rate is at the eastbound Irving Avenue approach to the intersection with 68th Street. Therefore, a receptor should also be specified at the nearest reasonable location to this intersection approach.

The probable critical receptor sites at this proposed development are shown in Figure A 1. Their grid coordinates, summarized in Table A 12, have been calculated based on the street dimensions presented in Table A 11 and reasonable distances away from the curbs.

9. Specify wind speed, mixing height, and stability class for each time period. Based on the data in Tables A 4 and A 5, wind speeds of 1.0 m/sec or less occur in conjunction with most wind directions and during all hours that the shopping center will be in operation. Therefore, this wind speed should be used in the analysis for all alternatives. As discussed above, D stability class is the most adverse condition likely during the 5 to 6 p.m. period and E stability is the most adverse for the 8 to 9 p.m. period. Reference to AP-101,[4] Figure 7, indicates that the mean winter afternoon mixing height for the metropolitan area in which the shopping center is located is 1000 meters. Mixing height for the 8 to 9 p.m. period is estimated to be midway between the morning (minimum) mixing height of 400 meters and the afternoon mixing height. Thus, the approximate 8 to 9 p.m. mixing height is 700 meters.

10. Select wind directions. Wind directions which put the line sources and queues upwind of the receptors plus wind directions nearly parallel to the major line sources should be considered. These

Table A 12. RECEPTOR SITE LOCATIONS

Receptor site	Coordinates, ft. x	y	Height, m
R 1	4483	1080	2
R 2	4498	1723	2
R 3	4505	2122	2
R 4	4350	1748	2
R 5	4200	1748	2
R 6	3275	1086	2

conditions can both be met for the five receptor sites by analysis of three different wind directions--200°, 290°, and 330°.

11. Code input data and run HIWAY model. In order to model the alternatives described above, 12 different data sets must be run: four different emission rates times three wind directions. Three different computer runs of the program will be made, one for each wind direction.

12. Tabulate and total the model-predicted concentrations at each receptor. The contribution from each of the 32 sources in each of the 12 alternatives can be recorded in a tabular format such as presented in Table 7, page 51. The subtotals (minus background) at the six receptor sites under each alternative are summarized in Table A 13.

13. Determine persistence factor for 8 hours. Using the equation presented in the Guidelines, the persistence factor can be calculated as follows:

$$p = \frac{\text{(Max. 8-hr average concentration)}}{\text{(Max. 1-hr concentration with wind speed} < 2 \text{ m/sec)}} \left(\frac{V_1}{V_8}\right),$$

where V_1 = traffic volume demand during hour in which highest CO concentration was observed

V_8 = average hourly traffic volume demand during 8-hour period in which highest CO concentrations were observed

Due to lack of concurrent traffic and CO data at the similar site, it is assumed that average traffic demand during the 8 hours is the same as during the hour with highest CO concentration, or $V_1/V_8 = 1.0$. With this assumption, the highest observed persistence factor during the year of data shown in Table A 6 is 0.603. The model-predicted concentrations using average 8-hour traffic volumes are multiplied by this empirical factor to estimate maximum 8-hour CO concentrations.

Table A 13. SUBTOTALS OF MODEL-PREDICTED CONTRIBUTIONS FROM 32 LINE SOURCES UNDER DIFFERENT ALTERNATIVES

	Unadjusted CO concentration at receptor site, ppm					
Alternative	1	2	3	4	5	6
5-6 p.m., winds 200°	30.0	27.8	24.8	4.4	3.1	neg.
5-6 p.m., winds 290°	28.2	36.2	14.8	29.7	10.6	56.1
5-6 p.m., winds 330°	27.7	22.4	13.9	22.3	17.6	24.1
8-9 p.m., winds 200°	14.6	18.1	22.1	5.3	3.9	neg.
8-9 p.m., winds 290°	21.1	31.2	10.0	34.9	17.6	23.4
8-9 p.m., winds 330°	20.4	17.3	6.3	23.6	17.7	22.5
12-8 p.m., winds 200°	22.3	16.6	18.8	2.8	2.8	neg.
12-8 p.m., winds 290°	18.0	34.2	10.4	29.2	10.4	31.2
12-8 p.m., winds 330°	18.6	14.9	8.0	20.8	16.1	23.0
3-11 p.m., winds 200°	18.8	22.2	22.9	4.9	3.4	neg.
3-11 p.m., winds 290°	24.2	28.6	10.4	29.4	14.2	31.3
3-11 p.m., winds 330°	22.3	20.4	9.9	20.1	14.2	22.7

14. Estimate background concentrations. Background values for the proposed site can be obtained from the limited sampling data at the site plus additional data from a non source oriented CO sampling station, using approach number 3, page 52. The estimated maximum background values are:

$$\text{1-hour } x_b = \frac{(2.5)\ (4.4)}{(2.9)} = 3.8 \text{ ppm}$$

$$\text{8-hour } x_b = \frac{(1.8)\ (2.5)}{(2.1)} = 2.1 \text{ ppm}$$

15. Summarize predicted CO concentrations and compare to NAAQS. After the adjusted 8-hour concentrations have been calculated using the persistence factor and appropriate background concentrations have been added, the resulting values can be compared to the NAAQS. The data shown in Table A 14 indicate that the 1-hour air quality standard of 35.0 ppm would be exceeded under certain conditions at three of the receptor sites, generally as a result of emissions from nearby queuing traffic lines. However, violation of the 8-hour standard would be more widespread, with concentrations above 9.0 ppm occurring at all six receptor sites, during both 8-hour time periods evaluated, and with prevailing winds from any of three directions.

Table A 14. PREDICTED MAXIMUM 1- AND 8-HOUR CO CONCENTRATIONS AT PROPOSED SITE

Alternative	CO concentration at receptor site, ppm					
	1	2	3	4	5	6
<u>1-hour</u>						
5-6 p.m., winds 200°	33.8	31.6	28.6	8.2	6.9	3.8
5-6 p.m., winds 290°	32.0	40.0	18.6	33.5	14.4	59.9
5-6 p.m., winds 330°	31.5	26.2	17.7	26.1	21.4	27.9
8-9 p.m., winds 200°	18.4	21.9	25.9	9.1	7.7	3.8
8-9 p.m., winds 290°	24.9	35.0	13.8	38.7	21.4	27.2
8-9 p.m., winds 330°	24.2	21.1	10.1	27.4	21.5	26.3
<u>8-hour</u>						
12-8 p.m., winds 200°	15.5	12.1	13.5	3.8	3.8	2.1
12-8 p.m., winds 290°	13.1	22.7	8.4	19.7	8.4	20.9
12-8 p.m., winds 330°	13.3	11.1	6.9	14.6	11.8	16.0
3-11 p.m., winds 200°	13.4	15.5	15.9	5.1	4.2	2.1
3-11 p.m., winds 290°	16.7	19.3	8.4	19.8	10.7	21.0
3-11 p.m., winds 330°	15.5	14.4	8.1	14.2	10.7	15.8

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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16. ABSTRACT

A procedure for characterizing emissions of carbon monoxide occurring within parking lots as line sources of pollution is described. A line source dispersion model (HIWAY) is then used to illustrate an approach for estimating the maximum impact of emissions from vehicles in parking lots on nearby 1- and 8- hour ambient concentrations of carbon monoxide.

17. KEY WORDS AND DOCUMENT ANALYSIS

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