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GUIDELINE FOR MODELING CARBON MONOXIDE FROM ROADWAY INTERSECTIONS

Office of Air Quality
Clean Air
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SECTION 1
INTRODUCTION

1.1 Overview

This guideline is designed to evaluate air quality impacts at one or more roadway intersections where vehicular traffic will cause or contribute to increased emissions of carbon monoxide (CO). The explicit purpose of this guideline is to provide a consistent, scientifically acceptable method for estimating the air quality impacts of vehicular traffic at intersections to determine if such impacts may exceed the National Ambient Air Quality Standards (NAAQS) for CO. The NAAQS for CO are as follows:

Averaging Period	NAAQS (ppm)
1 Hour	35
8 Hour	9

This guideline is appropriate for project level analyses in accordance with State Implementation Plans (SIPs), including conformity analyses. This guidance may also be used for Environmental Impact Statements (EISs). Development projects such as street and intersection reconfigurations, mall constructions, and other construction projects that could significantly affect traffic patterns will require air quality impact assessment. For such studies, the effect of the project on traffic, congestion, and subsequent air quality impacts must be studied. This guideline offers guidance for applying dispersion and emission modeling techniques for such analyses.

For SIP evaluations and urbanwide studies, the procedures in this guideline should be used in conjunction with an areawide model. This combined modeling technique will allow the determination of areas that may be in violation of the CO NAAQS, best suited locations for monitor siting, control strategy evaluations, and air quality characterization over broad geographic areas as input to population exposure studies.

The original EPA guidance for intersection CO modeling was to use the *Carbon Monoxide Hot Spot Guidelines* (EPA, 1978a) or the *Guidelines for Air Quality Maintenance Planning and Analysis Volume 9 (Revised): Evaluating Indirect Sources* (EPA, 1978b) (hereafter referred to as Volume 9) for intersection screening. If the results of screening modeling showed a potential for exceedances of the CO NAAQS, then refined analysis of intersections was necessary using Worksheet 2 of Volume 9 for traffic and emissions input to CALINE3 dispersion. Both the Hot Spot Guidelines and Volume 9 have been criticized as being outdated, inadequate, and difficult to use. These techniques are considered outdated for the following reasons:

- The major emissions component is the modal emissions factors which are based on pre-1977 vehicles.
- The correction factors to the modal emissions model are from the MOBILE1 emissions model which has been updated to the MOBILE5 emissions model (EPA, 1992a).
- The traffic component is based on the 1965 Highway Capacity Manual (HCM) which was updated in 1985 (TRB,1985).

These techniques are considered inadequate because they cannot handle overcapacity intersections and are considered difficult to use because they are in a workbook format rather than executable on a personal computer.

The guidance in this document updates the intersection techniques presented in Volume 9. The intent of this guideline is to provide techniques that reflect the current state of emissions calculations (MOBILE5 Emissions Model) and traffic flow and delay (1985 Highway Capacity Manual (HCM)). The EPA has completed studies to evaluate CO intersection modeling techniques (EPA, 1992b). Based on the results of these studies, the CAL3QHC (Version 2.0) model (EPA, 1992c) has been selected as the recommended CO intersection model in the Guideline on Air Quality Models (Revised) (EPA 1986) for intersection modeling. CAL3QHC contains the CALINE3 dispersion model and utilizes procedures in the

1985 Highway Capacity Manual to calculate queue length. The latest version of the MOBILE emissions model is used to calculate emissions input to the CAL3QHC model. Guidance is provided for the modeling of intersections in the form of CAL3QHC input specifications and application techniques.

1.2 Background

Air quality modeling has long been used to estimate CO concentrations at many locations throughout the country. Its primary use has been for analysis at the highway project level. Air quality modeling analyses for highway projects are performed to estimate the air quality pollutant concentrations that will result from the project. Modeling has also been used to aid in siting monitors. Intersection modeling has been useful in screening suspected areas to determine candidate monitor sites for worst case CO air quality. Urban area modeling has been used in some instances to aid in the siting of background monitors. In addition, urban area modeling has been used to evaluate the effects of control strategies for State Implementation Plans and to obtain population exposure estimates.

A number of CO models have been utilized for project level analyses. The *Guidelines for the Review of the Impact of Indirect Sources on Ambient Air Quality, Volume 9: Guidelines for Air Quality Maintenance, Planning, and Analysis* (EPA, 1975a), released in 1975, contains the first EPA recommended technique for project level analysis. This document contains procedures on estimating CO potential concentrations from hot spots such as congested intersections. The traffic component of the Volume 9 procedure is based on the 1965 Highway Capacity Manual (HRB,1965), emissions on the Modal Emissions Model (EPA, 1974), and dispersion on the HIWAY model (EPA, 1975b). In 1978, EPA released a revised version of Volume 9, entitled *Guidelines for Air Quality Maintenance Planning and Analyses Volume 9 (Revised): Evaluating Indirect Sources* (EPA, 1978b). The revised version was similar to the earlier version, except that it required more input data be provided by the user.

Also in 1978, the EPA released the Carbon Monoxide Hot Spot Guidelines (EPA, 1978a). These guidelines, also based on the 1965 Highway Capacity Manual, Modal Emissions Model, and HIWAY dispersion model, contain a number of procedures of varying complexity for highway project analyses. The screening procedure is the easiest to use because it requires the least input. It indicates whether a project has the potential to exceed the CO NAAQS, although it does not estimate concentrations. To obtain concentration estimates, the verification procedure must be utilized. This procedure provides a more thorough evaluation of hot spots than does the screening procedure using physical and operating characteristics specific to a location. Greater data requirements must be provided by the user of the verification procedure, although requirements are still not as demanding as with Volume 9.

The screening and verification procedures of the Carbon Monoxide Hot Spot Guidelines and Volume 9 are in a workbook format. The Intersection Midblock Model (IMM) (NYSDOT, 1982), a computerized model originally part of the Carbon Monoxide Hot Spot Guidelines, is based on the same principles as the verification procedure, but it allows added flexibility in performing an analysis because it is totally computer based. It has since been modified by the State of New York, including one modification that updated the HIWAY Model dispersion component with the HIWAY-2 Model (EPA, 1980).

Several states have developed their own models for project level analysis. The models TEXIN and its update, TEXIN2 (Bullin et al., 1990), were developed by Texas in 1983 and 1987, respectively; the Georgia Intersection Model (GIM) (EMI Consultants, 1985) was developed by Georgia in 1985; the CAL3Q model was developed by EPA Region I in 1987; and successive versions of the CALINE model were developed by California, with CALINE3 (Benson, 1979) in 1979 and CALINE4 (Benson, 1989) in 1984. Most of these models have been used in areas of the country outside the state in which they were originally developed. It should be noted that CALINE3 is simply a dispersion model and does not contain an emissions or traffic component as do the other models mentioned. In fact, the dispersion component of these other models is essentially CALINE3 with, in some cases, very minor modifications.

Because of its widespread use nationally, CALINE3 became the EPA recommended dispersion model for highway project level analysis in 1986. It produces comparable concentration estimates to HIWAY-2. In addition, there have been a number of criticisms raised with the traffic and emissions components of the Volume 9 and Carbon Monoxide Hot Spot Guidelines procedures. The EPA has completed studies to evaluate CO intersection modeling techniques (EPA, 1992b). Based on the results of these studies, the CAL3QHC (Version 2.0) model (EPA, 1992c) has been selected as the recommended CO intersection model in the Guideline on Air Quality Models (Revised) for intersection modeling. CAL3QHC contains the CALINE3 dispersion model and utilizes procedures in the 1985 Highway Capacity Manual to calculate queue length. The latest version of the MOBILE emissions model is used to calculate emissions input to the CAL3QHC model.

In an urban area, sources of mobile emissions are especially widespread. Ambient concentrations of CO may be high near locations where vehicles tend to accumulate, slow down, and idle for a period of time (e.g., at an intersection). The extent of this problem is a direct function of the number of vehicles, their operating mode, their movement, and the length of delay. Thus, the CO distribution across an urban area is not only a function of the distribution of major urban development in the area, but also of individual intersection, street, and traffic characteristics.

Mobile source emissions and air quality impact studies have been the subject of numerous State Implementation Plans and new highway/intersection impact studies in various parts of the United States. The scope of these studies has ranged from modeling (simplified rollback and detailed dispersion modeling analysis) to roadside monitoring programs. The increased understanding of the potential emission contributors (i.e., mobile sources) has allowed the development of reasonable and representative emission and dispersion modeling techniques. These techniques use specific data pertaining to the vehicles, traffic, and roadway configurations at an intersection. Some of the existing models are easy to use and provide a simplified characterization of vehicles and roadways by combining factors into conglomerate effects. Other techniques require the detailed discernment of individual roadway segments or link components, vehicle emissions by operating mode, and integration over link lengths.

This guideline recommends the use of the CAL3QHC (Version 2.0) model for intersections and the combined use of CAL3QHC (Version 2.0) and areawide models for overall urban area analysis.

Either the Urban Airshed Model (UAM) (EPA, 1990) or the RAM model (EPA, 1987) is recommended for urban area CO modeling. Exceedances of the CO NAAQS often occur during the period beginning with the evening rush hour traffic and extending to about midnight on cold, clear nights with strong nighttime radiation inversions and light and variable winds. Under these conditions, motor vehicle and other emissions, such as wood smoke, are trapped under the inversion. The rapid change in mixing height and stability combined with light and variable winds often lead to high CO concentrations that can be handled better by the UAM than the RAM model. The UAM is a numerical model that provides better treatment of the time-dependent change in meteorological conditions than the Gaussian RAM model. However, the UAM is a complex model to execute since it requires a great deal of input data, some of which are difficult to obtain. Thus, although the UAM is better able to handle the conditions leading to CO exceedances than the RAM model, the UAM is more resource intensive, difficult to execute, and costlier than the RAM model. Because of the high cost of collecting input data for and executing the UAM, it is routinely used to evaluate several high CO episodes in an urban area. Because the RAM model uses standard National Weather Service data for an entire year, it provides CO concentrations for each hour of an entire year.

1.3 Scope of Intersection Analyses

Evaluation of the air quality impact of an intersection requires adding the incremental impact of the intersection to background ambient levels at the site and then comparing the total with the NAAQS. The background CO concentrations are due to areawide mobile and stationary sources of emissions. Emphasis in this guidance document is on intersections. Intersections for analysis will be selected from those intersections whose conditions are suspected to be the most conducive to high concentration impacts. For project level analyses, the criteria for intersection modeling depends on whether the project has the potential to create an adverse air quality impact by either significantly increasing traffic or reducing distances from receptors where the public has general access.

The calculation of air quality impacts for intersections depends on the hour of the day, the day of the week, the month or season, the year of analysis, and the averaging time of concern. These factors affect both the traffic and emissions calculations. Generally, the highest concentrations would be expected during the peak hour of traffic. The peak hour traffic conditions are defined as the average or typical values during the hour of the day which usually records the peak hour traffic, rather than the worst case traffic conditions for the entire year.

An overall procedure is necessary for the consistent selection and analysis of intersections. This procedure includes the following:

- The gathering of data related to the project of concern, including traffic and operating characteristics, and roadway configurations and geometry.
- The screening of all intersections to determine the need for additional analysis.
- The ranking of all screened intersections.
- The computation of traffic flow conditions and emissions for intersections requiring further analysis, based on both those vehicles moving through the intersection without stopping (free-flow) and those that are delayed and stopped (queued vehicles).
- The selection of receptor locations.
- The use of dispersion models to calculate estimated concentrations due to intersections.
- The overall tabulation of total concentrations due to the intersection and background.

To provide guidance on the performance of the procedures outlined above, this report is divided into several sections that address each step of the evaluation of intersections. Section 2 provides procedures for selecting appropriate and reasonable receptor locations near intersections. Section 3 describes the procedure for ranking and selecting intersections for modeling. Section 4 presents the overall intersection modeling procedures. Section 5 provides examples and references are given in Section 6.

SECTION 2

RECEPTOR SITING

2.1 Receptor Site Selection

The locations at which concentrations are estimated are known as receptors. As a general rule, receptors should be located where the maximum total project concentration is likely to occur and where the general public is likely to have access. This means that receptors should be located at sites in the vicinity of those portions of the intersection where traffic is likely to be the greatest and the most congested, e.g., along a queue.

2.2 Criteria for Siting Intersection Receptors

Much was written regarding the selection of reasonable receptor locations for air quality impact analysis near intersections in the Volume 9 guidance (EPA, 1978b). The general criteria for receptor siting expressed in the Volume 9 guidance included: 1) places of expected 1-hour and 8-hour maximum concentrations, 2) places where the general public has access over the time periods specified by the NAAQS, and 3) reasonableness. Reasonableness is defined in terms of proximity to the intersection, but not on the roadway itself. Both specific and general locations are recommended for intersection analyses.

An objective of this document is to provide guidance for estimating maximum CO concentrations near an intersection. Roadways are not potential receptor sites. In addition, receptors should not be located within 3 meters of the traveled roadways which comprise the intersection, where vehicle turbulence does not allow current models to make valid concentration estimates. If there is a structure (i.e., building) within the 3 m zone, then the EPA Regional Office should be contacted for a determination of proper receptor siting.

To clarify what might generally be regarded as reasonable and unreasonable receptor sites, a few examples are cited here.

1. Examples of Reasonable Receptor Sites

- All sidewalks to which the general public has access on a more-or-less continuous basis.

- A vacant lot near an intersection, where the general public would have continuous access in the immediate vicinity.

- Portions of a nearby parking lot to which pedestrians have continuous access.

- In the vicinity of parking lot entrances and exits, provided a nearby area contains a public sidewalk, residences, or structures to which the general public is likely to have continuous access.

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

Within the context of these sites, the actual locations of the receptors should be as follows:

- At least 3 m from each of the traveled roadways that comprise the intersection and at a height of 1.8 m; these apply in general to all receptors with further refinements below.

- Nearby occupied lot -- nearest the edge within the lot to which the general public has continuous access. If this cannot be determined, the property line of the lot nearest to traffic lanes should be used.

- Vacant lot -- same as for occupied lot.

- Sidewalks -- present a problem in that the general public is unlikely to occupy a relatively small portion of the walkway continuously. Nevertheless, the general public does have access to the sidewalk as a whole on a continuous basis. Thus, it is appropriate to consider the whole sidewalk as a reasonable receptor site. For the analysis procedures in this guidance, a receptor should be located at least 3 m from each of the traveled roadways which comprise the intersection. If the width of the sidewalk allows, it is recommended that receptors be placed at the midpoint between the curb and the building line. At a minimum receptors should be located near the corner and at mid-block for each approach and departure at the intersection. Receptors should be placed on both sides of the road. For long approaches, it is recommended that receptors be located at 25 m and 50 m from the intersection corner. More receptors can be located where desired by the user.

- Any location near breathing height (1.8 m) to which the general public has continuous access.

2) Examples of Unreasonable Receptor Sites

- Median strips of roadways.
- Locations within the right-of-way on limited access highways.
- Within intersections or on crosswalks at intersections.
- Tunnel approaches.
- Within tollbooths.

For most studies, receptors should be placed at each approach on both sides of where the queues develop. In all cases mentioned above the receptors should be located on the adjacent sidewalk or at the right-of-way limit if no sidewalk exists. An example receptor siting of one intersection approach is shown in Figure 2-1.

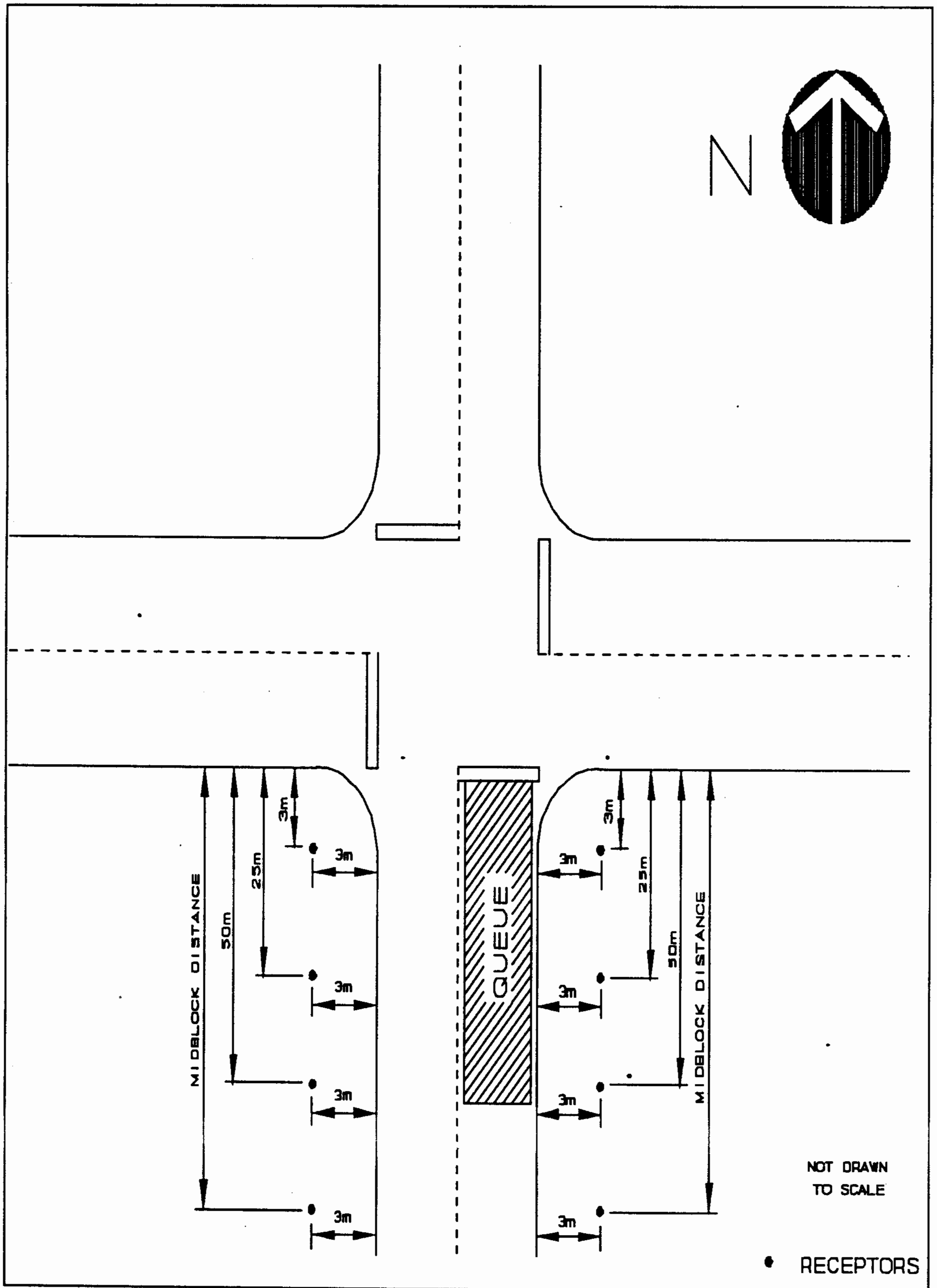

Figure 2-1. Example receptor siting on one intersection approach.

SECTION 3

INTERSECTION SELECTION PROCEDURE

3.1 Rationale

This guidance provides a ranking and selection procedure to allow the discernment of those intersections that could be potential hot spots, i.e., have high CO concentrations. The guidance will be used primarily to determine potential hot spots in a SIP analysis, but will also be useful for project level analysis when more than three intersections are affected. Intersections are first selected for analysis on the basis of the study objectives. Study objectives would include the characterization of potential CO hot spots for the development of a SIP attainment demonstration or a conformity analysis of projects to the SIP. All signalized intersections are reviewed for the potential to create an adverse air quality impact by either significantly increasing traffic or reducing roadway distances from receptors where the general public has access. The selection of intersections for modeling should be based on the ranking procedure discussed in Section 3.3. The calculation of Level-of-Service (LOS) for use in the ranking of intersections is discussed in Section 3.2.

3.2 Level-of-Service Determination

Level-of-Service (LOS) measures the operating conditions in the intersection and how these conditions affect traffic flow and delay. The LOS is a measure of the combined traffic volume, signal timing, and related congestion and delay. It is related both to the physical characteristics of the intersection and to various operating conditions that occur when the intersection is carrying variable traffic volumes (Garber, 1988).

In a signalized intersection, LOS is defined in terms of vehicle delay time (TRB, 1985). The Highway Capacity Manual (HCM) (TRB, 1985) states that LOS delay is:

> "... a measure of driver discomfort, frustration, fuel consumption, and lost travel time. Specifically, level-of-service criteria are stated in terms of the average stopped delay ..."

The following synopsis of each LOS is given in the HCM.

Level-of-Service A - describes operations with very low delay, i.e., less than 5.0 seconds per vehicle.

Level-of-Service B - describes operations with delays in the range of 5.1 to 15.0 seconds per vehicle. More vehicles stop at LOS B than at LOS A, which results in higher levels of average delay.

Level-of-Service C - describes operations with delays in the range of 15.1 to 25.0 seconds per vehicle. A significant number of vehicles stop at this level; however, many still pass through the intersection without stopping.

Level-of-Service D - describes operations with delays in the range of 25.1 to 40.0 seconds per vehicle. At LOS D, the influence of congestion becomes more noticeable. Many vehicles stop, and the proportion of vehicles not stopping declines.

Level-of-Service E - describes operations with delays in the range of 40.1 to 60.0 seconds per vehicle. This is considered to be the highest limit of acceptable delay.

Level-of-Service F - describes operations with delays in excess of 60.0 seconds per vehicle. This is considered to be unacceptable to most drivers. This condition often occurs with oversaturation, i.e., when arrival flow rates exceed the capacity of the intersection.

Intersections with the same LOS can be ranked by degree of delay. As the Level-of-Service decreases, volume-to-capacity ratios increase, progression of vehicles through the intersection decreases, long vehicle queues occur, and idle emissions increase. As part of the procedure for determining critical intersections, those intersections at LOS D, E, or F or those that have changed to LOS D, E, or F because of increased volumes of traffic or construction related to a new project in the vicinity should be considered for modeling. Intersections that are LOS A, B, or C probably do not require further analysis, i.e., the delay and congestion would not likely cause or contribute to a potential CO exceedance of the NAAQS.

3.3 Ranking and Selecting Intersections

The following steps should be used for ranking and selecting intersections for modeling:

1) Rank the top 20 intersections by traffic volumes;

2) Calculate the Level-of-Service (LOS) for the top 20 intersections based on traffic volumes;

3) Rank these intersections by LOS;

4) Model the top 3 intersections based on the worst LOS; and

5) Model the top 3 intersections based on the highest traffic volumes.

It is assumed that if the selected intersections do not show an exceedance of the NAAQS, none of the ranked intersections will. This assumption is based on the assumption that these intersections will have the highest CO impacts and that intersections with less traffic volumes and congestion will have lower ambient air impacts. Thus, if no exceedances of the CO NAAQS occur for the attainment year when the results of the intersection modeling are added to the urban areawide component of the CO concentration at the intersection, then the CO attainment demonstration is complete. If CO exceedances do occur, then further controls are necessary.

SECTION 4

INTERSECTION ANALYSIS

4.1 Evaluation Overview

The analysis procedures in this guidance document are specifically designed for screening analysis of signalized intersections using worst-case meteorological defaults. The use of measured meteorological conditions for a refined analysis will be considered on a case-by-case basis by the local EPA Regional Office. If the intersection modeling analysis is combined with Urban Airshed Model (UAM) results for a SIP analysis, then the measured meteorological conditions used by the UAM for temperature, wind speed, and wind direction should also be used in the CAL3QHC model.

For a SIP areawide analysis, these intersection impacts should be considered together with the contributions from areawide modeling. The areawide model should be the Urban Airshed Model or the RAM Model. These models are used in urban areas to: 1) show locations throughout the urban area with the highest areawide component of CO concentrations and magnitude of these concentrations, 2) evaluate the effects of control strategies for SIPs, 3) obtain characterization of ambient CO levels over broad geographic areas as an input to population exposure models, and 4) determine candidate sites for air quality monitors. As mentioned above, when UAM is combined with CAL3QHC results, the same meteorological conditions for temperature, wind speed, and wind direction should be used for both models. The CAL3QHC model should be run using the UAM hourly temperature, wind speed, and wind direction from the grid square where the intersection is located for each hour of the episode being modeled. The UAM modeled concentration from the grid cell where the intersection is located should be entered into the CAL3QHC model as the background concentration to determine the total impact for each hour. The results should then be averaged over 8 hours to determine the maximum 8-hour concentration.

Figure 4-1 outlines the general evaluation procedures a user would follow if performing a complete comprehensive analysis of multiple intersections, such as for a new project (i.e., a mall or major roadway construction) that would affect traffic on nearby roads, or evaluating intersection impacts for a State Implementation Plan (SIP). In the case where only a few or one intersection is involved, ranking and selection may not be required and the analysis of all sites under consideration may be important.

In Figure 4-1, the small number code in the upper left-hand corner of each box corresponds to the steps described in this section. As shown, the steps that should be followed are a logical sequence in the intersection evaluation procedure. For an individual intersection, the modeling steps are the same except that ranking by volume and LOS are not required. Each step is presented in detail in the following subsections.

4.2 Project/Intersection Description (Step 1)

Step 1 in this evaluation is to provide a good project or intersection related narrative, including diagrams. In the preparation of an air quality impact assessment for a new roadway project or evaluating existing intersections, a qualitative and quantitative description of the traffic and physical characteristics is needed. If a new sports complex or mall is planned, many existing roadways will be affected, and increased traffic will occur to service the facility for events or business. A study of traffic and roadway design and planning will have been performed by professional traffic engineers and planners to forecast the impacts on existing and future traffic levels. The increased intersection and roadway demands translate into higher potential air quality impacts than would have occurred without the project. For the assessment and potential mitigation of intersections, a descriptive and informative overview of each intersection is necessary. Such overviews would allow decision makers to arrive at informed conclusions and interpretations regarding estimated air quality impacts and to form mitigative measures to address potential "hotspots."

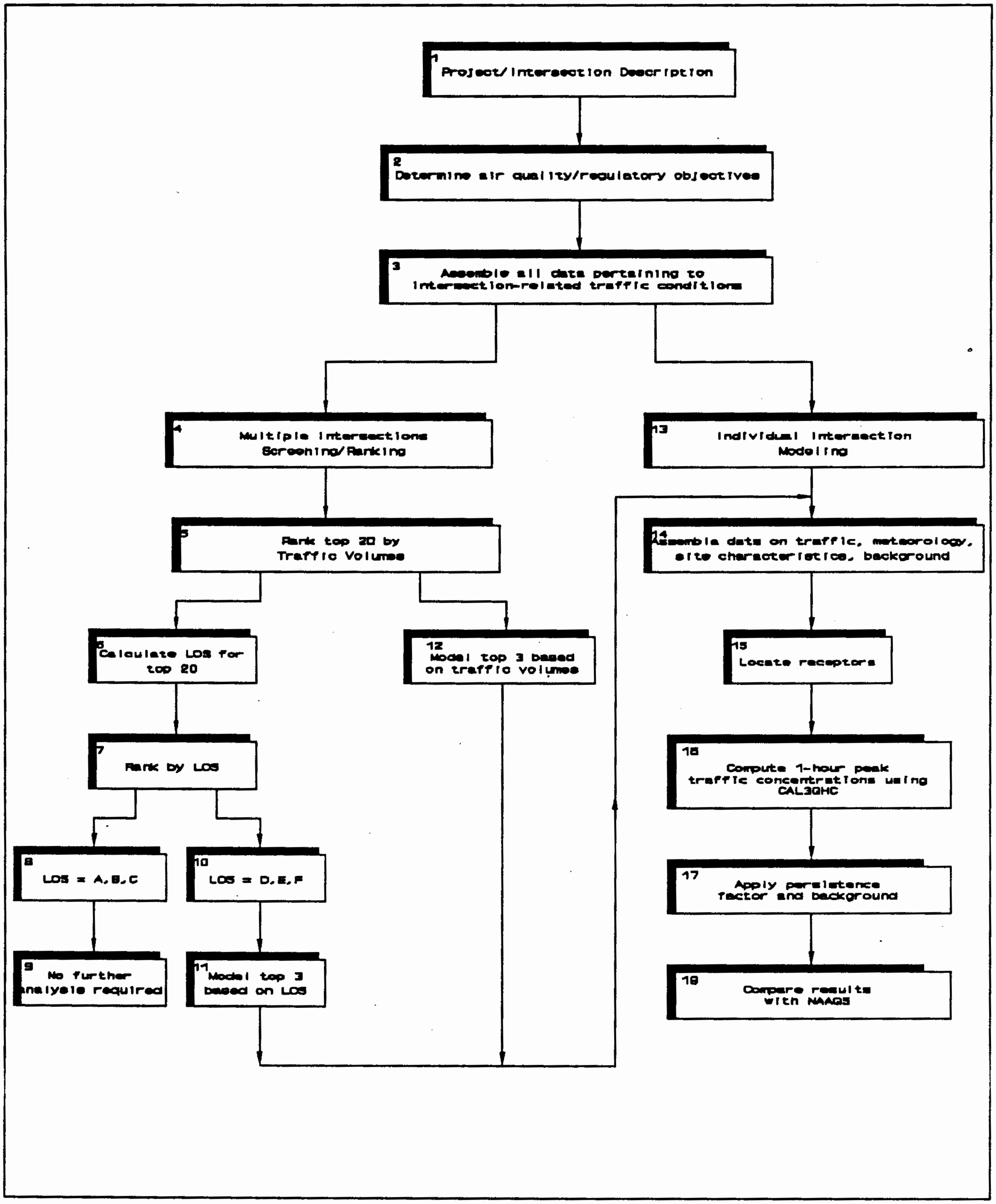

Figure 4-1. Overview of intersection evaluation procedures.

4.3 Air Quality Objectives (Step 2)

Determining the air quality objectives or goals of an analysis of air quality impact due to an intersection is the next required step. The objectives will dictate the level of analysis, the resources, and the amount of effort required. If a project permit review is involved, the specific objective may be to assess the worst case potential for exceeding either the 1-hour or 8-hour CO NAAQS.

4.4 Assembly of All Data (Step 3)

A data base is necessary to formulate inputs to the modeling procedure. Some items that should be included in the data base are as follows:

- A scaled map of the intersection and nearby approaches/departures.
- Traffic engineering characteristics of each approach/departure to be analyzed, i.e., number of lanes, road width, turning channels, type of intersection control, and signal timing.
- Through, turning, and total traffic volumes and speeds for each road for the average peak hour traffic.
- Link coordinates and specification of the coordinate origin.
- Receptor coordinates.
- Background and local CO air quality measurements.
- Meteorological data, if areawide modeling using RAM or UAM will be performed.
- Miscellaneous demographic data, such as urban/rural characterization and diurnal roadway traffic patterns.

4.5 Multiple Intersection Ranking (Steps 4 through 12)

Whenever the study objectives and project scope require the consideration of many intersections, steps 4 through 12 can be implemented. These steps provide a logical sequence of analysis that permits a quick review of intersections to determine which are likely to have the highest ambient air quality impacts based on the total volumes of traffic using the intersections and the delay of traffic (level-of-service) calculations. These two factors, number of vehicles and vehicle delay, are related directly to the emission production at the intersection and therefore provide a direct indicator of related air quality impacts (concentrations are directly proportional to emissions).

Step 4 is the identification of all signalized intersections of consequence identified in Steps 1 through 3. Rank the top 20 intersections by traffic volumes in Step 5. In Step 6, for the top 20 intersections ranked in Step 5, the user must calculate the level-of-service (LOS) for each intersection. This may be accomplished by using the worksheet techniques for signalized intersections given in Chapter 9 of the Highway Capacity Manual (HCM) (TRB, 1985) or by using one of the 1985 Highway Capacity Manual personal computer software packages that have been developed over the past several years. Basically, the level-of-service calculations utilize the number of lanes, lane width, red time, green time, total cycle time, approach speeds, lane capacities, turning movements, and other factors to adjust driver and traffic mix characteristics. In Step 7, the top 20 intersections should then be ranked by the LOS determined in Step 6.

The level-of-service calculations will provide an overall rating for the intersection in terms of a letter classification from A (the least delay and best operating) to F (the most delay and worst congestion and operation). Intersections that are calculated with a current or future level-of-service of A, B, or C (Step 8) need not be considered further because they do not have sufficient traffic volumes and delay to require further review (Step 9). For those intersections with a level-of-service D, E, or F, however, additional analysis (Step 10) is required to determine if these congested intersections should be reviewed further for air quality impacts. The remaining part of this procedure is to analyze the three highest LOS ranked intersections (Step 11) using the CAL3QHC model. Similarly, in Step 12, the three highest traffic ranked intersections should be modeled using the CAL3QHC model. An example of the procedures discussed in this section for ranking intersections is given in Section 5 of this report.

4.6 Individual Intersection Analysis (Steps 13 through 18)

When the multiple intersection screening using the traffic and LOS ranking (Steps 1 through 12) results in one or more intersections requiring further analysis, or when an individual intersection or group of intersections is being considered, the procedures in Steps 13 through 18 should be followed. This guidance is divided into two main components:

1) Steps 13 through 15: Assembling all required data including roadway geometry and receptor locations.

2) Steps 16 through 18: Applying the CAL3QHC model to calculate 1-hour and 8-hour concentrations for comparison with the NAAQS.

In a typical evaluation, the individual intersection or group of three highest ranked intersections based on traffic and LOS (from Steps 1 through 12) would be modeled to calculate 1-hour and 8-hour concentrations for comparison with the NAAQS. When all intersections of interest have been modeled, the analysis may stop. The next step is to mitigate the violating intersections through lane reconfiguration, signal timing, traffic diversion, exclusive vehicle allowances per lane, or other techniques and then to rerun the analysis for the adjusted scenarios.

4.7 Input Data Selection

The remainder of Section 4 provides specific guidance regarding individual inputs for the modeling of an intersection. The calculation of emissions from the movement and delay of vehicular traffic and air quality impacts through dispersion modeling requires specifying particular inputs describing the site geometry, signalization, and ambient meteorological conditions.

4.7.1 Ambient Conditions

Meteorological conditions must be specified for both emission estimates and dispersion modeling. Ambient temperature is required for input to the latest version of the MOBILE emission factor model (hereafter referred to as MOBILE). Wind speed, wind direction, atmospheric stability class, mixing height, and surface roughness are required for input to the CAL3QHC dispersion model.

<u>Temperature</u>

The temperature corresponding to each of the ten highest non-overlapping 8-hour CO monitoring values for the last three years should be obtained. The average 8-hour temperature for each event should be calculated and then all ten values should be averaged for use with MOBILE. The ten highest concentrations and the dates of their occurrence are available in the Aerometric Information Retrieval System (AIRS) from EPA's National Air Data Branch. For most major U.S. cities, these temperatures are available in the Local Climatological Data Summaries published by the U.S. Department of Commerce or from any airport meteorological station. As a simple alternative, the average temperature in January may be used instead of the above approach for determining temperature input to the latest version of the MOBILE emission factor model. When urban areawide modeling utilizing the Urban Airshed Model (UAM) is being used in conjunction with the CAL3QHC intersection model, each hour modeled in the UAM simulation should be modeled with CAL3QHC using the hourly temperature from the UAM grid square where the intersection is located.

<u>Wind Speed</u>

A worst-case wind speed of 1.0 m/s should be used in the CAL3QHC model for all analyses, except when urban areawide modeling using the Urban Airshed Model (UAM) is being performed in conjunction with the CAL3QHC intersection model. In such cases, each hour modeled in the UAM simulation should be modeled with CAL3QHC using the hourly wind speed from the UAM grid square where the intersection is located.

Wind Direction

For the applications of CAL3QHC, every 10° of wind direction from 0 to 350° (or a total of 36 directions) should be used, except when urban areawide modeling using the Urban Airshed Model (UAM) is being performed in conjunction with the CAL3QHC intersection model. In such cases, each hour modeled in the UAM simulation should be modeled with CAL3QHC using the hourly wind direction from the UAM grid square where the intersection is located.

Atmospheric Stability Class

The atmospheric stability class that should be used for intersection analyses varies by the urban/rural nature of the area surrounding the intersection. The following recommended stability classes should be used for the area of interest.

Area	Stability Class
Urban	D (4)
Rural	E (5)

If the land use classification technique of Auer (1978) indicates more than half of the area to be rural, the use of E stability is recommended. If the land use classification technique of Auer shows more than half of the area to be urban, the use of D stability is recommended.

Mixing Heights

A mixing height of 1000 m should be used for all 1-hour and 8-hour estimates. The CAL3QHC model, as with most mobile source models, is not sensitive to mixing height because the ambient impacts are very close to near ground-level sources.

Surface Roughness

Surface roughness (z_0) should be selected from the guidance provided in the CALINE3 manual. Table 4-1 which is reprinted from the CALINE3 manual provides the recommended values for z_o for various land uses. Some recommended values are 321 cm for a central business district area, 175 cm for an office area, and 108 cm for a suburban area.

TABLE 4-1

SURFACE ROUGHNESS LENGTHS (z_o) FOR VARIOUS LAND USES

Type of Surface	z_o (cm)
Smooth desert	0.03
Grass (5-6 cm)	0.75
Grass (4 cm)	0.14
Alfalfa (15.2 cm)	2.72
Grass (60-70 cm)	11.40
Wheat (60 cm)	22.00
Corn (220 cm)	74.00
Citrus orchard	198.00
Fir forest	283.00
City land-use	
Single family residential	108.00
Apartment residential	370.00
Office	175.00
Central business district	321.00
Park	127.00

4.7.2 Estimating 8-Hour Concentrations from 1-Hour Concentrations

The calculation of 8-hour concentration estimates from 1-hour concentration estimates is a technique that has been used since the initial distribution of Volume 9 in 1975. The primary focus in this calculation is on the relationship between 1-hour and 8-hour traffic volumes and meteorological conditions. Because the ratio of the 8-hour to 1-hour concentration estimate (persistence factor) represents a combination of the variability in both traffic and meteorological conditions, the ratio of measured monitored concentrations should be used to determine the persistence factor, since monitoring data include the effects of variability in both traffic and meteorological conditions.

The following specifications for the use of a persistence factor to estimate 8-hour concentrations from predicted maximum 1-hour CO concentrations are for application to the intersection techniques described in this document. The preferred method is to use monitoring data. The persistence factor should be based on values obtained using the ratio of the 8-hour to the maximum 1-hour measured CO concentration within the 8-hour period. This persistence factor should be calculated for each of the 10 highest non-overlapping 8-hour concentrations obtained from the latest three CO seasons of monitoring data and averaged. A CO season is generally defined as the period from October through April, but it may be longer or shorter in some areas of the country. If less than three CO seasons are not available then the use of one or two seasons of data would be allowed. If monitoring data are not available at all or there are less than 3 months of one CO season of data available, then use a 0.7 default factor to convert from a peak 1-hour concentration to a peak 8-hour concentration. The 0.7 factor is a reasonably conservative persistence factor based on studies of monitoring data throughout many regions of the country. Thus, EPA recommends the use of a 0.7 persistence factor in a local area where monitoring data are not available. If a persistence factor other than 0.7 is obtained through the use of monitored data in a local area, it should be used rather than 0.7.

4.7.3 Background Concentrations

Total CO concentrations are a combination of the intersection of interest and background concentrations due to other local sources (i.e., more distant roadways and parking lots or industrial sources). The contributions from other sources may be determined from monitoring data or urban areawide modeling.

For the purposes of this guidance, two levels of background determination are recommended on the basis of the study type.

1) State Implementation Plan (SIP)

For SIP analysis, urban area modeling using UAM or RAM should be used in conjunction with both current and projected (future) CO emission inventories to estimate background. The UAM or RAM CO concentration in the grid square where the intersection is located should be used for background.

2) Project Analysis

For new construction or a project level analysis, background concentrations should be determined using local monitoring data. The background concentration should be obtained from a representative background monitoring site not affected by the intersection of interest. Background monitored data should be adjusted for the future. This can be accomplished by multiplying the present CO background by the ratio of the future MOBILE CO emission factor to the current MOBILE CO emission factor and multiplying by the ratio of future to current traffic. If representative background monitoring data are not available, the EPA Regional Office should be contacted regarding the use of default background concentrations.

4.7.4 Other Input Data

Additional CAL3QHC required inputs are specified in this section to guide the user in the analysis of the air quality impact at an intersection.

Link length

On either side of the intersection, the length of the free-flow link should be the center-to-center distance from the intersection of interest to the next intersection. A maximum of 300 m for this distance is sufficient, but the user may specify a longer distance for completeness. The queue link should originate at the approach stop line and extend to the end of the queue.

Link Width

As in the CALINE3 model, 3 m should be added to either side of each free-flow link. For the queue links, no additional width should be added. The additional width is added to the free-flow links to account for the added mechanical turbulence caused by the moving vehicles.

Receptors

Receptors for the modeling should be located on each side of approach and departure links. The receptors should be located at least 3 m from the edge of each of the traveled roadways which converge at the intersection and where the general public has access (see Section 2). At a minimum, receptors should be located near the corner and at mid-block for each approach and departure at the intersection. Receptors should be placed on both sides of the roadways. In the case of long approaches, it is recommended that receptors be placed at 25 and 50 m from the intersection corner. More receptors can be located where desired by the user. The receptors should be placed vertically at 1.8 m above the ground.

Source Height

The source height should be specified as 0.0 m.

Hot/Cold Starts

Vehicular emissions are greatly affected by vehicular speed, ambient temperature, thermal state of the engine, vehicle age and mileage distribution, inspection and maintenance programs, and fuel volatility and other local requirements. It is recommended that most of these variables be as representative as possible for the analysis area rather than the default MOBILE values. One of the parameters that has the greatest effect on emissions is the percentage of vehicles that are in the cold start and hot start mode. In areas where the local air quality agency has compiled localized cold and hot start percentages, these measured values should be used. For areas that lack localized data, the use of Federal Test Procedure (FTP) conditions (20.6 percent cold start, 27.3 percent hot start) may be used as input to MOBILE.

Variations from these values may be required if conditions are different. Examples include traffic due to a parking lot at a place of employment (high number of cold starts) or a rural or suburban intersection with little nearby parking (high number of stabilized conditions). Extreme examples would include traffic exiting from a park and ride lot where there would be 100 percent cold starts or traffic exiting from a large tunnel where there would be 100 percent hot stabilized conditions.

Vehicle Speed

Vehicle speed should typically be less than the posted speeds. Congestion at the intersection can cause vehicle free-flow speeds to be less than posted or design speeds. It is recommended that the vehicle speed on the link be obtained from traffic engineers familiar with the area under consideration. The vehicle speed for a free-flow link represents the speed experienced by drivers travelling along the link in the absence of the delay caused by the intersection traffic signal. In the absence of recommended information from traffic engineers, the user should use the techniques in Chapter 11 of the Highway Capacity Manual (HCM) (TRB, 1985) to estimate free-flow vehicle speed. The free-flow speeds for arterials as recommended by the HCM are given in Table 4-2. The criteria for the classification of arterials for use in conjunction with the free-flow speeds given in Table 4-2 are presented in Table 4-3. Definitions of suburban, urban, and intermediate are contained in Chapter 11 of the Highway Capacity Manual (TRB, 1985). Considerable caution should be exercised in using these speeds since they represent the traffic operating environment with minimal to moderate pedestrian/parking frictions. In urban areas with significant pedestrian conflicts and/or parking activities (e.g., Central Business Districts, Fringe Business Districts), the use of substantially lower free-flow speeds (e.g., 15 to 20 mph) may be warranted.

TABLE 4-2

FREE FLOW SPEEDS FOR ARTERIALS (SOURCE: TRB, 1985)

Arterial Class	I	II	III
Range of free flow speeds (mph)	35 to 45	30 to 35	25 to 30
Typical free flow speeds (mph)	40	33	27

TABLE 4-3

ARTERIAL CLASS ACCORDING TO FUNCTION AND DESIGN CATEGORY (SOURCE: TRB, 1985)

Design Category	Principal Arterial	Minor Arterial
Suburban	I	II
Intermediate (Suburban/Urban)	II	III
Urban	III	III

SECTION 5

EXAMPLES

Two examples are presented in this section in order to describe the modeling procedures for a SIP attainment demonstration for the year 1995 and a project level analysis for the same year.

5.1 Example of a SIP Attainment Demonstration

Monitoring data for a single central business district monitoring site have indicated that the area is nonattainment for CO. To determine the extent of this nonattainment area and the need for mitigative measures for the current and future CO levels, a modeling analysis was conducted. The local planning agency has prepared average daily traffic (ADT) maps to assist in identifying major roadway corridors and intersections. An inventory of other sources of CO emissions in the area has also been prepared. This areawide inventory was used with the Urban Airshed Model (UAM) and nearby representative hourly meteorological data to model the current urban areawide background concentration of CO. The projected future emissions inventory was then used in the UAM with the same hourly meteorological data to estimate future urban areawide background concentration. These background or areawide concentrations were later added to the local source impacts from individual intersections.

A qualitative and quantitative description of the traffic and physical characteristics in the vicinity of the nonattainment area were compiled. The project related narrative with respect to the modeled intersections including diagrams were included in the final analysis report. The air quality objectives were analyzed in order to determine the level of analysis, the resources, and the amount of effort required to determine whether CO attainment will be reached in 1995 as required under the Clean Air Act Amendments of 1990. All the data required to determine the traffic, level-of-service, emissions, and air quality impacts were assembled. A scaled map of the nonattainment area including all intersections with approaches/ departures identified was obtained. The characteristics of each link including the number of lanes, road width, turning channels, type of intersection control, and signal timing were compiled. Also the through, turning, and total traffic volumes along with vehicle speeds for each link during average peak hourly traffic were obtained. Hourly UAM meteorological data for temperature, wind speed, and wind direction were compiled for input to the CAL3QHC intersection model. A land use analysis using the Auer (1978) land use technique was performed and the results indicated that more than 50% of the area is classified as urban. Thus, stability class D was used for the intersection modeling. Thus, stability class D was used for the intersection modeling. The default mixing height of 1000 meters was also used in CAL3QHC.

For this analysis, the first level in determining CO impacts from multiple locations involved the use of the ADT maps of the area to identify the major vehicular corridors. Any crossings of these major corridors were determined to be locations where air impacts could be consequential, especially if the location was also a signalized intersection. Nonsignalized intersections were not considered further. The results of this data gathering left 35 signalized intersection sites for further analysis.

5.1.1 Ranking by Volume and LOS

The 35 intersections were ranked by traffic volume and the top 20 intersections were identified. The top 20 intersections ranked by traffic volume are as follows:

Location	No. of vehicles/day
Main St. at Local St.	27,600
4th St. at Pine St.	26,286
Wood Ave. at Hurricane Ave.	24,708
Main St. at Pike Ave.	24,144
Vince Ave. at Robert Rd.	23,064
Conley St. at Mary St.	20,922
Town St. at Dodge Ave.	20,704
Spruce St. at Pine St.	19,980
3rd St. at Miami St.	18,306

2nd Ave. at Main St.	17,226
1st Ave. at Pine St.	16,970
Bull Run Rd. at Lard St.	16,142
Winn St. at Simpson Rd	14,644
Concord Ave. at Main St.	14,020
Lantern Lane at Fuller St.	13,645
Thoreau St. at Wood Ave.	13,600
Baker Ave. at Emerson Rd.	13,500
Twister Lane at Hawthorne St.	13,400
Academy Drive at Main St.	13,300
Front St. at Commercial St.	13,100

For the top 20 intersections ranked above for traffic volumes, the level-of-service (LOS) was calculated for each intersection. A computerized version of Chapter 9 of the 1985 Highway Capacity Manual (TRB, 1985) was used to calculate the LOS. The LOS is calculated using the number of lanes, lane width, red time, green time, total cycle time, approach speed, lane capacity, turning movement, and other factors to adjust driver and traffic mix characteristics. The computerized software also provided the capacity of saturated flows of each link which were later used in the dispersion modeling analysis. The top 20 intersections identified above were then ranked by the LOS for each intersection as follows:

Location	LOS
Main St. at Local St.	F
4th St. at Pine St.	F
Main St. at Pike Ave.	F
Vince Ave. at Robert Rd.	F
Conley St. at Mary St.	F
Town St. at Dodge Ave.	F
1st Ave. at Pine St.	F
Winn St. at Simpson Rd	F
Lantern Lane at Fuller St.	F
Wood Ave. at Hurricane Ave.	E
Spruce St. at Pine St.	E
2nd Ave. at Main St.	E
Bull Run Rd. at Lard St.	E
Concord Ave. at Main St.	E
Twister Lane at Hawthorne St.	E
3rd St. at Miami St.	D

Thoreau St. at Wood Ave.	D
Baker Ave. at Emerson Rd.	D
Academy Drive at Main St.	C
Front St. at Commercial St.	B

The intersections with the same LOS are ranked by the degree of delay associated with each intersection. The top three intersections ranked by traffic volume are as follows:

Main St. at Local St.
4th St. at Pine St.
Wood Ave at Hurricane Ave.

The top three intersections ranked by LOS are as follows:

Main St. at Local St.
4th St. at Pine St.
Main St. at Pike Ave.

Two of the intersections are found in both groups, thus the intersection modeling analysis will be performed for the following four intersections:

Main St. at Local St.
4th St. at Pine St.
Wood Ave at Hurricane Ave.
Main St. at Pike Ave.

Detailed model input and output data for the first intersection (Main St. at Local St.) are given in the following sections.

5.1.2 Emissions Modeling

The local air quality agency has compiled localized cold and hot start percentages, which were used as input to MOBILE. The hourly temperature data used in the UAM analysis were used with MOBILE. Also the local recommended values for the Inspection/Maintenance (I/M) and Anti-tampering (ATP) program specifications were used. No local data were available for the VMT mix or annual mileage accumulation rates by age or registration distributions, so MOBILE defaults were used. The base Reid Vapor Pressure (RVP) is assumed to be 9.0 psi and the calendar year is 1995. For the Main St. at Local St. intersection, the free-flow speed of each approach and departure link, as determined by traffic engineers, was 20 mph. The MOBILE input file is shown in Figure 5-1 and the corresponding MOBILE output is shown in Figure 5-2. From the output file, the free-flow (at 20 mph) and queue link emission rates are obtained (17.2 g/mi for the free flow and 259.1 g/hr for the idle or queue). The emission rates are then used as input to the CAL3QHC dispersion model.

```
1
MOBILE - Main St. at Local St.
1
1
1
1
1
2
1
2
1
1
2
4
2
2
1
1
82 30 60 20 0. 0. 75. 3 1 2222 1 11
84 60 20 2222 21 75.0 22112121
1 95 20.0 55.0 18.9 25.3 18.9
                 C55.0 55.0   9.0  9.0 95
```

Figure 5-1. MOBILE input file used in the example.

```
MOBILE - Main St. at Local St.
MOBILE4.1(4Nov91)

-M120 Warning:
+             MOBILE4.1 does not model most 1993 and later Clean Air Act
              requirements; Emission Factors for CY 1993 or later are affected.
 I/M program selected:
     Start year (January 1):               1982
     Pre-1981 MYR stringency rate:          30%
     First model year covered:             1960
     Last model year covered:              2020
     Waiver rate (pre-1981):                0.%
     Waiver rate (1981 and newer):          0.%
     Compliance Rate:                      75.%
     Inspection type:                      Manual decentralized
     Inspection frequency                  Annual
     Vehicle types covered:                LDGV - Yes
                                          LDGT1 - Yes
                                          LDGT2 - Yes
                                           HDGV - Yes
     1981 & later MYR test type:           Idle
 Anti-tampering program selected:
     Start year (January 1):               1984
     First model year covered:             1960
     Last model year covered:              2020
     Vehicle types covered:                LDGV , LDGT1, LDGT2, HDGV
     Type:                                 Decentralized
     Frequency:                            Annual
     Compliance Rate:                      75.0%
     Air pump system disablements:         Yes
     Catalyst removals:                    Yes
     Fuel inlet restrictor disablements:   No
     Tailpipe lead deposit test:           No
     EGR disablement:                      Yes
     Evaporative system disablements:      No
     PCV system disablements:              Yes
     Missing gas caps:                     No
 Total HC emission factors include evaporative HC emission factors.
-------------------------------------------------------------------------------
 Cal. Year: 1995          Region: Low          Altitude:  500. Ft.
                     I/M Program: Yes      Ambient Temp:  55.0 (F)
               Anti-tam. Program: Yes    Operating Mode:  18.9 / 25.3 / 18.9

                    Minimum Temp: 55. (F)  Maximum Temp: 55. (F)
                    Period 1 RVP:  9.0     Period 2 RVP:  9.0 Period 2 Yr: 1995
 Veh. Type:  LDGV  LDGT1  LDGT2   LDGT   HDGV   LDDV   LDDT   HDDV    MC  All Veh
+          ------ ------ ------ ------ ------ ------ ------ ------ ------ ------
 Veh. Spd.:  20.0   20.0   20.0          20.0   20.0   20.0   20.0   20.0
   VMT Mix: 0.602  0.189  0.078         0.035  0.004  0.001  0.084  0.007
 Composite Emission Factors (Gm/Mile)
 Exhst  CO: 15.17  17.92  21.40  18.94  53.96   1.66   1.85  11.47  23.72  17.21
 Hot Stabilized Idle Emission Factors (Gm/Hr)
  Idle  CO:260.97 301.23 366.89 320.43 299.54  22.57  33.61  50.52 230.61 259.09
-------------------------------------------------------------------------------
```

Figure 5-2. MOBILE output file for the input file listed in Figure 5-1.

5.1.3 Dispersion Modeling

The intersection at Main St. and Local St. is located in the suburban portion of the city near many small office complexes. The recommended surface roughness length for this type of land use is 175 cm (see Table 4-1). The Main St. and Local St. intersection is characterized by Main St., a four-lane, two-way street running north-south with average daily traffic of about 18,400 vehicles and a peak-hour volume of 1,500 vehicles in each direction. The cross-street (Local St.) is a one-way street toward the east with an average daily traffic volume of 9,200 vehicles and a peak-hour volume of 800 vehicles. Figure 5-3 shows the geometry of the intersection, including the coordinate endpoints of each link, the model assumed roadway widths, and the receptor locations.

The criteria presented in Section 2 were used in the selection of the receptor locations. Receptors were located on both sides of the street. The receptors were located near the sidewalk center, 3 m (10 ft) from the nearest lane edge at a height of 1.8 m (6 ft). Receptors were located at the corner, along with 25 and 50 m from the corner because the midblock distance was greater than 50 m.

All site geometry, land and receptor coordinates and configurations, traffic volume for the peak hour, and meteorological data were used to compile the CAL3QHC input file shown in Figure 5-4. The intersection modeling analysis results will be combined with UAM results for this SIP analysis. Therefore, the hourly temperature, wind speed, and wind direction from the UAM grid square where the intersection is located were also used in the CAL3QHC model. The UAM concentration from the grid square where the intersection is located was input to the CAL3QHC model as the background concentration to determine the total impact for each hour. The results were then averaged over 8 hours to determine the maximum 8-hour concentration. The CAL3QHC output file for one hour where the UAM background concentration is 3 ppm is shown in Figure 5-5.

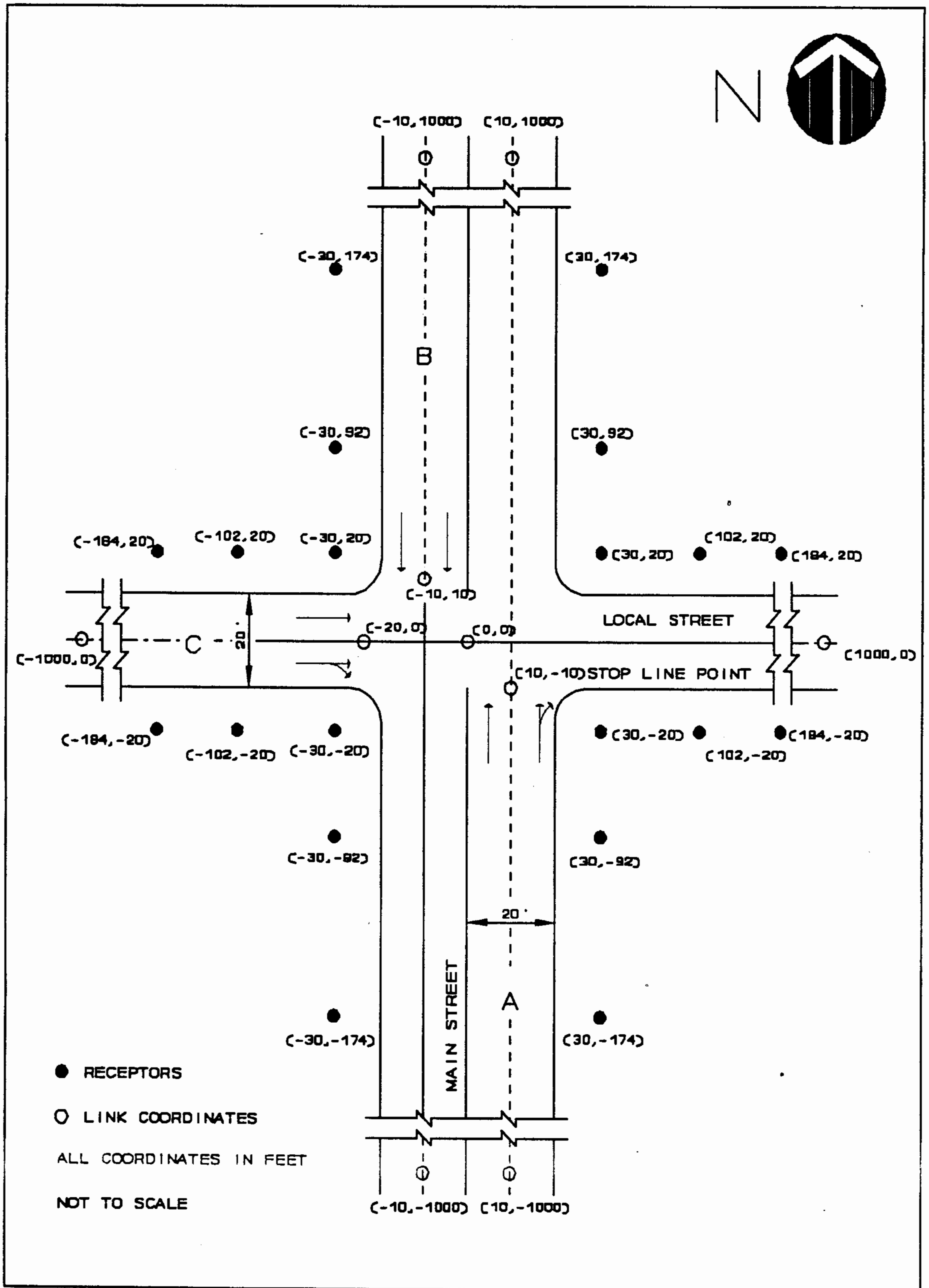

Figure 5-3. Geometric layout of Main St. and Local St. for example intersection.

```
Main Street at Local Street              60.175.   0.   0.20     .3048    1    0
REC 1                     30.      20.       6.
REC 2                    102.      20.       6.
REC 3                    184.      20.       6.
REC 4                     30.     -20.       6.
REC 5                    102.     -20.       6.
REC 6                    184.     -20.       6.
REC 7                     30.     -92.       6.
REC 8                     30.    -174.       6.
REC 9                    -30.     -20.       6.
REC 10                   -30.     -92.       6.
REC 11                   -30.    -174.       6.
REC 12                  -102.     -20.       6.
REC 13                  -184.     -20.       6.
REC 14                   -30.      20.       6.
REC 15                  -102.      20.       6.
REC 16                  -184.      20.       6.
REC 17                   -30.      92.       6.
REC 18                   -30.     174.       6.
REC 19                    30.      92.       6.
REC 20                    30.     174.       6.
MAIN ST. AND LOCAL ST. INTERSECTION      9  1   0
  1
Main St.NB Appr.    AG    10. -1000.    10.     0.   1500.17.2  0. 40.
  2
Main St.NB Queue    AG    10.   -10.    10. -1000.    0.   20.   2
        90        40       3.0 1500 259.1  1700 2 1
  1
Main St.NB Dep.     AG    10.     0.    10.  1000.   1500.17.2  0. 40.
  1
Main St.SB Appr.    AG   -10.     0.   -10.  1000.   1500.17.2  0. 40.
  2
Main St.SB Queue    AG   -10.    10.   -10.  1000.      0. 20.   2
        90        40       3.0 1500  259.1 1800 2 1
  1
Main St.SB Dep.     AG   -10.     0.   -10. -1000.   1500.17.2  0. 40.
  1
Local St. Appr.     AG     0.     0. -1000.     0.    800.17.2  0. 40.
  2
Local St. Queue     AG   -20.     0. -1000.     0.      0. 20.   2
        90        50       3.0  800  259.1 1400 2 3
  1
Local St. Dep.      AG     0.     0.  1000.     0.    800.17.2  0. 40.
 2. 10.4  1000. 3.0N
```

Figure 5-4. The CAL3QHC model input file used for the SIP attainment example.

```
                  CAL3QHC: LINE SOURCE DISPERSION MODEL - VERSION 2.0, JANUARY 1992              PAGE  1

JOB: Main Street at Local Street                         RUN: MAIN ST. AND LOCAL ST. INTERSECTION
DATE: 11/10/92   TIME: 13:33

 SITE & METEOROLOGICAL VARIABLES
 -------------------------------
 VS =    0.0 CM/S        VD =    0.0 CM/S       Z0 = 175. CM
  U =  2.0 M/S           CLAS =   4  (D)      ATIM =  60. MINUTES     MIXH =   1000. M   AMB =  3.0 PPM  BRG =  10. DEGREES

 LINK VARIABLES
 --------------
   LINK DESCRIPTION      *            LINK COORDINATES (FT)            *   LENGTH  BRG TYPE   VPH    EF      H    W    V/C QUEUE
                         *   X1         Y1         X2         Y2       *    (FT)  (DEG)            (G/MI)  (FT) (FT)        (VEH)
-------------------------*---------------------------------------------*------------------------------------------------------------
 1. Main St.NB Appr.     *     10.0    -1000.0       10.0        0.0 *   1000.   360. AG   1500.  17.2   0.0 40.0
 2. Main St.NB Queue     *     10.0      -10.0       10.0     -221.3 *    211.   180. AG    618. 100.0   0.0 20.0 0.88  10.7
 3. Main St.NB Dep.      *     10.0        0.0       10.0     1000.0 *   1000.   360. AG   1500.  17.2   0.0 40.0
 4. Main St.SB Appr.     *    -10.0        0.0      -10.0     1000.0 *   1000.   360. AG   1500.  17.2   0.0 40.0
 5. Main St.SB Queue     *    -10.0       10.0      -10.0      199.3 *    189.   360. AG    618. 100.0   0.0 20.0 0.83   9.6
 6. Main St.SB Dep.      *    -10.0        0.0      -10.0    -1000.0 *   1000.   180. AG   1500.  17.2   0.0 40.0
 7. Local St. Appr.      *      0.0        0.0    -1000.0        0.0 *   1000.   270. AG    800.  17.2   0.0 40.0
 8. Local St. Queue      *    -20.0        0.0     -129.4        0.0 *    109.   270. AG    772. 100.0   0.0 20.0 0.74   5.6
 9. Local St. Dep.       *      0.0        0.0     1000.0        0.0 *   1000.    90. AG    800.  17.2   0.0 40.0
```

Figure 5-5. The CAL3QHC model output file for the SIP attainment example.

JOB: Main Street at Local Street RUN: MAIN ST. AND LOCAL ST. INTERSECTION
DATE: 11/10/92 TIME: 13:33

ADDITIONAL QUEUE LINK PARAMETERS

LINK DESCRIPTION	CYCLE LENGTH (SEC)	RED TIME (SEC)	CLEARANCE LOST TIME (SEC)	APPROACH VOL (VPH)	SATURATION FLOW RATE (VPH)	IDLE EM FAC (gm/hr)	SIGNAL TYPE	ARRIVAL RATE
2. Main St.NB Queue	90	40	3.0	1500	1700	259.10	2	1
5. Main St.SB Queue	90	40	3.0	1500	1800	259.10	2	1
8. Local St. Queue	90	50	3.0	800	1400	259.10	2	3

RECEPTOR LOCATIONS

RECEPTOR	COORDINATES (FT) X	Y	Z
1. REC 1	30.0	20.0	6.0
2. REC 2	102.0	20.0	6.0
3. REC 3	184.0	20.0	6.0
4. REC 4	30.0	-20.0	6.0
5. REC 5	102.0	-20.0	6.0
6. REC 6	184.0	-20.0	6.0
7. REC 7	30.0	-92.0	6.0
8. REC 8	30.0	-174.0	6.0
9. REC 9	-30.0	-20.0	6.0
10. REC 10	-30.0	-92.0	6.0
11. REC 11	-30.0	-174.0	6.0
12. REC 12	-102.0	-20.0	6.0
13. REC 13	-184.0	-20.0	6.0
14. REC 14	-30.0	20.0	6.0
15. REC 15	-102.0	20.0	6.0
16. REC 16	-184.0	20.0	6.0
17. REC 17	-30.0	92.0	6.0
18. REC 18	-30.0	174.0	6.0
19. REC 19	30.0	92.0	6.0
20. REC 20	30.0	174.0	6.0

MODEL RESULTS

REMARKS : In search of the angle corresponding to the maximum concentration, only the first angle, of the angles with same maximum concentrations, is indicated as maximum.

WIND ANGLE (DEGR)	CONCENTRATION (PPM) REC1	REC2	REC3	REC4	REC5	REC6	REC7	REC8	REC9	REC10	REC11	REC12	REC13	REC14	REC15	REC16	REC17	REC18	REC19	REC20
10.	3.6	3.0	3.0	3.9	3.2	3.2	3.8	4.0	6.4	5.2	5.0	4.8	3.4	5.4	3.5	3.2	5.2	4.5	3.5	3.5

THE HIGHEST CONCENTRATION IS 6.40 PPM AT 10 DEGREES FROM REC9 .
THE 2ND HIGHEST CONCENTRATION IS 5.40 PPM AT 10 DEGREES FROM REC14.
THE 3RD HIGHEST CONCENTRATION IS 5.20 PPM AT 10 DEGREES FROM REC10.

Figure 5-5. Continued.

The maximum 1-hour UAM plus CAL3QHC modeled concentration was 6.4 ppm and the maximum 8-hour concentration was 4.0 ppm. The highest modeled CO concentrations for both the 1-hour and 8-hour averaging periods are less than the NAAQS, so further analysis of this intersection is not required. The modeling analysis was then conducted for the remaining three intersections discussed in Section 5.1.2.

5.2 Example of a Project Level Analysis

The same intersection example presented in Section 5.1 is used to demonstrate a project level analysis. The temperature corresponding to the ten highest non-overlapping 8-hour CO monitoring values for the last three years were obtained from nearby, representative monitors. The average 8-hour temperature for each of the ten highest events was calculated and then averaged over all ten events for use with MOBILE. For a project level analysis, the default meteorological data of a 1 m/s wind speed, every 10° of wind direction from 0 to 350°, and 1000 m mixing height were used as input to the CAL3QHC model. Since the project was located in an urban area, the neutral (D) stability class was also input to CAL3QHC. The 1-hour background concentration was obtained from a representative background monitoring site not affected by the Main St. and Local St. intersection. The 1-hour background concentration of 2.7 ppm was input to the CAL3QHC model. The CAL3QHC input file is shown in Figure 5-6 and the CAL3QHC output file associated with this project level analysis is presented in Figure 5-7.

The three most recent CO seasons (October through April) of monitoring data were used to calculate a persistence factor to convert from 1-hour to 8-hour concentrations. The persistence factor was calculated using the 10-highest non-overlapping 8-hour concentrations and the highest 1-hour concentration in each 8-hour period. The average of the ratios of the ten 8-hour to 1-hour values was determined to be 0.65. As shown in Figure 5-7, the maximum 1-hour concentration for this intersection is 9.1 ppm and the maximum 8-hour concentration is calculated to be 5.9 ppm using the 0.65 persistence factor.

```
Main Street at Local Street                    60.175.    0.    0.20      .3048     1     0
REC 1                      30.         20.         6.
REC 2                     102.         20.         6.
REC 3                     184.         20.         6.
REC 4                      30.        -20.         6.
REC 5                     102.        -20.         6.
REC 6                     184.        -20.         6.
REC 7                      30.        -92.         6.
REC 8                      30.       -174.         6.
REC 9                     -30.        -20.         6.
REC 10                    -30.        -92.         6.
REC 11                    -30.       -174.         6.
REC 12                   -102.        -20.         6.
REC 13                   -184.        -20.         6.
REC 14                    -30.         20.         6.
REC 15                   -102.         20.         6.
REC 16                   -184.         20.         6.
REC 17                    -30.         92.         6.
REC 18                    -30.        174.         6.
REC 19                     30.         92.         6.
REC 20                     30.        174.         6.
MAIN ST. AND LOCAL ST. INTERSECTION          9   1    0
  1
Main St.NB Appr.     AG     10. -1000.     10.      0.    1500.17.2  0. 40.
  2
Main St.NB Queue     AG     10.    -10.    10. -1000.     0.    20.    2
        90         40        3.0 1500 259.1  1700 2 1
  1
Main St.NB Dep.      AG     10.      0.    10.  1000.    1500.17.2  0. 40.
  1
Main St.SB Appr.     AG    -10.      0.   -10.  1000.    1500.17.2  0. 40.
  2
Main St.SB Queue     AG    -10.     10.   -10.  1000.      0. 20.    2
        90         40        3.0 1500  259.1 1800 2 1
  1
Main St.SB Dep.      AG    -10.      0.   -10. -1000.    1500.17.2  0. 40.
  1
Local St. Appr.      AG      0.      0. -1000.      0.     800.17.2  0. 40.
  2
Local St. Queue      AG    -20.      0. -1000.      0.      0. 20.    2
        90         50        3.0  800  259.1 1400 2 3
  1
Local St. Dep.       AG      0.      0.  1000.      0.     800.17.2  0. 40.
 1.  0.4 1000. 2.7Y 10   0 36
```

Figure 5-6. The CAL3QHC model input file used for the project level example.

CAL3QHC: LINE SOURCE DISPERSION MODEL - VERSION 2.0, JANUARY 1992 PAGE 1

JOB: Main Street at Local Street RUN: MAIN ST. AND LOCAL ST. INTERSECTION
DATE: 11/10/92 TIME: 13:39

SITE & METEOROLOGICAL VARIABLES

VS = 0.0 CM/S VD = 0.0 CM/S Z0 = 175. CM
U = 1.0 M/S CLAS = 4 (D) ATIM = 60. MINUTES MIXH = 1000. M AMB = 2.7 PPM

LINK VARIABLES

LINK DESCRIPTION	X1	Y1	X2	Y2	LENGTH (FT)	BRG (DEG)	TYPE	VPH	EF (G/MI)	H (FT)	W (FT)	V/C	QUEUE (VEH)
	LINK COORDINATES (FT)												
1. Main St.NB Appr.	10.0	-1000.0	10.0	0.0	1000.	360.	AG	1500.	17.2	0.0	40.0		
2. Main St.NB Queue	10.0	-10.0	10.0	-221.3	211.	180.	AG	618.	100.0	0.0	20.0	0.88	10.7
3. Main St.NB Dep.	10.0	0.0	10.0	1000.0	1000.	360.	AG	1500.	17.2	0.0	40.0		
4. Main St.SB Appr.	-10.0	0.0	-10.0	1000.0	1000.	360.	AG	1500.	17.2	0.0	40.0		
5. Main St.SB Queue	-10.0	10.0	-10.0	199.3	189.	360.	AG	618.	100.0	0.0	20.0	0.83	9.6
6. Main St.SB Dep.	-10.0	0.0	-10.0	-1000.0	1000.	180.	AG	1500.	17.2	0.0	40.0		
7. Local St. Appr.	0.0	0.0	-1000.0	0.0	1000.	270.	AG	800.	17.2	0.0	40.0		
8. Local St. Queue	-20.0	0.0	-129.4	0.0	109.	270.	AG	772.	100.0	0.0	20.0	0.74	5.6
9. Local St. Dep.	0.0	0.0	1000.0	0.0	1000.	90.	AG	800.	17.2	0.0	40.0		

Figure 5-7. The CAL3QHC model output file for the project level example.

JOB: Main Street at Local Street RUN: MAIN ST. AND LOCAL ST. INTERSECTION
DATE: 11/10/92 TIME: 13:39

ADDITIONAL QUEUE LINK PARAMETERS

LINK DESCRIPTION	CYCLE LENGTH (SEC)	RED TIME (SEC)	CLEARANCE LOST TIME (SEC)	APPROACH VOL (VPH)	SATURATION FLOW RATE (VPH)	IDLE EM FAC (gm/hr)	SIGNAL TYPE	ARRIVAL RATE
2. Main St.NB Queue	90	40	3.0	1500	1700	259.10	2	1
5. Main St.SB Queue	90	40	3.0	1500	1800	259.10	2	1
8. Local St. Queue	90	50	3.0	800	1400	259.10	2	3

RECEPTOR LOCATIONS

RECEPTOR	COORDINATES (FT) X	Y	Z
1. REC 1	30.0	20.0	6.0
2. REC 2	102.0	20.0	6.0
3. REC 3	184.0	20.0	6.0
4. REC 4	30.0	-20.0	6.0
5. REC 5	102.0	-20.0	6.0
6. REC 6	184.0	-20.0	6.0
7. REC 7	30.0	-92.0	6.0
8. REC 8	30.0	-174.0	6.0
9. REC 9	-30.0	-20.0	6.0
10. REC 10	-30.0	-92.0	6.0
11. REC 11	-30.0	-174.0	6.0
12. REC 12	-102.0	-20.0	6.0
13. REC 13	-184.0	-20.0	6.0
14. REC 14	-30.0	20.0	6.0
15. REC 15	-102.0	20.0	6.0
16. REC 16	-184.0	20.0	6.0
17. REC 17	-30.0	92.0	6.0
18. REC 18	-30.0	174.0	6.0
19. REC 19	30.0	92.0	6.0
20. REC 20	30.0	174.0	6.0

Figure 5-7. Continued.

JOB: Main Street at Local Street RUN: MAIN ST. AND LOCAL ST. INTERSECTION

MODEL RESULTS

REMARKS : In search of the angle corresponding to the maximum concentration, only the first angle, of the angles with same maximum concentrations, is indicated as maximum.

WIND ANGLE RANGE: 0.-360.

WIND ANGLE (DEGR)	CONCENTRATION (PPM) REC1	REC2	REC3	REC4	REC5	REC6	REC7	REC8	REC9	REC10	REC11	REC12	REC13	REC14	REC15	REC16	REC17	REC18	REC19	REC20
0.	5.1	3.1	2.9	5.7	3.6	3.4	6.1	6.5	8.5	6.3	5.9	5.8	3.4	5.9	3.1	2.9	5.6	4.7	4.9	4.7
10.	3.9	2.8	2.7	4.4	3.2	3.1	4.4	4.7	9.1	6.8	6.6	6.2	3.5	7.1	3.5	3.1	6.6	5.3	3.8	3.7
20.	3.1	2.7	2.7	3.5	3.1	3.1	3.4	3.4	8.6	6.6	6.4	6.6	3.6	7.3	3.9	3.2	7.0	5.5	3.1	3.1
30.	2.9	2.7	2.7	3.3	3.2	3.2	3.0	2.9	7.4	6.2	6.3	7.0	3.9	7.0	4.1	3.4	6.8	5.6	2.9	2.9
40.	2.8	2.7	2.7	3.2	3.2	3.2	3.0	2.9	6.4	5.8	5.9	7.0	4.2	6.6	4.2	3.5	6.6	5.7	2.8	2.8
50.	2.9	2.8	2.8	3.3	3.3	3.3	3.0	2.9	5.9	5.7	5.8	7.2	4.5	6.3	4.2	3.6	6.3	5.9	2.8	2.8
60.	2.8	2.8	2.8	3.4	3.4	3.4	2.9	2.9	5.6	5.7	5.7	7.1	4.8	6.1	4.2	3.6	6.1	5.9	2.7	2.7
70.	2.9	2.9	2.9	3.5	3.5	3.5	2.9	2.8	5.6	5.6	5.4	6.8	5.4	6.1	4.4	3.8	5.9	5.8	2.7	2.7
80.	3.1	3.1	3.1	3.6	3.5	3.5	2.9	2.8	5.6	5.5	5.4	6.2	5.6	6.2	4.6	4.4	5.8	5.8	2.7	2.7
90.	3.4	3.4	3.4	3.4	3.4	3.4	2.8	2.7	5.9	5.5	5.4	5.4	5.3	6.6	5.5	5.3	6.0	5.9	2.8	2.7
100.	3.6	3.5	3.5	3.1	3.1	3.1	2.7	2.7	5.6	5.3	5.3	4.5	4.4	6.4	6.3	5.6	6.0	5.9	2.9	2.8
110.	3.5	3.5	3.5	2.9	2.9	2.9	2.7	2.7	5.4	5.3	5.3	4.3	3.8	6.4	6.8	5.3	6.2	6.0	2.9	2.8
120.	3.4	3.4	3.4	2.8	2.8	2.8	2.7	2.7	5.5	5.5	5.4	4.1	3.6	6.4	7.0	4.8	6.3	6.3	2.9	2.9
130.	3.3	3.3	3.3	2.9	2.8	2.8	2.8	2.8	5.7	5.6	5.3	4.1	3.6	6.6	7.1	4.5	6.4	6.4	3.0	2.9
140.	3.2	3.2	3.2	2.8	2.7	2.7	2.8	2.8	5.9	5.8	5.2	4.1	3.5	6.9	6.9	4.2	6.8	6.7	3.0	2.9
150.	3.3	3.2	3.2	2.9	2.7	2.7	2.9	2.9	6.1	5.9	5.1	4.0	3.4	7.5	6.9	3.9	7.5	7.2	3.0	2.9
160.	3.7	3.1	3.1	3.3	2.7	2.7	3.2	3.1	6.3	6.0	5.2	3.8	3.2	8.2	6.5	3.6	8.0	7.6	3.4	3.3
170.	4.8	3.2	3.1	4.4	2.8	2.7	4.2	3.8	6.1	5.7	5.1	3.5	3.1	8.4	6.1	3.5	7.7	7.9	4.3	4.4
180.	6.5	3.7	3.4	6.0	3.1	2.9	5.7	5.0	5.1	4.9	4.7	3.1	2.9	7.7	5.8	3.4	6.7	6.8	5.7	5.7
190.	7.4	4.0	3.5	7.2	3.5	3.1	6.8	5.8	3.9	3.9	3.7	2.8	2.7	6.5	5.3	3.1	5.1	5.1	6.6	6.6
200.	7.2	4.5	3.7	7.3	3.9	3.2	7.1	6.2	3.1	3.1	3.1	2.7	2.7	5.7	5.2	3.1	4.2	3.8	6.7	6.6
210.	6.4	4.8	4.0	7.0	4.2	3.4	6.9	6.3	2.9	2.9	2.9	2.7	2.7	5.6	5.3	3.2	3.8	3.2	6.7	6.7
220.	5.9	4.7	4.1	6.6	4.2	3.6	6.6	6.3	2.8	2.8	2.8	2.7	2.7	5.6	5.1	3.2	3.7	3.0	6.5	6.3
230.	5.9	4.7	4.2	6.3	4.2	3.7	6.3	6.2	2.9	2.8	2.8	2.8	2.8	5.9	4.9	3.3	3.4	2.9	6.4	6.0
240.	6.2	4.8	4.2	6.1	4.2	3.7	6.1	6.1	2.8	2.7	2.7	2.8	2.8	6.0	4.6	3.4	3.1	2.9	6.2	5.8
250.	6.7	5.0	4.5	6.3	4.4	3.8	5.9	5.8	3.0	2.7	2.7	2.9	2.9	5.9	4.2	3.5	3.0	2.8	5.9	5.4
260.	7.0	5.3	4.6	6.7	4.6	4.1	5.8	5.8	3.5	2.7	2.7	3.1	3.1	5.4	3.8	3.5	2.9	2.8	5.6	5.4
270.	6.9	5.1	4.6	7.6	5.2	4.6	6.0	5.9	4.4	2.8	2.7	3.5	3.4	4.4	3.5	3.4	2.8	2.7	5.5	5.4
280.	6.1	4.5	4.1	7.8	5.4	4.6	6.1	5.9	5.4	2.9	2.8	3.8	3.5	3.5	3.1	3.1	2.7	2.7	5.3	5.2
290.	5.6	4.3	3.7	7.5	5.0	4.4	6.5	6.0	5.9	3.0	2.8	4.2	3.5	3.0	2.9	2.9	2.7	2.7	5.3	5.0
300.	5.5	4.1	3.6	7.0	4.7	4.2	6.8	6.4	6.0	3.1	2.9	4.6	3.4	2.8	2.8	2.8	2.7	2.7	5.5	5.0
310.	5.7	4.1	3.6	6.6	4.6	4.2	7.1	6.6	5.9	3.4	2.9	4.9	3.3	2.9	2.8	2.8	2.8	2.8	5.6	4.8
320.	5.8	4.0	3.4	6.4	4.6	4.0	7.5	7.1	5.6	3.7	3.0	5.1	3.2	2.8	2.7	2.7	2.8	2.8	5.7	4.7
330.	6.0	3.9	3.3	6.5	4.6	3.9	8.0	7.6	5.6	3.8	3.2	5.3	3.2	2.9	2.7	2.7	2.9	2.9	5.8	4.8
340.	6.2	3.7	3.2	6.8	4.2	3.6	8.1	7.8	5.9	4.2	3.7	5.2	3.1	3.3	2.7	2.7	3.2	3.1	5.8	5.0
350.	6.0	3.4	3.1	6.5	3.9	3.5	7.4	7.8	6.9	5.0	4.7	5.3	3.1	4.4	2.8	2.7	4.2	3.7	5.5	5.1
360.	5.1	3.1	2.9	5.7	3.6	3.4	6.1	6.5	8.5	6.3	5.9	5.8	3.4	5.9	3.1	2.9	5.6	4.7	4.9	4.7
MAX	7.4	5.3	4.6	7.8	5.4	4.6	8.1	7.8	9.1	6.8	6.6	7.2	5.6	8.4	7.1	5.6	8.0	7.9	6.7	6.7
DEGR.	190	260	260	280	280	270	340	340	10	10	10	50	80	170	130	100	160	170	200	210

THE HIGHEST CONCENTRATION IS 9.10 PPM AT 10 DEGREES FROM REC9 .
THE 2ND HIGHEST CONCENTRATION IS 8.40 PPM AT 170 DEGREES FROM REC14.
THE 3RD HIGHEST CONCENTRATION IS 8.10 PPM AT 340 DEGREES FROM REC7 .

Figure 5-7. Continued.

SECTION 6

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16. ABSTRACT

Carbon Monoxide (CO) State Implementation Plan (SIP) attainment demonstrations and project-level conformity analysis are required under the Clean Air Act Amendments of 1990. Intersection modeling is recommended to meet these requirements. The purpose of this document is to provide guidance for performing CO intersection modeling. The modeling guidance includes selecting intersections, siting receptors, meteorological inputs, background concentrations, estimating 8-hour concentrations from 1-hour concentrations, and examples.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Carbon Monoxide (CO) Intersection Modeling State Implementation Plan (SIP) Clean Air Act Amendments Hot Spot Modeling		

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