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EVALUATION OF CO INTERSECTION MODELING TECHNIQUES USING A NEW YORK CITY DATABASE

Office of Air Quality Planning and Standards
Clean Air
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Evaluation of CO Intersection Modeling Techniques Using a New York City Database

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Technical Support Division
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Notice

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1.0 INTRODUCTION

1.1 Overview of the Analysis

The United States Environmental Protection Agency (EPA) is interested in updating the guidance for modeling carbon monoxide (CO) generated by mobile sources at intersections. The current guidance from EPA for modeling CO concentrations at roadway intersections is to use the "Carbon Monoxide Hot Spot Guidelines" (EPA, 1978) or the "Guidelines for Air Quality Maintenance Planning and Analysis Volume 9 (Revised): Evaluating Indirect Sources" (EPA, 1979) for screening intersections. If the screening calculations show a potential for exceeding the National Ambient Air Quality Standards (NAAQS) for CO, then refined analyses are required using Worksheet 2 of Volume 9 for traffic and emissions estimates and the CALINE3 dispersion model for concentration estimates. Both the Hot Spot Guidelines and Volume 9 have been criticized as being outdated, inadequate, and difficult to use. These techniques are considered outdated because (1) the major emissions components are modal emissions factors which are based on emissions from pre-1977 vehicles; (2) correction factors to the modal emissions model are calculated from the MOBILE1 emissions model, which has since been updated to MOBILE4 (EPA, 1989); and (3) the traffic component is based on the 1965 Highway Capacity Manual (HCM), which has since been updated to 1985 (TRB, 1985). These techniques are considered inadequate because they cannot handle overcapacity intersections. Also, these techniques are considered difficult to use because they are in a workbook format rather than coded as a model for use on a personal computer.

This document describes the procedures followed and results obtained in evaluating the performance of eight modeling techniques in simulating concentrations of CO at the six intersections monitored as part of the Route 9A Reconstruction Project in New York City. The eight modeling techniques evaluated include:

CAL3QHC	-	1985 Highway Capacity Manual Modified CAL3Q Model
FHWAINT	-	Federal Highway Administration (FHWA) Intersection Model
GIM	-	Georgia Intersection Model
EPAINT	-	EPA Intersection Model
CALINE4	-	California Line Source Model
VOL9MOB4	-	MOBILE4 Modified Volume 9 Technique
TEXIN2	-	Texas Intersection Model
IMM	-	Intersection Midblock Model

Only two of the intersection techniques, IMM and CALINE4, include street canyon options for modeling CO concentrations. These options have not been evaluated in this study. While several of the intersections are located near significant buildings that may promote the formation of circulations typically associated with street canyons, most of the emphasis is placed on evaluating model performance at the less complex sites. The New York City database includes meteorological, CO, and traffic observations for six different intersections. Detailed traffic information is available from the numerous videotapes available at each site.

A complete phase I model evaluation study was conducted using MOBILE4 emissions estimates. The phase I evaluation included all eight intersection modeling techniques at all six intersections. In late 1991, the MOBILE4.1 (EPA, 1991) emissions model, an update to MOBILE4, was released. Thus, a phase II evaluation utilizing MOBILE4.1 was conducted using a subset of the intersection models. As will be shown in Section 6.0 (Model Performance Results), of the three EPA intersection models (EPAINT, VOL9MOB4, and CAL3QHC), CAL3QHC performed best using MOBILE4. Of the two models utilizing the FHWA advocated average speed approach rather than explicit queuing (FHWAINT and GIM), GIM performed better. Therefore, the phase II MOBILE4.1 analysis was performed for the following five models: CAL3QHC, GIM, IMM, TEXIN2, and CALINE4. When collecting and compiling the New York City database, the best quality assurance procedures (analysis and comparison of data) were followed at two of the six intersection sites, Site #1 (West/Chambers) and Site #2 (34th/8th). A uniform wind analysis (similar wind speed and direction for different meteorological monitors at the same intersection) conducted for each site (DiCristofaro et al., 1991) indicated that Sites #5 (34th/12th) and #1 are best in terms of unhindered approach wind flows and wind field uniformity. Thus, the phase II MOBILE4.1 analysis was performed for the intersections at Sites #1, 2, and 5.

Two types of statistical evaluations of differences between observed and modeled CO concentrations are performed. First, the EPA Model Evaluation Support System (MESS) is used to calculate a standard set of performance measures and statistical estimators. Both paired and unpaired data sets are used. Second, a scoring scheme recommended by the EPA is used to rank the models and to evaluate the significance of the results.

1.2 Study Objectives

The ultimate objective of this study is to determine which of the eight intersection modeling techniques most accurately simulates the highest measured CO concentrations and whether the performance of that technique is significantly different than the other modeling techniques. In order to achieve this objective, many other questions needed to be addressed, such as:

- Does one model consistently display bias (i.e. overprediction or underprediction)?
- Is one model significantly better than another model (e.g. at the 95% confidence level)?
- How well do the models reproduce the dynamic variability of the observations?
- How does the model performance vary among sites?

- Are the mean errors small due to the balancing of large underpredictions with large overpredictions?

- How does model performance vary with meteorological conditions?

- How is model performance altered by the use of observed versus worst-case meteorological data?

1.3 Report Organization

The eight intersection modeling techniques evaluated in this study are summarized in Section 2.0. Also included is a summary of the input data required for each modeling technique. Section 3.0 includes a description of the six New York City intersections and the data collected. Also included is a uniform wind analysis of the observations. The modeling methodology used in this study including a description of the model input data and the dispersion modeling techniques is presented in Section 4.0. Section 5.0 presents a discussion of the two types of statistical evaluations used to assess model performance. The model performance results, including a limited number of graphs and tables for the phase I MOBILE4.0 analysis and detailed results for the phase II MOBILE4.1 analysis, are presented in Section 6.0. Also included in Section 6.0 are the scoring scheme results. Section 7.0 presents a summary of the model evaluation results and the references are listed in Section 8.0. Detailed results for the phase I MOBILE4.0 analysis are presented in Appendix A and residual plots using the phase II MOBILE4.1 results are presented in Appendix B.

2.0 INTERSECTION MODELING TECHNIQUES

2.1 Overview of Modeling Techniques

The eight modeling techniques evaluated include CAL3QHC, FHWAINT, GIM, EPAINT, CALINE4, VOL9MOB4, TEXIN2, and IMM. Six of these models are currently in use and two are proposed for use. All of the models use the latest version of the MOBILE emission factor model in some capacity, i.e., to estimate idle and cruise speed component emissions or to adjust modal emissions to the scenario conditions not considered by the modal model. The two models proposed for use, EPAINT and FHWAINT, are concatenations of suggestions made by members of the EPA/FHWA CO Intersection Modeling Work Group. The CAL3QHC model combines the CALINE3 dispersion model (Benson, 1979) with a traffic algorithm to calculate queuing based on the 1985 Highway Capacity Manual (HCM) (TRB, 1985). The GIM, TEXIN2, IMM, and CALINE4 models are procedures that have been used over the past several years in various state programs (some of these models were revised in the past year and these revised versions are tested in this evaluation).

It is important to note that most of these modeling techniques are incomplete (i.e., they do not include all necessary components for modeling CO from an intersection). The VOL9MOB4, GIM, FHWAINT, and EPAINT models are emission and traffic movement models only. These models use signalization, traffic volumes, and roadway capacities to estimate traffic movements and emissions. Roadway capacities were calculated using the 1985 HCM and emissions were calculated using MOBILE4 (Phase I Analysis) and MOBILE4.1 (Phase II Analysis). These four modeling techniques used the CALINE3 line source dispersion model to calculate ambient concentrations under a variety of meteorological conditions. Two of the modeling techniques, CAL3QHC and CALINE4, are dispersion models; CAL3QHC includes a traffic movement model and CALINE4 includes a modal emissions model. MOBILE4 (or MOBILE4.1) modeling must be conducted separately in order to obtain the emissions. Finally, TEXIN2 and IMM are inclusive emission, traffic movement, and dispersion models. TEXIN2 includes CALINE3 dispersion techniques and IMM includes HIWAY2 dispersion calculations. These two models also directly incorporate the MOBILE4 model so that emissions estimates are calculated internally. These two models have been revised to use MOBILE4.1 for the phase II modeling analysis.

For the phase I analysis using MOBILE4, the model combinations required are summarized below:

<u>Model No. 1</u>

HCM + MOBILE4 + EPAINT + CALINE3

<u>Model No. 5</u>

MOBILE4 + CAL3QHC

Model No. 2

HCM + MOBILE4 + FHWAINT + CALINE3

Model No. 3

HCM + MOBILE4 + VOL9MOB4 + CALINE3

Model No. 4

HCM + MOBILE4 + GIM + CALINE3

Model No. 6

MOBILE4 + CALINE4

Model No. 7

TEXIN2 (includes MOBILE4)

Model No. 8

IMM (includes MOBILE4)

For the phase II analysis using MOBILE4.1 emissions estimates, the model combinations required are summarized below:

Model No. 1

HCM + MOBILE4.1 + GIM + CALINE3

Model No. 2

HCM + MOBILE4.1 + CAL3QHC (Version 2.0)

Model No. 3

MOBILE4.1 + CALINE4

Model No. 4

TEXIN2 (includes MOBILE4.1)

Model No. 5

IMM (includes MOBILE4.1)

Note that a revised version of CAL3QHC (Version 2.0) was used for the second-phase modeling analysis so that differences in performance between phase I and phase II are not solely due to replacing MOBILE4.1 with MOBILE4. Version 2.0 of CAL3QHC allows the user to input the saturation flow rate, signal type, and arrival rate. Other changes include modification of the queue delay and queue length calculations.

2.2 Model Summaries

Primary differences among the eight modeling techniques are due to emission, traffic, and roadway characterizations rather than dispersion modeling methods. Each of the eight models evaluated except IMM use a form of the CALINE3 model for dispersion estimates. The IMM model uses HIWAY2 dispersion modeling techniques. Each model is briefly described below along with the additional model components required to estimate ambient CO levels. Table 1 describes the input data needed for each model.

TABLE 1

INTERSECTION MODEL INPUT REQUIREMENTS

Intersection Model Inputs	Inputs Required for Each of Eight Intersection Modeling Techniques							
	EPAINT +HCM +MOBILE4 +CALINE3	FHWAINT +HCM +MOBILE4 +CALINE3	VOL9MOB4 +HCM +MOBILE4 +CALINE3	GIM +HCM +MOBILE4 +CALINE3	CAL3QHC +MOBILE4 +HCM (for Version 2.0)	CALINE4 +MOBILE4	TEXIN2	IMM
Roadway Configuration:								
Arterial Class	X	X						
Midblock to Midblock Distance	X (m)	X (m)						
Number of Lanes in Approach		X	X	X	X		X	X
Number of Links	C	C	C	C	X	X	X	
Link Coordinates	C (ft, m)	C (ft, m)	C (ft, m)	C (ft, m)	X (ft, m)	X (ft, m)	X	X (km)
Type of Link (At, Fill, Depress, Bridge)	C	C	C	C	X	X	X	X
Link Width							X (m)	X (m)
Number of exclusive left-turn lanes							X	
Exclusive right-turn lanes							X	
Mixing Zone Width	C (ft, m)	C (ft, m)	C (ft, m)	C (ft, m)	X (ft, m)	X (ft, m)		
Number of Lanes in Queue					X			
Stopline Distance						X (ft, m)		
Coordinates of Intersection Center								X
Width of top of cut section								X (m)
Fraction of Volume/Lane								X
Street Canyon?								X
Street Canyon Dimensions								X (m)

M - used in MOBILE4 model exclusively and separately from subject model
X - used in subject model (and in other models which are linked to subject model)
C - used in CALINE3 model

TABLE 1 (Continued)

Intersection Model Inputs	Inputs Required for Each of Eight Intersection Modeling Techniques							
	EPAINT +HCM +MOBILE4 +CALINE3	FHWAINT +HCM +MOBILE4 +CALINE3	VOL9MOB4 +HCM +MOBILE4 +CALINE3	GIM +HCM +MOBILE4 +CALINE3	CAL3QHC +MOBILE4 +HCM (for Version 2.0)	CALINE4 +MOBILE4	TEXIN2	IMM
Emissions:								
Year of Analysis	X	X	X	M	M	M	X	X
Vehicle Miles Traveled Mix (optional)	M	M	M	M	M	M	X	X
Tampering Data (optional)	M	M	M	M	M	M	X	X
Inspection/Maintenance (optional)	M	M	X	M	M	M	X	X
Registration/Mileage Accrual Rates (optional)	M	M	M	M	M	M	X	X
Air conditioning/Loading/Towing (optional)	M	M	M	M	M	M	X	X
Source Emission Height	C, X (ft, m)	C, X (ft, m)	C, X (ft, m)	C, M (ft, m)	X (ft, m)	X (ft, m)	X (ft, m)	X (m)
Hot/Cold Start Percentages	M	M	M	M	M	M	X	X
ASTM Volatility Class	M	M	M	M	M	M	X	X
Reid Vapor Pressure of Gas	M	M	M	M	M	M	X	X
Idle Emission Factor					X (g/veh-min)	X (g/veh-min)		
Composite Emission Factor at Speed				X (g/veh-mi)	X (g/veh-mi)	X @ 16 mph (g/veh-mi)		
Pollutant Type	M	M	M	M	M	X		X
Molecular Weight						X		
Region (High or Low)	M	M	M	M	M	M		X
Observed Queue Length (optional)								X (m)
Observed Delay (optional)								X (s)

M - used in MOBILE3 model exclusively and separately from subject model
X - used in subject model (and in other models which are linked to subject model)
C - used in CALINE3 model

TABLE 1 (Continued)

Intersection Model Inputs	Inputs Required for Each of Eight Intersection Modeling Techniques							
	EPAINT +HCM +MOBILE4 +CALINE3	FHWAINT +HCM +MOBILE4 +CALINE3	VOL9MOB4 +HCM +MOBILE4 +CALINE3	GIM +HCM +MOBILE4 +CALINE3	CAL3QHC +MOBILE4 +HCM (for Version 2.0)	CALINE4 +MOBILE4	TEXIN2	IMM
Dispersion/Meteorology:								
Temperature Per Hour	X (°F)	X (°F)	X (°F)	X (°F)	M (°F)	M (°F), X (°C)	M (°F)	X (°F)
Wind Speed	C (m/s)	C (m/s)	C (m/s)	C (m/s)	X (m/s)	X (m/s)	X (m/s)	X (m/s)
Wind Direction	C (deg)	C (deg)	C (deg)	C (deg)	X (deg)	X (deg)	X (deg)	X (deg)
Atmospheric Stability Class	C	C	C	C	X	X	X	X
Mixing Height	C (m)	C (m)	C (m)	C (m)	X (m)	X (m)	X (m)	X (m)
CO Background Concentration	C (ppm)	C (ppm)	C (ppm)	C (ppm)	X (ppm)	X (ppm)	X (ppm)	
Surface Roughness	C (cm)	C (cm)	C (cm)	C (cm)	X (cm)	X (cm)	X (cm)	
Averaging Time	C (min)	C (min)	C (min)	C (min)	X (min)		X (min)	
Settling Velocity	C (cm/s)	C (cm/s)	C (cm/s)	C (cm/s)	X (cm/s)	X (cm/s)		
Deposition Velocity	C (cm/s)	C (cm/s)	C (cm/s)	C (cm/s)	X (cm/s)	X (cm/s)		
Altitude of Site						X (ft, m)		
Standard Deviation of Wind Direction						X (deg)		
Receptors:								
Number of Receptors	C	C	C	C	X	X	X	X
Location of Receptors (x, y)	C (ft, m)	C (ft, m)	C (ft, m)	C (ft, m)	X (ft, m)	X (ft, m)	X (m)	X (km)
Height of Receptors	C (ft, m)	C (ft, m)	C (ft, m)	C (ft, m)	X (ft, m)	X (ft, m)	X (m)	X (m)

M - used in MOBILE4 model exclusively and separately from subject model
X - used in subject model (and in other models which are linked to subject model)
C - used in CALINE3 model

TABLE 1 (Continued)

Intersection Model Inputs	Inputs Required for Each of Eight Intersection Modeling Techniques							
	EPAINT +HCM +MOBILE4 +CALINE3	FHWAINT +HCM +MOBILE4 +CALINE3	VOL9MOB4 +HCM +MOBILE4 +CALINE3	GIM +HCM +MOBILE4 +CALINE3	CAL3QHC +MOBILE4 +HCM (for Version 2.0)	CALINE4 +MOBILE4	TEXIN2	IMM
Traffic/Signalization:								
Free Flow Speed Per Approach	M,X (mph)	M,X (mph)	X (mph)	M,X (mph)	M (mph)	X (mph)	X (mph)	X(IN/OUT, mph)
Green Time Per Approach	X (s)	X (s)	X (s)	X (percent)				X (s)
Total Cycle Time	X (s)	X (s)	X (s)	X (s)	X (s)		X (s)	X (s)
Approach Traffic Volume Per Hour	C,X (veh/hr)	C,X (veh/hr)	C,X (veh/hr)	C (veh/hr)	X (veh/hr)	X (veh/hr)	X(veh/hr)	X (veh/hr)
Running Time Per Mile	X (s/mi)							
Total Capacity Service Volume/Green Time	X (veh/hr)		X (veh/hr)	X (veh/lane)				X (veh/hr lane)
Number of Signal Phases							X	X
Fraction of vehicles turning left per link							X	
Fraction of vehicles turning right per link							X	
Left-Turn Signalization Type							X	
Initial Queue (optional)				X (m)				
Red Time					X (s)			
Single Vehicle Clearance Time					X (s)			
Deceleration/Acceleration Speeds								X (mph/s)
Deceleration/Acceleration Time						X (s)		
Average No. Veh. per Cycle per Lane						X		
Avg. No. Veh. Delayed per Cycle Per Lane						X		
Departure Traffic Volume per Hour						X		
Vehicle Idle Time at Stopline						X (s)		
Vehicle Idle Time at End of Queue						X (s)		

M - used in MOBILE4 model exclusively and separately from subject model.
X - used in subject model (and in other models which are linked to subject model).
C - used in CALINE3 Model.

2.2.1 EPA Intersection (EPAINT) Model

An EPA-proposed traffic and queuing technique for estimating CO emissions from approaches to intersections is referred to as the EPAINT (EPA Intersection) model (PEI, 1988). This technique falls into the class of a mobile source model that estimates vehicular emissions and queuing at an intersection. The EPAINT model requires the external use of both MOBILE4 and the 1985 Highway Capacity Manual (HCM). The technique explicitly treats vehicles that are delayed at an intersection. In the EPAINT technique, vehicle movements are separated into a free-flow component and a delayed or queued component. The combination of the two overlapping roadway segments yields the EPAINT estimate of CO emissions and the distances over which they apply at each approach to the intersection.

In the EPAINT model, the arterial speed is adjusted for vehicle volumes, roadway capacity, and any other roadside frictions (i.e., driveways, businesses, and cross streets) that reduce capacity. This speed is used to estimate an adjusted free-flow speed on the roadway segment. The HCM Chapter 11 technique for estimating arterial speed was modified for use in EPAINT by excluding the effects of delay from the average arterial speed calculation. The composite CO emissions for the segment are calculated via MOBILE4 by using the modified arterial speed and other ambient and operating conditions.

Excess emissions due to delay are calculated in EPAINT by using an adjusted idle emission factor from MOBILE4, the total approach delay time per vehicle, and the volume of traffic on the approach. For this evaluation, the MOBILE4 idle emissions were adjusted by using the ratio of a scenario composite emission to a base-case composite emission at 2.5 mph. The idle emissions are applied over an excess emissions distance calculated by queuing techniques given in the Institute of Traffic Engineering (ITE) Handbook. This model was not tested with the MOBILE4.1 emissions model.

In order to facilitate the use of the EPAINT model and to make the model consistent with current modeling guidelines, the following changes were made to the computer algorithm:

- Code was converted from an interactive mode to batch mode;
- More than one link at a time may be modeled;
- The idle and base idle vehicle speed was changed from 5.0 to 2.5 mph;
- Allow the vehicle mix, annual mileage accumulation rates, registration distribution, refueling emissions options, RVP (Reid Vapor Pressure), I/M (Inspection/ Maintenance) and ATP (Anti-Tampering Program) parameters to be input to the model, rather than fixed as constants within the code; and

- Allow the thermal states for idle and scenario conditions to be input to the model, rather than fixed as constants within the code.

The adjusted free-flow and queuing emissions estimated by EPAINT are input to the CALINE3 dispersion model. Input link information to CALINE3 is tailored to fit the EPAINT-generated queue lengths for each scenario. The EPAINT results are formatted to the gram-per-vehicle mile input units required by CALINE3.

2.2.2 FHWA Intersection (FHWAINT) Model

While the EPAINT model divides the vehicles into a free-flow component and a delayed component, the FHWA-proposed technique, known as the FHWAINT (FHWA Intersection) model (PEI, 1988), calculates an adjusted vehicle speed and related composite CO emission on the approach to accommodate vehicle delay. This technique estimates the emissions over a length of user-selected roadway (segment) on the basis of the volume to capacity (V/C) ratio. The V/C ratio is used to determine the average speed of a vehicle over the whole segment, which includes the effects of the delay of the vehicle at an intersection. FHWAINT includes the current MOBILE4 model to estimate the composite CO emissions at the adjusted vehicle speed. The HCM model is used to calculate the roadway capacities. The use of FHWAINT for V/C ratios greater than 1.0 is not recommended by FHWA. The resulting emissions represent a composite free-flow and queuing link with the overall cycle being represented by a lower vehicle speed (and subsequent higher CO emissions).

Changes to the FHWAINT computer algorithm, similar to the changes discussed above for the EPAINT model, were made in order to facilitate the use of the FHWAINT model and to make the model consistent with the other models being evaluated. For example, the idle and base idle vehicle speed was changed from 5.0 to 2.5 mph. Also, the vehicle mix, annual mileage accumulation rates, registration distribution, refueling emissions options, RVP, I/M, ATP, and thermal states were input to the model rather than fixed as constants.

The FHWAINT-calculated composite emissions are input to the CALINE3 dispersion model. The FHWAINT technique assumes that the free-flow and queuing emissions have been accounted for by the adjusted speeds of the approaches; thus, no queue links are included in the dispersion modeling. All other CALINE3 components of the analysis are identical to routine CALINE3 applications. This model was not tested with the MOBILE4.1 emissions model.

2.2.3 VOLUME9/MOBILE4 (VOL9MOB4)

The previous versions of the VOLUME9 model used the MOBILE1 model for adjusting emissions, the VOLUME9 Appendix B capacity analyses (based on the 1965 Highway Capacity Manual analysis), and the HIWAY model. In keeping with current recommendations but including the basic techniques in VOLUME9, the MOBILE4 emissions, 1985 Highway Capacity Manual calculations for roadway capacity, and the CALINE3 model were used to supplement the VOLUME9 analysis. This is referred to as the VOLUME9-MOBILE4 technique or VOL9MOB4. For delay, queue length, and excess emission calculations, the procedures previously used in Volume 9 have been maintained and follow the 1965 Webster Techniques. The VOLUME9 (EPA, 1979) Worksheet 2 calculations for determining emissions and traffic at an intersection have been computerized to allow quicker calculations and direct access to the MOBILE4 model. Worksheet 2 specifically addresses the calculation of excess emissions and the length of roadway over which they take place. The HCM model is used to calculate the roadway capacities.

The overall emissions in VOL9MOB4 consist of free-flow, acceleration, and deceleration emissions, which are estimated based on the Modal model (Kunselman, 1974) for a 1977 base case. The idling emissions are based on MOBILE4 and are tabulated in the same mass/ vehicle/ distance units as free-flow emissions. Estimates of these emissions are based on the number of vehicles, the proportion of vehicles that stop, and the average vehicle delay time.

The excess emission segment length (resulting from queuing, acceleration, and deceleration) is the greater length arrived at by two separate techniques. The first is the length needed for a vehicle to decelerate from cruise speed to a stop and then accelerate back to cruise speed. The second length is calculated as a function of the number of vehicles that stop and an average vehicle length (8 m). The greater of the acceleration/deceleration length or queuing length is used for excess emissions. The free-flow roadway length is user-specified. The results of this procedure are input to the CALINE3 model for all dispersion estimates. Separate free-flow and excess emission links are modeled with CALINE3. As shown in Table 1, the input requirements for VOL9MOB4 are similar to EPAINT and FHWAINT. This model was not tested with the MOBILE4.1 emissions model.

Changes to the VOL9MOB4 computer algorithm, similar to the changes discussed above for the EPAINT model, were made in order to facilitate the use of the VOL9MOB4 model and to make the model consistent with the other models being evaluated. For example, the idle and base idle vehicle speed was changed from 5.0 to 2.5 mph. Also, the vehicle mix, annual mileage accumulation rates, registration distribution, refueling emissions options, RVP, I/M, ATP, and thermal states were input to the model rather than fixed as constants.

2.2.4 Georgia Intersection Model (GIM)

The Georgia Intersection Model (GIM) technique calculates traffic flow and emissions from intersections, based on a modified U.S. EPA VOLUME9 approach (EMI, 1985). This model was designed by the Georgia Department of Transportation (GDOT) to handle under-capacity, at-capacity, and over-capacity scenarios. The output of GIM is designed to be input directly into an air dispersion model; in this case, the CALINE3 model is used. The HCM model is used to calculate the roadway capacities. MOBILE4 model emission estimates are necessary for GIM use. This modeling technique was also evaluated using the MOBILE4.1 emissions model.

The GIM model calculates an effective excess emissions length of roadway from the point at which vehicles begin to decelerate upstream of an intersection. This distance includes the length of road where cars slow down and where they queue in the upstream direction. Over this length, vehicle speeds are reduced to account for delays caused by vehicles slowing and stopping at the intersection. The GIM model calculates the average speed over this distance (thereby accounting for the delay) and estimates the average CO emission rate using MOBILE4 emissions factors for vehicles traversing the affected length. Using this approach, the use of modal emission factors is not necessary. The GIM output defines finite line source segments with their associated CO emission rates, which are used as input for the CALINE3 dispersion model. Roadway segments are not separated into idle and free-flow emission components. The user, however, must generate emissions using MOBILE4 for those portions of the roadway that are not associated with the effective excess emission lengths, i.e., any free flow extensions beyond the GIM-generated links that complete the characterization of the approach and departure links.

2.2.5 CAL3QHC

The CAL3QHC (EPA, 1992) model was developed by EPA Regional Offices I and IV to calculate CO concentrations at intersections. The CAL3QHC model is a hybrid of the CALINE3 line source dispersion model and an algorithm for estimating vehicular queue lengths at signalized intersections. No modal emissions due to acceleration or deceleration are included in this model explicitly; instead, they are included implicitly in the Federal test procedure cycles in the MOBILE4 calculations. The models and techniques used in CAL3QHC are 1) the MOBILE4 model emissions, which are estimated separately from CAL3QHC for free-flow and idling (adjusted to scenario conditions); 2) the delay procedures of the 1985 Highway Capacity Manual (and associated queuing); and 3) the CALINE3 dispersion model. The latter two components are included directly in the CAL3QHC model.

In the CAL3QHC model the excess emissions or linear source strength for stopping vehicles are based on the red time, the number of lanes, and adjusted MOBILE4 idle emissions (adjusted for cold/hot starts, temperature, vehicle mix, etc.). The emission rate is then set equal to a constant (100 g/veh·mi) and the number of vehicles that represent the linear source strength is calculated. The queue length is calculated on the basis of traffic volume, signal cycle time, red time, clearance lost time, and a vehicle length of 6 meters. The queue represents only the idling emissions. Free-flow emissions are handled separately by another, overlapping roadway segment length. These links are then used in the CALINE3 portion of the CAL3QHC model with associated roadway and receptor geometry and meteorological conditions.

A revised version of CAL3QHC (Version 2.0) was tested with the MOBILE4.1 emissions model. The revised version of the model addressed comments received in response to the Fifth Air Quality Conference. The objectives of the modifications to the CAL3QHC model were to: 1) give the user more freedom of choice (in terms of capacity determination, signal type, and arrival rate); 2) base the choices on recommendations from the 1985 Highway Capacity Manual (HCM); and 3) keep the same input/output formats from the original version. These modifications affect the calculation of the V/C ratios and queue length.

The three new input variables that can be specified or set by default are:

1) Saturation Flow Rate or Hourly Capacity per Lane

   The saturation flow rate is determined by the user depending on the characteristics and operation of the intersection. If no input value is used, the program assumes 1600 vehicles per hour (vph) as representative of an urban intersection.

2) Signal Type

   The signal type may be set to either pretimed, actuated, or semiactuated. The default value is pretimed.

3) Arrival Rate

   The arrival rate may be set to either worst progression (dense platoon at beginning of red), below average progression (dense platoon during middle of red), average progression (random arrivals), above average progression (dense platoon during middle of green), and best progression (dense platoon at beginning of green). The model assumes random arrivals as the default.

The signal type and arrival rate are used by CAL3QHC (Version 2.0) to calculate the progression adjustment factor that will affect the delay calculation. Two other internal modifications to the model include adjusting the queue delay and the queue length. The delay for the queue calculation is based on the total approach delay in the new version rather than the stopped delay as used in the original version. In addition, the third term of the original Webster formula for the queue length calculation has been reinstated. This will only have an effect on low V/C ratios.

2.2.6 CALINE4

The CALINE4 model (Benson, 1989) is a line source air quality model developed by the California Department of Transportation as an update to the previous CALINE3 model. The

CALINE4 model includes the capability of handling modal modeling components including delay at an intersection by treating individual vehicle delay, acceleration, deceleration, and free-flow. Cumulative modal emission profiles are constructed for each link based on speed, acceleration/deceleration rates, idle (delay time), and traffic volumes on each link. The CALINE4 model includes modal emissions and dispersion components, but does not include a traffic model component. The emissions from stopped vehicles are based on an emissions profile that is generated from an assumed constant annual rate of vehicles. The cumulative emission profile is then generated as a function of the time spent by each vehicle in each mode. The MOBILE4 emissions are required for both a specified set of vehicle operating conditions for a composite emission factor as well as a scenario adjusted idle factor. This model was tested with both MOBILE4 and MOBILE4.1 emissions.

2.2.7 TEXIN2

The TEXIN2 model (Bullin et al., 1990) was developed by the Texas Transportation Institute (TTI). The MOBILE4 model is incorporated directly into TEXIN2 such that the user specifies the vehicle speed, year of analysis, temperature, and other operating conditions and scenario specifications for the overall model. No idle adjustments for ambient temperature and hot/cold start conditions are made. A revised version of the TEXIN2 model with MOBILE4.1 emissions was also tested. For this version of the model, the idle adjustments were automatically made by MOBILE4.1.

Traffic is handled by the TEXIN2 model by using the Critical Movement Analysis (CMA) Operations and Design Technique. The CMA technique treats the intersection as a unit and considers conflicting movements that must be accommodated. The resulting traffic volumes are used together with cruise and excess emissions to form the source terms for each link. Excess emissions are calculated as a function of two vehicle operating modes: 1) vehicles slowing but not stopping; and 2) vehicles that stop and idle. For the first component, a composite emission rate for one-half the link free-flow speed is used along with approach delay and time in the queue. For stopping vehicles, the unadjusted MOBILE4 idle factor is used along with adjusted modal emissions factors for acceleration and deceleration.

TEXIN2 treats each leg of an intersection as a link and individual lanes are not considered in the model. TEXIN2 also includes traffic delay calculations as well as the CALINE3 dispersion modeling component. One adjustment made by TEXIN2 to the CALINE3 model is the application of a factor for low wind speed cases.

2.2.8 Intersection Midblock Model (IMM)

The Intersection Midblock Model (IMM) (NYDOT, 1982) was originally developed by GCA Corporation under contract to the EPA in 1978 as part of the Carbon Monoxide Hot Spot Modeling Guidelines (EPA, 1978), but was later revised and updated by the New York

Department of Transportation. The IMM model combines the use of various components required for a highway, street, or intersection analysis into one computerized technique. The IMM model was based originally on the VOLUME 9 techniques using an excess emissions approach including modal emissions. The model includes modal emission calculations for delayed vehicles at an intersection which are calculated on the basis of vehicle stopping and starting movements. The IMM model has been updated with MOBILE4 for making emission estimates and adjustments of modal emissions. The model is capable of estimating CO concentrations at receptors near intersections, at midblock locations, and in street canyons. The IMM model will accept data for two intersections with a maximum of four phases per intersection. The HIWAY2 model for line source dispersion calculations is used for all atmospheric transport and dispersion analyses. A revised version of the IMM model with MOBILE4.1 emissions was also tested.

Emissions from accelerating/decelerating vehicles and idling vehicles are assigned to pseudolinks which are lengths along the link where the emissions emanate on average. The acceleration/deceleration rates are used to compute the pseudolinks. Traffic signal characteristics and capacity service volumes are used to calculate the queue length and delay time which then determine the idle emissions. The cruise and acceleration/deceleration emissions are calculated by use of the EPA Modal Analysis Model (Kunselman, 1974), which has been incorporated in IMM.

3.0 THE NEW YORK CITY DATABASE

3.1 Description of the Six New York Intersections

A major air quality monitoring study was conducted in 1989-1990 in response to the proposed reconstruction of a portion of Route 9A in New York City. The reconstruction is proposed for the southernmost five miles of the roadway from Battery Place to West 59th Street. As part of the monitoring project, meteorological and CO air quality data were collected at two background sites and six different intersections. These sites are all located in midtown or lower Manhattan, and are shown in Figure 1. Three of the sites (Site #1 West/Chambers; Site #5 12th/34th; and Site #6 Brooklyn Battery Tunnel) are on the Route 9A Right-of-Way. Layouts that identify locations of the meteorological monitors (labeled as M1, M2, etc.), the CO monitors (labeled as P1, P2, etc.), and nearby buildings at each intersection are shown in Figures 2 through 7.

Two of the six intersections are "unobstructed" sites with relatively few nearby buildings or structures. Site #1 is located at the intersection of West Street (Route 9A) and Chambers Street in the vicinity of Battery Park City along the Hudson River. The site is relatively open with a parking lot on the southeast side of the intersection and low buildings (5 to 30 m) extending from the east southeast to the north northeast of the intersection. Site #5 lies along the Hudson River at West 34th Street and 12th Avenue (Route 9A) adjacent to the Jacob Javits Exposition Center. There is virtually unobstructed flow over the Hudson River from the south southwest to the north. There are low buildings (one to three stories) to the east and south. Site #5, along with Site #1, represent the best intersections with respect to unobstructed flows.

Two of the six intersections are street-canyon sites. Site #2 is a midtown intersection at 34th Street and 8th Avenue. The intersection is one block north of Madison Square Garden and the General Post Office Building. There are skyscrapers up to approximately 100 to 150 m in height on all sides of the intersection. Site #4 is a midtown intersection at West 57th Street and 7th Avenue at Carnegie Hall. This is also a street-canyon setting with tall buildings (up to 70 stories) on all sides.

The final two intersections analyzed are complicated by a number of factors. Site #3 lies at the convergence of Columbus Avenue, Broadway, and West 65th Street in the vicinity of Philharmonic Hall and the Lincoln Center. There are five and six-story buildings on all sides, although the intersection center is relatively open. Of the six intersections analyzed, this site has the most complicated configuration (e.g., adjacent traffic lights and intersections). Site #6 is at the intersection of the Brooklyn Battery Tunnel with West Street (Route 9A). Data were collected at two sites (6A and 6B) in the vicinity of the tunnel. Because traffic data are not available from Site #6B, only Site #6A was analyzed. There are tall buildings from eight to forty-four stories on all sides of the intersection. This site is complicated by an overhang associated with the Port of New York Authority Building under which traffic departs from the tunnel.

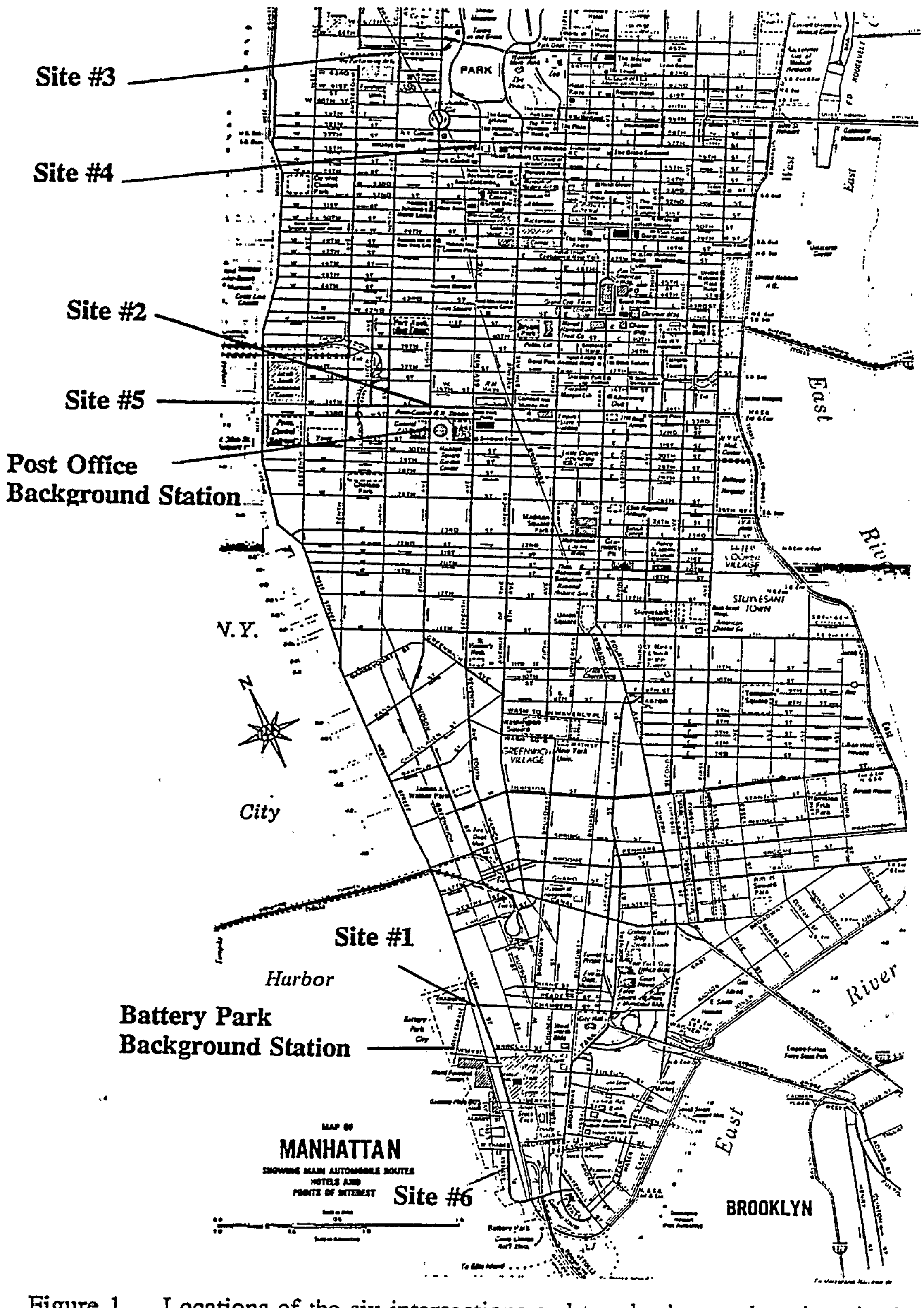


Figure 1. Locations of the six intersections and two background stations in the New York City database.

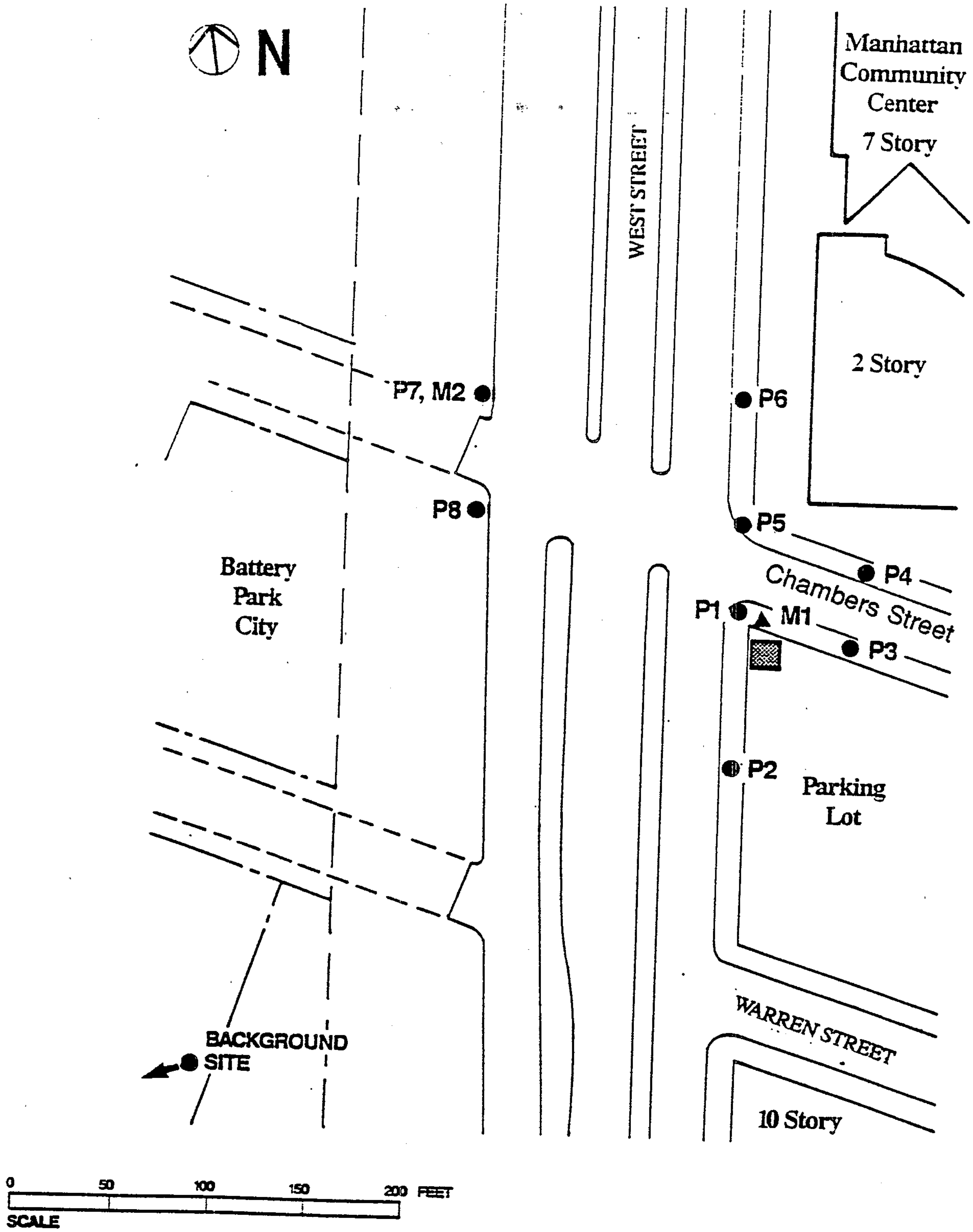


Figure 2. Site #1, West/Chambers, location map. The Battery Park background site is also shown.

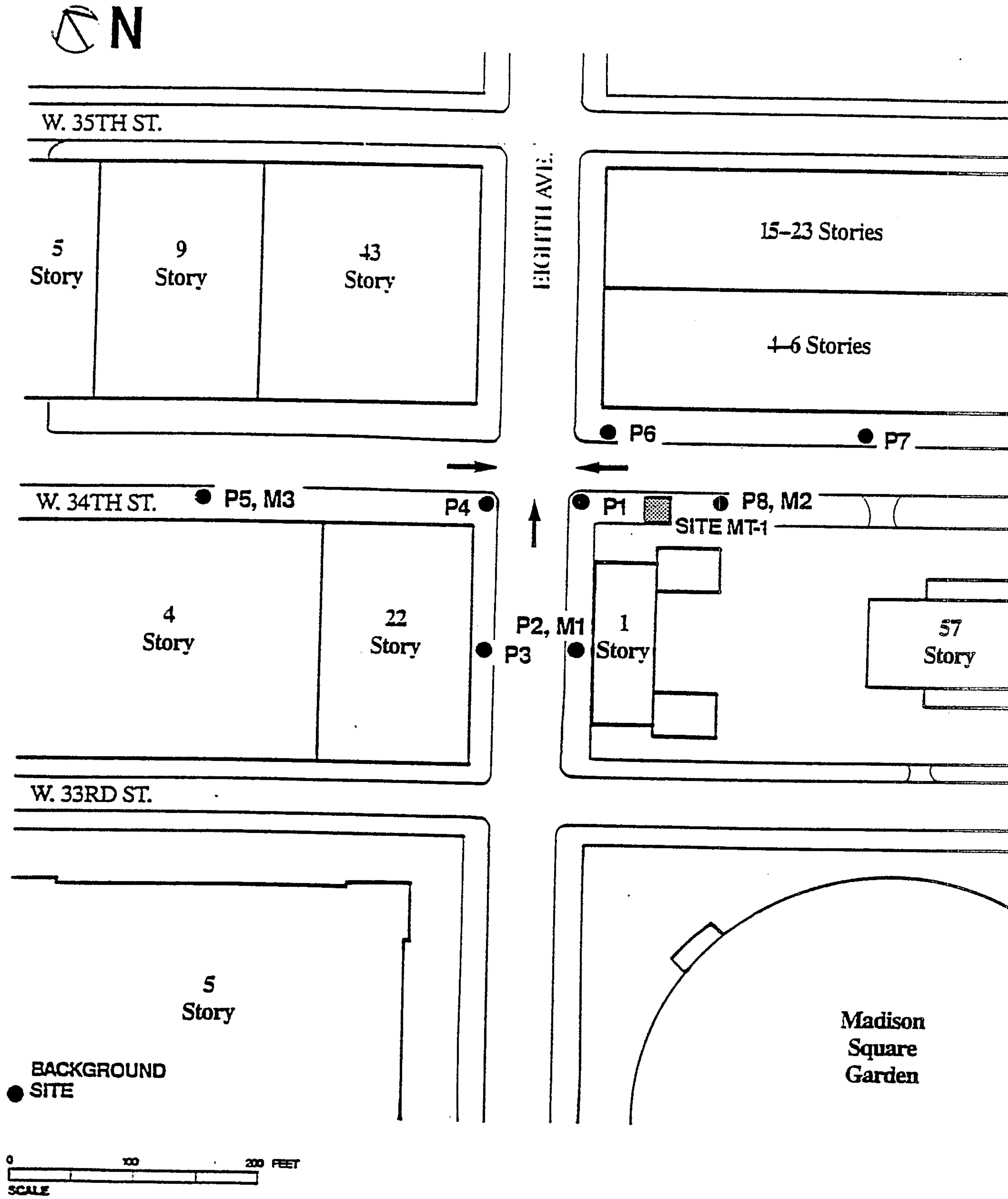


Figure 3. Site #2, 34th/8th, location map. The Post Office background site is also shown.

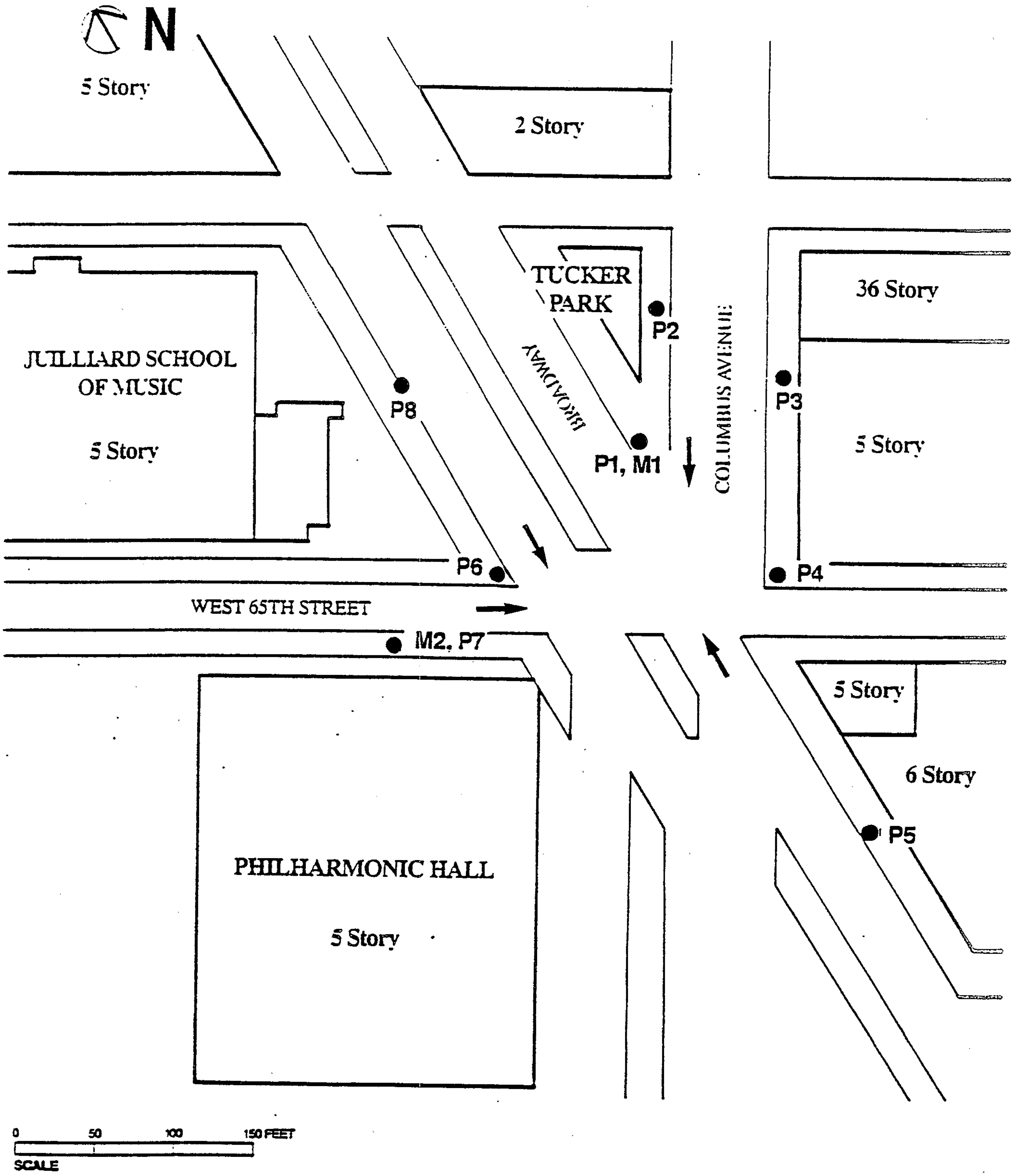


Figure 4. Site #3, 65th/Broadway, location map.

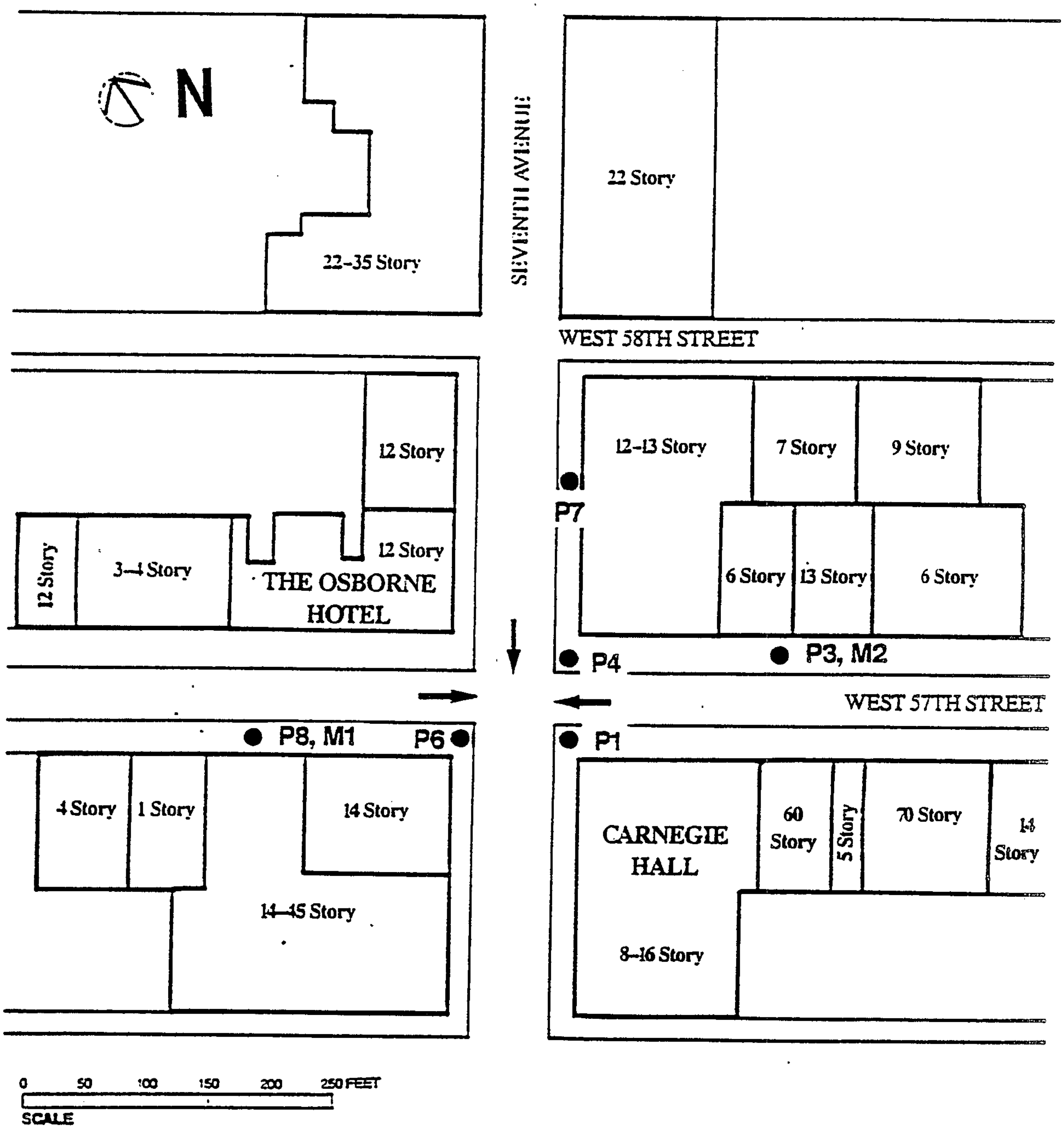


Figure 5. Site #4, 57th/7th, location map.

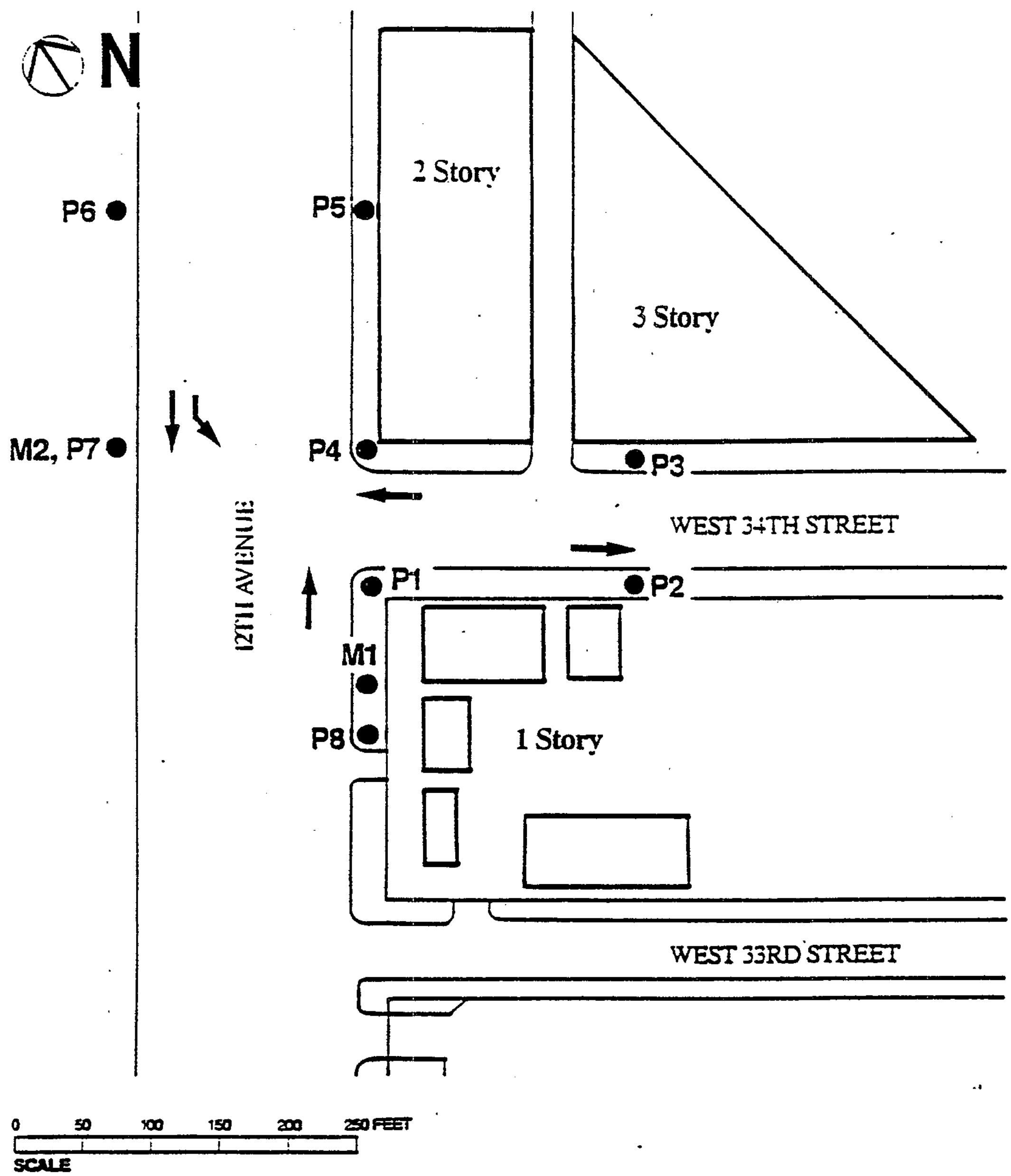


Figure 6. Site #5, 34th/12th, location map.

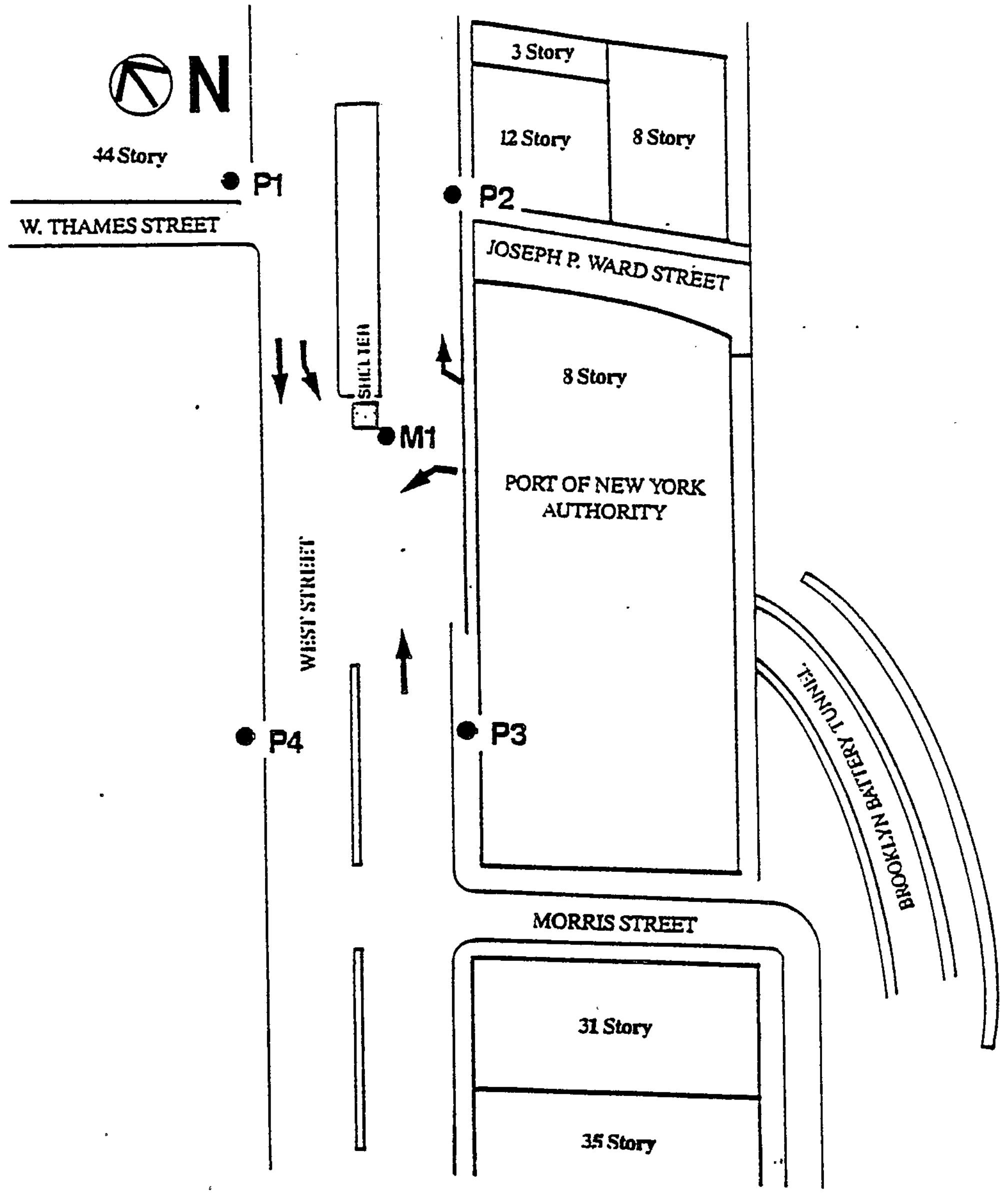


Figure 7. Site #6A, Battery Tunnel, location map.

There are two sites which collected background data. One background site is located on the Battery Park City landfill near Sites #1 and 6. The second background site is located on top of the General Post Office Building across the street from Madison Square Garden one block south of Site #2 and near Sites #3, 4, and 5.

3.2 Description of the Data Collected

The configuration, operation, data processing, and quality assurance/quality control practices for this program conformed, as close as possible, to the provisions of EPA's Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD) (EPA, 1987a). The meteorological data collected at each intersection include wind direction, wind speed, temperature, and sigma theta (σ_θ). The background site at Battery Park provides both meteorological and CO measurements, but only CO measurements from the rooftop are available at the Post Office site. A summary of the available meteorological and CO monitoring data is given in Table 2. The meteorological measurements were taken at a height of 10 m ± 1 m. The CO probe heights for each monitor and site are given in Table 3. Further details concerning the monitoring program are given in ENSR (1988).

In order to obtain detailed information concerning the traffic characteristics, a series of video cameras were used to film the traffic at each site. Three months of continuous traffic data were collected at each site producing approximately 13,000 hours of video recordings. A limited number of videotaped hours were examined for the Route 9A Study in order to obtain detailed information about the local traffic (see Table 2). The traffic data were concurrent with the observed CO data. The examined traffic data are comprised of the top 50 hours of CO concentrations observed for each of three months at Sites #1 and 2 and the top 25 hours observed for each of three months at the remaining sites. Some sites listed in Table 2 have less than the maximum 150 or 75 hours over the entire three-month period, because we have used only those hours for which all monitors at a site had observed CO concentrations greater than 3 ppm.

Traffic-related variables that are available for each selected hour are listed in Table 4. All traffic data were obtained from videotapes except for the acceleration/deceleration rates and the cruise speed. The acceleration/deceleration rates and cruise speeds were obtained through the use of a vehicle outfitted with a travel-log machine that recorded instantaneous speed versus time while traveling. Cruise speeds were taken directly from the strip charts created in this way; acceleration/deceleration rates were determined from the slope of the lines on the strip charts (Conway and Zamurs, 1991). The modified average speed is the total travel time less the average stop delay time on the link.

The traffic data at each site are reported for a number of intersection segments or links. For example, at Site #1, the traffic data are reported for 17 different links of the West/ Chambers intersection (e.g., westbound, northbound, other nearby intersections). Other data

TABLE 2

SUMMARY OF THE AVAILABLE ROUTE 9A
RECONSTRUCTION PROJECT MONITORING DATA

Site No.	Location	Collection Period	# of Met Towers	# of CO Monitors	# of Examined Traffic Hours
1	West/Chambers	2/89 - 5/89	2	8	142
2	34th/8th	5/89 - 11/89	3	8	143
3	65th/Broadway	11/89 - 1/90	2	8	66
4	57th/7th	11/89 - 1/90	2	6	74
5	34th/12th	8/89 - 12/89	2	8	75
6A	Battery Tunnel	11/89 - 3/90	1	4	75
6B	Battery Tunnel	11/89 - 3/90	1	4	0
Bkgrd	Battery Park	1/89 - 4/90	1	1	-
Bkgrd	Post Office	5/89 - 4/90	0	1	-

TABLE 3

CO PROBE HEIGHTS (FEET) FOR EACH MONITOR

Site No.	CO Monitor							
	P1	P2	P3	P4	P5	P6	P7	P8
1	10.50	9.50	10.00	10.00	9.75	10.00	9.00	10. 0
2	9.84	9.84	9.84	9.84	9.84	9.84	9.84	9.84
3	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
4	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
5	9.84	9.84	9.84	9.84	9.84	9.84	9.84	9.84
6A	9.84	9.84	9.84	9.84				

TABLE 4

SUMMARY OF AVAILABLE HOURLY TRAFFIC DATA
FOR EACH INTERSECTION SEGMENT

Vehicle Mix (Fraction)

Automobiles
Fleet Medallion NYC Taxis
Non-Fleet Medallion NYC Taxis
Non-Medallion NYC Taxis
Light-Duty Trucks
Heavy-Duty Gas Trucks
Heavy-Duty Diesel Trucks

Traffic Data

Volume (vehicles per hour)
Average Speed (mph)
Stopped Delay (sec)
"Modified" Average Speed (mph)
Queued Vehicles (vehicles per lane)
Cruise Speed on Block (mph)
Cruise Speed on Downstream Block (mph)
Number of Lanes
Cycle Time (sec)
Acceleration Rate (mph/sec)
Deceleration Rate (mph/sec)

available on an average basis for each intersection include the thermal state conditions which were obtained from field interviews and the average turn movements.

3.3 Analysis of the Observations

3.3.1 Analysis of the Wind Structure

In order to evaluate the appropriateness of the collected data for the model evaluation study, a series of data distribution analyses were prepared for each intersection site using all available hourly averaged data. It is preferred that the wind field at an intersection be uniform for the intersection modeling techniques. Thus, comparisons were made of wind direction, sigma theta, and wind speed at the different meteorological monitors at each intersection site. The entire analysis is discussed in detail in DiCristofaro et al. (1991). For this report, two different types of data plots using all available hourly-averaged data over the entire collection period at each site are presented:

Plot Type 1

$\cos(\theta)$ vs. wind direction (WD) where the angle θ is the difference in wind direction between two different monitors

Values of $\cos(\theta)$ equal to one indicate perfect wind direction alignment between the two monitors, values approaching 0.0 indicate measurements that differ by 90°, and values approaching -1.0 indicate 180° difference in flow that may be associated with street canyon rotors. For this data analysis, spatially uniform wind fields are arbitrarily defined by those cases for which $\cos(\theta) \geq 0.85$, or the wind direction measurements are within 32° of each other.

Plot Type 2

$\frac{|WS1 - WS2|}{\overline{WS}}$ vs. wind direction where WS1 is the measured wind speed at Meteorological Monitor #1, WS2 is the measured wind speed at Meteorological Monitor #2, and $\overline{WS}$ is measured average wind speed.

Values of $\frac{|WS1 - WS2|}{\overline{WS}}$ equal to 0.0 indicate perfect agreement between wind speed measurements. For this data analysis, uniform wind speed fields are arbitrarily defined as those hours for which $\frac{|WS1 - WS2|}{\overline{WS}} \leq 0.4$.

Plot types 1 and 2 for Site #1 are shown in Figures 8 and 9. In general, Site #1 is relatively open with a parking lot on the southeast side and low buildings to the northeast. As shown in Figure 8, the majority of the values of cos(θ) are greater than 0.85. The gaps or sparsity of Monitor 1 wind direction data from 0 to 75° and 130 to 190° indicate the blocking influence of nearby buildings (see Subsection 3.1). The wind speed difference (plot type 2) plotted as a function of the Monitor 1 wind directions are shown in Figure 9. The majority of the $\frac{|WS1 - WS2|}{\overline{WS}}$ data are less than 0.4 which is indicative of uniform winds.

Site #2 is located near Penn Plaza in an area of very tall buildings. Meteorological measurements were made at three different locations, two on West 34th Street and one on 8th Avenue. Plot types 1 and 2 for Site #2 are shown in Figures 10 through 13. The wind direction measurements from Meteorological Monitors #1 and 2 are compared in Figure 10. As shown in Figure 3, Meteorological Monitor #1 is located on 8th Avenue and Monitor #2 is located on 34th Street. The data indicate the presence of complex flows including street canyon rotors and strongly channeled flows. As shown in Figure 12, non-uniformity in wind directions is also found using Meteorological Monitors #2 and 3 which are both on 34th Street. Although, the uniformity in wind direction is poor at Site #2, the uniformity in wind speed is good (see Figures 11 and 13).

Plot types 1 and 2 for Site #3 are shown in Figures 14 and 15. Figure 14 indicates large differences in θ with large gaps at both wind direction monitors. The large wind direction gap is due to the presence of Philharmonic Hall and the Julliard School of Music which lie to the southwest and west of Monitor #1. The wind speed differences shown in Figure 15 also indicate non-uniform wind fields.

Site #4 is located at West 57th Street and 7th Avenue near Carnegie Hall. A variety of building heights from 1 to 70 stories are located in the vicinity of the intersection. For Site #4, plot types 1 and 2 are shown in Figures 16 and 17. In Figure 16, the values of cos(θ) plotted versus the wind direction at Meteorological Monitor #1 indicate uniform wind directions clustered from 90 to 140° and from 280 to 330°. Figure 17 indicates that this site is not uniform in terms of wind speeds.

Site #5 is located near the Jacob Javits Exposition Center along the docks on the Hudson River. There is a wide fetch with little or no building influences from 200 through 30°. The buildings to the east and south are three stories or less. Plot types 1 and 2 for Site #5 are shown in Figures 18 and 19. The majority of the cos(θ) data plotted in Figure 18 approach 1.0 for almost all wind directions. There is some scatter in the data from 35 to 110° due to the influence of the buildings on Meteorological Monitor #1. The wind speed differences versus the Monitor #1 wind directions, shown in Figure 19, are almost all less than 0.4. The largest wind speed differences occur around 180 and 360°.

Site #6 near the Battery Tunnel is divided into two separate sites, 6A and 6B. There is one meteorological tower at each site, which are almost two blocks apart. As shown in Figures 20 and 21, the wind field at this site does not appear to be uniform.

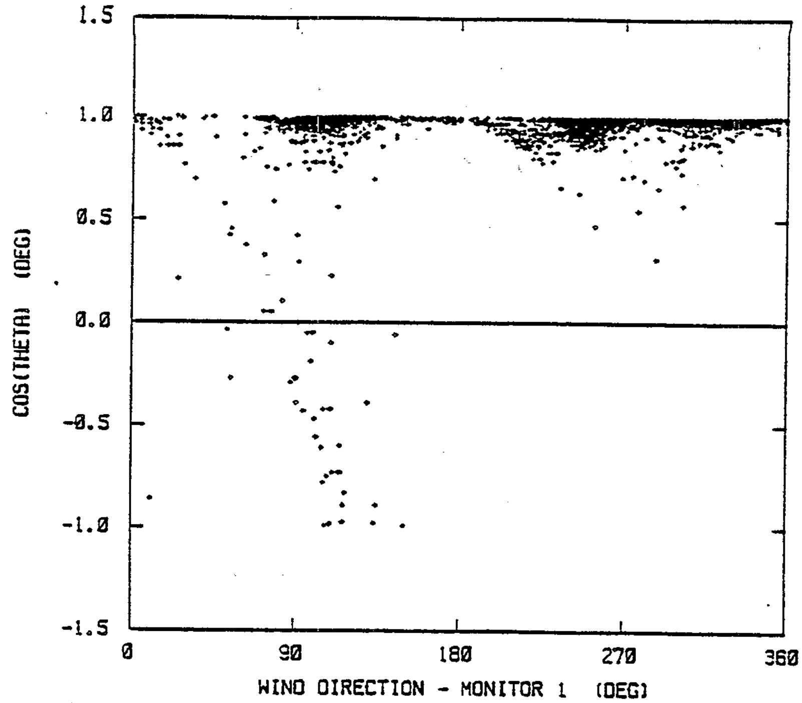


Figure 8. Cos(θ), where θ is the wind direction difference between Monitors 1 and 2, as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #1.

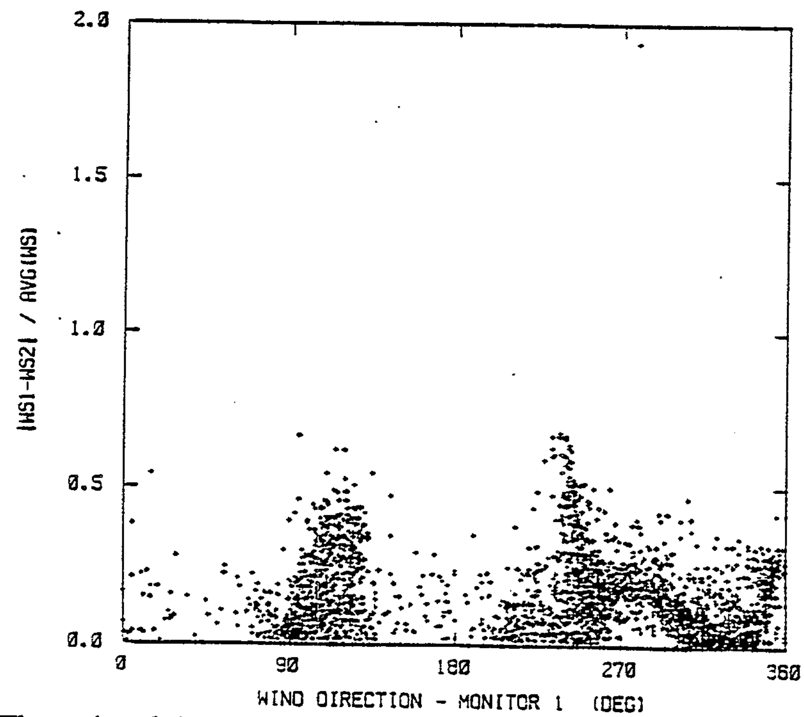


Figure 9. The ratio of the wind speed difference between Monitors 1 and 2 to the average wind speed at the same monitors as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #1.

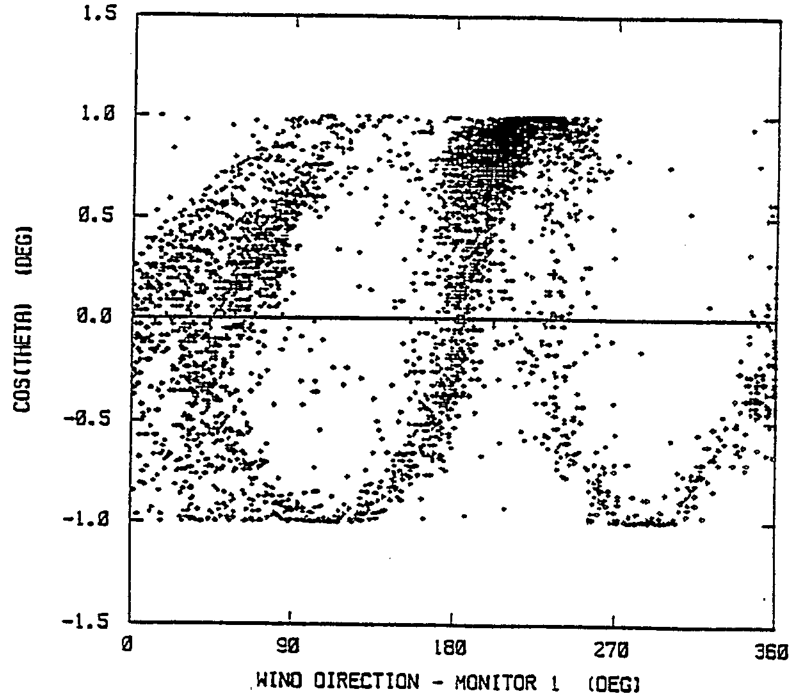


Figure 10. Cos(θ), where θ is the wind direction difference between Monitors 1 and 2, as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #2.

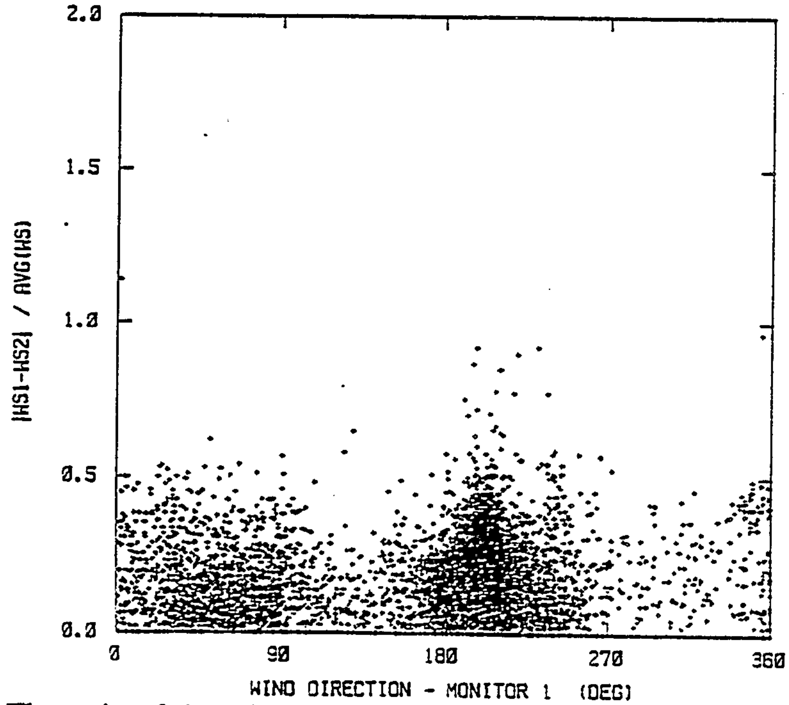


Figure 11. The ratio of the wind speed difference between Monitors 1 and 2 to the average wind speed at the same monitors as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #2.

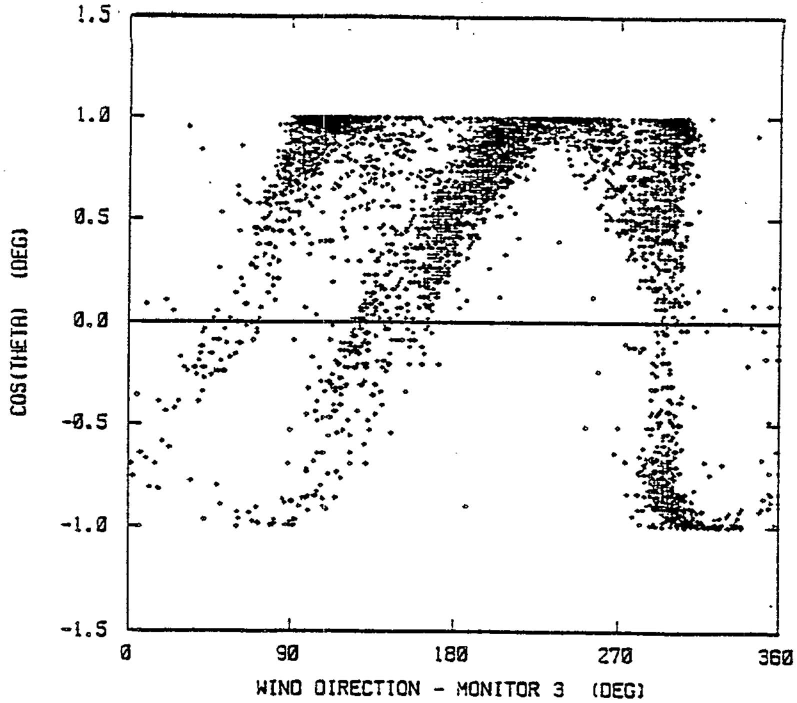


Figure 12. Cos(θ), where θ is the wind direction difference between Monitors 2 and 3, as a function of the wind direction at Monitor 3 for all 1-hour average data at Site #2.

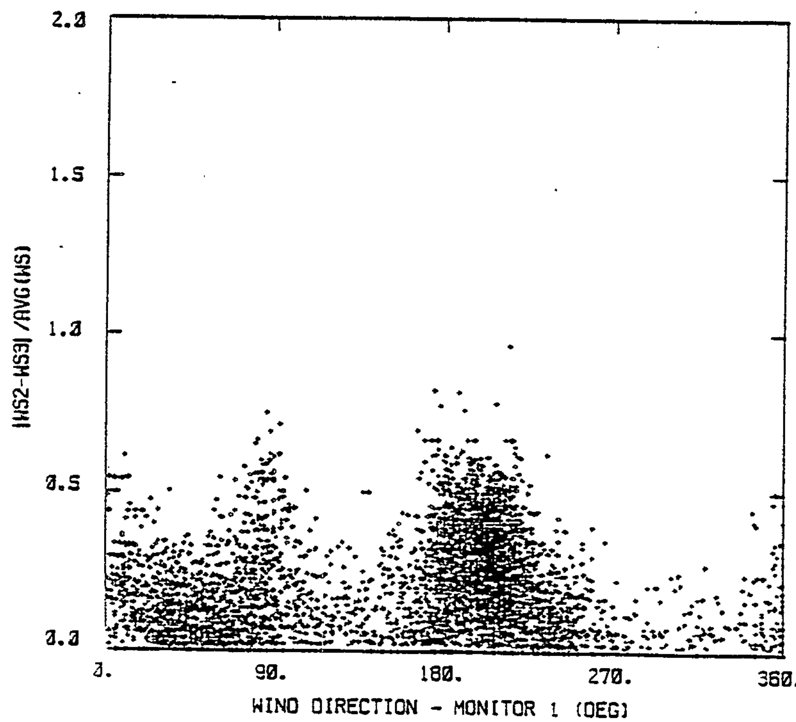


Figure 13. The ratio of the wind speed difference between Monitors 2 and 3 to the average wind speed at the same monitors as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #2.

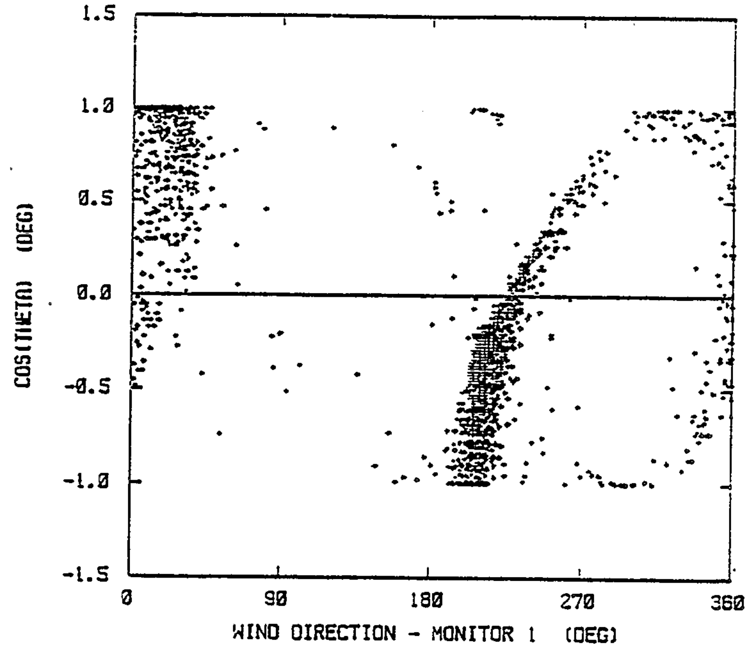


Figure 14. Cos(θ), where θ is the wind direction difference between Monitors 1 and 2, as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #3.

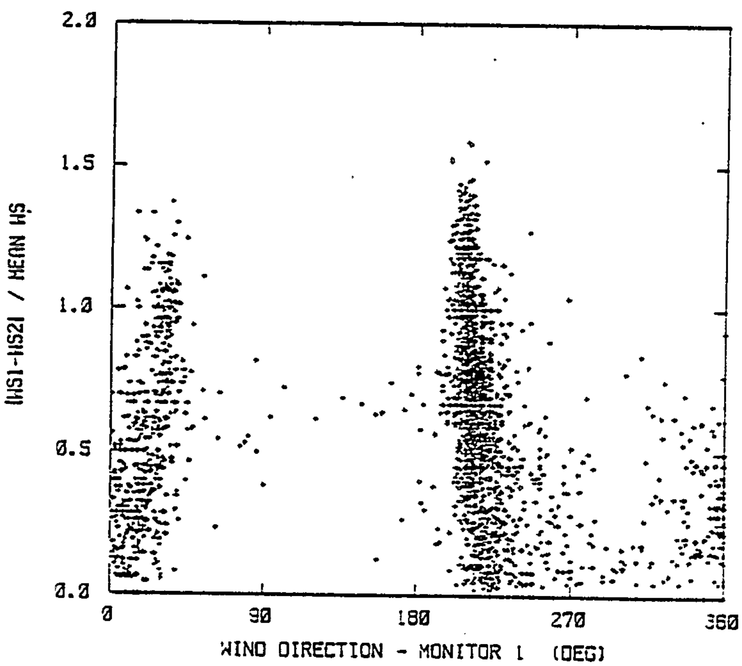


Figure 15. The ratio of the wind speed difference between Monitors 1 and 2 to the average wind speed at the same monitors as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #3.

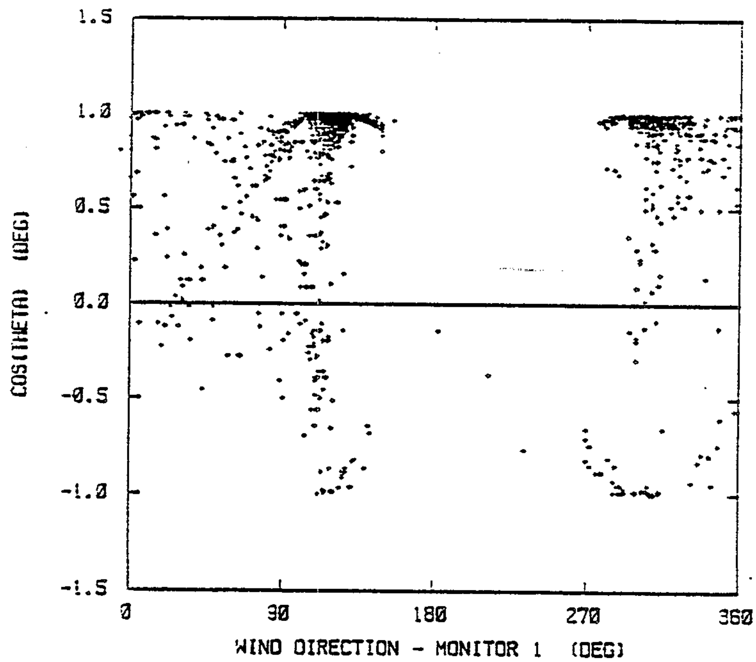


Figure 16. Cos(θ), where θ is the wind direction difference between Monitors 1 and 2, as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #4.

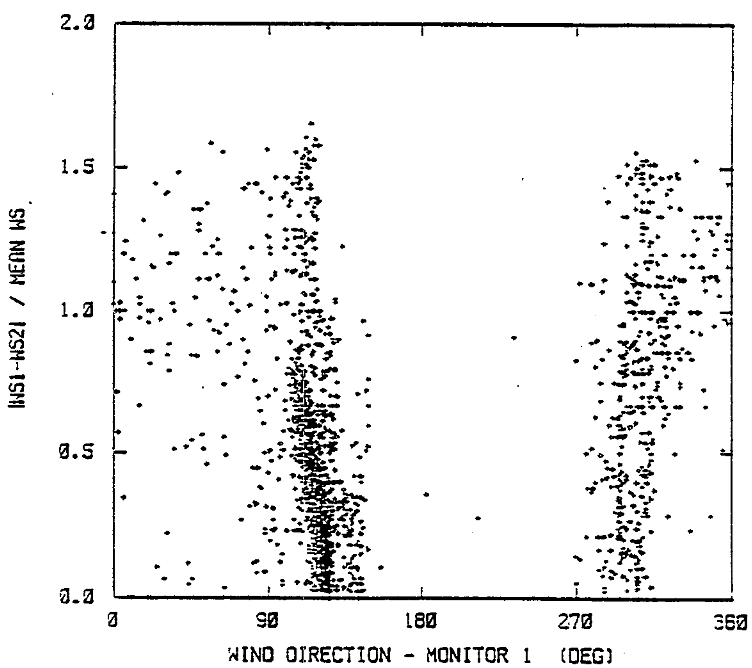


Figure 17. The ratio of the wind speed difference between Monitors 1 and 2 to the average wind speed at the same monitors as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #4.

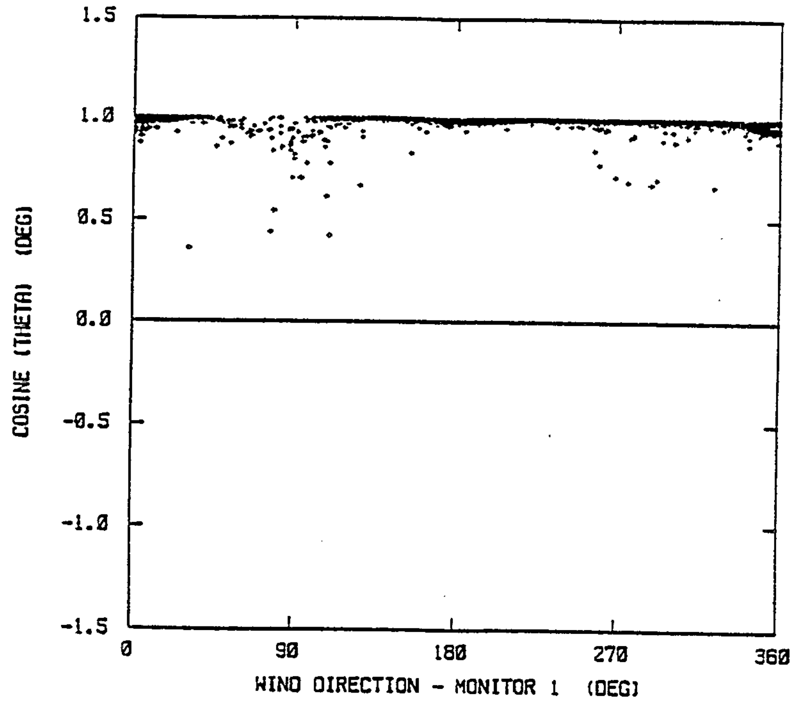


Figure 18. Cos(θ), where θ is the wind direction difference between Monitors 1 and 2, as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #5.

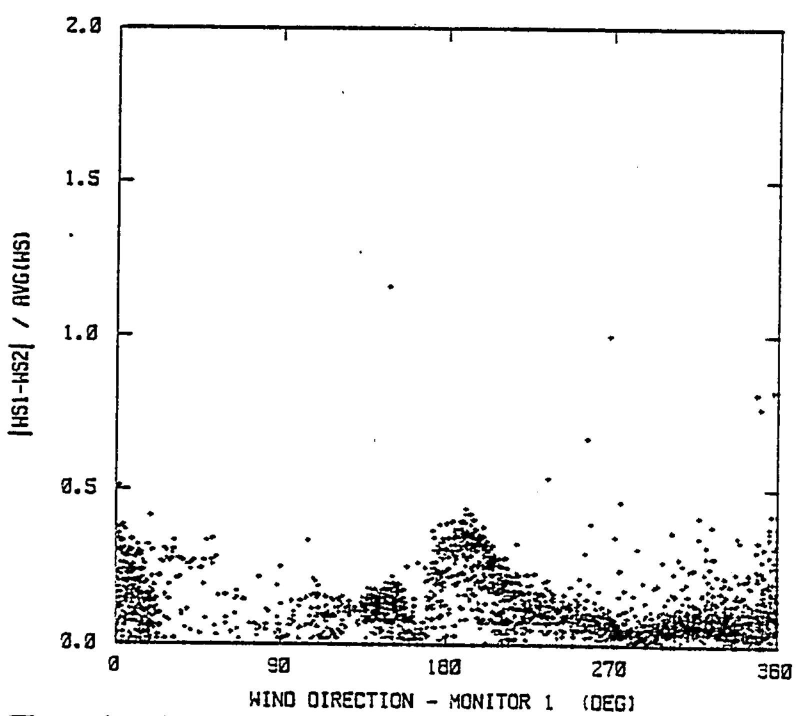


Figure 19. The ratio of the wind speed difference between Monitors 1 and 2 to the average wind speed at the same monitors as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #5.

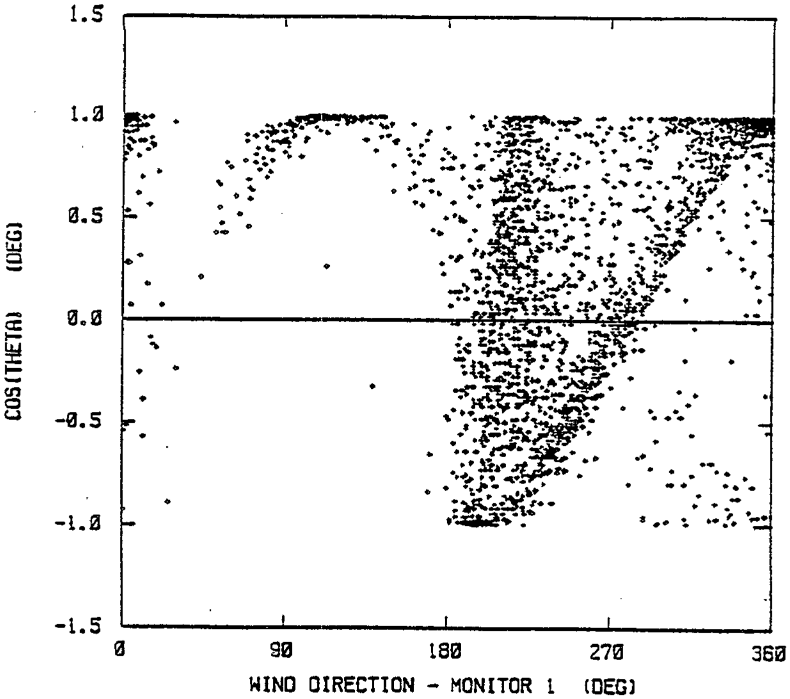


Figure 20. Cos(θ), where θ is the wind direction difference between Monitors 1 and 2, as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #6.

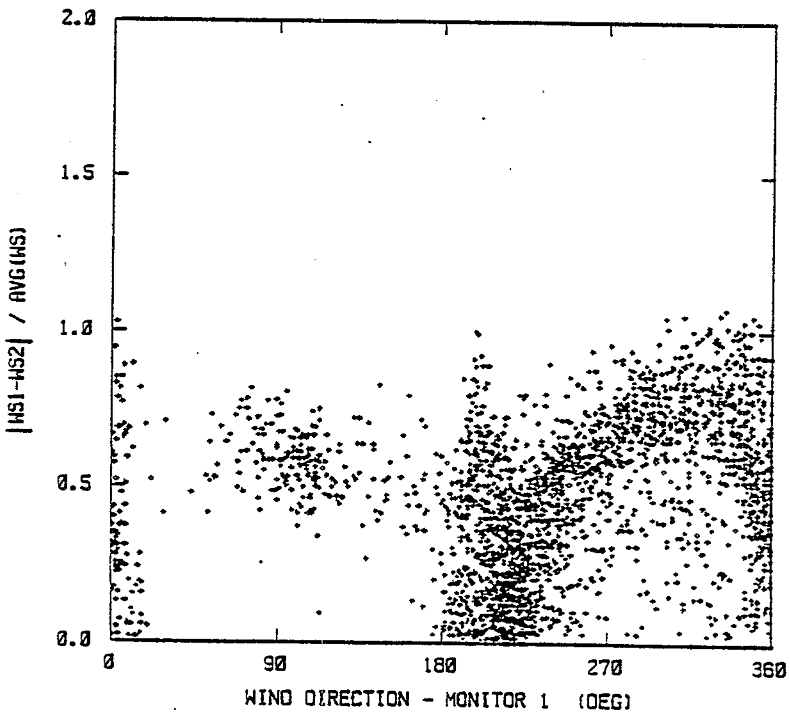


Figure 21. The ratio of the wind speed difference between Monitors 1 and 2 to the average wind speed at the same monitors as a function of the wind direction at Monitor 1 for all 1-hour average data at Site #6.

The results of the uniform wind analysis (DiCristofaro et al., 1991) indicate that Sites #5 and #1 are best in terms of unhindered approach flows and wind field uniformity. The presence of complex flows including street canyon rotors and strongly channeled flows are indicated at the remaining sites, although the uniformity of wind speeds is good at Site #2.

3.3.2 Characterization of the Wind Speed and Stability Class for Modeled Hours

Tables 5 and 6 present tabulations of stability and wind speed, respectively for all modeled hours. As shown in Table 5, there are more hours classified as unstable at all sites except Sites #3, 4 and 6. If the neutral and stable hours are combined then there are more neutral/stable hours for all sites except Sites #2 and 5. As shown in Table 6, Sites #3, 4, and 6 have predominantly light wind speeds (≤ 6 mph) for almost all modeled hours.

3.3.3 Traffic Counts

The total number of vehicles modeled at each site (e.g., all modeled links at each intersection) as a function of the model hour is shown graphically in Figure 22. On average, there is very little variation in traffic counts from one hour to the next because most of the traffic data are associated with rush-hour conditions. This is not surprising, since the hours were selected on the basis of the maximum observed CO concentrations. The traffic counts are lowest on average at Site #4 and highest at Site #6.

TABLE 5

TABULATION OF STABILITY CLASSIFICATION BY SITE

Site	# of Hours	Stability Classification Unstable	Neutral	Stable
1	142	62	57	23
2	143	86	44	13
3	66	24	16	26
4	74	23	34	17
5	75	39	26	10
6	75	21	36	18

TABLE 6

TABULATION OF WIND SPEED BY SITE

Site	# of Hours	Wind Speed ≤ 6 mph	> 6 mph
1	142	98	44
2	143	121	22
3	66	66	0
4	74	73	1
5	75	56	19
6	75	75	0

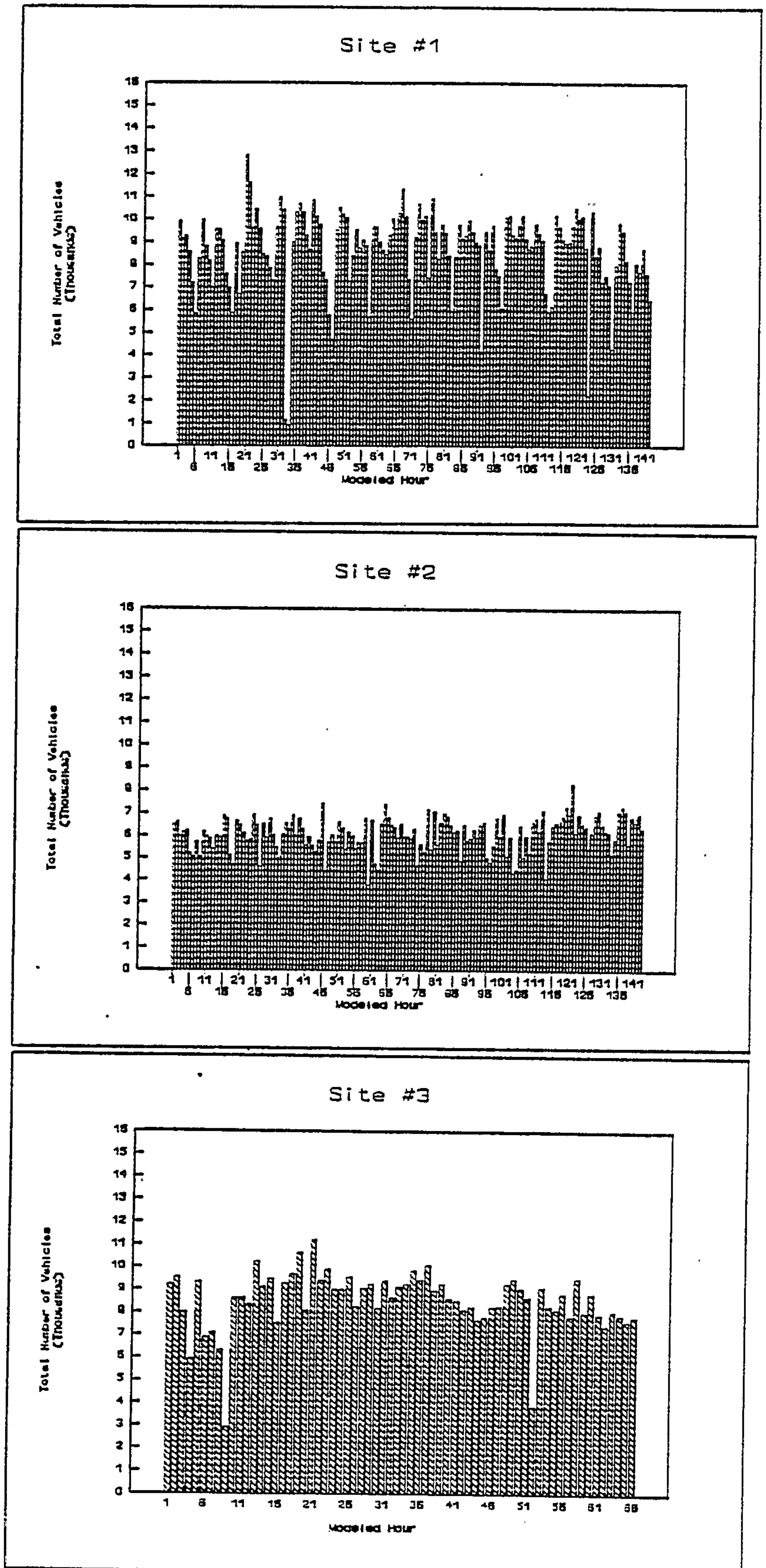


Figure 22. The number of vehicles modeled versus the consecutive model hour at each site.

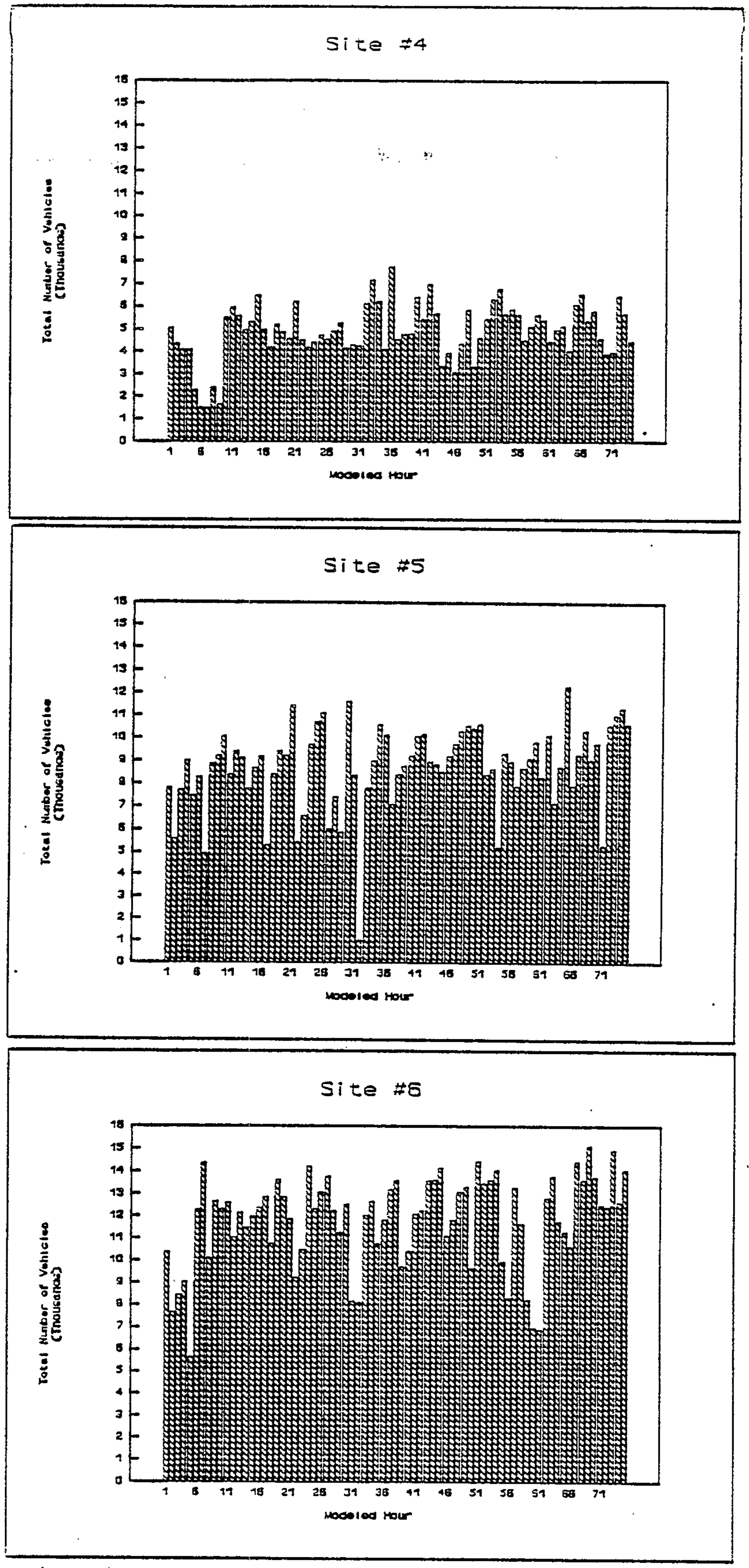


Figure 22. The number of vehicles modeled versus the consecutive model hour at each site (Continued).

4.0 MODELING METHODOLOGY

4.1 Model Input Data

4.1.1 Intersection Configurations

A summary of the intersection data used to specify all modeled links at each site is presented in Table 7. The link ID, intersection street names, the number of lanes, link width, total modeled link length, and whether the link is an approach or departure roadway are summarized. A link is considered to be any lane group that is considered to be a separate line source and can be characterized separately from other sources. The link length shown in Table 7 is with respect to the center of the intersection to the center of the adjacent intersection.

Each of the eight models evaluated requires a slightly different characterization of the intersection data. Overlapping free-flow and queue and/or excess emission links are required by the EPAINT, CAL3QHC, and VOL9MOB4 modeling techniques. For these three models, each free-flow link is modeled using the distance from the center of the adjacent intersection to the center of the modeled intersection. The modeled queues and/or excess emission links are modeled from the stop lines. The GIM model requires the designation of separate free-flow and excess emission links. Each link modeled by the GIM model consists of an arrival link at cruise emissions, an excess emission link adjoining the arrival link to the intersection center, and a departure link in the opposite direction. If the excess emission link is estimated by the GIM model to be greater than the overall length of the link, then an arrival portion of the link is not modeled. The FHWAINT model only requires the midblock-to-midblock distances over which the adjusted emissions for the vehicle speed are applied. No excess emission links are specified in the FHWAINT model. The TEXIN2 and CALINE4 models only require the specification of general link coordinates for each leg of the intersection. For example, when applying the TEXIN2 model at Site #1, the West Street and Service Road approach lanes were combined into one group of lanes. The TEXIN2, CALINE4, and IMM models internally calculate the link and departure components, including the excess emission links. The IMM model requires the link approach and departure coordinates. The queue links are internally calculated by the IMM model and are superimposed over the approach links.

The intersection configurations for each site used in the modeling analysis are shown in Figures 23 through 28. Only a portion of the total modeled links is shown in these figures. The actual modeled link lengths are given in Table 7. Also shown in these figures are the locations of the CO monitors (labeled as P1, P2, etc.) and the meteorological monitors (labeled as M1, M2, etc.).

The intersection configuration for Site #1 (West/Chambers) is shown in Figure 23. Nine separate links (five approach and four departure) were used in the modeling analysis at Site

TABLE 7

SUMMARY OF INTERSECTION CONFIGURATIONS

SITE #1

Link ID	Intersection	Number of Lanes	Width (ft)	Length (ft)	Approach/ Departure
WN-340	West NB @ Chambers	3	36	790	A
WN-410	West NB @ Main Line	3	36	1572	D
WS-510	West SB @ Chambers	3	36	1633	A
WS-620	West SB @ Barclay	3	36	1023	D
WN-350	Service NB @ Chambers	3	36	772	A
WN-420	Service NB @ 1600'	3	36	1576	D
WS-520	West SB @ Chambers (left)	1	12	1643	A
CW-210	Chambers WB @ West	2	23	685	A
CW-110	Chambers EB @ Greenwich	1	16	606	D

SITE #2

Link ID	Intersection	Number of Lanes	Width (ft)	Length (ft)	Approach/ Departure
TE-108	34th EB @ 8th	2	24	920	A
TE-107	34th EB @ 7th	2	24	852	D
TW-208	34th WB @ 8th	2	24	914	A
TW-209	34th WB @ 9th	2	24	855	D
EN-334	8th NB @ 34th	4	48	300	A
EN-335	8th NB @ 35th	4	48	262	D

SITE #3

Link ID	Intersection	Number of Lanes	Width (ft)	Length (ft)	Approach/ Departure
SB-520	West 65th EB @ Broadway	2	24	882	A
SB-530	West 65th EB @ Central Park W.	2	24	930	D
SB-650	Broadway NB @ 65th	3	36	355	A
SB-660	Broadway NB @ 66th	3	36	248	D
SB-865	Broadway SB @ 65th	3	36	345	A
SB-864	Broadway SB @ 64th	3	36	267	D
SB-965	Columbus SB @ 65th	3	36	258	A
SB-964	Columbus SB @ 64th	4	48	242	D

TABLE 7 (continued)

SUMMARY OF INTERSECTION CONFIGURATIONS

SITE #4

Link ID	Intersection	Number of Lanes	Width (ft)	Length (ft)	Approach/ Departure
SF-870	57th EB @ 7th	2	24	631	A
SF-860	57th EB @ Ave of Amer.	2	24	844	D
SF-670	57th WB @ 7th	2	24	939	A
SF-675	57th WB @ Broadway	2	24	525	D
SF-570	7th SB @ 57th	4	48	315	A
SF-560	7th SB @ 56th	4	48	252	D

SITE #5

Link ID	Intersection	Number of Lanes	Width (ft)	Length (ft)	Approach/ Departure
TN-340	12th NB @ W 34th	2	24	1174	A
TN-390	12th NB @ W 39th	2	24	1174	D
SN-340	Service NB @ W 34th	3	30	1177	A
SN-390	Service NB @ W 39th	2	24	1177	D
TS-340	12th SB @ W 34th	2	24	1179	A
TS-300	12th SB @ W 30th	2	24	1179	D
TL-340	12th SB (left turn) @ W 34th	1	12	1342	A
SS-340	Service SB @ W 34th	1	12	1172	A
SS-300	Service SB @ W 30th	1	12	1172	D
TW-115	34th EB @ 10th	2	24	995	A
TE-110	34th SB @ 12th	3	36	912	D

SITE #6

Link ID	Intersection	Number of Lanes	Width (ft)	Length (ft)	Approach/ Departure
WT-110	West NB @ Tunnel	4	48	257	A
WT-120	West NB @ Liberty	3	36	1330	D
WT-125	West NB @ Liberty (left)	1	11	1318	D
WT-330	West SB @ Tunnel Underpass	2	24	1104	A
WT-320	West SB @ Tunnel	3	36	1487	A
WT-310	West SB @ Morris	2	24	221	D
WT-410	Service SB @ Morris	2	24	221	D
WT-500	Tunnel WB @ West	5	60	509	A
WT-510	Tunnel EB (Entrance)	2	25	474	D

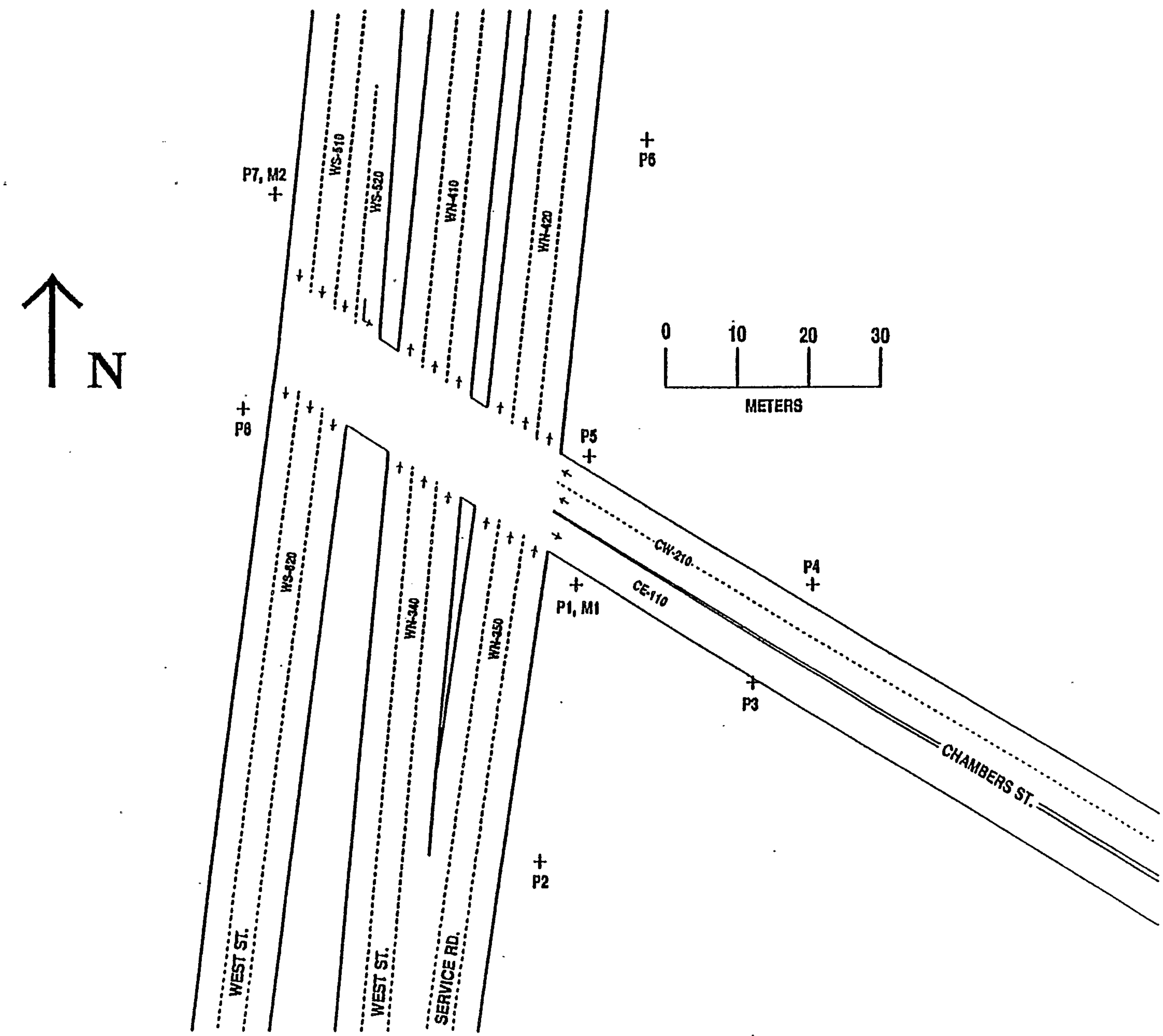


Figure 23. The intersection configuration for Site #1 (West/Chambers) used in the modeling analysis.

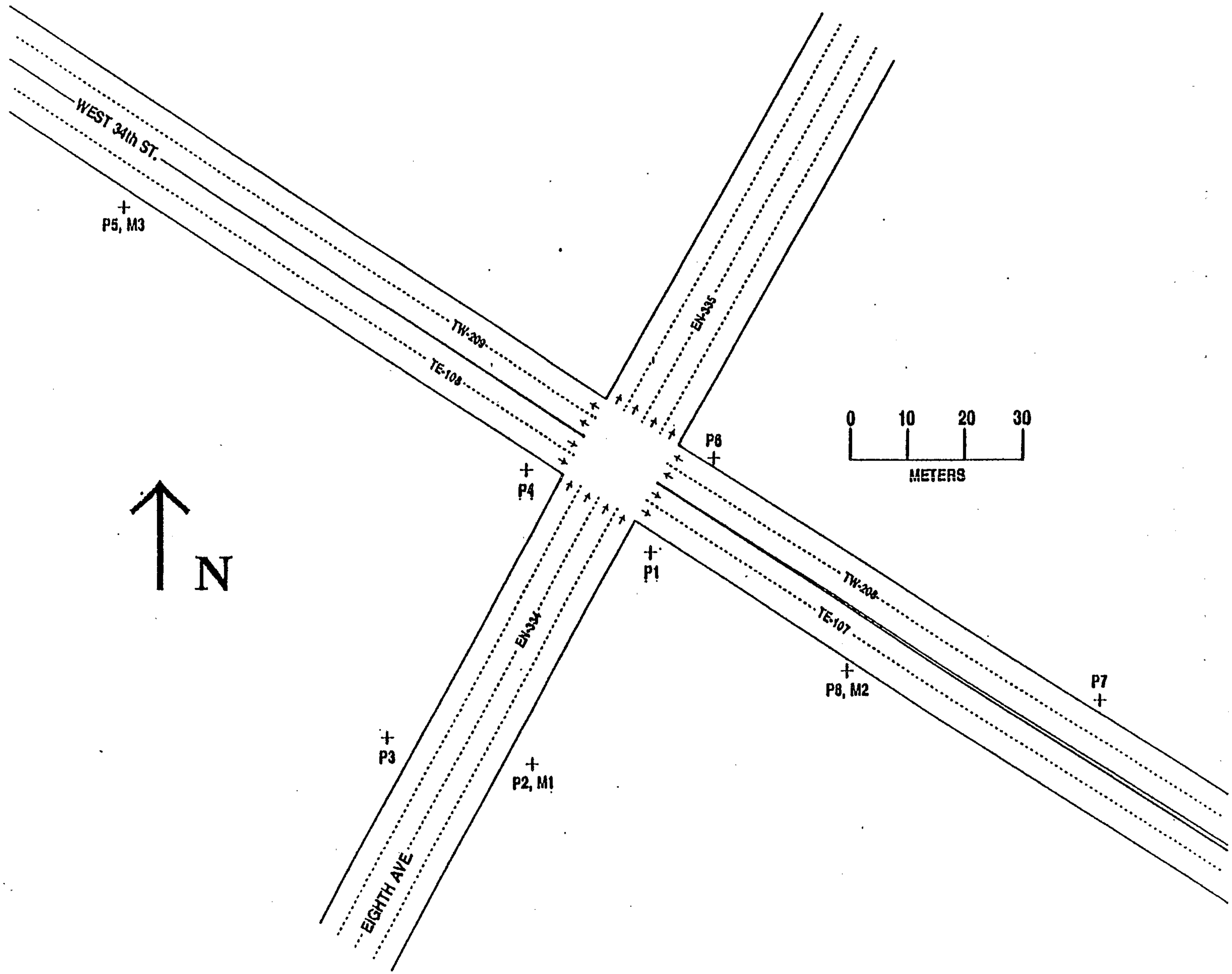


Figure 24. The intersection configuration for Site #2 (34th/8th) used in the modeling analysis.

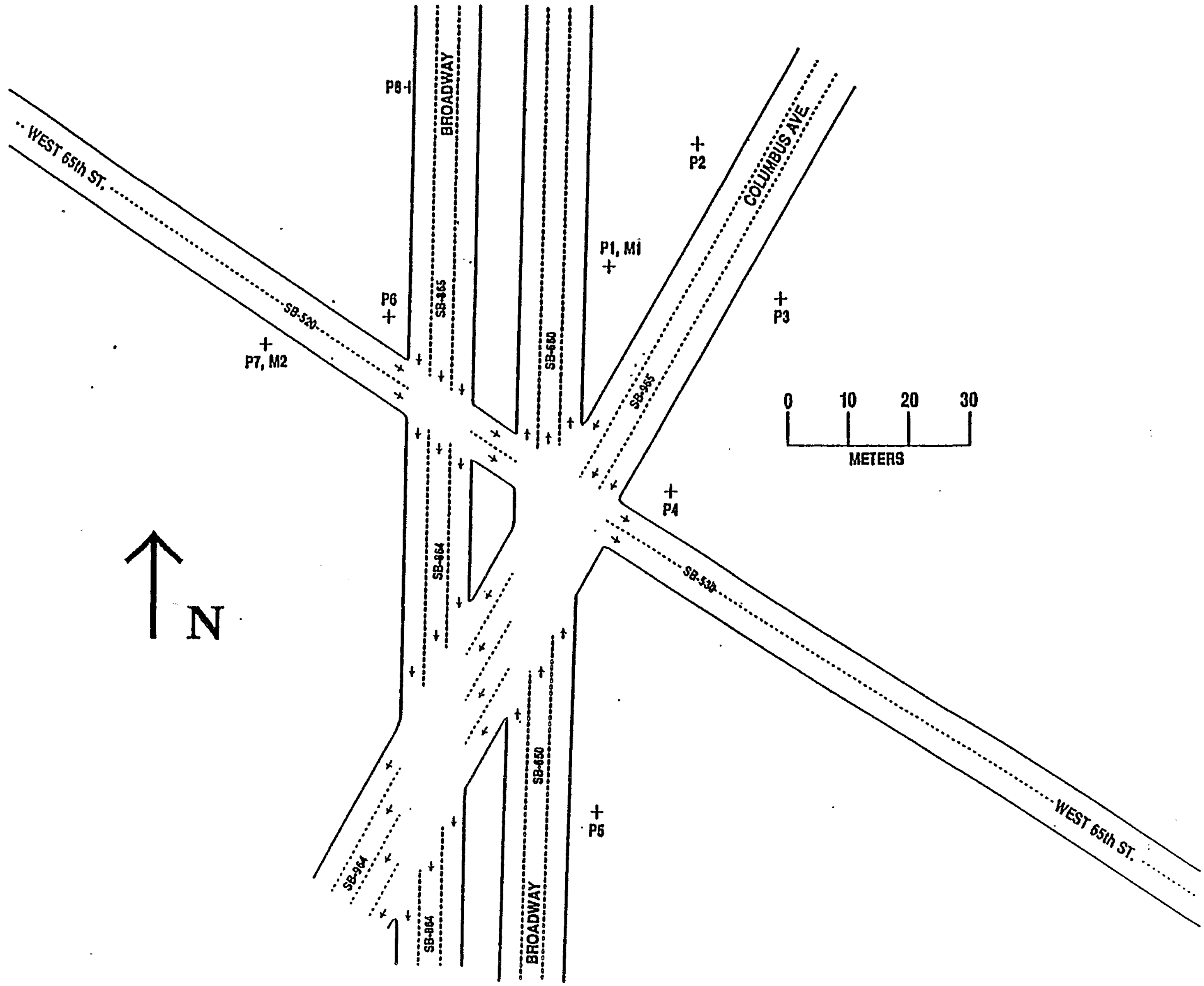


Figure 25. The intersection configuration for Site #3 (65th/Broadway) used in the modeling analysis.

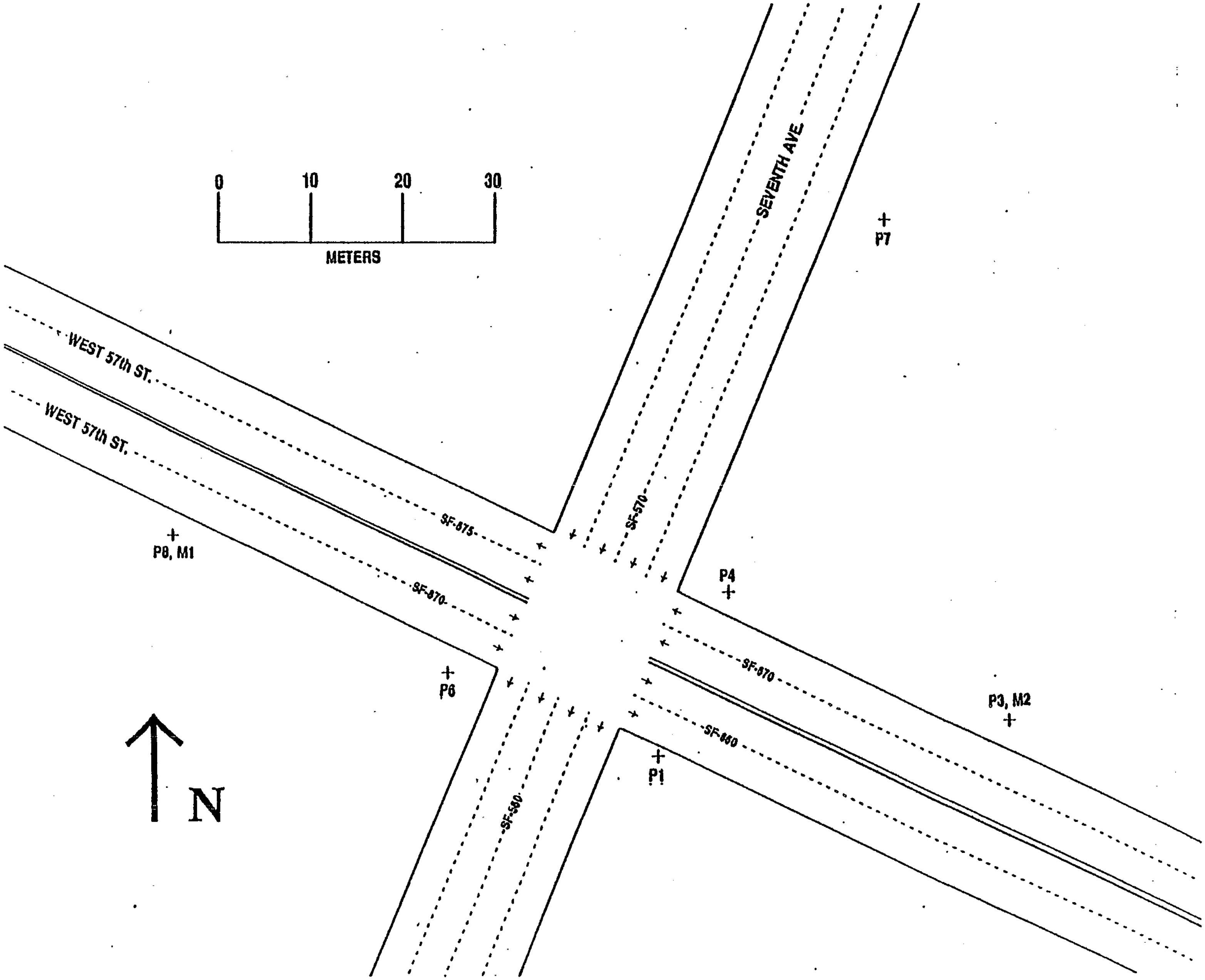


Figure 26. The intersection configuration for Site #4 (57th/7th) used in the modeling analysis.

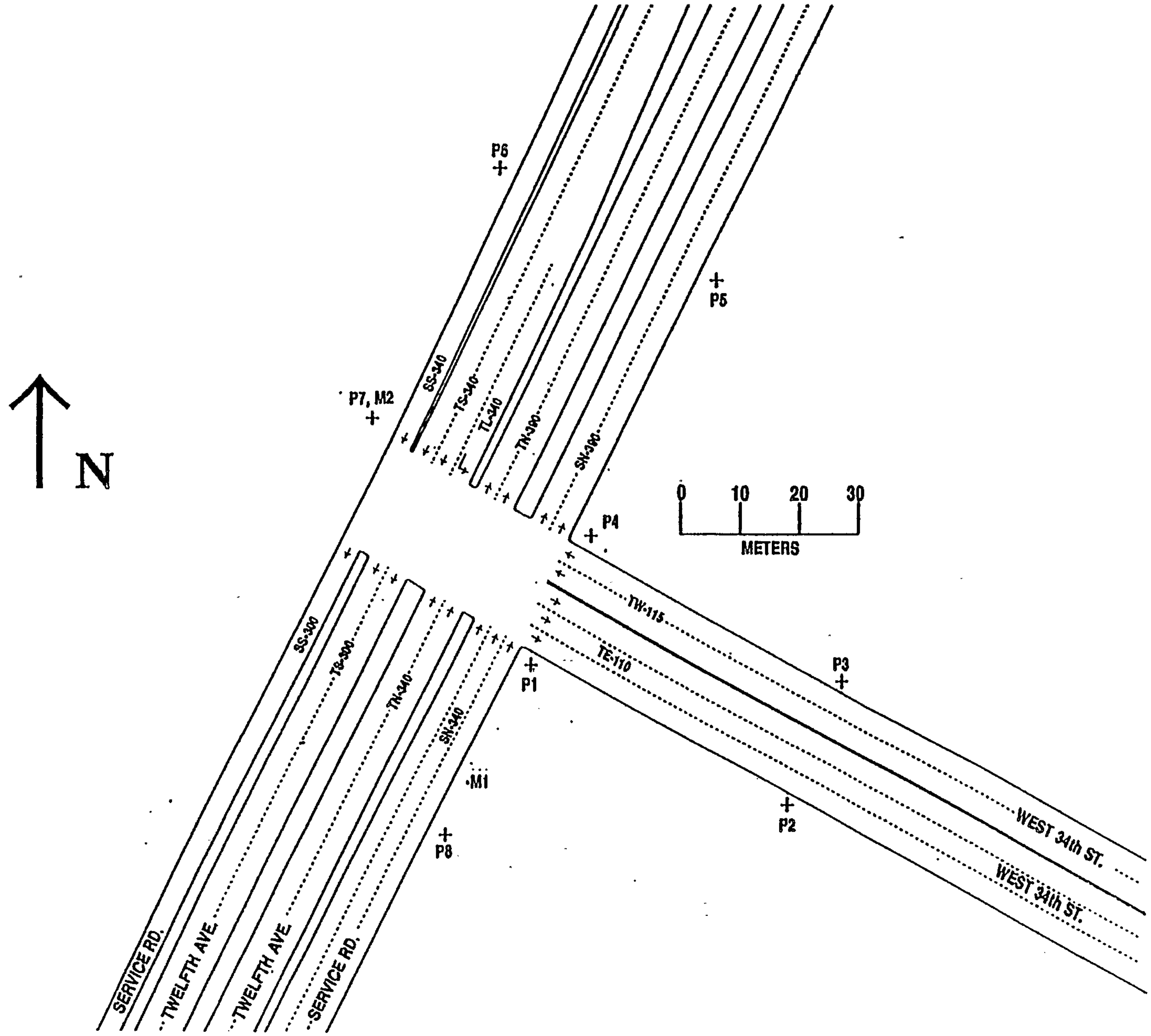


Figure 27. The intersection configuration for Site #5 (34th/12th) used in the modeling analysis.

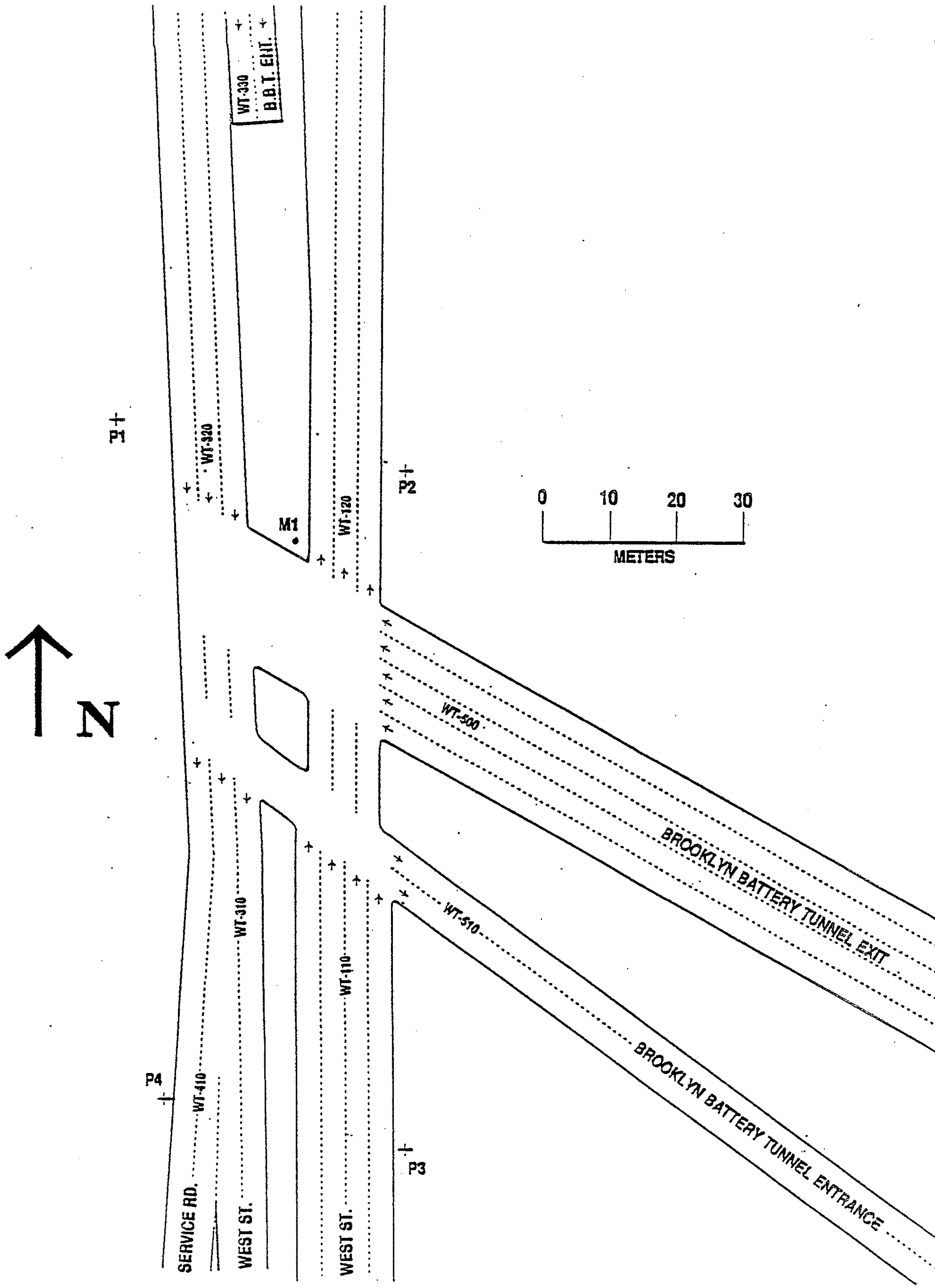


Figure 28. The intersection configuration for Site #6 (Battery Tunnel) used in the modeling analysis.

#1. Before approaching the West/Chambers intersection, the northbound portion of West Street divides in two with the formation of a Service Road. The southbound left-turn lane on West Street was modeled as a separate link. The configuration shown for Site #2 (34th/8th) in Figure 24 consists of four one-way northbound lanes on 8th Avenue and two approach and two departure lanes on West 34th Street. The Site #3 (65th/Broadway) configuration shown in Figure 25 is the most complicated intersection of the six modeled. The intersection consists of four approach links (Columbus Avenue southbound, Broadway north and southbound, and West 65th Street eastbound) and four departure links. The intersection configuration for Site #4 (57th/7th), shown in Figure 26, consists of four one-way southbound lanes on 7th Avenue and two approach and two departure lanes on West 57th Street. The Site #5 (34th/12th) configuration shown in Figure 27 indicates that there are six different approach links and five departure links used in the modeling analysis. On this portion of Route 9A, 12th Avenue includes a separate north and southbound service road which were modeled as separate links. The southbound left-turn lane on 12th Avenue was modeled as a separate link. Finally, the intersection configuration for Site #6 (Battery Tunnel), shown in Figure 28, consists of four approach links and five departure links. The WT-330 link represents the Route 9A entrance to the Brooklyn Battery Tunnel and the WT-500 link represents the tunnel exit. The traffic associated with the WT-500 link must pass under an overhang associated with the Port of New York Authority Building before intersecting West Street.

4.1.2 Traffic and Emissions Characterization

As discussed in Section 3.0, the approach and departure traffic counts for each modeled link were obtained by manual processing of the videotapes. The capacity or saturated flow to each approach of the intersection was calculated using the computerized version of Chapter 9 of the 1985 Highway Capacity Manual (TRB, 1985). The actual average green time for each signal phase was used along with an average (or random) arrival progression factor. Average traffic volumes and turn information (left, thru, right) for each link were used along with the average percent red times. The percent red time for four periods during the day along with the calculated average saturated flow rates for each link are shown in Table 8. The percent red time and cycle time were used to calculate the green time for four different time periods for those models requiring the input of green time. Yellow time was assumed to be zero for all analyses. The segment running time per mile was input to the EPAINT model using the recommended values in HCM (TRB, 1985) based on the cruise speed and the average segment length.

Overcapacity conditions were modeled by the EPAINT, FHWAINT, and VOL9MOB4 models at a few links and sites. Overcapacity conditions exist when the fraction of vehicles that stop is greater than one in the VOL9MOB4 model and when the volume to capacity (V/C) ratio is greater than 1.2 in the EPAINT and FHWAINT models. When overcapacity conditions were modeled at a particular link, the respective model did not produce any emissions for that link. Thus, in order to compensate for overcapacity conditions, the

TABLE 8

SUMMARY OF SATURATED FLOW AND PERCENT RED TIME

SITE #1

Link ID	Saturated Flow (vehicles)	Percent Red Time Time Period (EST) 5-9	10-14	15-18	19-4
WN-340	4811	0.533	0.408	0.642	0.408
WN-410	-999	0.275	0.275	0.275	0.275
WS-510	4811	0.266	0.275	0.417	0.275
WS-620	-999	0.325	0.325	0.325	0.325
WN-350	4768	0.533	0.408	0.642	0.408
WN-420	-999	0.275	0.275	0.275	0.275
WS-520	1524	0.733	0.867	0.775	0.867
CW-210	3019	0.766	0.766	0.625	0.766
CE-110	-999	0.529	0.529	0.529	0.529

SITE #2

Link ID	Saturated Flow (vehicles)	Percent Red Time Time Period (EST) 5-9	10-14	15-18	19-4
TE-108	2149	0.572	0.572	0.572	0.572
TE-107	-999	0.569	0.569	0.569	0.569
TW-208	2688	0.572	0.572	0.572	0.572
TW-209	-999	0.569	0.569	0.569	0.569
EN-334	6205	0.470	0.470	0.470	0.470
EN-335	-999	0.412	0.412	0.412	0.412

SITE #3

Link ID	Saturated Flow (vehicles)	Percent Red Time Time Period (EST) 5-9	10-14	15-18	19-4
SB-520	2688	0.670	0.670	0.670	0.670
SB-530	-999	0.679	0.679	0.679	0.679
SB-650	4321	0.670	0.670	0.670	0.670
SB-660	-999	0.419	0.419	0.419	0.419
SB-865	4099	0.670	0.670	0.670	0.670
SB-864	-999	0.330	0.330	0.330	0.330
SB-965	4199	0.660	0.660	0.660	0.660
SB-964	-999	0.346	0.346	0.346	0.346

Note: Saturated flow values of -999 indicate departure links.

TABLE 8 (continued)

SUMMARY OF SATURATED FLOW AND PERCENT RED TIME

SITE #4

Link ID	Saturated Flow (vehicles)	Percent Red Time Time Period (EST) 5-9	10-14	15-18	19-4
SF-870	2755	0.608	0.608	0.608	0.608
SF-860	-999	0.632	0.632	0.632	0.632
SF-670	2637	0.606	0.606	0.606	0.606
SF-675	-999	0.571	0.571	0.571	0.571
SF-570	6324	0.461	0.461	0.461	0.461
SF-560	-999	0.411	0.411	0.411	0.411

SITE #5

Link ID	Saturated Flow (vehicles)	Percent Red Time Time Period (EST) 5-9	10-14	15-18	19-4
TN-340	3208	0.525	0.525	0.525	0.525
TN-390	-999	0.193	0.375	0.375	0.375
SN-340	4234	0.525	0.525	0.525	0.525
SN-390	-999	0.193	0.375	0.375	0.375
TS-340	3208	0.208	0.375	0.375	0.375
TS-300	-999	0.250	0.250	0.250	0.250
TL-340	1524	0.717	0.858	0.858	0.858
SS-340	1604	0.208	0.375	0.375	0.375
SS-300	-999	0.250	0.250	0.250	0.250
TW-115	2430	0.833	0.667	0.667	0.667
TE-110	-999	0.733	0.733	0.733	0.733

SITE #6

Link ID	Saturated Flow (vehicles)	Percent Red Time Time Period (EST) 5-9	10-14	15-18	19-4
WT-110	6144	0.567	0.422	0.422	0.422
WT-120	-999	0.508	0.508	0.508	0.508
WT-125	-999	0.508	0.508	0.508	0.508
WT-330	3600	0.000	0.000	0.000	0.000
WT-320	4811	0.567	0.422	0.422	0.422
WT-310	-999	0.433	0.433	0.433	0.433
WT-410	-999	0.000	0.000	0.000	0.000
WT-500	6961	0.467	0.622	0.622	0.622
WT-510	-999	0.000	0.000	0.000	0.000

Note: Saturated flow values of -999 indicate departure links.

overcapacity link was merged with another link or the volume was set to capacity. For example, at Site #5, the left turn lane (TL-340) was modeled as overcapacity by EPAINT for five different hours. When this link (TL-340) was merged with TS-340, the V/C ratio was less than 1.2 and emissions from the link were calculated.

When applying the CALINE4 model, the amount of time the first car spends in the queue (IDT1) was set to the red time and the vehicle idle time at the end of the queue (IDT2) was set to zero (Benson, 1991). The value of NDLA, the length of the queue or the number of cars per lane that are queued when the light turns green, input to the CALINE4 model was calculated using the following steps:

(1) NDLA = (number of vehicles/number of lanes) · percent red time

(2) "Ripple" or Propagation Time of the Queue = NDLA · 2.5 sec/car

(3) Adjusted Percent Red Time = (red time + propagation time)/cycle time

(4) Adjusted NDLA = (number of vehicles/number of lanes) · adjusted percent red time

The value of NDLA was adjusted in order to account for a "ripple" or propagation speed estimated at 2.5 sec/vehicle. Also, in the CALINE4 model, if the calculated length of the queue plus the deceleration length is greater than the link length with respect to the stop line, then the model will stop with an error. Therefore, for these traffic conditions, the link length was reset to the length of the queue plus the deceleration length.

The hourly traffic data contain four types of vehicle speeds for each link: cruise speed on the block, cruise speed on the downstream block, average speed, and "modified" average speed. The "modified" average speed is the total travel time less the average stop delay time on the link. For this modeling analysis, the cruise speed on the block for each link was used for the approach speed. For the TEXIN2 model, a traffic volume weighted average of the cruise speeds over the modelled lane group was used. For those models which require a departure speed, we specified the cruise speed on the downstream block associated with the approach lane being modeled. The traffic cruise speeds for each link modeled are presented in Table 9 for four different time periods. At Site #2 there were a few exceptions to the traffic speeds used with respect to the time period.

One of the purposes of this model evaluation study is to evaluate the intersection modeling techniques using commonly available data. Therefore, the cruise speed rather than the average or "modified" average speed was used in the evaluation. Also, the observed queue lengths were not used so that the queuing algorithms for each model could be tested.

Emissions were estimated using the MOBILE4 and MOBILE4.1 emissions model. The Inspection/Maintenance (I/M) program specifications for the MOBILE4 and 4.1 modeling were set as follows:

TABLE 9

TRAFFIC CRUISE SPEEDS (MPH) USED IN MODELING ANALYSIS

SITE #1

Link	Time Period (EST) 6-9	10-14	15-18	19-5
WN-340	29.3	28.9	31.8	36.1
WN-410	30.4	32.8	27.0	40.8
WS-510	34.2	31.4	31.9	39.4
WS-620	30.5	28.8	21.8	38.4
WN-350	29.3	28.9	31.8	33.9
WN-420	30.4	32.8	27.0	35.7
WS-520	34.2	31.4	31.9	37.3
CW-210	18.5	17.2	17.3	22.0
CE-110	20.4	20.1	16.7	24.1

SITE #2

Link	Time Period (EST) 7-9	10-14	15-18	19-6
TE-108	17.2	12.9	12.3	25.6
TE-107	20.1	7.6	12.4	30.6
TW-208	20.8	18.5	16.0	30.5
TW-209	20.6	23.2	20.9	31.3
EN-334	22.5	9.8	13.3	33.7
EN-335	22.2	10.8	15.5	27.9
Exceptions:	10-25-89 Hr. 18 11-08-89 Hr. 15	9-16-89 Hr. 19	8-17-89 Hr. 8	8-14-89 Hr. 8 10-27-89 Hr. 7

SITE #3

Link	Time Period (EST) 7-9	10-14	15-18	19-6
SB-520	21.3	19.3	21.3	30.1
SB-530	18.1	15.9	16.0	20.8
SB-650	17.5	14.2	15.9	13.2
SB-660	23.3	17.8	20.4	18.2
SB-865	18.7	16.2	17.2	16.2
SB-864	21.9	18.0	19.3	26.2
SB-965	17.6	15.1	16.8	29.5
SB-964	18.2	20.0	18.3	29.0

TABLE 9 (continued)

TRAFFIC CRUISE SPEEDS (MPH) USED IN MODELING ANALYSIS

SITE #4

Link	Time Period (EST) 7-9	10-14	15-18	19-6
SF-870	24.0	20.5	20.8	32.8
SF-860	23.5	24.3	17.6	24.2
SF-670	23.6	17.0	22.8	25.1
SF-675	18.7	14.3	23.2	23.6
SF-570	12.6	18.8	15.9	20.1
SF-560	18.5	19.9	17.3	23.2

SITE #5

Link	Time Period (EST) 7-9	10-14	15-18	19-6
TN-340	31.0	34.7	28.4	38.1
TN-390	29.5	33.6	22.9	38.5
SN-340	32.0	31.4	28.4	35.3
SN-390	28.5	30.5	22.9	34.4
TS-340	32.8	28.6	27.8	36.0
TS-300	32.9	31.0	27.5	39.3
TL-340	32.8	28.6	27.8	36.0
SS-340	35.1	33.5	30.9	42.0
SS-300	37.8	37.8	34.1	43.5
TW-115	25.8	27.7	27.5	29.8
TE-110	25.4	25.0	23.7	27.6

SITE #6

Link	Time Period (EST) 7-9	10-14	15-18	19-6
WT-110	15.9	15.2	15.0	29.1
WT-120	19.3	28.3	29.1	35.8
WT-125	19.3	28.3	29.1	35.8
WT-330	30.6	30.9	33.5	35.1
WT-320	30.6	30.9	33.5	35.1
WT-310	29.0	30.4	28.3	34.4
WT-410	29.0	30.4	28.3	34.4
WT-500	34.3	44.5	34.2	46.1
WT-510	36.6	43.5	30.7	47.8

- Start year - 1982
- Pre-1981 MYR stringency rate - 30%
- First model year covered - 1960
- Last model year covered - 2020
- Waiver rate (pre-1981) - 0.0%
- Waiver rate (1981 and newer) - 0.0%
- Compliance rate - 75%
- Inspection type - Manual decentralized
- Inspection frequency - Annual
- Vehicle types covered - LDGV, LDGT1, LDGT2, HDGV
- 1981 and later MYR test type - Idle

The Anti-Tampering Program (ATP) program specifications for the MOBILE4 and 4.1 modeling were:

- Start year - 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%
- 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 (Yes for MOBILE4.0)

· PCV system disablements - Yes

· Missing gas caps - No

The MOBILE4.1 model will only model an ATP with an evaporative system inspection and provide appropriate emission credits if a gas cap inspection is also included. If the user indicates that an evaporative system inspection is performed, but that a gas cap inspection is not performed, an error message will be issued and execution of the run will stop (EPA, 1991). The New York DEP (Nudelman, 1991) recommends not using the evaporative control systems check when using MOBILE4.1.

Mileage accumulation rates and registration distributions recommended by the New York DEC for automobiles are listed in Table 10. The MOBILE4.1 emissions model requires an additional five years of data (Years 21 to 25) for the mileage accumulation rates and registration distributions. Data for Years 21 to 25 were not available from the New York DEC when the MOBILE4.1 modeling was conducted. As recommended by the New York DEP (Nudelman, 1991), the values for years 21 to 25 were set to zero.

As noted in Section 3.0, hourly vehicle mixes were available for each link for seven vehicle categories: automobiles, fleet medallion New York City taxis, non-fleet medallion New York City taxis, non-medallion New York City taxis, light-duty trucks, heavy-duty gas trucks, and heavy-duty diesel trucks. The mileage accumulation rates, registration distributions, I/M (Inspection/Maintenance) program parameters, and ATP (Anti-Tampering Program) parameters are different for each vehicle category. A large percentage of the vehicles in Manhattan are taxis which differ from automobiles in the following manner:

1) The taxi turnover rate is high so the vehicles are newer. Thus, taxis tend to have installed more current control technologies.

2) Taxis are constantly cruising so they are almost always hot; whereas, the thermal states of automobiles vary during the day.

3) Taxis have been subject to the I/M program longer than automobiles. Also, the I/M program is more strict for taxis than automobiles.

4) In late 1989, taxis were subjected to centralized inspections three times per year.

TABLE 10

MILEAGE ACCUMULATION RATES AND REGISTRATION DISTRIBUTIONS USED IN MODELING ANALYSIS FOR AGES 1-25

Mileage Accumulation Rate by Age (Years 1 to 25)

0.12900	.12400	.12000	.11400	.11000	.10600	.10000	.09600	.09100	.08600	.08100	.07700	.07200	.06700	.06300	.05700	.05300	.04800	.04400	.03800	.00000	.00000	.00000	.00000	.00000	LDGV
0.14000	.12500	.11200	.10000	.09000	.08400	.07700	.07200	.06700	.06300	.05900	.05500	.05300	.04900	.04700	.04500	.04200	.03900	.03900	.03900	.00000	.00000	.00000	.00000	.00000	LDGT1
0.14100	.12700	.11300	.10200	.09200	.08500	.07800	.07200	.06800	.06400	.05900	.05600	.05400	.04900	.04700	.04600	.04200	.03900	.03900	.03900	.00000	.00000	.00000	.00000	.00000	LDGT2
0.18800	.16900	.15400	.13900	.12600	.11300	.10100	.09200	.08400	.07700	.07200	.06500	.06000	.05600	.05300	.04900	.04700	.04500	.04500	.04500	.00000	.00000	.00000	.00000	.00000	HDGV
0.12900	.12400	.12000	.11400	.11000	.10600	.10000	.09600	.09100	.08600	.08100	.07700	.07200	.06700	.06300	.05700	.05300	.04800	.04400	.03800	.00000	.00000	.00000	.00000	.00000	LDDV
0.14000	.13500	.13100	.12500	.11600	.10800	.09800	.08700	.08300	.06600	.06100	.05500	.04900	.04500	.04100	.03800	.03400	.02800	.02800	.02800	.00000	.00000	.00000	.00000	.00000	LDDT
0.62900	.59800	.54200	.48500	.42800	.39100	.35200	.32700	.30800	.29600	.29000	.28300	.27700	.26500	.24600	.22000	.18200	.15700	.15700	.15700	.00000	.00000	.00000	.00000	.00000	HDDV
0.03700	.02500	.01900	.01400	.01100	.00700	.00500	.00400	.00200	.00200	.00200	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	MC

TABLE 10 (continued)

MILEAGE ACCUMULATION RATES AND REGISTRATION DISTRIBUTIONS
USED IN MODELING ANALYSIS FOR AGES 1-25

Registration Distribution by Age (Years 1 to 25)

.0462	.0882	.0989	.0940	.0863	.0829	.0641	.0577	.0588	.0615	.0641	.0540	.0437	.0290	.0175	.0143	.0128	.0096	.0068	.0096	.0000	.0000	.0000	.0000	.0000	LDGV
.0406	.0864	.0992	.1156	.0883	.0816	.0589	.0513	.0477	.0471	.0634	.0468	.0393	.0283	.0179	.0221	.0182	.0154	.0121	.0198	.0000	.0000	.0000	.0000	.0000	LDGT1
.0586	.1066	.0871	.0974	.0783	.0609	.0399	.0378	.0366	.0452	.0808	.0642	.0474	.0351	.0226	.0246	.0236	.0170	.0119	.0244	.0000	.0000	.0000	.0000	.0000	LDGT2
.0551	.1038	.0951	.1039	.0879	.0642	.0389	.0368	.0381	.0455	.0527	.0414	.0329	.0237	.0284	.0301	.0335	.0280	.0214	.0386	.0000	.0000	.0000	.0000	.0000	HDGV
.0462	.0882	.0989	.0940	.0863	.0829	.0641	.0577	.0588	.0615	.0641	.0540	.0437	.0290	.0175	.0143	.0128	.0096	.0068	.0096	.0000	.0000	.0000	.0000	.0000	LDDV
.0406	.0864	.0992	.1156	.0883	.0816	.0589	.0513	.0477	.0471	.0634	.0468	.0393	.0283	.0179	.0221	.0182	.0154	.0121	.0198	.0000	.0000	.0000	.0000	.0000	LDDT
.0558	.1001	.1108	.0968	.0943	.0831	.0503	.0482	.0453	.0570	.0501	.0371	.0243	.0135	.0208	.0229	.0235	.0189	.0171	.0301	.0000	.0000	.0000	.0000	.0000	HDDV
.1330	.1450	.1380	.1160	.1230	.1140	.0690	.0440	.0240	.0090	.0850	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	MC

The idle emission factors from taxis are significantly lower than those from other automobiles. For conservative modeling purposes, no adjustments were made to account for lower emissions from taxis. Thus, for MOBILE4 and MOBILE4.1 modeling purposes, the auto mileage accumulation rates, registration distributions, I/M program parameters, ATP parameters, and refueling loss parameters for automobiles were used. The hourly vehicle mixes for each link were combined in the following manner:

LDGV (Light Duty Gas Vehicles) = automobiles + fleet medallion taxis + non-fleet medallion taxis + non-medallion taxis

LDDT (Light Duty Diesel Trucks) = 1.8% Light Duty Trucks for MOBILE4
0.8% Light Duty Trucks for MOBILE4.1

LDGT1 (Light Duty Gas Trucks Category 1) = 58.7% Light Duty Trucks for MOBILE4
67.8% Light Duty Trucks for MOBILE4.1

LDGT2 (Light Duty Gas Trucks Category 2) = 39.5% Light Duty Trucks for MOBILE4
31.4% Light Duty Trucks for MOBILE4.1

HDGV (Heavy Duty Gas Vehicles) = heavy duty gas trucks

MC (Motorcycles) = 0

LDDV (Light Duty Diesel Vehicles) = 0

The factors used to calculate the LDDT, LDGT1, and LDGT2 distributions are based on the MOBILE4 and MOBILE4.1 default values for 1989.

The thermal state conditions for each modeled link were obtained from field interviews during the monitoring program for four different time periods. The percent cold thermal states used in the modeling analysis are presented in Table 11. For most models, the thermal state conditions were input as a function of the link. However, for the IMM model, a traffic volume weighted average was used to calculate single values for the percentage of hot starts and percentage of cold starts for the hour being modeled. Similarly, the TEXIN2 model only allows the input of thermal state conditions based on the lane segment groups input to the model. The modeling analysis assumes that there were no hot starts and the catalytic and non-catalytic cold starts were equal.

The Reid Vapor Pressure (RVP) and ASTM class were specified based on the time of year:

2/89 - 5/89 RVP = 11.5 psi (MOBILE4); ASTM = C
RVP = 11.9 psi (MOBILE4.1)

TABLE 11

THERMAL STATES (% COLD) USED IN MODELING ANALYSIS

SITE #1

Link	Hour Range (EST) 5-9	10-14	15-18	19-4
WN-340	6.9	12.1	17.0	18.8
WN-410	6.9	12.1	17.0	18.8
WS-510	6.9	12.1	3.4	4.5
WS-620	6.9	12.1	3.4	4.5
WN-350	6.9	12.1	17.0	18.8
WN-420	6.9	12.1	17.0	18.8
WS-520	6.9	12.1	12.7	13.1
CW-210	6.9	12.1	7.8	13.1
CE-110	6.9	12.1	12.7	13.1

SITE #2

Link	Hour Range (EST) 5-9	10-14	15-18	19-4
TE-108	6.9	5.4	8.0	15.1
TE-107	6.9	8.1	8.0	15.1
TW-208	6.9	14.0	15.0	15.1
TW-209	6.9	14.0	15.0	15.1
EN-334	8.5	12.1	12.1	19.0
EN-335	8.5	12.1	12.1	19.0

SITE #3

Link	Hour Range (EST) 5-9	10-14	15-18	19-4
SB-520	10.0	6.0	23.4	23.1
SB-530	15.3	12.6	23.4	23.1
SB-650	16.9	20.8	25.0	18.1
SB-660	16.9	20.8	25.0	18.1
SB-865	14.0	16.1	21.2	22.9
SB-864	18.3	16.1	21.2	22.9
SB-965	25.0	20.0	24.4	22.3
SB-964	21.6	17.3	24.4	22.3

TABLE 11 (continued)

THERMAL STATES (% COLD) USED IN MODELING ANALYSIS

SITE #4

Link	Hour Range (EST)			
	5-9	10-14	15-18	19-4
SF-870	14.3	9.4	25.3	25.1
SF-860	14.3	9.4	25.3	25.1
SF-670	13.0	5.3	9.5	8.9
SF-675	13.0	5.3	9.5	8.9
SF-570	11.3	13.5	18.3	15.6
SF-560	11.3	13.5	18.3	15.6

SITE #5

Link	Hour Range (EST)			
	5-9	10-14	15-18	19-4
TN-340	13.6	18.9	14.1	9.8
SN-340	13.6	18.9	14.1	9.8
TS-340	7.5	8.5	15.4	6.7
TL-340	7.5	8.5	15.4	6.7
SS-340	7.5	8.5	15.4	6.7
TW-115	22.0	18.0	26.0	19.0
TE-110	8.0	6.0	14.0	11.0

SITE #6

Link	Hour Range (EST)			
	5-9	10-14	15-18	19-4
WT-110	7.0	15.0	27.0	12.0
WT-120	3.8	9.6	17.5	7.7
WT-125	3.8	9.6	17.5	7.7
WT-330	15.0	15.0	17.0	18.0
WT-320	15.0	15.0	17.0	18.0
WT-310	8.2	10.0	13.6	12.0
WT-410	8.2	10.0	13.6	12.0
WT-500	0.0	0.0	0.0	0.0
WT-510	11.6	15.0	22.5	15.5

8/89 - 9/89	RVP = 9.0 psi; ASTM = A
After 9/89	RVP = 11.5 psi; ASTM = C RVP = 11.9 psi (MOBILE4.1)

The RVP values are different for MOBILE4 and MOBILE4.1 because the accepted maximum input values are different for the two different versions of the emissions model.

MOBILE4 idle emissions are calculated at 75°F, 0% cold starts, 0% hot starts, 2.5 mph, and 9.0 psi RVP. In order to adjust the MOBILE4 idle emissions to the scenario conditions being modeled, and idle correction factor (ICF) was calculated by dividing the composite MOBILE4 emission factor at the condition of interest by the composite MOBILE4 emission factor based on the MOBILE4 idle condition, assuming a travel speed of 2.5 mph:

$$ICF = \frac{MOBILE4\,Scenario\,(year, hot/cold\,\%, temp, RVP, 2.5mph)}{MOBILE4\,Idle\,(year, 0/0/0, 75\,F, RVP{=}9.0, 2.5\,mph)} \qquad (1)$$

The idle emission factor in g/veh min for the models utilizing an idle correction factor (CAL3QHC, EPAINT, CALINE4, VOL9MOB4, and IMM) was calculated using:

$$Idle\,Emission = \frac{MOBILE4\,Idle\ X\ ICF}{60} \qquad (2)$$

The idle adjustment is performed automatically by the MOBILE4.1 emissions model, so no external corrections were needed for MOBILE4.1. It should be noted that there is a major difference between the MOBILE4 and MOBILE4.1 versions of TEXIN2 because the MOBILE4 version did not include an idle correction and the most recent version (MOBILE4.1) automatically includes the idle correction.

4.1.3 Meteorological and Background Data

The hourly-averaged temperature data from the meteorological towers at each site were averaged to calculate a site-specific hourly value. For the remaining meteorological input data (wind speed, wind direction, sigma theta, stability class), the meteorological tower closest to the CO monitor location was used. Mixing heights of 1000 m were used, since the results are not affected if the mixing height is between 100 and 1000 m high and mixing heights below 100 m in Manhattan rarely occur.

In addition to the use of the observed meteorological data, a subset of hours (top 10 at each site) were modeled using the regulatory default meteorological conditions described below:

Wind Speed = 1 m/s
Stability Class = D
Sigma-Theta (σ_θ) = 25°
Observed Temperature
"Worst-Case" Wind Direction Angle (determined using 10° increments)

The closest background concentration (Battery Park or the Post Office Station) was subtracted out of the observed concentration at the monitors at each intersection site. All modeling was performed for one hour averages only. After the removal of the background concentrations, a screening threshold of 0.5 ppm was used. For example, when both the observed and predicted concentrations at a monitor are less than 0.5 ppm, that data pair was eliminated from the data set.

4.2 Dispersion Modeling Techniques

Atmospheric dispersion of the vehicular CO emission at each site was simulated using either the CALINE3 or HIWAY2 models. Only IMM4 uses the HIWAY2 dispersion methodology; all the other models evaluated use the CALINE3 model. As discussed in Section 2.0, the CALINE3 or HIWAY2 dispersion algorithms are included in the CAL3QHC, TEXIN2, CALINE4, and IMM models. The CALINE3 model was run separately for the EPAINT, FHWAINT, VOL9MOB4, and GIM modeling techniques.

Each modeled roadway was divided into free-flow traffic links and queuing or excess-emission links, as required for each model. As recommended in the CALINE3 User's Manual, an additional six meters (three meters for each side of the roadway) was added to the actual width for CALINE3 dispersion modeling to account for wake-induced plume dispersion. Turbulence is assumed to be zero for queued vehicles, so no additional width was added for the queuing links. All mobile source heights were modeled at 0.0 m and all links were assumed to be at grade.

A surface roughness length of 3.21 m was used for approach flows over numerous city blocks. Lower values of the surface roughness length (0.03 m) were used at Site #5 (34th/12th) when the intersection was exposed to flows over the Hudson River without intervening buildings. For modeling CO concentrations, the settling velocity and deposition velocity were set at zero because CO is a gaseous emission. An averaging time of 60 minutes was used. The CO probe heights for each CO monitor listed in Table 3 were used. Finally, a temperature-sensitive conversion of the modeled concentrations from mg/m^3 to parts per million (ppm) was conducted.

In order to facilitate the model evaluation study and to minimize model input errors, a series of computer programs were written for each model. The resulting "RUN" programs read all input data from a series of standard files for each site (i.e., meteorological file, hourly traffic data, site information file, etc.); prepare the necessary input files for all models; invoke the models; and list the results. For example, the "RUN" program for the GIM model, called RUNGIM, performs the following steps for each modeled hour:

1) Set Up the MOBILE4 input file

2) Run MOBILE4

3) Set Up the GIM input file

4) Run GIM

5) Set Up the CALINE3 input file using the MOBILE4 and GIM results

6) Run CALINE3

7) Output the hourly predicted CO concentrations

5.0 STATISTICAL EVALUATION PROTOCOL

Two types of statistical evaluations of differences between observed and modeled CO concentrations were performed. First, the EPA Model Evaluation Support System (MESS) was used to calculate a standard set of performance measures and statistical estimators. Second, a scoring scheme recommended by the EPA was used to rank the models and to evaluate the significance of the results. Results of the statistical analyses are presented in Section 6.0 and the Appendices.

5.1 The Model Evaluation Support System (MESS)

The Model Evaluation Support System (MESS) (EPA, 1987), a computerized system that EPA uses for evaluating the accuracy of air quality models, was used to generate some of the statistics presented in this report. The Statistical Evaluation Subsystem or SES was used to calculate the standard set of performance measures and statistical estimators as recommended by the AMS Workshop on Statistical Data Analyses (Fox, 1981). Both paired and unpaired data sets were used.

5.1.1 Paired Statistics

For paired comparisons, the performance measures are based on an analysis of concentration residuals either paired in time, paired in space, or paired in both time and space. A summary of the paired statistics which were generated by SES for each site and set of data is given in Table 12. A select group of these statistics are presented in Section 6.0 and the Appendices. For each site, the statistical analyses were performed for the highest observed and predicted values for each hour (paired in time but not in space). Also, the highest observed and predicted concentrations at each monitor for each site (paired by monitor but not in time) were grouped for statistical analysis. Fully paired comparisons (space and time) were made for observed and predicted concentrations at each monitor and for each meteorological data subset. Model bias is indicated by the average,

$$Bias = \frac{1}{N}\sum_{i=1}^{N} d_i \qquad (3)$$

with a value of zero representing no bias. In Equation 3, d_i is the residual defined as the observed concentration (C_o) minus the predicted concentration (C_p) for the i_{th} data pair. The measures of noise or scatter are computed using the following:

TABLE 12

ARRAY OF CALCULATED PERFORMANCE MEASURES AND STATISTICS PAIRED IN TIME AND/OR LOCATION

	Highest per event paired in time	Highest per monitor paired by location	All Data paired in time and location	All Events at each monitor paired in time	Meteorological Subsets of events paired in time and location
Number of events	X	X	X	X	X
Averaged observed	X	X	X	X	X
Averaged predicted	X	X	X	X	X
Difference of averages	X (C.I.)*	-	X (C.I.)	X (C.I.)	X (C.I.)
Average difference	X (C.I.)	X (C.I.)	X (C.I.)	X (C.I.)	X (C.I.)
σ_d	X (C.I.)	X (C.I.)	X (C.I.)	X (C.I.)	X (C.I.)
RMSE	X	X	X	X	X
AAD**	X	X	X	X	X
Correlation coefficient					
Pearson R	X (C.I.)	X (C.I.)	X (C.I.)	X (C.I.)	X (C.I.)
Variance comparison	X (C.I.)	X (C.I.)	X (C.I.)	X (C.I.)	X (C.I.)

* C.I. = 95% confidence interval
** AAD = Average Absolute Difference

$$Variance = \frac{1}{N-1}\sum_{i=1}^{N}(d_i-\bar{d})^2 \quad (4)$$

$$Gross\ or\ Mean\ Square\ Variability = \frac{1}{N}\sum_{i=1}^{N} d_i^2 \quad (5)$$

$$Average\ Absolute\ Residual = \frac{1}{N}\sum_{i=1}^{N} |d_i| \quad (6)$$

where $\bar{d}$ is the average residual (bias), and N is the number of data pairs. When the bias approaches zero due to the cancellation of over- and underpredictions, the average absolute residual or error can be a more meaningful measure.

For the paired comparisons, SES estimates confidence intervals on the average residual by means of the one-sample t-test. This parametric test incorporates the assumption that the residuals follow a normal distribution. As is discussed in Section 5.2, a bootstrap resampling technique is also used to generate confidence intervals. The bootstrap technique yields a non-parametric statistic because it does not invoke any assumptions regarding the statistical distribution of the data.

5.1.2 Unpaired Statistics

For unpaired comparisons, fewer performance statistics are used. The statistical analyses generated by SES for the N (where N = 25) highest observed and predicted values, regardless of time or location, are summarized in Table 13. The statistics are calculated for each site and each set of data (i.e., all hours, uniform wind hours, meteorological subsets). The statistics for the uniform wind hours and meteorological subsets are not presented in this report. Model bias is calculated as the difference between the average observed value and the average predicted value. The ratio of the variances of the observed and predicted values are calculated to indicate whether the distribution of values in the data sets are comparable. The frequency distribution of the observed values are compared with the predicted concentrations.

5.1.3 MESS Analysis Products

As part of MESS, the Standardized SAS Graphics Subsystem or SSGS is used to provide additional statistical tables and graphic displays of selected performance statistics. SSGS generates output for two general classes of applications. The A-type application sorts the input data for each group and uses only the high-25 concentrations for analysis. The A-type

TABLE 13

ARRAY OF CALCULATED PERFORMANCE MEASURES AND STATISTICS FOR THE "N" HIGHEST (UNPAIRED) DATA SETS (WHERE N IS 25)

	Average Observed	Average Predicted	Difference of Averages	Variance Comparison	Frequency Distribution
All stations/ all events	X	X	X (C.I.)*	X (C.I.)	X
By station/ all events	X	X	X (C.I.)	X (C.I.)	X
Subsets by meteorological conditions	X	X	X (C.I.)	X (C.I.)	X

* C.I. = 95% confidence interval

statistics are not paired in space or time, and include results for the following data groups:

- A composite of all receptors;
- Each individual receptor;
- Each stability class;
- Each wind speed class (e.g., high: $u > 4$ m/s; medium: $2 < u \leq 4$ m/s; low: $u < 2$ m/s);

The statistics for each individual receptor, stability class, and wind speed class are not presented in this report.

The B-type application uses all concentrations above a selected threshold (0.5 ppm in this evaluation) for each data group. The B-type data are paired, so a larger and more comprehensive list of statistical comparisons are generated. All of these statistics are calculated for each of the A-type data groups described above.

In addition to the tabular displays of selected performance statistics for each of the A and B-type statistics, the following graphical displays were generated:

- Bias of the standard deviation versus the bias of the averages for the A (High 25) and B (All data) type statistics.
- Quantile-quantile plots in which the high 25 observed and predicted concentrations were plotted against each other. Since each of the 25 values is displayed for each model, this graph is useful for detecting both the overall model bias and the points at which the model performance is especially good or bad.
- Concentration versus cumulative frequency with observed plus multiple models per plot. Only concentrations above 50 percent frequency were plotted. On a site-by-site basis, these plots are useful in evaluating the overall performance of each model.

5.2 Model Evaluation Scoring Scheme

5.2.1 Screening Test

The EPA (Cox, 1988) has suggested the use of a screening test for model performance, which would normally be applied to reduce the number of models evaluated using refined methods. This screening test was applied to the results obtained during phase I of this study, in which MOBILE4.0 rather than MOBILE4.1 was used to estimate emissions. The performance measure used for the screening test is the absolute fractional bias defined as

$$AFB = |FB| = 2 \left| \frac{(OB - PR)}{(OB + PR)} \right| \quad (7)$$

where OB and PR refer to the averages of the observed and predicted highest 25 values matched only by rank. The absolute fractional bias of the standard deviation is also used where OB then refers to the standard deviation of the 25 highest observed values and PR refers to the standard deviation of the 25 highest predicted values. If AFB tends to exceed 0.67 (factor of two) for either the average or the standard deviation, consideration may be given to excluding that model from further evaluation due to its limited credibility for refined regulatory analysis. In this evaluation of intersection models for CO, we ranked the eight techniques by AFB in order to help indicate which of the models would be evaluated in phase II of the study, in which MOBILE4.1 is used to estimate emissions.

5.2.2 Refined Evaluation

The U.S. EPA has developed a method for aggregating component results of model performance into a single performance measure that may be used to compare the overall performance of two or more models (Cox, 1988; Cox and Tikvart, 1990). The bootstrap resampling technique (Efron, 1982) is used to determine the significance of differences in composite performance between models. Results from different data bases are combined using a technique related to meta-analysis to produce an overall result.

The EPA's scoring system for refined evaluations is divided into two separate components. The "scientific or diagnostic component" refers to the evaluation of peak concentrations during specific meteorological conditions at each monitor and the "operational component" refers to the evaluation of peak averages independent of meteorological condition or spatial location. The averages evaluated in the operational component are those for which regulatory standards must be met (e.g., 3-hour and 24-hour averages). The capability of models to predict concentrations at specific locations and meteorological conditions subject to the limitations of the data base is tested using the scientific component. The New York City data base contains mostly non-consecutive, one-hour observations, thereby limiting the evaluation to one-hour averages. There is a regulatory standard for one-hour average CO concentrations, so the dataset allows both diagnostic and operational components to be evaluated. Typically, monitors are located adjacent to an intersection, so that they record near-field concentrations during varying meteorological and traffic conditions. A diagnostic evaluation could focus on aspects of the performance that are related to wind speed, wind direction, stability, and traffic counts, for example. However, the wind direction aspect will not be addressed in this evaluation. In essence, it is believed that uncertainties in the "true" wind direction, coupled with a sparse monitoring network and a distributed source (intersecting line sources), preclude any attempt to accurately delineate the ability of a model to reproduce spatial relationships contained in the measured concentrations. Instead, the performance will be evaluated only on the basis of the peak modeled and observed concentrations during each hour at each intersection. This choice eliminates any difference between datasets for a diagnostic and an operational evaluation.

Blocking

Several subsets of the dataset for each site are formed in order to block the data according to parameters related to significant modeling variables. Thus, differences in model performance under different model regimes may be assessed. In this case, the relevant parameters are wind speed, stability class, and traffic counts (a crude measure of emission rate). The total number of vehicles modeled at each site as a function of the model hour is presented in Figure 22 in Section 3.0. There is very little variation in traffic counts from one hour to the next because most of the traffic data are associated with rush-hour conditions. This is not surprising, since the hours were selected on the basis of the maximum observed CO concentrations. Since there is not much variation in the traffic data, this parameter does not appear to be useful when examining the scientific component. The wind speeds from the tower closest to the monitor with the maximum observed concentration are tabulated for each site in Table 6 in Section 3.0. Sites 3, 4, and 6 have an uneven distribution of wind speeds compared with the other three sites. The stability classifications for each site are shown in Table 5 in Section 3.0. The stabilities seem to be more evenly distributed across each class and over all sites.

The combined wind speed (using 6 mph or 2.7 m/s) and stability classifications are presented in Table 14 for the three sites used in the MOBILE4.1 evaluation: Sites #1, 2, and 5. A wind speed of 6 mph was chosen in order to ensure a sufficient number of samples in each data category. In the bottom portion of the table the light wind speed cases ($u \leq 6$ mph) are classified as either unstable or neutral/stable. For the high wind speed cases ($u > 6$ mph) all stability classes are combined into one group since the stability is not as important in this category. Overall the wind speed/stability classification seems to be a good manner in which to classify the data. It is important to choose a classification that maintains an equitable distribution of the hours across subsets. When confidence intervals are estimated for each class, these should be based on as many data points as possible. The blocked bootstrap resampling method is used to estimate confidence limits, as described later in this section. The wind speed/stability classification shown in the lower portion of Table 14 was used for the blocking criteria.

Primary Performance Measure

Both AFB (absolute fractional bias) and FB (fractional bias) are used in the comprehensive evaluation. FB is used in the diagnostic evaluations, so that the tendency of a model to underpredict or overpredict can be characterized. However, the AFB is used when combining results for various categories or sites so that cancellation of overpredictions or underpredictions do not occur.

TABLE 14

TABULATION OF WIND SPEED/STABILITY CLASSIFICATION BY SITE

Site	# of Hours	u ≤ 6 mph (2.682 m/s) Unstable	Neutral	Stable	u > 6 mph Unstable	Neutral	Stable
1	142	49	33	16	13	24	7
2	143	77	31	13	9	13	0
5	75	34	12	10	5	14	0

Site	# of Hours	u ≤ 6 mph Unstable	Neutral/Stable	u > 6 mph All stabilities
1	142	49	49	44
2	143	77	44	22
5	75	34	22	19

When calculating either FB or AFB, the "robust highest concentration," RHC, is used rather than the mean of the highest 25 concentrations. As discussed by Cox and Tikvart (1990), the RHC is preferred in this type of statistical evaluation because of its stability. Also, the bootstrap distribution of the RHCs is not artificially bounded at the maximum predicted or observed concentration, which allows for a continuous range of concentrations. The RHC is based on a tail exponential fit to the upper end of the distribution and is calculated as follows

$$RHC = x(n) + (\bar{x} - x(n)) \log\frac{(3n - 1)}{2} \tag{8}$$

where $\bar{x}$ = average of the n-1 largest values
x(n) = nth largest value
n = number of values exceeding the threshold value (n=26 or less)

The size of the three intersection data sets requires the value of n to be less than 26. The value of n is nominally set to 11 so that the number of values averaged ($\bar{x}$) is 10. A threshold of 0.5 ppm is used.

From the overview of the data at Sites 1, 2, and 5 shown in Table 14, it appears that several wind speed/stability class blocks can be identified and used in the diagnostic evaluation. Within each block, a RHC is estimated for both predicted and observed concentrations, and corresponding values of FB are formed. Therefore, several "results" are obtained for each model. An operational evaluation based on RHC values is also made, because the RHC for the dataset as a whole may be different than that for any of the blocks. Furthermore, such an "overall" RHC is not a simple average of the RHC values for each block because the RHC is not a "mean" statistic. To provide an overall assessment of model performance, all of these "results" are factored in when creating an overall performance measure.

Composite Performance Measure

A composite performance measure (CPM) is calculated for each model as a weighted linear combination of the individual absolute fractional bias components. The operational component is given a weight that is equal to the weight of the combined scientific components. The results from the different data bases (intersections) are given equal weight. The CPM is defined as

$$CPM = \frac{1}{2}AVG(AFB(i)) + \frac{1}{2}AFB(1) \tag{9}$$

where AFB(i) = Absolute fractional bias weighted for each diagnostic category i,
AFB(1) = Absolute fractional bias for the operational one-hour averages.

The wind speed (u) $\leq$ 6 mph and neutral/stable category is weighted more than the other two categories because of the importance of this category for regulatory modeling purposes. Thus, the average of AFB(i) is

$$AVG(AFB(i)) = 0.5\ AFB(u \leq 6\ mph,\ Neutral/Stable) + 0.25\ AFB(u \leq 6\ mph,\ Unstable) + 0.25\ AFB(u > 6\ mph,\ All\ stabilities) \quad (10)$$

Model Comparison Measures

All of the performance measures already discussed quantify the performance of one model in reproducing the RHC observed. An ideal model will produce values of FB based on the RHC's that are equal to zero. Any "real" evaluation will result in non-zero values. By estimating confidence intervals for these results, we are able to quantify the significance of these non-zero values. If the 95% confidence interval about FB for one of the models should overlap zero, then we may conclude that the hypothesis that FB for this model equals zero cannot be rejected with 95% confidence, so we may say that the difference from zero is not significant. But when we compare the performance of the models, we would also like to know if differences in their performance are significant. Therefore, difference measures, such as

$$\Delta FB(A,B) = FB(A) - FB(B) \quad (11)$$

are also formed and the 95% confidence intervals about them are estimated. Then we can assess whether differences in the performance of models A and B are significant.

Differences in combined measures are also calculated. The CPM is used to calculate pairs of differences between the models because the purpose of the analysis is to contrast the overall performance among the models. The difference between the performance of one model and another is the model comparison measure (MCM) defined simply as

$$MCM(A,B) = CPM(A) - CPM(B) \quad (12)$$

where CPM(A) = Composite performance measure for Model A
CPM(B) = Composite performance measure for Model B

For the five models compared using the MOBILE4.1 emissions methodology, there are ten comparison measures computed. The MCM is used to judge the statistical significance of the apparent superiority of any one model over another.

Confidence Intervals

The bootstrap resampling technique is used to estimate confidence intervals on the various measures described above. In applying the bootstrap procedure, observed and predicted one-hour data are resampled for each intersection. Sampling is done with replacement, so some hours are represented more than once. This process is repeated 1000 times so that sufficient samples are available to calculate the standard error of each measure. At each site, the resampling recognizes the blocks selected for the diagnostic evaluation. This assures that each of the 1000 variants of the original dataset retained the same number of samples from each diagnostic category. Had we not blocked the data in this way, one of the 1000 variants might, for example, only consist of a few samples associated with the largest wind speed (repeated many times). The bootstrap resampling method allows the standard deviation, s_{ij}, of any performance measure to be estimated, from which confidence limits can be calculated:

$$\textit{95\% Confidence Limits} = \textit{Measure} \pm c\, s_{ij} \qquad (13)$$

The standard error is simply the standard deviation of the measure over all of the bootstrap-generated outcomes. If the measure involves a single comparison, such as FB for a single model, then the value of c can be set equal to the student-t parameter.

Difference measures such as ΔFB or MCM require that simultaneous confidence intervals be found for each pair of models in order to ensure an adequate confidence level and to protect against falsely concluding that two models are different The method of Cleveland and McGill (1984) is used to calculate c. In this method, c is found such that for 95 percent of the 1,000 bootstrap i-tuples,

$$\frac{|\Delta_{ij} - \Delta_{ijk}|}{s_{ij}(\Delta_{ijk})} \le c \qquad (14)$$

where Δ_{ij} = model comparison difference measure for model pair i, j,
Δ_{ijk} = model comparison difference measure for model pair i, j and bootstrap replication k, and
s_{ij} = standard deviation of all the Δ_{ijk} values.

For this analysis, c is found for each of the three intersections (c_i),

$$\frac{|M_{ijl} - M_{ijkl}|}{s_{ij}(M_{ijkl})} \leq c_l \qquad (15)$$

where M_{ijl}	=	model comparison difference measure (ΔFB or MCM) for the lth database, and ith and jth model,
i and j	=	1 to 5 for each model combination,
k	=	1 to 1000 for each bootstrap,
l	=	intersection database, and
$s_{ij}(M_{ijkl})$	=	lth standard deviation of M_{ijkl} for bootstrap replications 1 to 1000.

The model comparison difference measure (M_{ijl}) is based on differences in CPM and FB in between models. Using CPM, for example, the difference in CPM values between models i and j is calculated as

$$M_{ijl} = (CPM_{il} - CPM_{jl}) \qquad (16)$$

for the primary data set, and

$$M_{ijkl} = (CPM_{ikl} - CPM_{jkl}) \qquad (17)$$

for each bootstrap replication of the dataset.

Composite Model Performance Measure

The foregoing sections have identified how performance is quantified, how specific performance measures are found, how these are combined into a single measure for each model at each intersection, how differences in these measures between models are calculated, and how confidence intervals are found for all of these. What remains to be done is to calculate composite measures across all sites (intersections) used in the evaluation. A composite model comparison measure (CM) is suggested by Cox and Tikvart (1990):

$$CM = \frac{\sum (W_l M_l)}{\sum (W_l)} \qquad (18)$$

where M_l	=	model comparison measure for the lth data base,
W_l	=	$1.0/S_l^2$, and
S_l	=	bootstrap estimated standard error for the lth data base.

Using the model comparison difference measure of Equation 16, bootstrap outcomes for the composite measure can be written as

$$CM_{ijk} = \frac{\sum_{1}^{l}\left(\frac{M_{ijkl}}{s_{ij}(M_{ijkl})^2}\right)}{\sum_{1}^{l}\left(\frac{1}{s_{ij}(M_{ijkl})}\right)^2} \tag{19}$$

With this definition, a confidence interval on CM follows that of Equation 15, so that the value of c for FB or CPM is the value that satisfies the 95 percent criterium for

$$\frac{|CM_{ij} - CM_{ijk}|}{s_{ij}(CM_{ijk})} \le c \tag{20}$$

where

$$CM_{ij} = \frac{\sum_{1}^{l}\left(\frac{(M_{ijl})}{s_{ij}(M_{ijl})^2}\right)}{\sum_{1}^{l}\left(\frac{1}{s_{ij}(M_{ijl})}\right)^2} \tag{21}$$

For each model pair, simultaneous confidence limits are placed on the composite performance CM_{ij} as with the lth intersection. If the confidence limits do not overlap zero, then the difference between the models tested is significant for these databases.

5.2.3 Summary of Scoring Scheme

In summary, the steps taken (see Section 6.2) in providing a scoring of each model analyzed are as follows:

1) At each site, calculate the RHC for the peak one-hour observed and predicted concentrations paired by time over all data and for each category (i.e., unstable, neutral/stable). Calculate the FB of the RHC with confidence limits and the ΔFB with confidence limits. Summarize the model performance by category.

2) Calculate the CPM for each model at each site. The smaller the CPM, the better the overall performance of the model.

3) Calculate the MCM with confidence limits for each model pair at each site.

4) Combine the results from all sites by calculating CM and S for each model pair and accompanying simultaneous confidence limits.

5) Summarize the overall scores and significance of the results.

The following types of plots are presented in Section 6.2:

1) FB with confidence limits for each model as a function of the site and category (i.e., meteorology);

2) The operational (or 1-hour) FB with confidence limits for each model as a function of each site;

3) The operational ΔFB with confidence limits among the models as a function of each site;

4) CPM for each model as a function of the site;

5) MCM with confidence limits among the models for each site; and

6) CM with confidence limits among the models over all sites.

5.2.4 Limitations of the Scoring Scheme

The traffic data available from the New York City data base are comprised of the top 50 hours of CO concentrations observed for each of three months at Sites #1 and 2 and the top 25 hours observed for each of three months at the remaining sites. This initial grouping of the data could add a bias to the results in that it ignores situations that may have resulted in large estimates of CO in spite of the relatively small values that were actually measured.

The large variability in the source of CO that arises due to its sensitivity to vehicle operations tends to produce a dataset in which consecutive hours are likely to be independent in spite of possible serial correlations in the meteorological data. Therefore, we have not applied procedures to safeguard against improperly assessing the independence of the data used in the evaluation. We have selected the "highest" 50 or 25 hours from each month of the set to retain the influence of each month in the statistics. The effect of doing this has not been assessed.

Also, the weighting used in calculating a combined score remains arbitrary. The results of the study should be viewed in its entirety, so that conclusions reached on the basis of the final combined measure recognize information contained in the individual measures.

6.0 MODEL PERFORMANCE RESULTS

6.1 Phase I Results: 8 Models/6 Sites Using MOBILE4.0 Emissions

Numerous statistics, plots, and tables have been produced in order to characterize the performance of the eight intersection modeling techniques when using MOBILE4.0 as the emissions model. A select number of graphs and tables are presented in this subsection. Appendix A contains a number of other analyses, including the regulatory default results, the normal probability plots, quantile-quantile plots of the high-25 observed and predicted values, scatterplots of observed versus predicted values using all modeled hours, and model performance tables with all observed and predicted data paired in time/location, time, and location for each of the six sites analyzed.

6.1.1 Paired and Unpaired Statistics

All eight intersection modeling techniques using the MOBILE4.0 emissions were tested at the six New York City intersections described in Section 3.0. As described in Section 5.0, the Model Evaluation Support System (MESS), a computerized system that EPA uses for evaluating the accuracy of air quality models, was used to generate most of the statistics. Both paired and unpaired data sets were generated.

The average residuals (observed minus predicted CO concentration) matched by time/location, time, and location, along with the 25-highest average unpaired values, are presented for each site in Figures 29 through 34. These figures characterize the degree to which each modeling technique either overestimates or underestimates the observed concentrations at each site. Note that the mean residual is negative when a model tends to overestimate the observed concentrations. When time-paired residuals are used (whether or not paired by location as well), the TEXIN2 model has the smallest residual values for four of the six sites. Furthermore, all eight models indicate underpredictions when paired in time at Sites #1 through #5. TEXIN2 and EPAINT overpredict when paired in time at Site #6. The FHWAINT and VOL9MOB4 modeling techniques display the largest bias, on average. When the average residuals are based on concentrations paired by location only, TEXIN2 performs best at Sites #1, 2, and 5; GIM performs best at Site #3; CAL3QHC performs best at Site #4; and CALINE4 performs best at Site #6. Once again, on average, FHWAINT and VOL9MOB4 display the largest bias. The average of residuals based on the highest unpaired 25 predicted and observed concentrations indicate that no one model outperforms all other models, although TEXIN2 displays the smallest bias at three of the sites (Sites #1, 2, and 5). VOL9MOB4 performs best at Site #3, CAL3QHC performs best at Site #4, and CALINE4 performs best at Site #6.

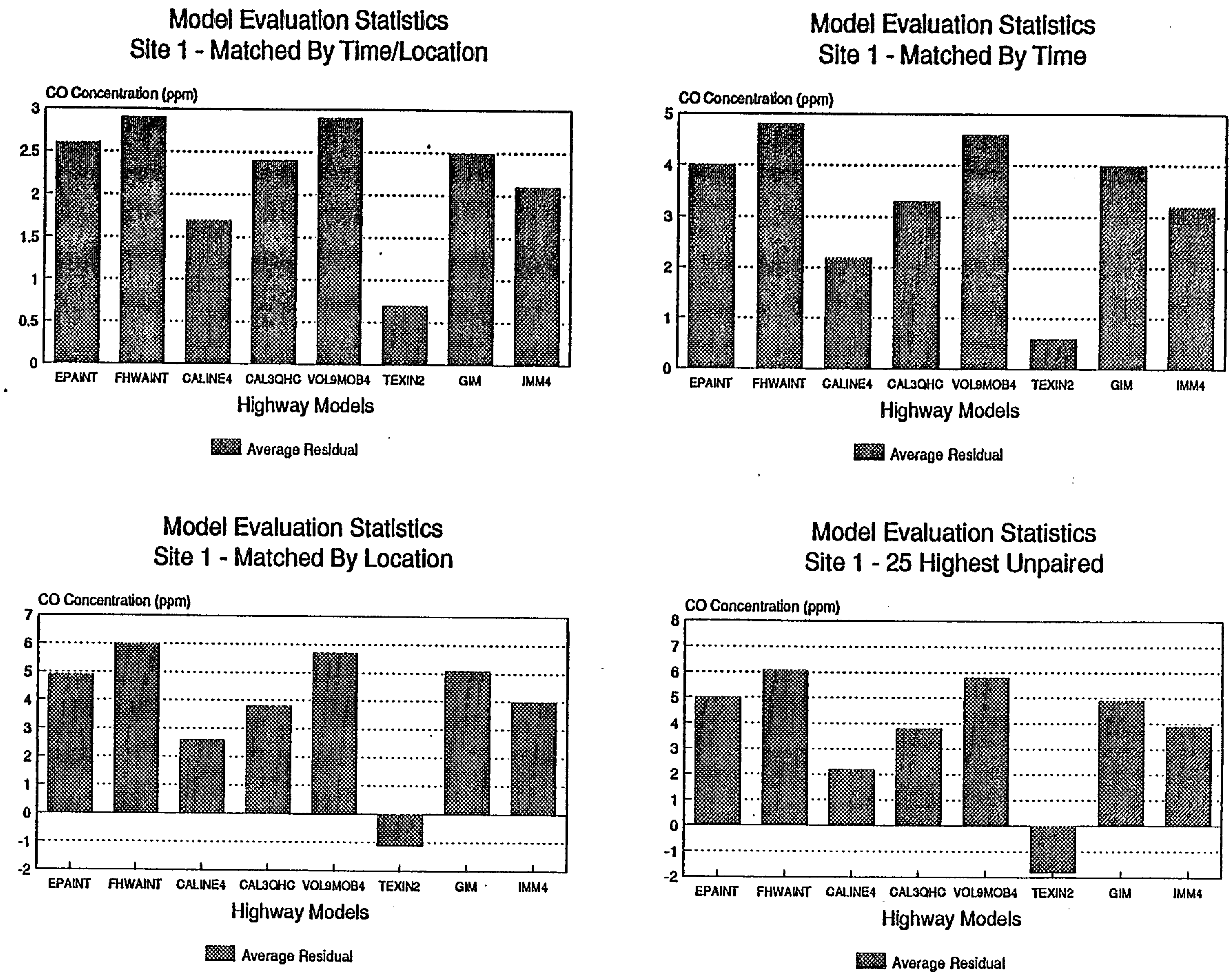


Figure 29. Average residual matched by time/location, time, and location, along with the 25-highest unpaired values for the phase I MOBILE4.0 analysis at Site #1.

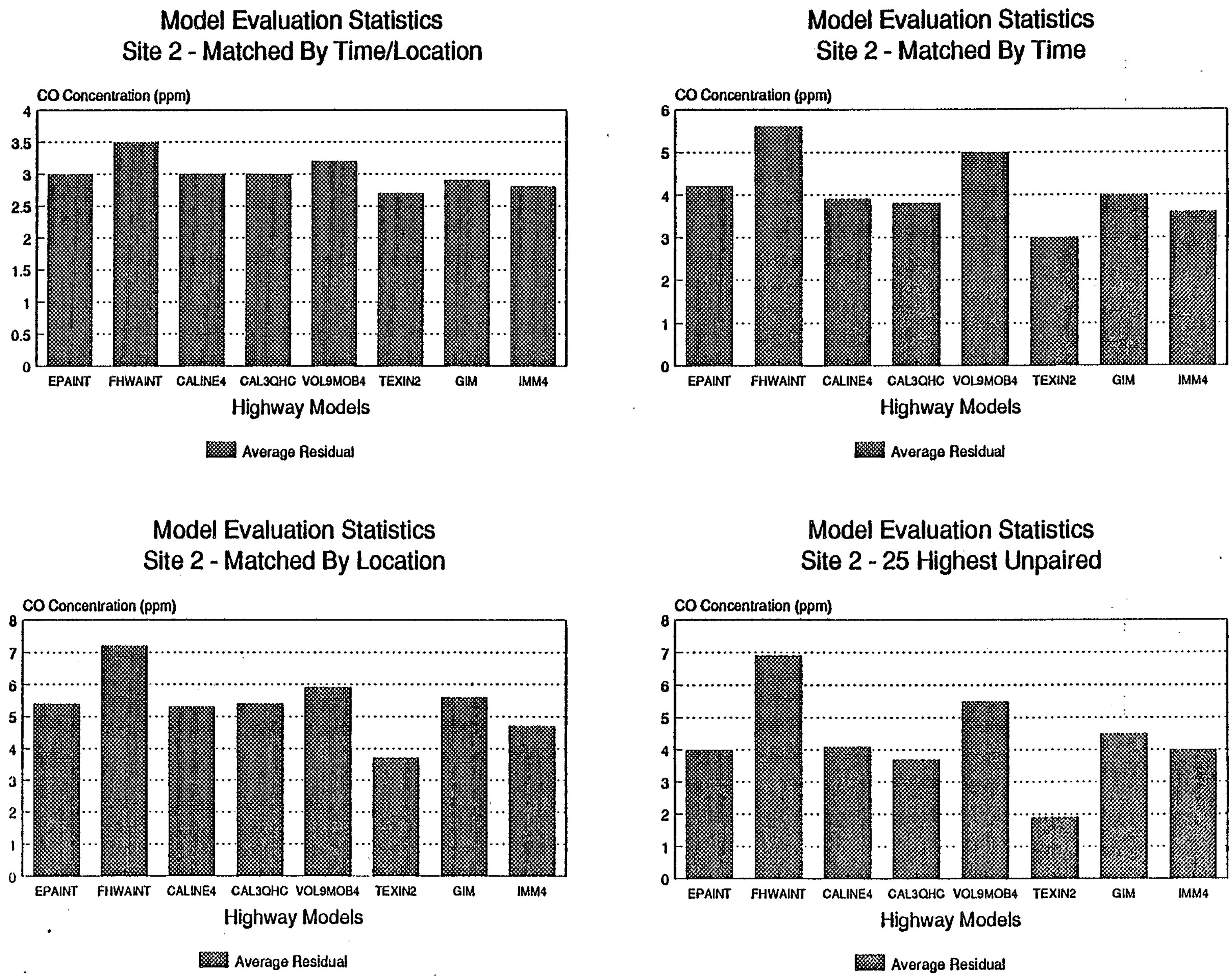


Figure 30. Average residual matched by time/location, time, and location, along with the 25-highest unpaired values for the phase I MOBILE4.0 analysis at Site #2.

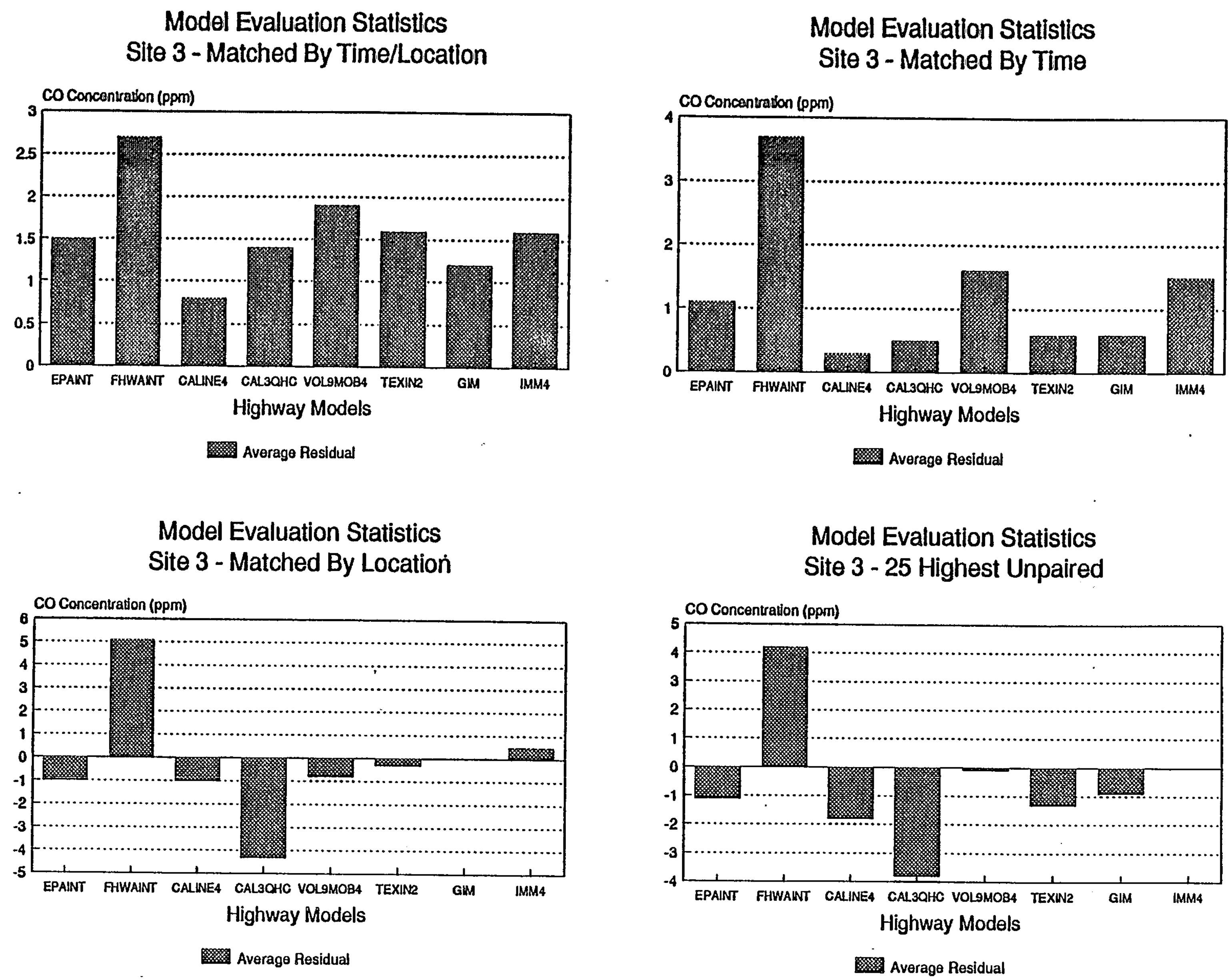


Figure 31. Average residual matched by time/location, time, and location, along with the 25-highest unpaired values for the phase I MOBILE4.0 analysis at Site #3

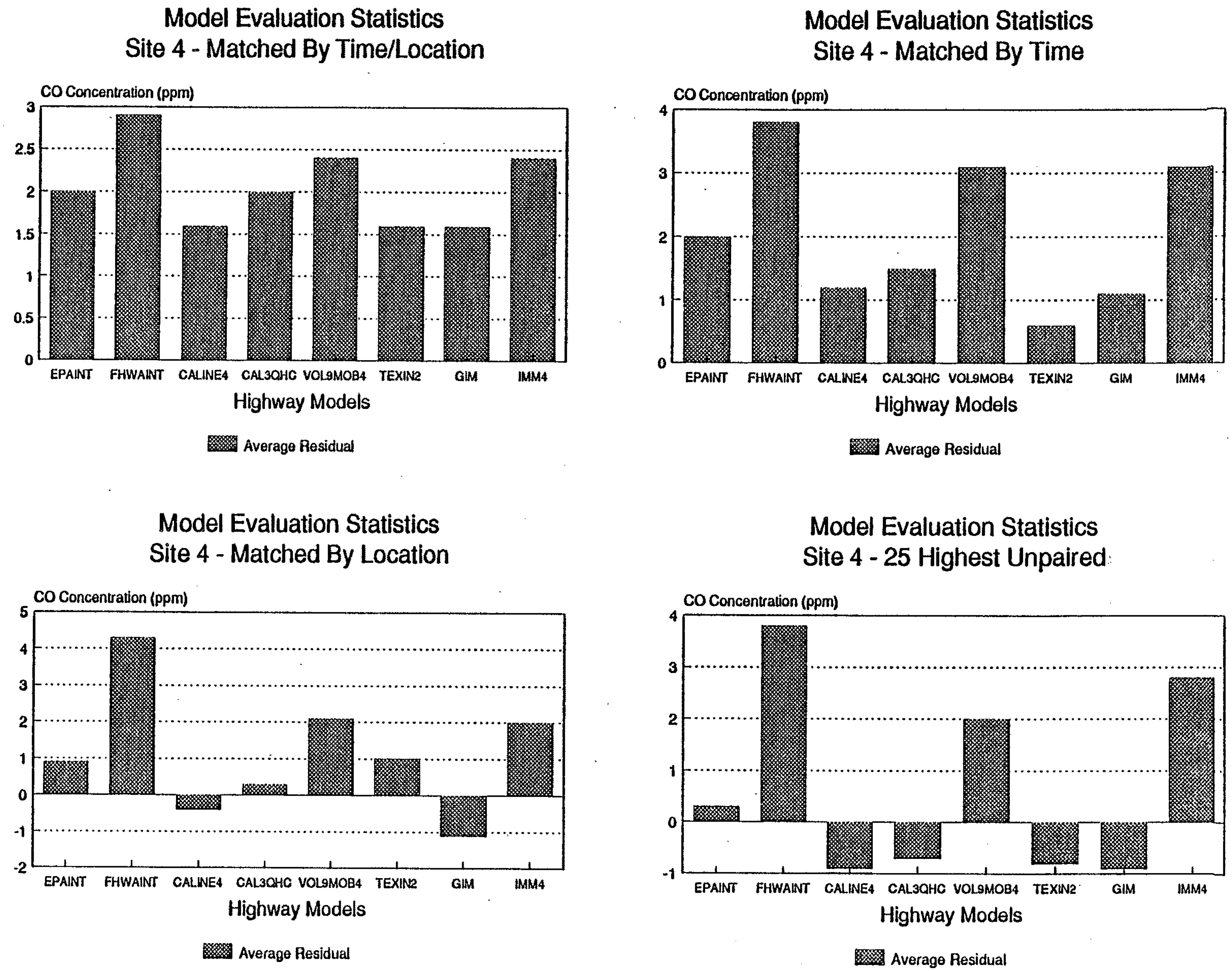


Figure 32. Average residual matched by time/location, time, and location, along with the 25-highest unpaired values for the phase I MOBILE4.0 analysis at Site #4.

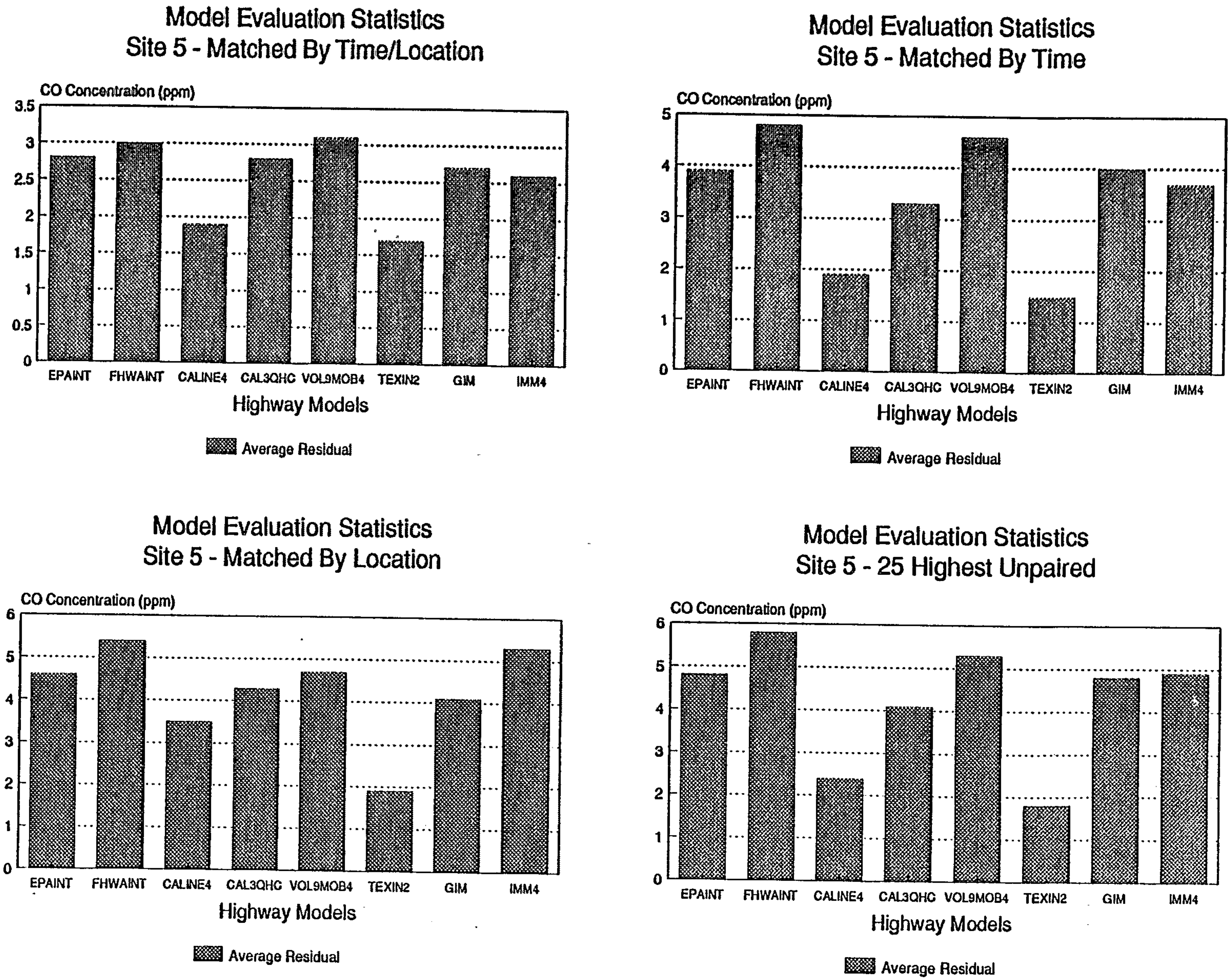


Figure 33. Average residual matched by time/location, time, and location, along with the 25-

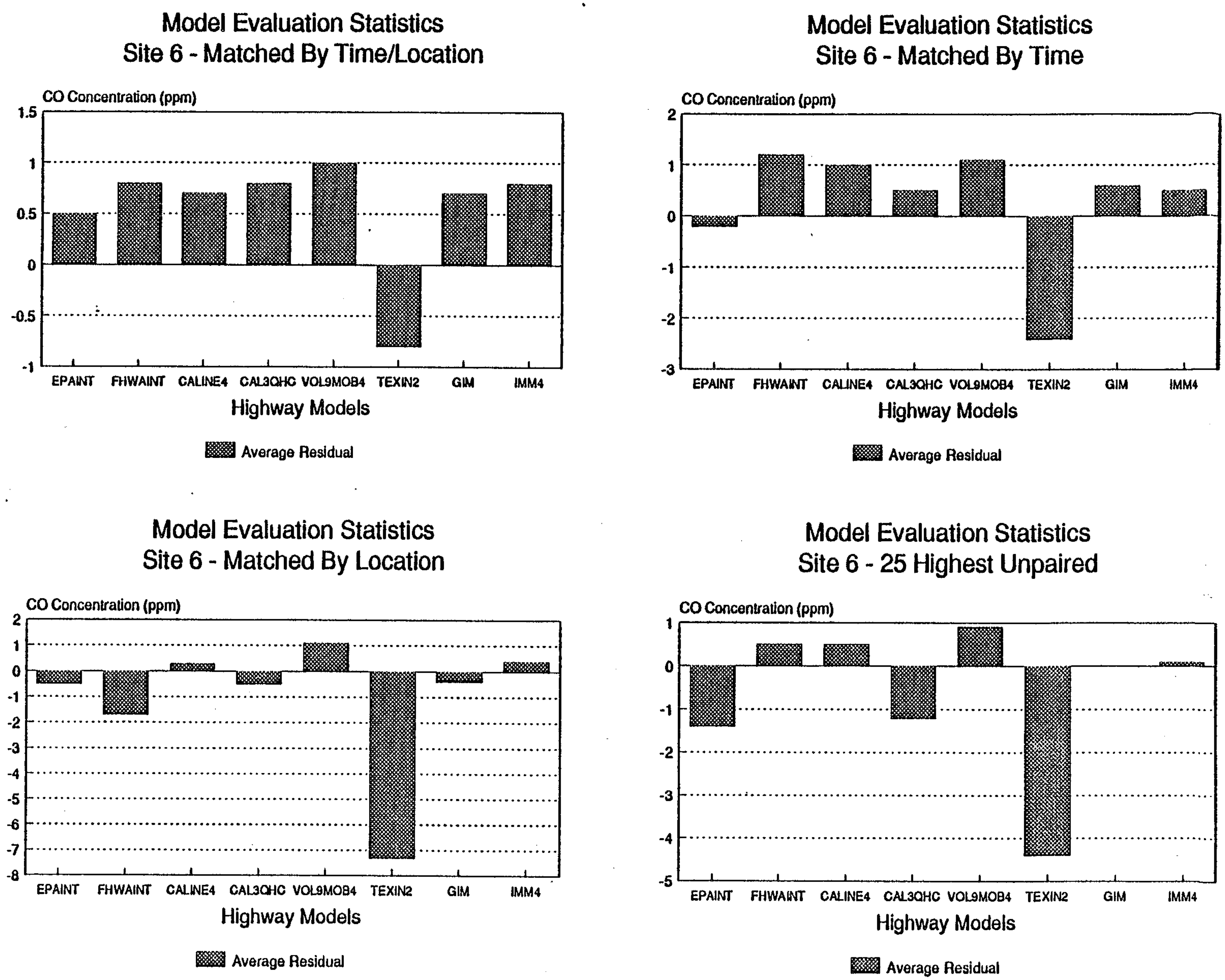


Figure 34. Average residual matched by time/location, time, and location, along with the 25-highest unpaired values for the phase I MOBILE4.0 analysis at Site #6.

Sites #1, 2, and 5 appear qualitatively different from the other three sites in that the relative performance of the models is independent of whether the residuals are obtained from paired or unpaired concentrations, or whether all data are used or just the "top 25." In contrast, the ordering of the models in terms of how near zero their bias becomes, changes at Sites #3, 4, and 6 when concentrations are no longer paired in time. This behavior might indicate the presence at these sites of factors that are not properly resolved in the data, or that are not properly addressed in the model.

A second way of characterizing the performance of these models is shown in Figures 35 through 40. Here, the fractional bias between the mean predicted and the mean observed CO concentration is labelled as the "bias of the average," while the fractional bias between the standard deviation of the predicted concentrations and the standard deviation of the observed concentrations is labelled as the "bias of the standard deviation." This presentation provides a convenient means of identifying those models which produce results that are within a factor of two of the observed values. Models with absolutely no bias in the average concentration, and no bias in the standard deviation of the concentrations would be marked at the center of its graph. Any symbol that lies within the central rectangle exhibits a mean and standard deviation that is within a factor of two of those observed. With the exception of Site #3, more models fall in the center rectangle when the top-25 concentrations are characterized, than when all concentrations in excess of 0.5 ppm are characterized. As a group, the models are seen to perform best at Site #6, while most tend to underestimate concentrations at Sites #1, 2, and 5.

6.1.2 Screening Results

The screening procedure discussed in Section 5.0 has been used to characterize the performance of the eight CO modeling techniques at six sites with the MOBILE4.0 emissions methodology. Tables 15 through 20 present the top-25 (unpaired) observed and predicted concentrations for each site. Included are the average and standard deviation of the top-25 predicted and observed concentrations. Also presented are the FB and the AFB of the average and standard deviation. These values have been plotted in the right-half side of Figures 35 through 40. In the screening procedure, emphasis is placed on those models with a fractional bias within $\pm$ 0.67 (the factor-of-two region). That is, if both the AFB of the average and standard deviation are $\leq$ 0.67 (factor of two), then the models are typically included in further evaluations. Table 21 presents a summary of those models which meet the screening criteria for each site using MOBILE4.0 emissions. No models meet the screening criteria at all sites. Of the three EPA intersection models (EPAINT, VOL9MOB4, and CAL3QHC), CAL3QHC performed best. Of the two models utilizing the FHWA advocated average speed approach rather than explicit queuing (FHWAINT and GIM), GIM performed best. These results were used to design the scope of phase II of this evaluation. Therefore, the MOBILE4.1 analysis was performed for five models: CAL3QHC, GIM, IMM, TEXIN2, and CALINE4.

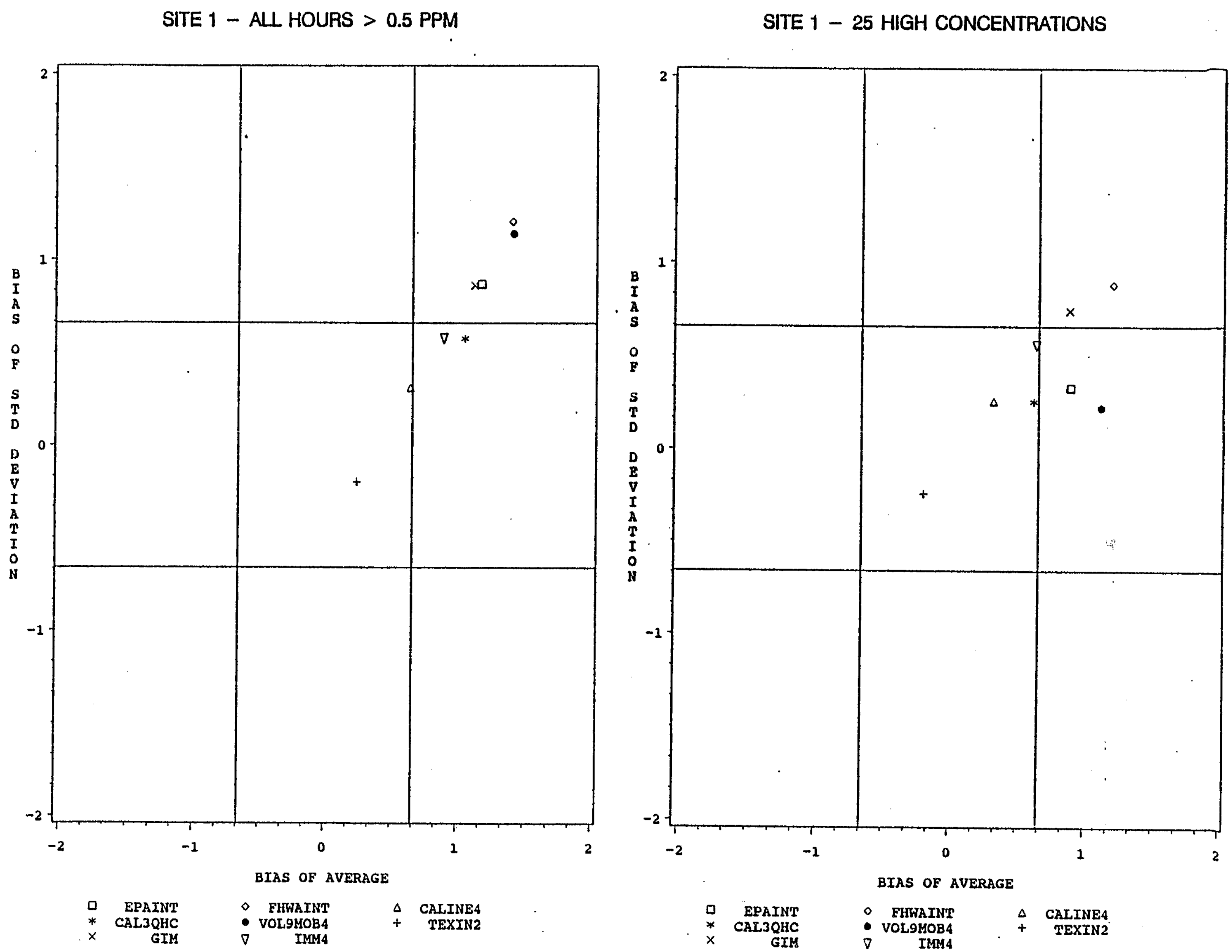


Figure 35. The bias of the average versus the bias of the standard deviation for all concentrations (paired) greater than 0.5 ppm (left-side) and the top-25 (unpaired) concentrations (right-side) for the phase I MOBILE4.0 analysis at Site #1.

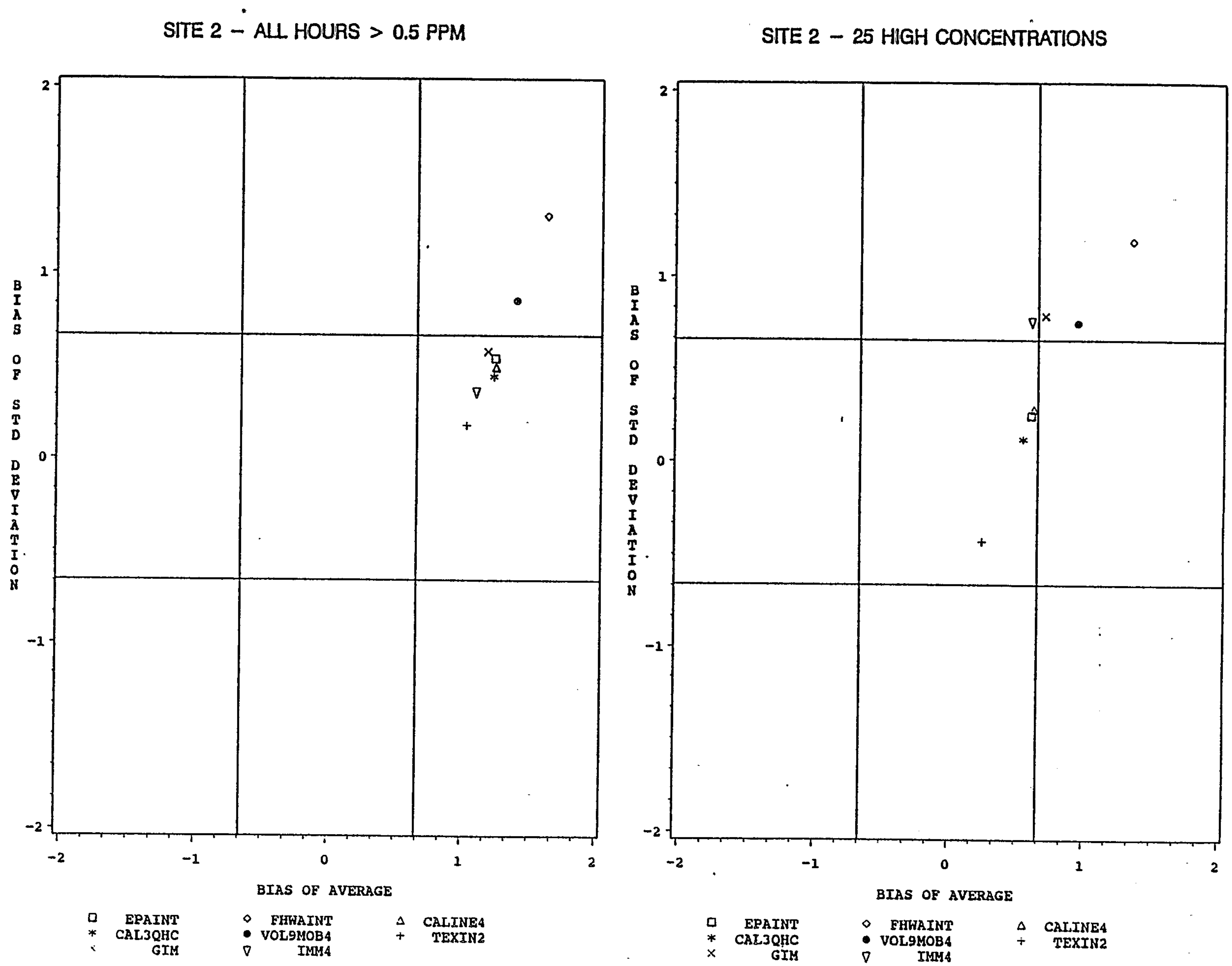
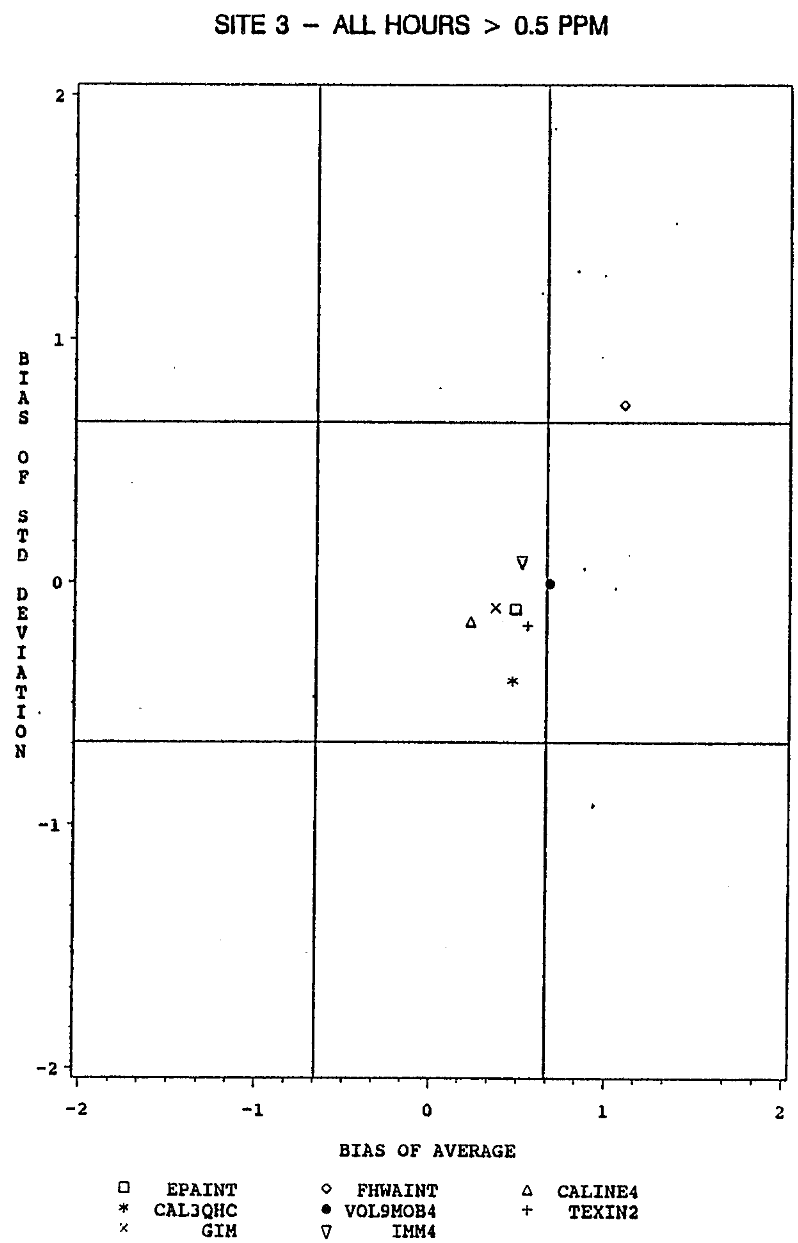


Figure 36. The bias of the average versus the bias of the standard deviation for all concentrations (paired) greater than 0.5 ppm (left-side) and the top-25 (unpaired)



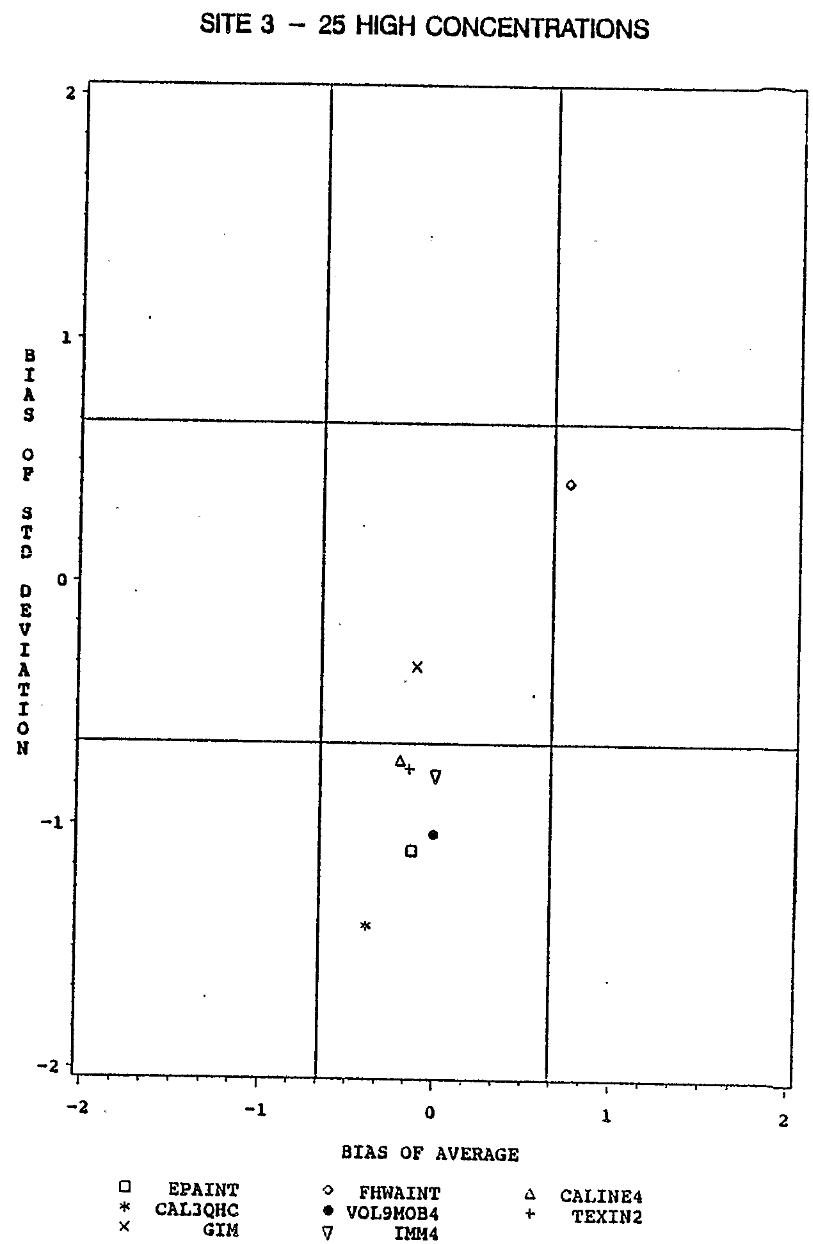


Figure 37. The bias of the average versus the bias of the standard deviation for all concentrations (paired) greater than 0.5 ppm (left-side) and the top-25 (unpaired) concentrations (right-side) for the phase I MOBILE4.0 analysis at Site #3.

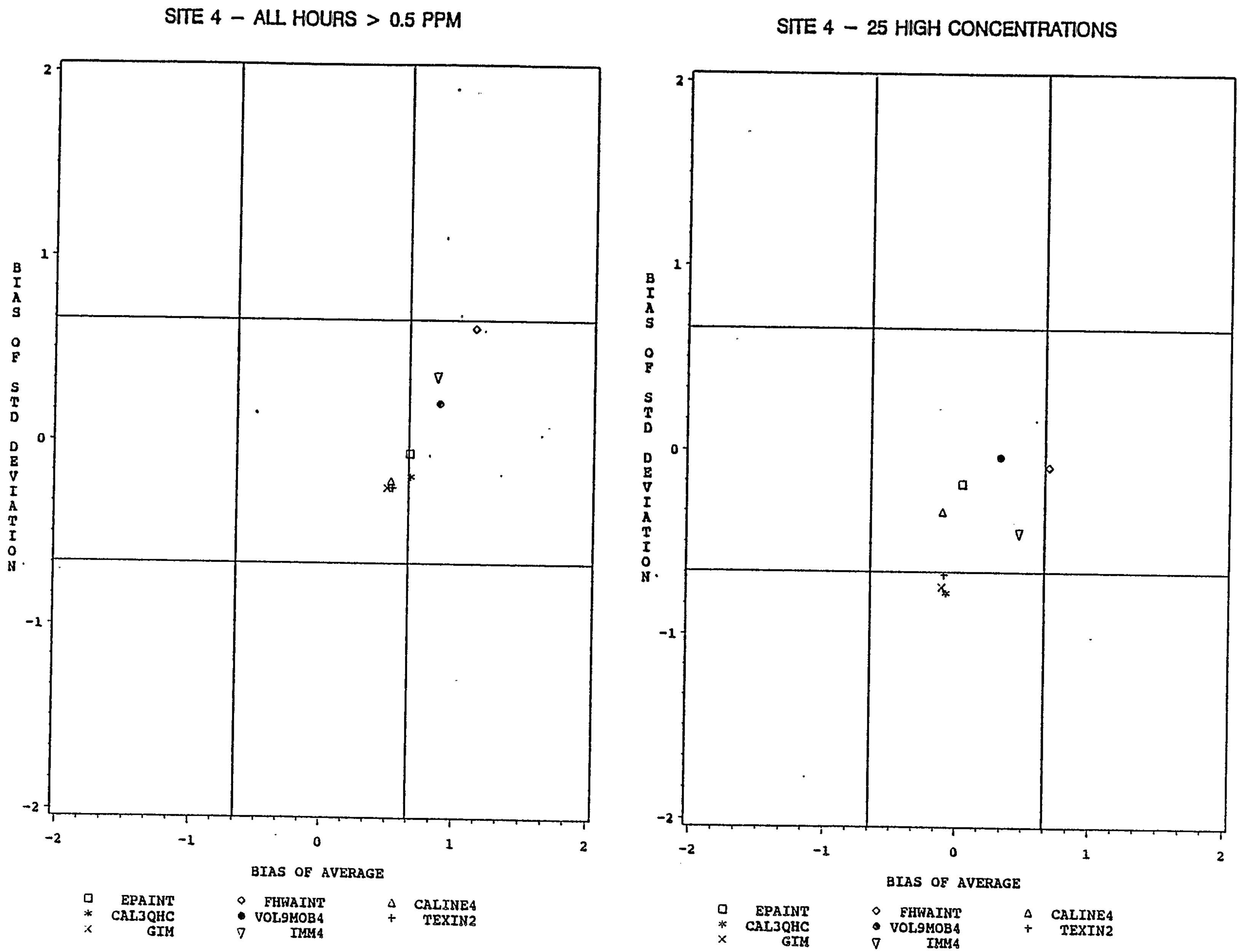


Figure 38. The bias of the average versus the bias of the standard deviation for all concentrations (paired) greater than 0.5 ppm (left-side) and the top-25 (unpaired)

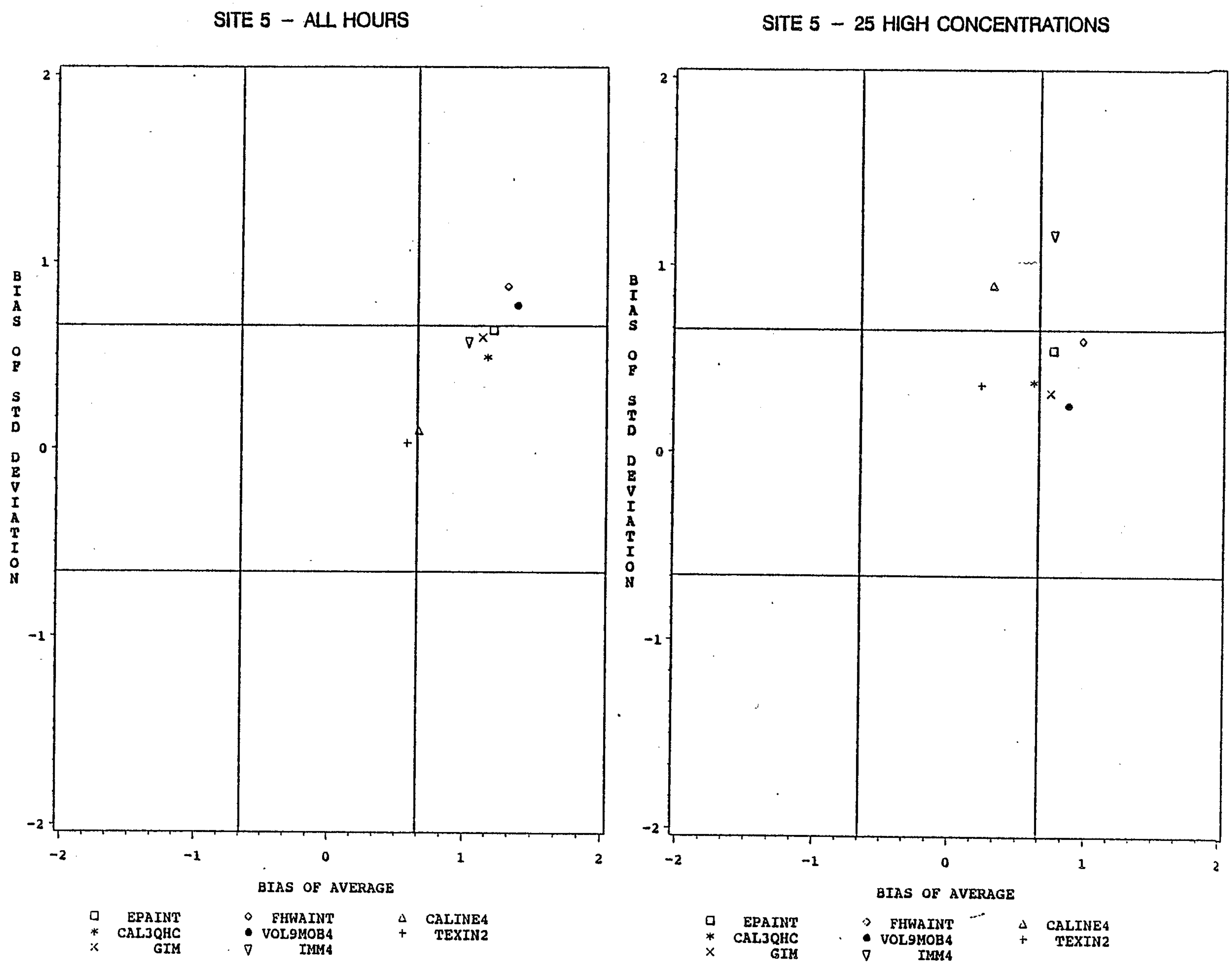


Figure 39. The bias of the average versus the bias of the standard deviation for all concentrations (paired) greater than 0.5 ppm (left-side) and the top-25 (unpaired) concentrations (right-side) for the phase I MOBILE4.0 analysis at Site #5.

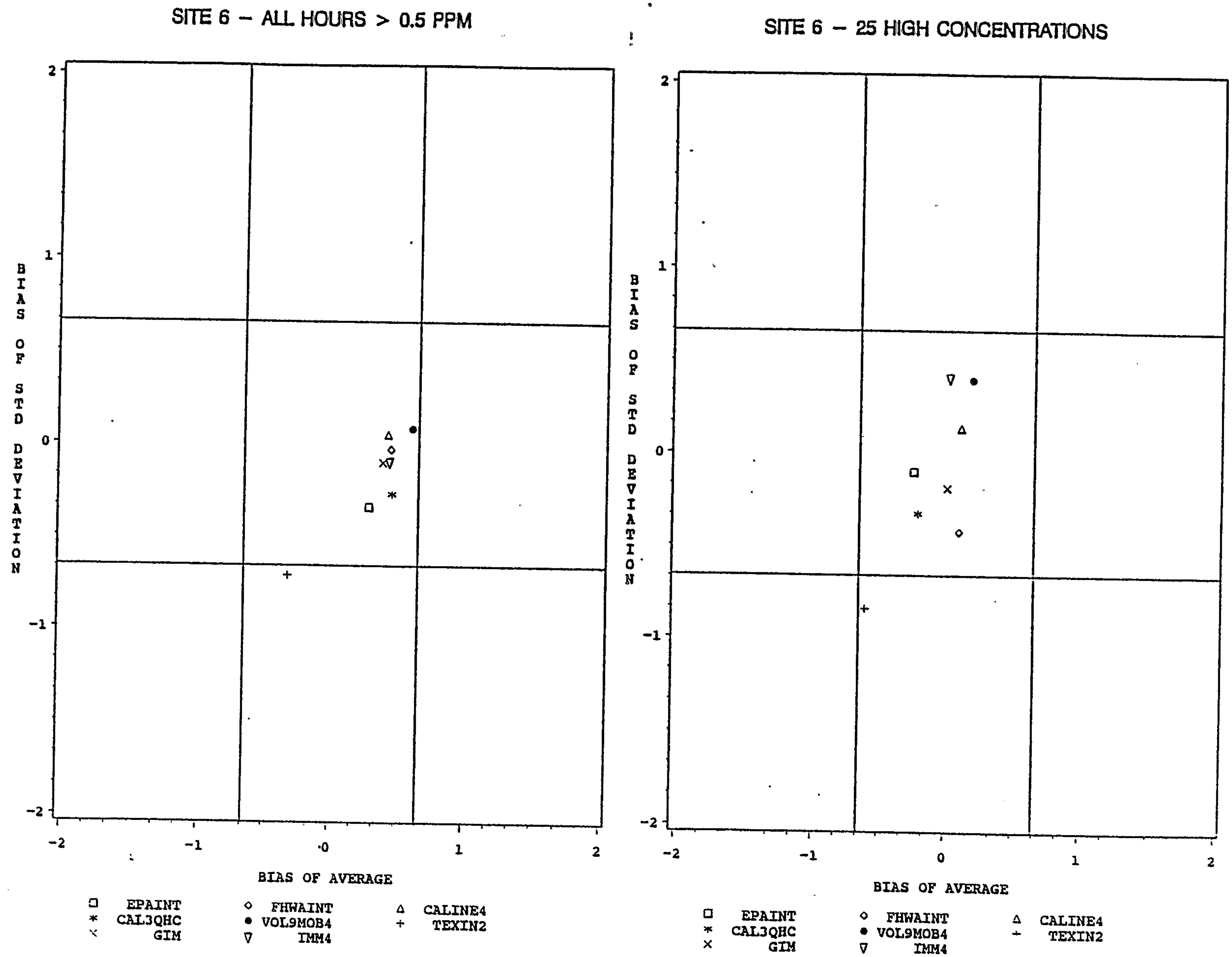


Figure 40. The bias of the average versus the bias of the standard deviation for all concentrations (paired) greater than 0.5 ppm (left-side) and the top-25 (unpaired)

TABLE 15

SCREENING TEST RESULTS FOR SITE #1
USING MOBILE4.0 EMISSIONS METHODOLOGY

Rank	Obs	EPA	FHW	V9M	C3Q	IMM	TEX	GIM	CAL
1	10.6	5.0	2.8	4.2	6.7	5.2	13.3	4.3	7.3
2	9.6	4.5	2.7	3.9	5.7	5.0	11.2	3.8	6.8
3	9.1	3.7	2.5	3.4	4.6	4.8	11.1	3.6	6.8
4	9.0	3.6	2.3	2.9	4.5	4.7	10.8	3.4	6.7
5	8.7	3.6	2.3	2.8	4.4	4.7	10.8	3.4	6.7
6	8.6	3.4	2.3	2.4	4.4	4.6	10.5	3.3	6.6
7	8.4	3.1	2.1	2.4	4.2	4.5	10.4	3.3	6.1
8	8.3	3.1	2.1	2.3	4.2	4.4	10.3	3.3	6.0
9	8.2	3.0	2.0	2.2	4.2	4.3	10.1	3.2	5.9
10	8.2	3.0	2.0	2.2	4.2	4.3	9.8	3.2	5.9
11	8.2	2.9	2.0	2.2	4.1	4.2	9.8	3.1	5.9
12	8.0	2.9	1.9	2.1	4.1	4.0	9.8	3.1	5.8
13	7.8	2.9	1.9	1.9	4.0	4.0	9.5	3.1	5.7
14	7.6	2.8	1.9	1.9	4.0	3.9	9.5	3.0	5.6
15	7.5	2.8	1.9	1.9	4.0	3.9	9.4	3.0	5.5
16	7.5	2.7	1.8	1.9	3.9	3.8	9.4	2.9	5.5
17	7.4	2.7	1.8	1.9	3.9	3.8	9.2	2.8	5.5
18	7.4	2.7	1.8	1.8	3.9	3.8	9.0	2.8	5.4
19	7.4	2.7	1.8	1.8	3.9	3.8	8.9	2.8	5.3
20	7.4	2.6	1.7	1.8	3.9	3.7	8.9	2.8	5.2
21	7.3	2.6	1.7	1.8	3.9	3.7	8.8	2.8	5.1
22	7.3	2.6	1.7	1.8	3.8	3.7	8.7	2.7	5.1
23	7.3	2.6	1.6	1.8	3.7	3.7	8.7	2.7	5.1
24	7.3	2.6	1.6	1.7	3.7	3.6	8.7	2.7	5.1
25	7.2	2.6	1.6	1.7	3.7	3.6	8.6	2.7	5.0
AVG:	8.1	3.1	2.0	2.3	4.2	4.1	9.8	3.1	5.8
FB:		0.90	1.21	1.12	0.62	0.64	-0.20	0.88	0.32
AFB:		0.90	1.21	1.12	0.62	0.64	0.20	0.88	0.32
St.Dev.	0.85	0.61	0.33	0.68	0.66	0.47	1.09	0.39	0.66
FB:		0.33	0.88	0.23	0.26	0.57	-0.24	0.74	0.26
AFB:		0.33	0.88	0.23	0.26	0.57	0.24	0.74	0.26

TABLE 16

SCREENING TEST RESULTS FOR SITE #2
USING MOBILE4.0 EMISSIONS METHODOLOGY

Rank	Obs	EPA	FHW	V9M	C3Q	IMM	TEX	GIM	CAL
1	11.5	6.5	2.3	4.3	7.1	5.6	10.3	5.1	7.7
2	10.5	6.1	2.2	4.0	6.7	5.4	10.3	5.0	5.8
3	10.4	6.0	2.2	3.7	6.4	5.3	10.1	4.9	5.0
4	10.2	5.3	2.0	3.7	6.2	5.2	9.8	4.9	4.8
5	10.2	5.3	1.9	3.6	6.0	5.1	8.3	4.9	4.7
6	9.1	5.2	1.8	3.3	5.4	5.0	7.6	4.3	4.7
7	8.8	5.2	1.7	3.3	5.4	4.9	7.0	4.1	4.6
8	8.5	5.0	1.7	3.2	5.3	4.8	6.9	4.0	4.6
9	8.4	4.9	1.6	3.1	5.1	4.7	6.4	4.0	4.6
10	8.3	4.8	1.6	3.0	4.9	4.7	6.4	3.9	4.6
11	8.2	4.7	1.6	3.0	4.9	4.6	6.0	3.9	4.5
12	8.1	4.5	1.6	2.9	4.9	4.5	5.9	3.9	4.4
13	8.1	4.3	1.6	2.9	4.6	4.5	5.8	3.9	4.3
14	8.1	4.3	1.5	2.9	4.4	4.4	5.8	3.9	4.2
15	8.1	4.2	1.5	2.9	4.3	4.3	5.8	3.8	4.1
16	8.0	4.0	1.5	2.8	4.2	4.2	5.6	3.8	4.1
17	8.0	3.9	1.5	2.8	4.2	4.2	5.6	3.8	4.0
18	7.9	3.9	1.4	2.7	4.1	4.1	5.5	3.8	4.0
19	7.8	3.8	1.4	2.6	4.1	4.1	5.5	3.8	4.0
20	7.7	3.7	1.4	2.6	4.0	4.1	5.5	3.8	3.9
21	7.7	3.7	1.4	2.6	4.0	4.1	5.4	3.8	3.9
22	7.7	3.6	1.4	2.5	3.9	4.1	5.4	3.7	3.9
23	7.6	3.6	1.4	2.5	3.9	4.0	5.4	3.6	3.9
24	7.6	3.6	1.4	2.5	3.8	4.0	5.3	3.6	3.7
25	7.5	3.6	1.4	2.4	3.8	4.0	5.2	3.6	3.6
AVG:	8.6	4.5	1.6	3.0	4.9	4.6	6.7	4.1	4.5
FB:		0.61	1.36	0.95	0.55	0.61	0.25	0.71	0.63
AFB:		0.61	1.36	0.95	0.55	0.61	0.25	0.71	0.63
St.Dev.	1.11	0.86	0.28	0.50	0.98	0.49	1.71	0.48	0.83
FB:		0.25	1.20	0.75	0.13	0.77	-0.43	0.79	0.29
AFB:		0.25	1.20	0.75	0.13	0.77	0.43	0.79	0.29

TABLE 17

SCREENING TEST RESULTS FOR SITE #3
USING MOBILE4.0 EMISSIONS METHODOLOGY

Rank	Obs	EPA	FHW	V9M	C3Q	IMM	TEX	GIM	CAL
1	10.2	20.1	5.5	19.5	31.6	15.8	14.4	11.9	17.3
2	9.6	19.6	4.9	16.6	29.1	11.2	14.3	11.3	14.4
3	9.0	11.0	4.4	9.5	13.4	11.1	13.7	11.1	11.5
4	9.0	11.0	4.3	8.1	12.3	9.4	10.8	11.1	10.7
5	9.0	9.9	4.3	8.1	11.5	9.2	10.5	10.3	10.3
6	8.8	9.4	4.0	7.9	11.5	9.1	10.3	10.2	9.9
7	8.8	8.4	3.7	7.8	11.3	8.4	10.3	9.3	9.9
8	8.2	8.3	3.6	7.6	11.0	7.9	9.5	8.9	9.9
9	8.2	8.3	3.6	7.1	10.9	7.9	9.3	8.9	9.6
10	7.8	8.3	3.4	7.1	10.7	7.9	9.1	8.8	9.5
11	7.6	8.2	3.4	7.0	10.4	7.8	8.9	8.5	9.3
12	7.6	7.9	3.4	6.9	10.3	7.5	8.6	8.5	9.2
13	7.3	7.8	3.3	6.9	10.2	7.2	8.4	8.1	9.0
14	7.2	7.5	3.3	6.9	9.9	7.2	8.4	8.0	8.9
15	7.2	7.5	3.2	6.8	9.6	7.2	8.4	8.0	8.8
16	7.2	7.5	3.1	6.7	9.3	6.7	7.7	8.0	8.7
17	7.0	7.3	3.1	6.4	8.9	6.5	7.6	7.8	8.6
18	7.0	7.1	3.1	6.4	8.6	6.4	7.1	7.7	8.6
19	7.0	7.1	3.1	6.3	8.6	6.3	7.1	7.5	8.5
20	6.9	6.8	3.0	6.3	8.5	6.0	7.1	7.4	8.3
21	6.8	6.7	3.0	6.3	8.5	5.8	7.0	7.4	7.8
22	6.8	6.6	3.0	6.2	8.2	5.6	6.9	7.3	7.6
23	6.8	6.6	3.0	6.2	8.1	5.5	6.9	7.3	7.5
24	6.7	6.6	3.0	5.8	8.1	5.3	6.9	7.3	7.4
25	6.7	6.5	2.9	5.8	8.0	5.2	6.8	7.2	7.4
AVG:	7.8	8.9	3.5	7.8	11.5	7.8	9.0	8.7	9.5
FB:		-0.13	0.75	-0.01	-0.39	0.00	-0.15	-0.11	-0.20
AFB:		0.13	0.75	0.01	0.39	0.00	0.15	0.11	0.20
St.Dev.	1.02	3.53	0.67	3.21	5.85	2.34	2.29	1.45	2.20
FB:		-1.10	0.42	-1.03	-1.40	-0.78	-0.77	-0.34	-0.73
AFB:		1.10	0.42	1.03	1.40	0.78	0.77	0.34	0.73

TABLE 18

SCREENING TEST RESULTS FOR SITE #4
USING MOBILE4.0 EMISSIONS METHODOLOGY

Rank	Obs	EPA	FHW	V9M	C3Q	IMM	TEX	GIM	CAL
1	9.6	9.1	6.1	7.3	12.4	8.0	12.1	12.4	10.3
2	8.9	8.9	5.1	6.7	11.8	7.9	10.8	11.8	10.3
3	8.7	8.9	4.8	6.7	11.4	6.5	10.7	11.4	10.0
4	8.6	8.7	4.4	6.6	10.6	5.4	10.4	10.3	9.8
5	8.3	8.4	4.4	6.5	10.0	5.3	10.3	10.2	9.6
6	8.2	7.8	4.4	6.1	9.4	5.1	9.1	9.6	9.3
7	7.5	7.4	4.3	5.9	9.3	5.0	9.0	9.4	9.3
8	7.5	7.4	4.0	5.8	8.1	5.0	8.9	9.2	9.2
9	7.5	7.3	4.0	5.8	7.8	4.9	8.9	9.1	8.7
10	7.3	7.2	3.8	5.3	7.7	4.9	8.7	8.7	8.6
11	7.1	7.1	3.5	5.3	7.7	4.4	8.3	8.7	8.3
12	7.0	7.1	3.5	5.3	7.6	4.4	8.0	7.6	8.2
13	7.0	7.1	3.3	4.9	7.3	4.3	7.8	7.5	8.2
14	7.0	7.0	3.2	4.9	7.2	4.1	7.6	7.4	8.0
15	6.9	6.8	3.2	4.9	7.1	3.9	7.4	7.3	7.9
16	6.9	6.6	3.0	4.8	7.0	3.9	7.4	7.1	7.9
17	6.9	6.5	3.0	4.8	7.0	3.8	7.4	7.0	7.8
18	6.9	6.5	3.0	4.8	7.0	3.8	7.2	6.9	7.5
19	6.8	6.4	2.9	4.7	6.8	3.8	7.1	6.8	7.5
20	6.8	6.3	2.8	4.6	6.8	3.5	6.5	6.8	7.4
21	6.8	6.3	2.8	4.6	6.6	3.5	6.4	6.7	7.3
22	6.7	6.2	2.8	4.6	6.5	3.4	6.4	6.7	6.9
23	6.7	6.1	2.7	4.6	6.3	3.4	6.2	6.6	6.8
24	6.7	6.0	2.6	4.5	6.1	3.4	6.2	6.6	6.6
25	6.7	5.6	2.6	4.4	5.8	3.3	6.1	6.5	6.5
AVG:	7.4	7.1	3.6	5.4	8.1	4.6	8.2	8.3	8.3
FB:		0.03	0.69	0.32	-0.08	0.47	-0.10	-0.12	-0.12
AFB:		0.03	0.69	0.32	0.08	0.47	0.10	0.12	0.12
St.Dev.	0.82	0.99	0.90	0.85	1.86	1.29	1.67	1.80	1.15
FB:		-0.18	-0.09	-0.03	-0.77	-0.44	-0.68	-0.74	-0.33
AFB:		0.18	0.09	0.03	0.77	0.44	0.68	0.74	0.33

TABLE 19

SCREENING TEST RESULTS FOR SITE #5
USING MOBILE4.0 EMISSIONS METHODOLOGY

Rank	Obs	EPA	FHW	V9M	C3Q	IMM	TEX	GIM	CAL
1	15.5	7.6	6.1	7.5	10.2	5.4	10.5	8.2	8.1
2	14.6	6.0	5.1	7.2	7.4	5.1	9.6	7.6	8.0
3	10.4	5.8	4.8	6.7	6.0	4.7	9.5	7.0	7.5
4	9.9	5.4	4.5	4.9	5.4	4.5	9.1	5.4	7.4
5	9.6	4.8	4.2	4.6	4.8	4.4	8.6	5.2	7.4
6	9.3	4.6	4.1	4.4	4.6	4.2	8.3	4.2	7.3
7	8.9	4.4	3.2	4.4	4.5	4.2	7.4	3.9	6.9
8	8.7	4.3	3.2	3.6	4.5	4.1	7.3	3.9	6.7
9	8.6	4.0	3.2	3.1	4.4	4.1	6.9	3.8	6.5
10	8.6	3.8	2.7	3.1	4.4	3.9	6.7	3.8	6.4
11	8.4	3.5	2.5	2.8	4.3	3.8	6.6	3.7	6.2
12	8.4	3.4	2.5	2.7	4.3	3.8	6.5	3.5	6.2
13	8.0	3.3	2.4	2.7	4.2	3.8	6.5	3.5	6.1
14	8.0	3.2	2.4	2.5	4.1	3.7	6.2	3.5	6.0
15	8.0	3.2	2.3	2.5	4.1	3.7	6.1	3.2	5.9
16	7.9	3.2	2.3	2.5	4.1	3.7	6.0	3.1	5.9
17	7.6	3.2	2.3	2.5	4.0	3.6	6.0	3.1	5.9
18	7.6	3.2	2.3	2.5	4.0	3.6	6.0	3.1	5.9
19	7.5	3.2	2.3	2.4	3.9	3.6	5.9	3.1	5.9
20	7.5	3.2	2.3	2.4	3.9	3.5	5.9	3.1	5.8
21	7.4	3.1	2.2	2.3	3.9	3.5	5.8	3.0	5.8
22	7.4	3.1	2.2	2.3	3.8	3.4	5.8	3.0	5.6
23	7.4	3.1	2.2	2.3	3.8	3.4	5.8	3.0	5.6
24	7.4	3.0	2.2	2.3	3.8	3.4	5.7	2.9	5.6
25	7.2	3.0	2.1	2.2	3.7	3.3	5.7	2.9	5.5
AVG:	8.8	3.9	3.0	3.5	4.6	3.9	7.0	4.0	6.4
FB:		0.76	0.98	0.87	0.62	0.76	0.23	0.74	0.31
AFB:		0.76	0.98	0.87	0.62	0.76	0.23	0.74	0.31
St.Dev.	2.07	1.18	1.12	1.60	1.41	0.54	1.44	1.50	0.79
FB:		0.55	0.60	0.26	0.38	1.17	0.36	0.32	0.90
AFB:		0.55	0.60	0.26	0.38	1.17	0.36	0.32	0.90

TABLE 20

SCREENING TEST RESULTS FOR SITE #6
USING MOBILE4.0 EMISSIONS METHODOLOGY

Rank	Obs	EPA	FHW	V9M	C3Q	IMM	TEX	GIM	CAL
1	8.1	10.2	9.9	6.5	10.3	6.2	20.3	9.5	6.6
2	7.5	8.8	8.4	5.4	10.2	6.1	13.5	8.2	6.4
3	7.0	7.8	7.5	5.3	7.9	6.0	11.9	7.1	6.1
4	7.0	7.6	5.9	5.0	7.4	5.9	11.3	5.4	6.1
5	5.0	7.4	5.5	4.8	7.0	5.9	11.0	5.2	5.2
6	4.8	6.9	5.1	4.3	6.9	5.7	9.8	5.1	5.0
7	4.8	6.9	4.3	4.2	6.8	5.3	9.2	5.0	4.8
8	4.8	6.7	4.3	4.1	6.8	5.3	9.2	5.0	4.8
9	4.8	6.5	4.3	4.0	6.6	5.1	9.1	4.8	4.7
10	4.6	6.4	4.3	4.0	6.5	5.0	8.7	4.6	4.5
11	4.6	6.4	4.2	3.9	6.0	5.0	8.6	4.6	4.5
12	4.6	6.4	4.0	3.9	6.0	4.9	8.6	4.6	4.4
13	4.6	6.2	3.7	3.9	5.9	4.6	8.5	4.5	4.3
14	4.5	5.8	3.7	3.8	5.7	4.5	8.3	4.4	4.0
15	4.4	5.7	3.6	3.7	5.6	4.5	8.3	4.3	4.0
16	4.4	5.7	3.5	3.7	5.2	4.4	8.2	4.3	3.9
17	4.4	5.6	3.4	3.7	5.1	4.4	8.2	4.2	3.9
18	4.3	5.6	3.4	3.6	5.1	4.3	8.0	4.1	3.7
19	4.3	5.5	3.4	3.6	5.0	4.2	8.0	4.1	3.7
20	4.3	5.2	3.3	3.6	4.9	4.1	7.7	4.1	3.6
21	4.3	5.2	3.3	3.6	4.8	4.1	7.6	4.0	3.5
22	4.2	5.2	3.3	3.5	4.7	4.1	7.4	4.0	3.5
23	4.2	5.1	3.3	3.4	4.7	4.1	7.3	4.0	3.4
24	4.1	5.1	3.2	3.4	4.4	4.0	7.1	4.0	3.3
25	4.1	5.1	3.2	3.4	4.3	4.0	7.0	3.9	3.3
AVG:	4.9	6.4	4.5	4.1	6.2	4.9	9.3	4.9	4.4
FB:		-0.25	0.10	0.19	-0.22	0.02	-0.61	0.01	0.11
AFB:		0.25	0.10	0.19	0.22	0.02	0.61	0.01	0.11
St.Dev.	1.13	1.26	1.74	0.76	1.58	0.74	2.78	1.37	0.99
FB:		-0.11	-0.43	0.40	-0.33	0.41	-0.84	-0.19	0.14
AFB:		0.11	0.43	0.40	0.33	0.41	0.84	0.19	0.14

TABLE 21

SUMMARY OF EPA SCREENING TEST RESULTS FOR EACH MODEL EVALUATED IN THE NEW YORK CITY CO INTERSECTION MODELING ANALYSIS (USING MOBILE4.0 EMISSIONS METHODOLOGY)

Site	EPA	FHW	V9M	C3Q	IMM	TEX	GIM	CAL
1				X	X	X		X
2	X			X		X		X
3							X	
4	X		X		X			X
5				X		X		
6	X	X	X	X	X		X	X
Total Over All Sites	3	1	2	4	3	3	2	4
Total Over Sites #1,2,5	1	0	0	3	1	3	0	2

Note: X indicates that the FB of the average and standard deviation is within ± 0.67 (factor-of-two)

6.2 Phase II Results: 5 Models/3 Sites Using MOBILE4.1 Emissions

The MOBILE4.1 analysis was limited to the three least complex intersections with the best quality data. When collecting and compiling the New York City database, the best quality assurance procedures were followed at Site #1 (West/Chambers) and Site #2 (34th/8th). The uniform wind analysis summarized in Section 3.3 indicated that Sites #5 (34th/12th) and #1 are best in terms of unhindered approach wind flows and wind field uniformity. Thus, the MOBILE4.1 analysis was performed for the two intersections with the best wind field uniformity (Sites #1 and #5) and one complex intersection (Site #2) which has the best quality-assured data. As discussed in subsection 6.1.2, the MOBILE4.1 analysis includes: CAL3QHC, GIM, IMM, TEXIN2, and CALINE4.

6.2.1 Paired and Unpaired Statistics

All average observed and predicted CO concentrations paired in time and location and greater than the threshold value of 0.5 ppm are presented in Table 22. TEXIN2 exhibits the smallest average difference (or bias) between the observed and predicted concentrations at all three sites. At Site #1, the bias for TEXIN2 is 0.0 ppm which means there is no model bias when the observed and predicted concentrations are paired in time and location. However, the standard deviation of the residual values is greatest for TEXIN2 at all three sites evaluated. Furthermore, the average absolute residual and the root mean square error for TEXIN2 is comparable with the other four models evaluated. The average absolute residual or error is more meaningful when the bias approaches zero due to the cancellation of over- and underpredictions. The correlation coefficient is highest for IMM at Site #1, GIM at Site #2, and TEXIN2 at Site #5. The variance is significantly lower for the TEXIN2 model at all three sites. For the paired comparisons, the confidence limits were estimated using the one-sample student-t test.

The highest observed and predicted CO concentrations paired in time only are presented in Table 23. Once again, the smallest average difference between the observed and predicted concentrations is found using TEXIN2 at all three sites. At Site #1, TEXIN2 overpredicts the highest observed concentrations by 0.7 ppm; whereas, all other models underpredict the highest observed concentrations. At Sites #2 and 5, all models evaluated indicate an underprediction of the highest observed concentrations. The standard deviation of the residuals is largest for TEXIN2 at all three sites.

Table 24 presents the highest observed and predicted CO concentrations paired by station only. All models evaluated underpredict the highest observed concentrations except for TEXIN2 at Site #1, where TEXIN2 overpredicts by 3.9 ppm. At Site #1, CALINE4 displays the smallest average difference or bias between the observed and predicted concentrations. At Sites #2 and 5, the smallest bias is found using TEXIN2. The standard deviation of the residuals is largest for TEXIN2 at Sites #1 and 2, and IMM at Site #5. The root mean square error is largest for TEXIN2 at Site #1, CALINE4 at Site #2, and IMM at Site #5. The

TABLE 22

ALL OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) PAIRED IN TIME AND LOCATION USING MOBILE4.1 EMISSIONS

SITE #1

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
CALINE4	1072	3.4	1.6	1.4	1.7	1.8	1.7
CAL3QHC	1058	3.5	2.2	2.1	2.3	1.8	1.7
TEXIN2	1074	3.4	0.0	-0.1	0.2	2.8	2.7
GIM	1058	3.5	2.5	2.4	2.6	1.7	1.6
IMM4	1058	3.5	1.9	1.8	2.0	1.7	1.6

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	1.9	2.4	1.9	0.457	1.665	1.477	1.877
CAL3QHC	1.8	2.8	2.3	0.406	2.427	2.151	2.738
TEXIN2	3.0	2.8	2.1	0.400	0.395	0.351	0.445
GIM	1.7	3.0	2.5	0.456	5.899	5.228	6.655
IMM4	1.7	2.5	2.1	0.479	2.363	2.095	2.666

SITE #2

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
CALINE4	1098	3.9	3.0	2.9	3.1	1.6	1.6
CAL3QHC	1098	3.9	2.8	2.7	2.9	1.7	1.6
TEXIN2	1098	3.9	2.4	2.3	2.5	1.9	1.8
GIM	1098	3.9	2.9	2.8	3.0	1.6	1.5
IMM4	1098	3.9	2.7	2.6	2.8	1.7	1.6

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	1.7	3.4	3.0	0.334	2.538	2.255	2.857
CAL3QHC	1.8	3.3	2.9	0.341	1.780	1.581	2.003
TEXIN2	2.0	3.1	2.7	0.354	0.951	0.845	1.071
GIM	1.7	3.3	2.9	0.372	3.032	2.693	3.413
IMM4	1.8	3.2	2.8	0.354	1.680	1.492	1.891

TABLE 22 (continued)

ALL OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) PAIRED IN TIME AND LOCATION USING MOBILE4.1 EMISSIONS

SITE #5

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
CALINE4	587	3.8	1.8	1.6	2.0	2.3	2.2
CAL3QHC	586	3.8	2.6	2.4	2.8	2.1	2.0
TEXIN2	587	3.8	1.4	1.2	1.6	2.5	2.3
GIM	587	3.8	2.7	2.5	2.8	1.9	1.8
IMM4	586	3.8	2.4	2.2	2.6	2.1	2.0

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	2.4	2.9	2.3	0.246	1.059	0.901	1.245
CAL3QHC	2.2	3.3	2.8	0.232	1.802	1.532	2.119
TEXIN2	2.6	2.8	2.1	0.277	0.779	0.663	0.916
GIM	2.0	3.3	2.8	0.259	3.149	2.677	3.703
IMM4	2.2	3.2	2.6	0.182	2.362	2.008	2.778

TABLE 23

HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) EVENT BY EVENT (PAIRED IN TIME) USING MOBILE4.1 EMISSIONS

SITE #1

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
CALINE4	142	5.8	2.0	1.8	2.2	1.4	1.2	1.5
CAL3QHC	142	5.8	2.8	2.6	3.0	1.3	1.1	1.4
TEXIN2	142	5.8	-0.7	-1.2	-0.1	3.2	2.9	3.6
GIM	142	5.8	3.9	3.8	4.1	1.1	0.9	1.2
IMM4	142	5.8	2.7	2.5	3.0	1.3	1.2	1.5

SITE #2

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
CALINE4	143	6.6	3.8	3.6	4.1	1.4	1.3	1.6
CAL3QHC	143	6.6	3.5	3.2	3.8	1.8	1.6	2.0
TEXIN2	143	6.6	2.3	1.9	2.6	2.3	2.1	2.6
GIM	143	6.6	4.0	3.7	4.2	1.5	1.4	1.7
IMM4	143	6.6	3.3	3.0	3.5	1.6	1.4	1.8

SITE #5

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
CALINE4	75	6.2	1.6	1.1	2.2	2.3	2.0	2.8
CAL3QHC	75	6.2	2.7	2.2	3.3	2.4	2.0	2.8
TEXIN2	75	6.2	0.8	0.2	1.4	2.6	2.2	3.1
GIM	75	6.2	3.9	3.4	4.4	2.1	1.8	2.5
IMM4	75	6.2	3.3	2.9	3.8	2.1	1.8	2.5

TABLE 24

HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS PAIRED BY STATION USING MOBILE4.1 EMISSIONS

SITE #1

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
CALINE4	8	8.4	2.2	0.4	4.0	2.0	1.3
CAL3QHC	8	8.4	3.0	1.4	4.7	1.8	1.2
TEXIN2	8	8.4	-3.9	-7.6	-0.3	4.1	2.7
GIM	8	8.4	5.0	3.6	6.4	1.6	1.0
IMM4	8	8.4	3.1	2.0	4.3	1.3	0.9

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	4.0	2.9	2.3	-0.405	1.089	0.218	5.440
CAL3QHC	3.7	3.5	3.0	0.178	0.562	0.113	2.809
TEXIN2	8.4	5.5	5.0	-0.221	0.108	0.022	0.540
GIM	3.2	5.2	5.0	-0.168	2.245	0.449	11.214
IMM4	2.6	3.3	3.1	0.112	3.896	0.780	19.459

SITE #2

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
CALINE4	8	8.6	5.7	3.8	7.5	2.1	1.4
CAL3QHC	8	8.6	4.7	2.3	7.2	2.7	1.8
TEXIN2	8	8.6	2.8	-0.3	5.9	3.5	2.3
GIM	8	8.6	5.5	3.7	7.2	2.0	1.3
IMM4	8	8.6	4.3	2.4	6.2	2.2	1.4

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	4.2	6.0	5.6	0.334	1.333	0.267	6.656
CAL3QHC	5.5	5.4	4.7	0.197	0.655	0.131	3.269
TEXIN2	7.1	4.3	3.7	0.313	0.284	0.057	1.417
GIM	4.0	5.8	5.5	0.278	2.381	0.477	11.891
IMM4	4.4	4.8	4.3	0.124	2.181	0.437	10.895

TABLE 24 (continued)

HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS PAIRED BY STATION USING MOBILE4.1 EMISSIONS

SITE #5

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
CALINE4	8	9.4	3.1	-0.2	6.5	3.7	2.5
CAL3QHC	8	9.4	2.8	-0.6	6.2	3.8	2.5
TEXIN2	8	9.4	0.5	-2.7	3.6	3.5	2.3
GIM	8	9.4	4.0	0.9	7.1	3.5	2.3
IMM4	8	9.4	4.5	1.0	8.0	4.0	2.6

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	7.6	4.7	3.1	-0.407	2.721	0.545	13.589
CAL3QHC	7.7	4.5	3.0	0.005	1.090	0.218	5.444
TEXIN2	7.2	3.4	2.6	0.073	1.252	0.251	6.252
GIM	7.1	5.1	4.0	0.049	1.464	0.293	7.313
IMM4	8.0	5.8	4.5	-0.850	4.186	0.838	20.907

average absolute residual is smallest at Site #1 for CALINE4 and is smallest at Sites #2 and 5 for TEXIN2. The largest negative correlation coefficients are found using CALINE4 at Site #1 and IMM at Site #5. At Site #2, the largest positive correlation (0.334) is found using CALINE4.

The 25-highest observed and predicted CO concentrations over all hours and monitors are tabulated in Table 25 for each of the sites. At Sites #1 and 2, TEXIN2 predicts peak concentrations which exceed the peak observed values. The highest-25 averaged observed and predicted CO concentrations, unpaired in time or location, are summarized in Table 26. All of the models underpredict the highest-25 concentrations at all three sites except for TEXIN2 at Site #1. At Site #1, TEXIN2 overpredicts the 25-highest observed concentrations by 3.9 ppm on average. CALINE4 displays the smallest bias at Site #1 and TEXIN2 displays the smallest bias at the other two sites (only 0.5 ppm at Site #2 and 0.6 ppm at Site #5). Furthermore, TEXIN2 has the smallest variance at all three sites. These results are similar to the paired by station results in Table 24.

A summary of the average residual formed from predicted and observed concentrations paired by time/location, time, and location, and the 25-highest unpaired concentrations is shown in Figures 41 through 43. Also shown for comparison are the residuals using the MOBILE4.0 emissions model. For most models evaluated, the residuals are lower using the MOBILE4.1 emissions model. At Site #1, TEXIN2 overpredicts by a larger amount when using MOBILE4.1 emissions rather than MOBILE4.0 emissions for the statistics matched by location and the 25-highest unpaired values. When the residuals are paired by time only, TEXIN2 overpredicts using the MOBILE4.1 emissions; whereas, the model underpredicted the observed concentrations using the MOBILE4.0 emissions. When comparing the two different versions of the MOBILE emissions model, the bias is largest for TEXIN2. TEXIN2 does not include an idle correction factor. The MOBILE4.1 emissions model automatically corrects the emissions for idle conditions. When the MOBILE4.0 version of the TEXIN2 model was applied, no idle corrections factors were applied. However, when the MOBILE4.1 version of TEXIN2 was evaluated, the idle correction factors were automatically calculated by the MOBILE4.1 emissions model causing an increase in the predicted concentrations. When comparing the MOBILE4.0 versus the MOBILE4.1 results using the CAL3QHC model, one should be reminded that a revised version of the model (Version 2) was tested using the MOBILE4.1 emissions model. Further details are found in Subsection 2.2.5.

Scatterplots of all hourly observed and predicted concentrations at all receptors are shown in Figures 44 through 46 for each model and site. The diagonal line in each plot represents the perfect fit line. TEXIN2 displays a more even distribution of observed versus predicted concentrations at each of the sites, especially at Site #1. However, TEXIN2 also displays the largest overpredictions. Note that the display is limited to maximum values of 15 ppm. There are some hourly concentrations predicted by TEXIN2 that exceed 15 ppm.

The cumulative frequency distribution of the observed and predicted concentrations are presented in Figure 47. At Site #1, TEXIN2 overpredicts the observed concentration

TABLE 25

25 HIGHEST PREDICTED AND OBSERVED CO CONCENTRATIONS (PPM)
USING MOBILE4.1 EMISSIONS

SITE #1

Rank	Observed	CALINE4	CAL3QHC	TEXIN2	IMM	GIM
1	10.6	7.9	8.1	17.0	6.1	4.5
2	9.6	7.3	6.3	14.5	6.0	4.1
3	9.1	7.3	6.2	14.2	5.8	3.7
4	9.0	7.2	5.4	14.2	5.7	3.6
5	8.7	7.2	5.1	14.1	5.6	3.5
6	8.6	7.0	5.0	14.0	5.4	3.5
7	8.4	6.4	5.0	13.9	5.3	3.4
8	8.3	6.4	4.9	13.6	5.2	3.4
9	8.2	6.3	4.8	13.4	5.2	3.3
10	8.2	6.2	4.8	13.3	5.1	3.3
11	8.2	6.2	4.7	13.2	5.0	3.2
12	8.0	6.2	4.7	13.0	4.8	3.2
13	7.8	6.1	4.7	12.8	4.7	3.2
14	7.6	6.0	4.6	12.8	4.7	3.1
15	7.5	5.9	4.6	12.5	4.7	3.1
16	7.5	5.9	4.5	11.9	4.6	3.0
17	7.4	5.9	4.4	11.8	4.6	3.0
18	7.4	5.8	4.4	11.7	4.5	2.8
19	7.4	5.6	4.4	11.7	4.5	2.8
20	7.4	5.6	4.2	11.6	4.5	2.8
21	7.3	5.5	4.2	11.5	4.5	2.8
22	7.3	5.5	4.2	11.2	4.4	2.8
23	7.3	5.3	4.2	11.2	4.4	2.8
24	7.3	5.3	4.2	11.1	4.3	2.8
25	7.2	5.3	4.2	11.0	4.3	2.8

SITE #2

Rank	Observed	CALINE4	CAL3QHC	TEXIN2	IMM	GIM
1	11.5	5.5	7.8	12.8	6.3	5.3
2	10.5	5.2	7.4	12.5	5.9	5.2
3	10.4	5.1	7.4	12.4	5.4	5.2
4	10.2	5.0	7.0	12.2	5.4	4.9
5	10.2	5.0	6.9	9.6	5.3	4.8
6	9.1	4.9	6.8	9.1	5.2	4.5
7	8.8	4.8	6.2	8.4	5.1	4.3
8	8.5	4.8	6.1	8.4	5.0	4.2
9	8.4	4.8	6.0	7.8	4.9	4.1
10	8.3	4.7	5.9	7.6	4.9	4.1
11	8.2	4.6	5.9	7.6	4.9	4.1
12	8.1	4.4	5.7	7.2	4.8	4.0
13	8.1	4.3	5.4	7.2	4.8	4.0
14	8.1	4.3	5.3	7.2	4.8	4.0
15	8.1	4.3	5.2	7.0	4.8	4.0
16	8.0	4.2	5.0	6.9	4.7	3.9
17	8.0	4.2	4.9	6.6	4.7	3.9
18	7.9	4.2	4.8	6.5	4.7	3.9
19	7.8	4.1	4.8	6.5	4.7	3.9
20	7.7	4.1	4.8	6.4	4.7	3.9
21	7.7	4.0	4.7	6.3	4.7	3.9
22	7.7	4.0	4.5	6.3	4.6	3.8
23	7.6	3.9	4.5	6.3	4.6	3.8
24	7.6	3.9	4.4	6.3	4.6	3.7
25	7.5	3.8	4.4	6.2	4.5	3.7

TABLE 25 (continued)

25 HIGHEST PREDICTED AND OBSERVED CO CONCENTRATIONS (PPM)
USING MOBILE4.1 EMISSIONS

SITE #5

Rank	Observed	CALINE4	CAL3QHC	TEXIN2	IMM	GIM
1	15.5	8.6	11.1	12.4	6.5	8.6
2	14.6	8.6	9.6	11.8	6.1	7.8
3	10.4	8.0	7.3	10.6	5.7	7.2
4	9.9	7.9	7.0	10.5	5.4	5.7
5	9.6	7.8	5.5	9.4	5.3	5.3
6	9.3	7.7	5.4	9.2	5.0	4.4
7	8.9	7.4	5.4	8.9	5.0	4.1
8	8.7	7.2	5.4	8.3	4.8	4.0
9	8.6	6.9	5.3	8.1	4.5	4.0
10	8.6	6.8	5.3	7.8	4.5	3.8
11	8.4	6.8	5.3	7.6	4.5	3.7
12	8.4	6.5	5.3	7.6	4.4	3.6
13	8.0	6.4	5.1	7.6	4.4	3.6
14	8.0	6.4	5.0	7.5	4.4	3.6
15	8.0	6.4	5.0	7.4	4.3	3.3
16	7.9	6.4	4.8	7.3	4.3	3.3
17	7.6	6.3	4.7	7.2	4.2	3.3
18	7.6	6.3	4.7	7.2	4.2	3.2
19	7.5	6.2	4.6	6.9	4.2	3.2
20	7.5	6.2	4.6	6.8	4.1	3.2
21	7.4	6.1	4.6	6.8	4.1	3.2
22	7.4	6.1	4.6	6.7	4.0	3.1
23	7.4	6.0	4.5	6.7	4.0	3.1
24	7.4	5.9	4.5	6.7	4.0	3.0
25	7.2	5.9	4.5	6.7	3.9	3.0

TABLE 26

25 HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) UNPAIRED IN TIME OR LOCATION USING MOBILE4.1 EMISSIONS

SITE #1

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	8.1	5.8	2.3	1.9	2.7	1.512	0.666	3.429
CAL3QHC	8.1	4.5	3.5	3.1	4.0	1.452	0.640	3.293
TEXIN2	8.1	11.9	-3.9	-4.5	-3.2	0.381	0.168	0.863
GIM	8.1	3.0	5.0	4.7	5.4	5.151	2.269	11.680
IMM4	8.1	4.6	3.4	3.0	3.8	2.744	1.209	6.221

SITE #2

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	8.6	4.5	4.1	3.6	4.6	5.600	2.467	12.698
CAL3QHC	8.6	5.7	2.9	2.3	3.5	1.114	0.491	2.526
TEXIN2	8.6	8.1	0.5	-0.5	1.5	0.261	0.115	0.592
GIM	8.6	4.2	4.4	3.9	4.8	5.153	2.270	11.684
IMM4	8.6	5.0	3.6	3.1	4.1	6.717	2.959	15.231

SITE #5

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
CALINE4	8.8	6.8	2.0	1.0	2.9	6.192	2.728	14.041
CAL3QHC	8.8	5.6	3.2	2.2	4.3	1.650	0.727	3.742
TEXIN2	8.8	8.1	0.6	-0.4	1.7	1.601	0.705	3.631
GIM	8.8	4.2	4.6	3.6	5.7	1.772	0.781	4.019
IMM4	8.8	4.6	4.2	3.3	5.1	9.024	3.975	20.462

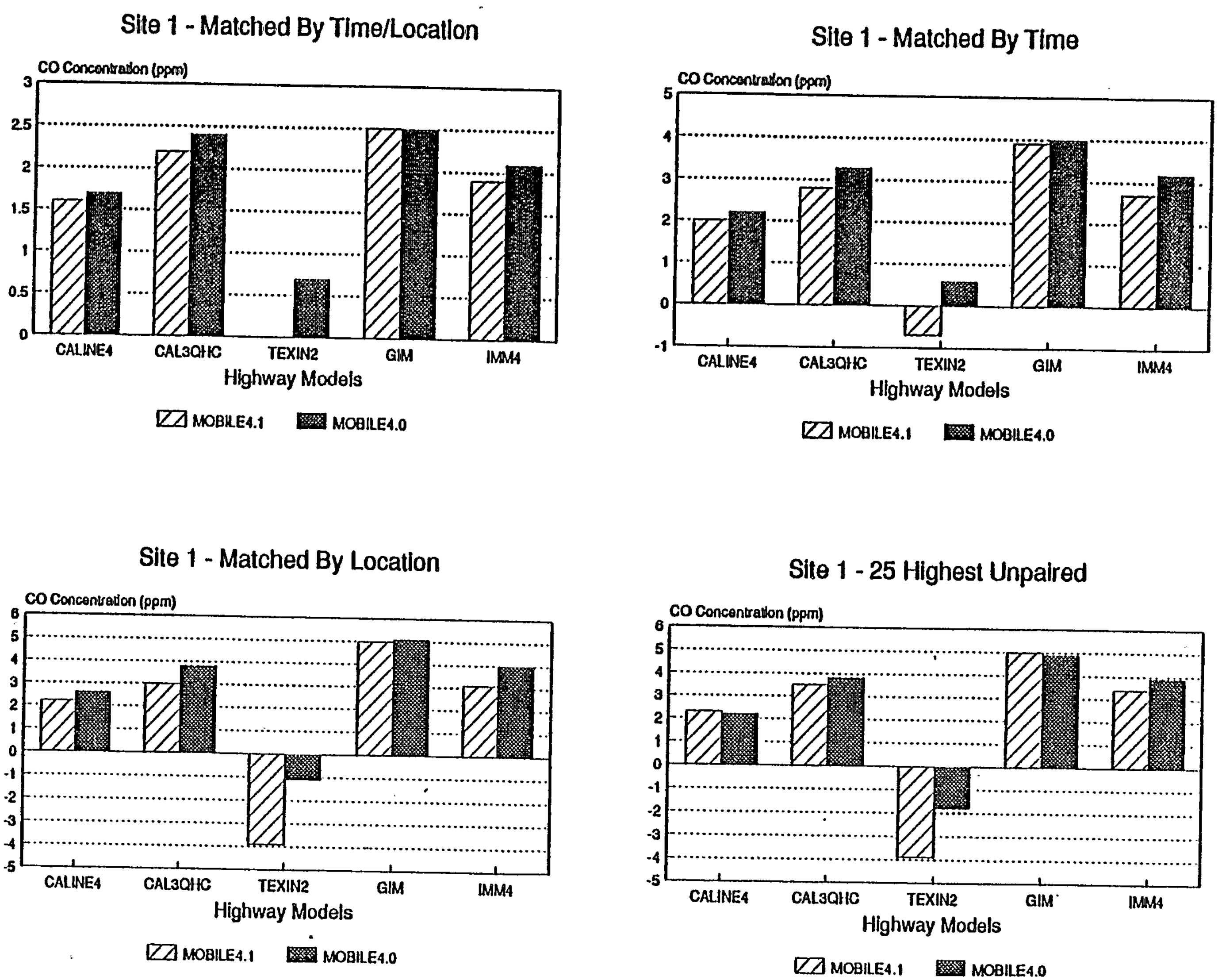


Figure 41. Average residual matched by time/location, time, and location, along with the 25-highest unpaired values for the phase II MOBILE4.1 anlysis at Site #1. Also shown for comparison are the residuals using MOBILE4.0 emissions.

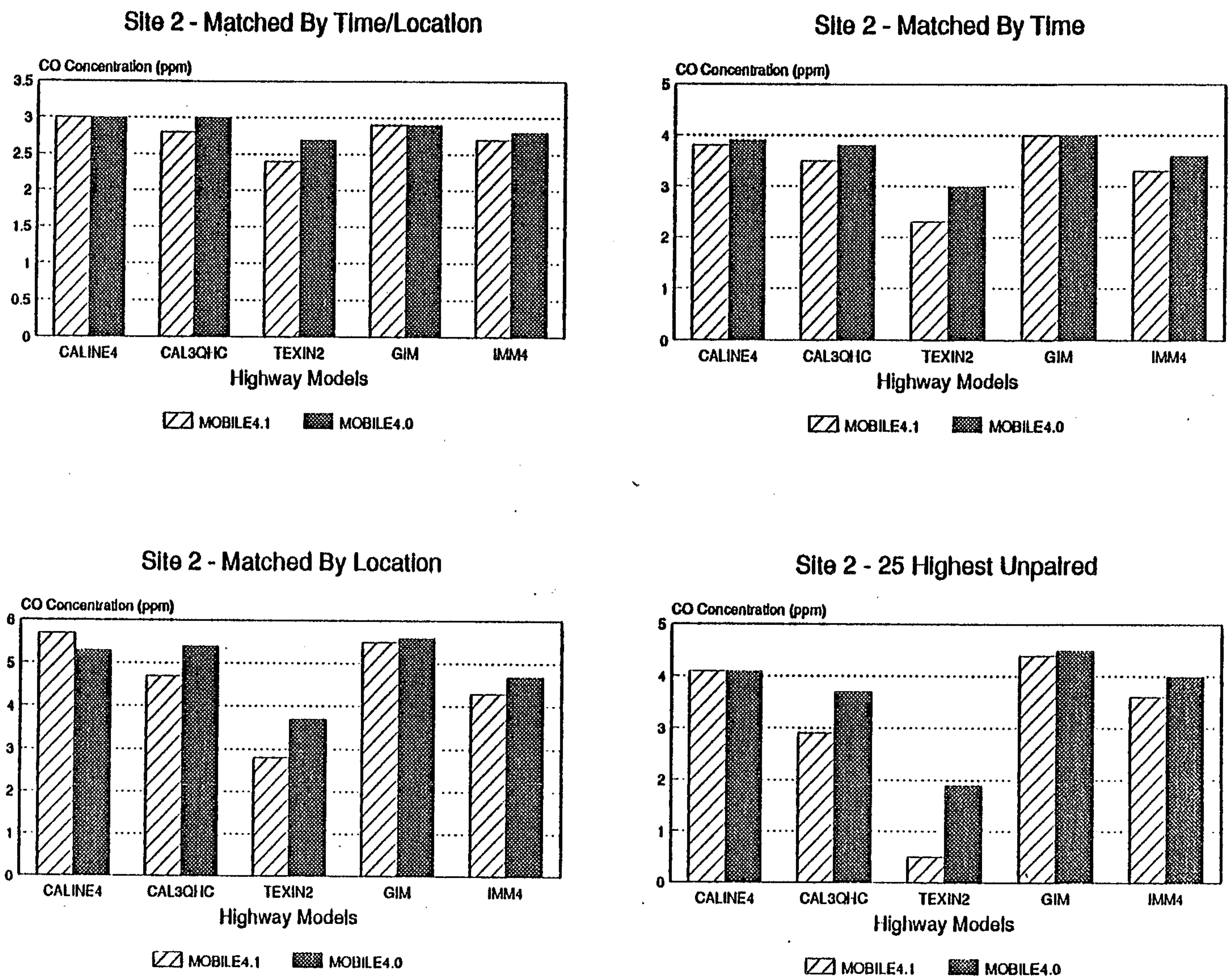


Figure 42. Average residual matched by time/location, time, and location, along with the 25-highest unpaired values for the phase II MOBILE4.1 anlysis at Site #2. Also shown for comparison are the residuals using MOBILE4.0 emissions.

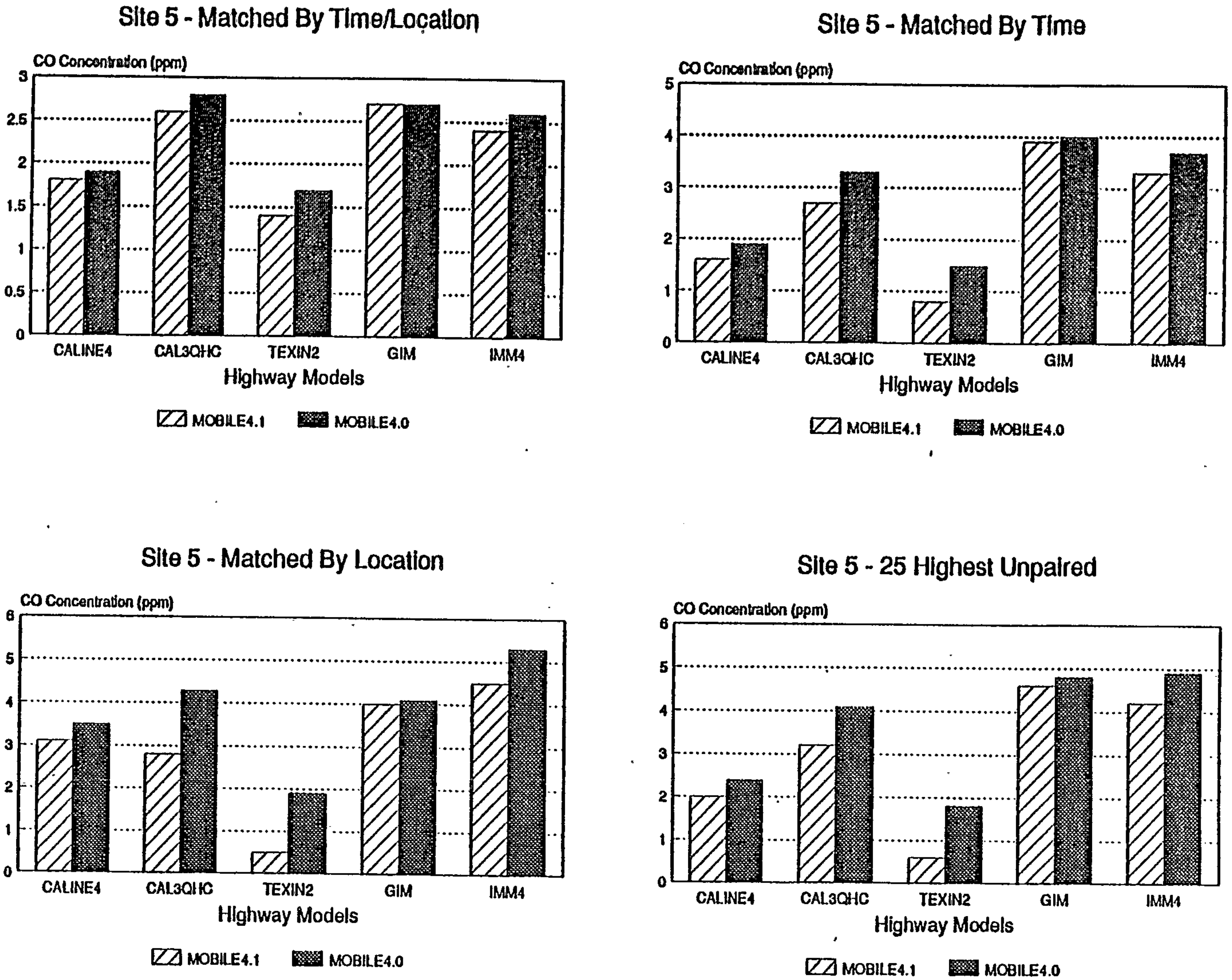


Figure 43. Average residual matched by time/location, time, and location, along with the 25-highest unpaired values for the phase II MOBILE4.1 anlysis at Site #5. Also shown for comparison are the residuals using MOBILE4.0 emissions.

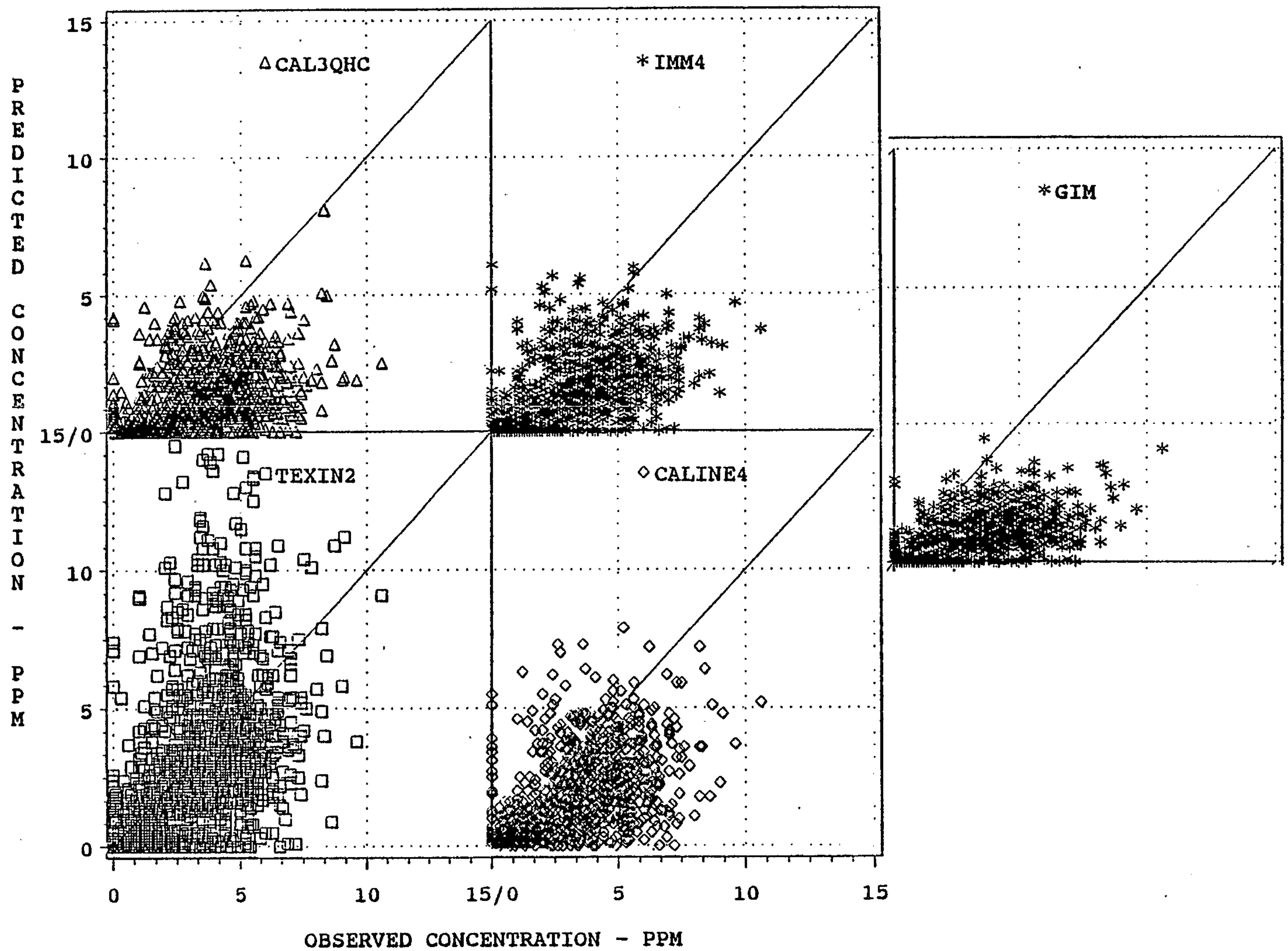


Figure 44. Scatterplots of observed versus predicted concentrations for the phase II MOBILE4.1 analysis at Site #1.

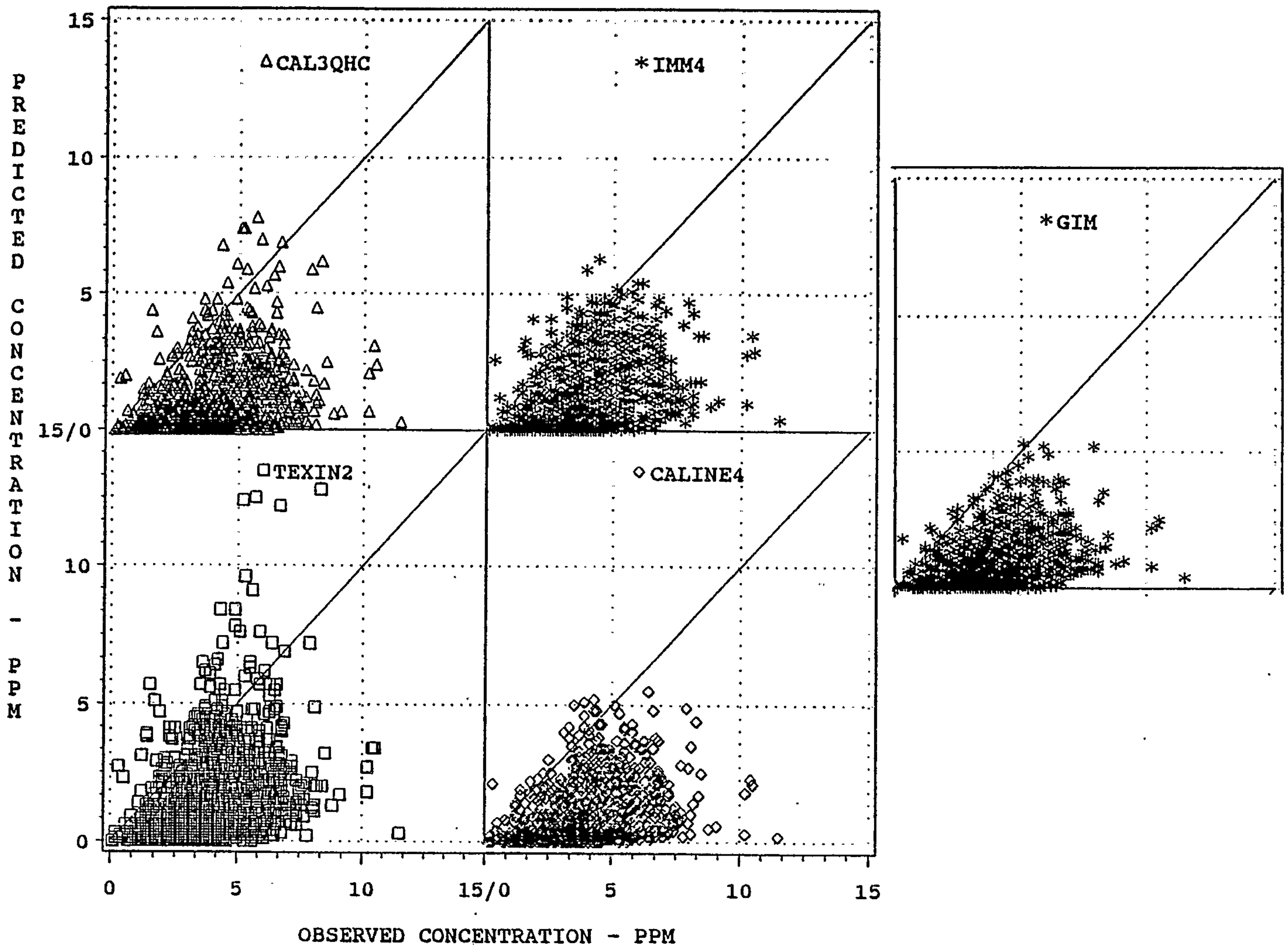


Figure 45. Scatterplots of observed versus predicted concentrations for the phase II MOBILE4.1 analysis at Site #2.

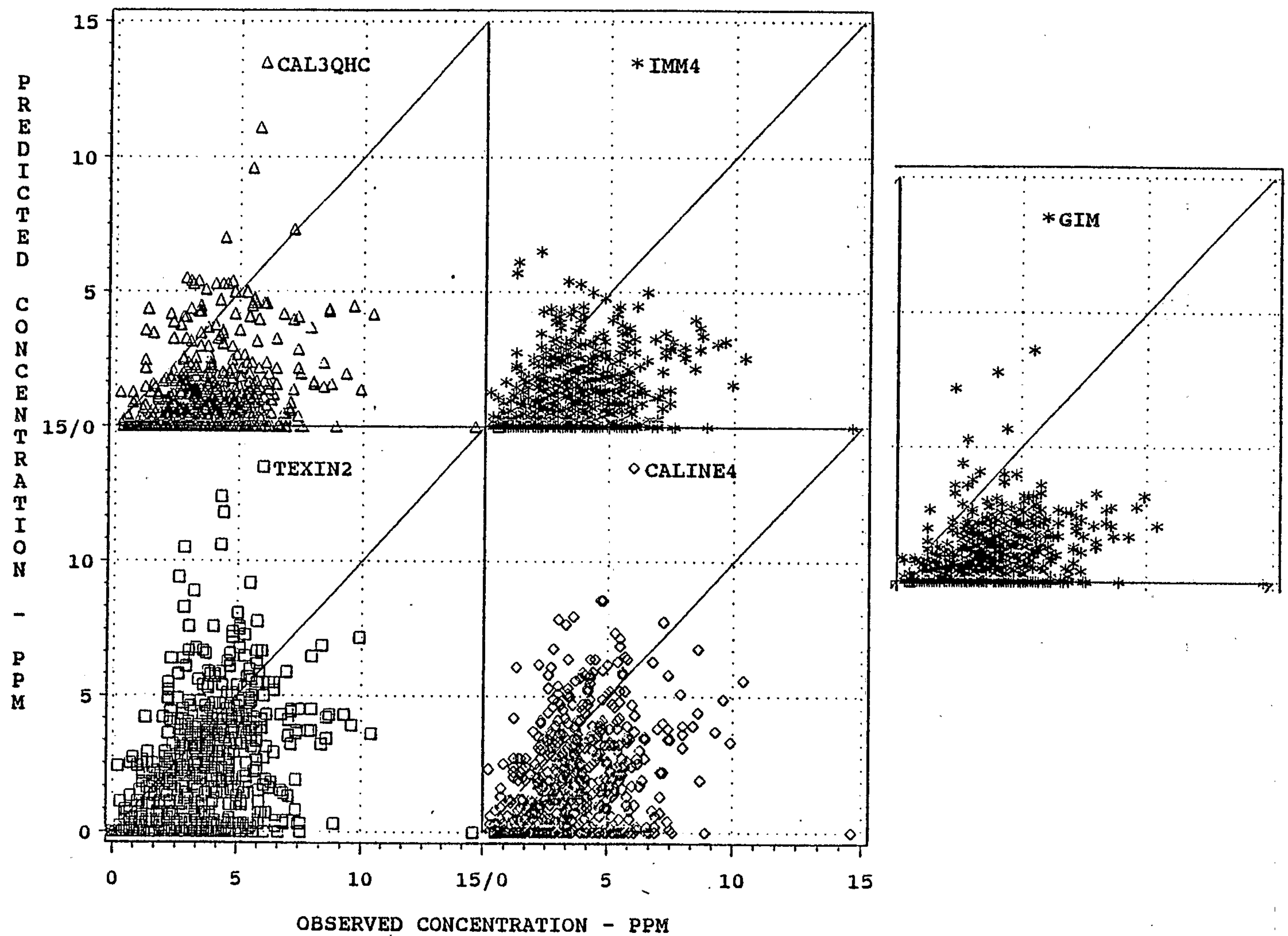


Figure 46. Scatterplots of observed versus predicted concentrations for the phase II MOBILE4.1 analysis at Site #5.

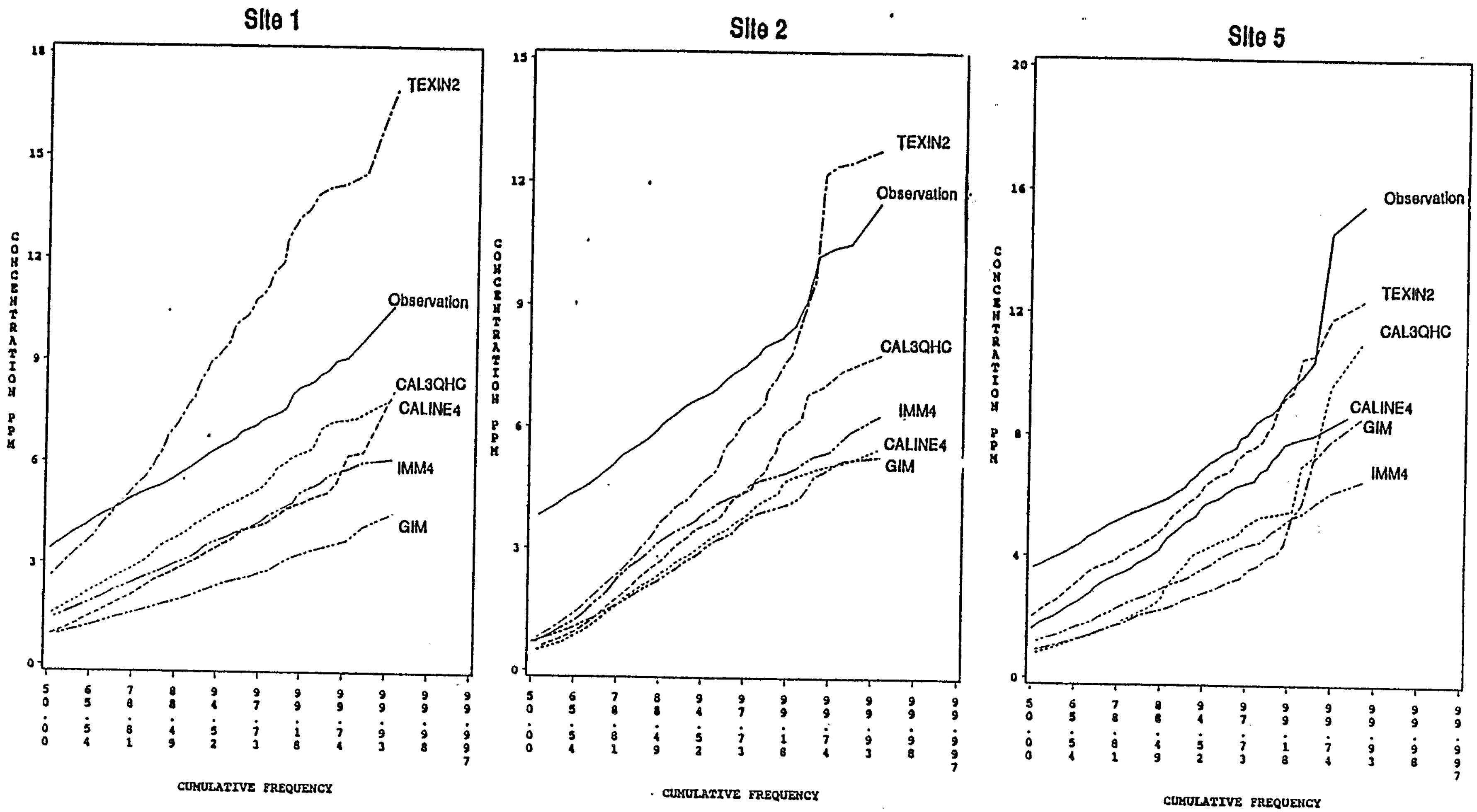


Figure 47. The cumulative frequency of observed and predicted concentrations for the phase II MOBILE4.1 analysis at Sites #1, 2, and 5.

distribution by a large amount. All other models display underpredictions. CAL3QHC and CALINE4 are very similar at the upper end of the cumulative frequency distribution. At Site #2, TEXIN2 overpredicts only at the highest end of the distribution. On average, all models underpredict the observed cumulative frequency distribution at Site #5. For this site, the cumulative frequency distribution for TEXIN2 most closely resembles the observed cumulative distribution.

The 25-highest predicted concentrations are plotted against the observed concentrations in Figure 48. The solid, unmarked line is the 1:1 perfect fit line. As found in the cumulative frequency distribution plots, TEXIN2 overpredicts the 25-highest observed concentrations by a large amount at Site #1. All other models evaluated underpredict the 25-highest concentrations. At Sites #2 and 5, TEXIN2 more closely follows the perfect fit line than any of the other models evaluated. At all three sites, the next "best" model is CAL3QHC, although at Site #1, CALINE4 predicts concentrations that are, on average, higher than the concentrations predicted using CAL3QHC.

The fractional bias of the average (FB) is plotted versus the fractional bias of the standard deviation (FS) for all concentrations greater than the threshold value of 0.5 ppm in Figure 49 and for the 25-high concentrations for each model evaluated in Figure 50. All five models evaluated are displayed for each intersection site. The center of the plot represents a model with zero fractional bias and standard deviation or a "perfect" model. A positive value of FB indicates that the model is underpredicting. When concentrations from all hours are used to compute averages and standard deviations (Figure 49), nearly all models produce standard deviations that are within a factor of two of the standard deviation of the observed concentrations. However, only TEXIN2 and CALINE4 produce averages that are within a factor of two of the observed averages at Sites #1 and #5. Generally, all models tend to underestimate the observed average at all three sites, with the exception of TEXIN2 at Site #1. When only the 25-highest observed and predicted concentrations are characterized (Figure 50), the overall bias towards underestimating the average observed concentration is reduced. In fact all of the models except GIM produce an average concentration that is within a factor of two of the observed concentrations at all three sites. However, the standard deviation of predicted concentrations are more dissimilar to the standard deviation of the observed concentrations for the high 25 concentrations.

6.2.2 Diagnostic Analysis

The statistical model evaluation results presented above are concerned only with the bias, variance, and distribution functions of the data sets. They do not allow investigation of whether the model is scientifically correct. For example, a model that has compensating errors and gives right answers for the wrong reasons will still be judged "excellent" by the statistical procedures. In order to investigate whether the models are consistent with scientific knowledge, the model residuals (Predicted/Observed in a logarithmic system) are plotted versus hour of the day, wind direction, wind speed, ambient temperature, Pasquill-Gifford

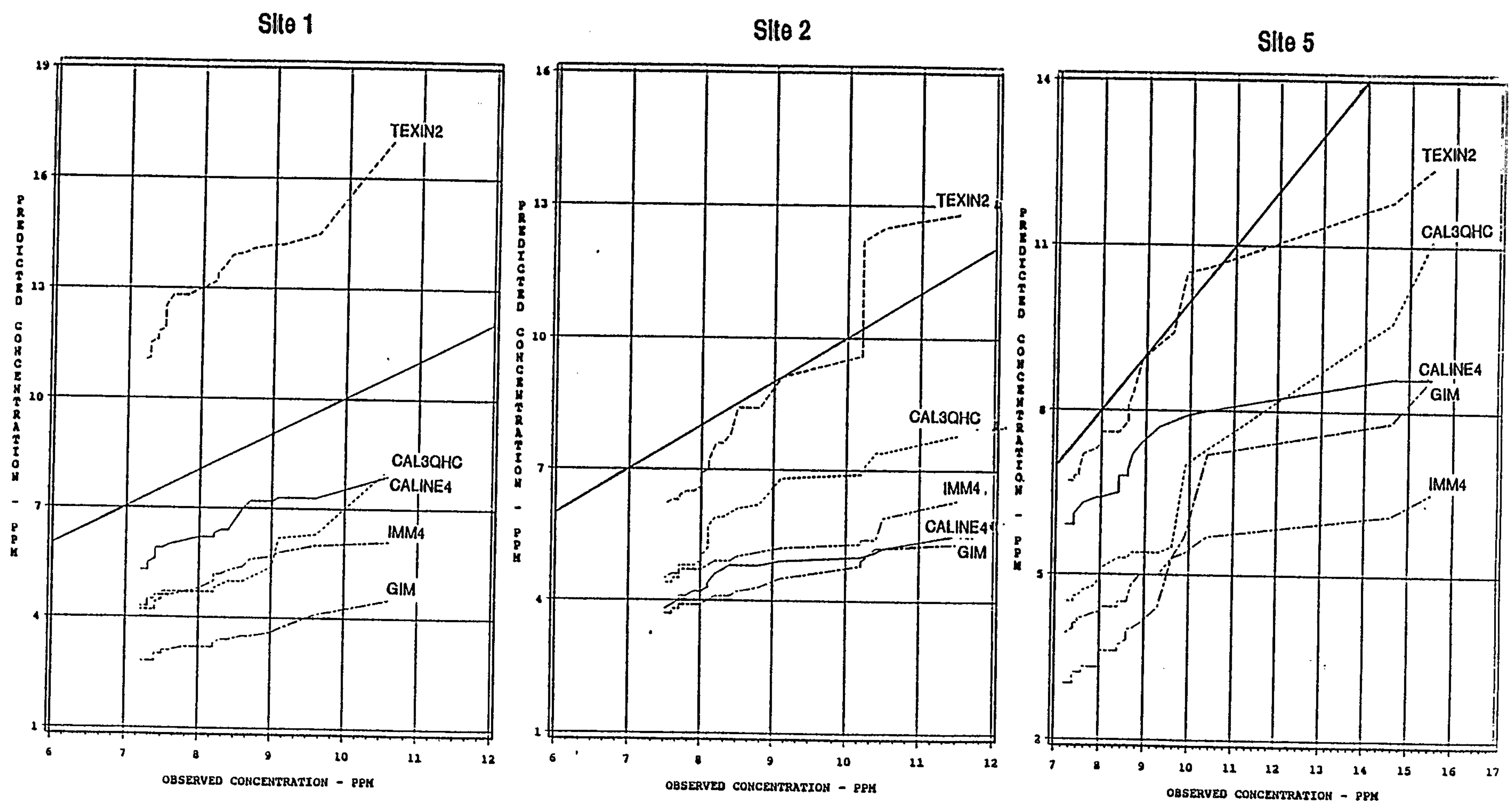


Figure 48. The 25-highest observed versus predicted concentrations for the phase II MOBILE4.1 analysis at Sites #1, 2, and 5. The solid, unmarked line is the 1:1 perfect fit.

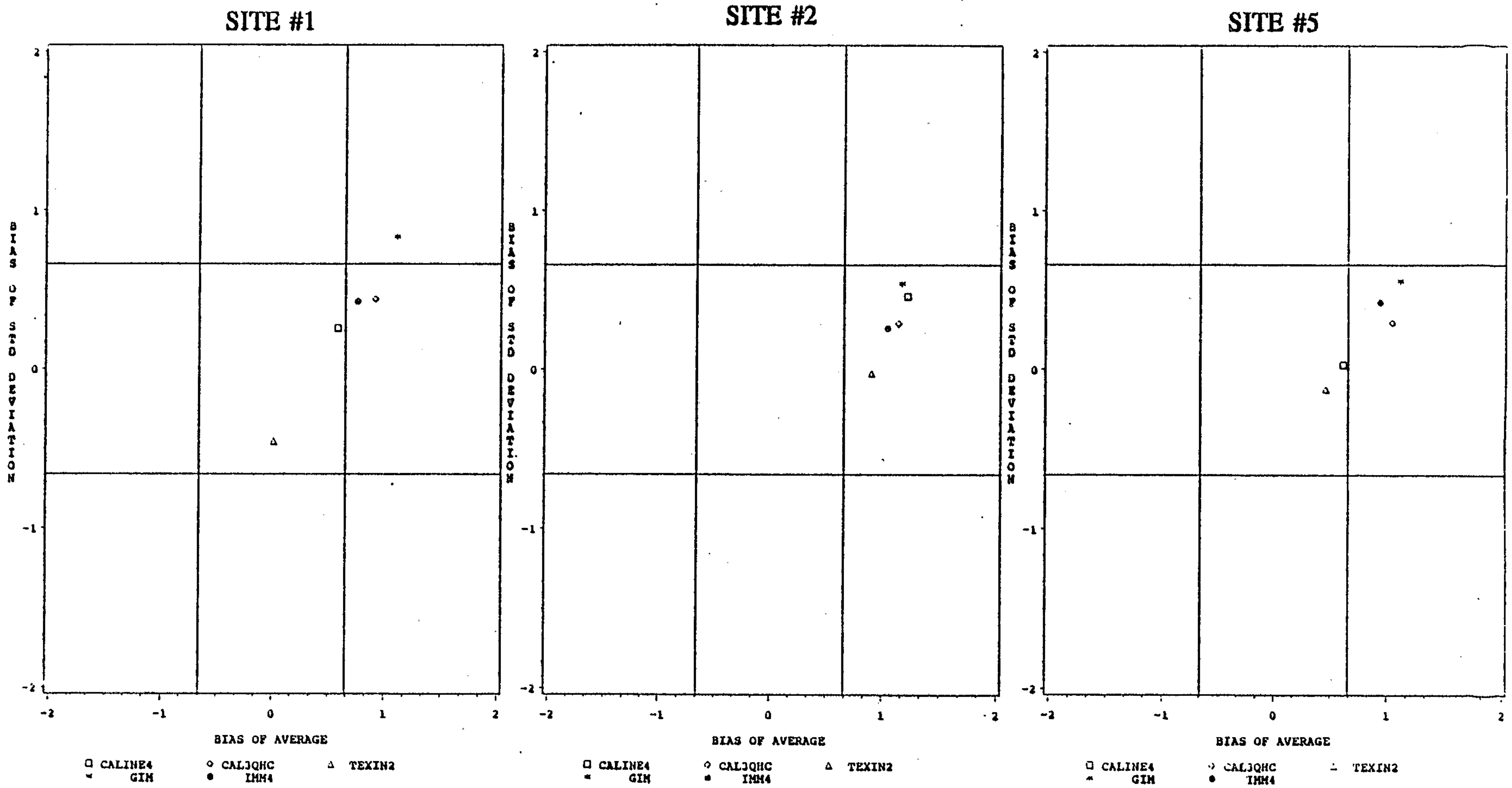


Figure 49. The bias of the average versus the bias of the standard deviation for all concentrations greater than 0.5 ppm for the phase II MOBILE4.1 analysis at Sites #1, 2, and 5.

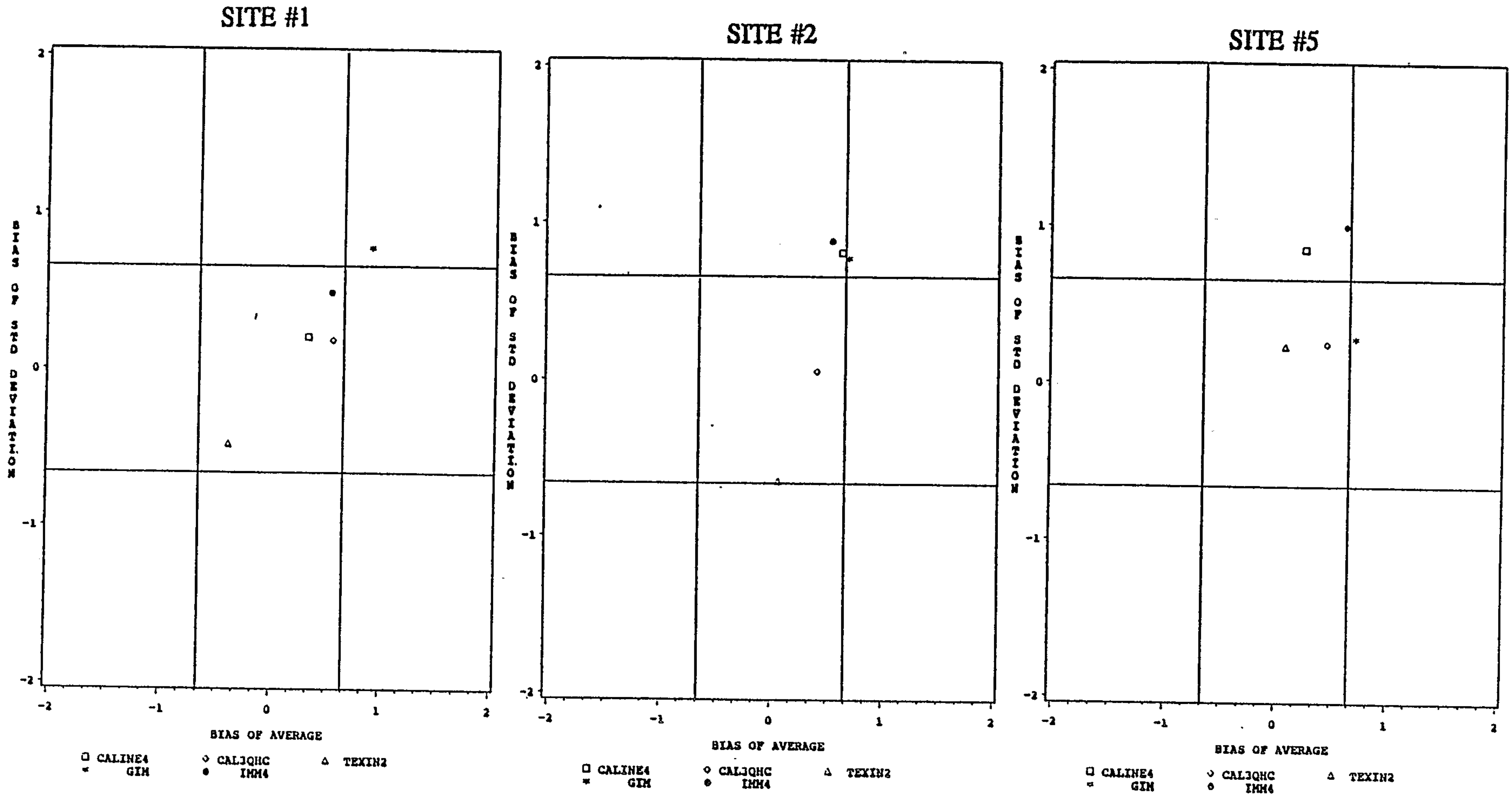


Figure 50. The bias of the average versus the bias of the standard deviation for the 25-high concentrations for the phase II MOBILE4.1 analysis at Sites #1, 2, and 5.

stability class, and the traffic volume. These plots are presented in Appendix B. The residuals are grouped and plotted by means of box plots. Grouping is necessary because of the large number of data points. The cumulative distribution function (cdf) of the residuals within each group is represented by the 2nd, 16th, 50th, 84th, and 98th percentiles. The five significant points in the cdf are represented using a box pattern. The number of observations used in each box pattern are labelled near the bottom of each plot as "N = #." The solid horizontal line represents the perfect fit and the dashed lines represent a factor-of-two. The residuals of a good model should not exhibit any trend with model variables and should not exhibit large deviations from unity (i.e. the residual boxes should be compact).

We would expect there to be little variation among models in patterns displayed when the residuals are plotted against meteorological variables, because the dispersion modules are very similar. The overall mean of the residuals for each model vary, but the underlying pattern is indeed similar. The same is true for the variation by time-of-day, and even traffic volume. Hence, it appears that differences among these models primarily arise in how the emissions are determined and allocated to the various links used to describe each intersection.

In spite of there being no inter-model variations evident in these plots, it is useful to examine the results for one model to see if any deficiencies might exist in the dispersion modules. We have examined the results for TEXIN2 with this in mind. No trends toward increasing or decreasing residuals are seen in the plots for Site #1 (Figure B-1). At Site #2, however, it appears that predicted concentrations tend to increase, relative to the observed concentrations, as the atmosphere becomes more stably stratified (Figure B-6). Similarly, the same trend can be seen by comparing the daytime residuals with those in the evening. No such inference can be made at Site #5, possibly as a result of their being too few stably-stratified periods to plot.

Another feature resolved by this type of plot is the present of "outliers", so long as they occur more than 2% of the time. At Site #1, several such outliers appear in the form of very low predicted concentrations, relative to the median value predicted in a category. The low value seems to be associated with either the hour of day, the wind direction, or the ambient temperature. Because the wind direction sector between 225° and 270° at Site #1 corresponds to large buildings nearby, the flow could be disturbed, and considerably more complex, which could lead to poorer model performance. Such an explanation is tentative, however, and more detailed analyses would be needed to confirm such a hypothesis.

6.2.3 Regulatory Worst-Case Analysis

The ten hours with the highest observed concentrations were used to compare the predicted concentrations using the regulatory default meteorology with the predicted concentrations using the observed meteorology. The comparisons for each site are presented in Table 27. The regulatory default or worst-case meteorological conditions are defined as:

TABLE 27

COMPARISON OF TOP-TEN OBSERVED CONCENTRATIONS WITH PREDICTED CONCENTRATIONS USING REGULATORY DEFAULT AND OBSERVED METEOROLOGY USING MOBILE4.1

SITE #1 - West & Chambers

Mo	Dy	Yr	Hr Beg	TAVG F	WDM1 deg	WDM2 deg	WSM1 mph	WSM2 mph	SC1	SC2	Obs ppm	Regulatory Default C3Q ppm	GIM ppm	TEX ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	GIM ppm	TEX ppm	IMM ppm	CAL ppm
3	29	89	18	68.2	299	339	1.9	1.5	3	3	10.6	7.5	4.7	10.5	7.1	9.8	5.1	4.1	9.1	4.7	7.2
3	29	89	17	70.5	301	338	2.6	2.2	3	3	9.1	9.8	5.6	18.0	8.6	13.0	6.3	3.1	11.7	4.7	7.9
3	15	89	17	66.6	162	181	4.1	4.8	4	4	9.0	9.8	5.4	17.6	8.3	12.7	2.3	1.7	6.6	2.2	4.2
4	3	89	19	57.8	130	134	2.9	3.7	6	6	8.6	7.0	3.1	8.8	5.9	6.7	8.1	3.5	6.8	4.3	4.1
5	24	89	17	61.2	322	334	5.4	5.3	4	4	8.2	10.4	5.8	11.7	8.4	13.1	4.6	2.3	5.4	3.1	6.3
4	14	89	6	38.6	306	315	4.2	4.1	4	4	7.8	8.2	5.4	23.1	8.6	8.3	2.9	2.6	13.6	3.9	3.8
4	4	89	14	69.0	131	142	4.2	5.5	2	2	7.6	10.0	5.9	17.7	10.0	10.9	1.7	1.4	5.0	3.4	3.6
3	29	89	16	70.7	315	338	4.7	3.8	3	2	7.5	9.8	5.9	18.1	10.0	13.5	4.1	2.0	7.7	3.1	5.9
5	9	89	6	50.8	313	324	2.9	2.5	3	3	7.5	8.0	5.1	22.4	7.2	8.9	3.8	2.8	14.5	4.0	6.2
3	29	89	15	69.6	323	342	5.6	4.7	3	3	7.4	9.9	5.9	18.1	9.4	13.6	3.6	1.7	6.8	3.0	5.9

SITE #2 - 34th /8th

Mo	Dy	Yr	Hr Beg	TAVG F	WDM1 deg	WDM2 deg	WDM3 deg	WSM1 mph	WSM2 mph	WSM2 mph	SC1	SC2	SC3	Obs ppm	Regulatory Default C3Q ppm	GIM ppm	TEX ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	GIM ppm	TEX ppm	IMM ppm	CAL ppm
8	13	89	16	77.5	221	232	208	4.8	4.2	3.4	2	2	1	11.5	5.4	4.3	6.3	4.1	4.8	1.9	1.3	2.4	2.4	2.1
10	26	89	11	68.7	72	137	303	4.0	4.3	3.2	2	2	2	10.5	8.0	7.1	9.4	7.1	6.4	2.4	2.5	3.4	3.2	2.1
10	25	89	16	71.5	175	236	282	3.4	2.9	2.9	3	3	3	10.4	7.0	6.1	10.1	6.5	6.2	4.3	4.0	6.3	4.4	3.3
9	12	89	14	78.5	194	267	299	4.2	4.2	4.2	2	2	2	10.2	6.9	6.3	7.5	6.4	6.0	2.3	2.2	2.7	2.8	1.9
8	14	89	8	76.1	199	235	213	5.0	3.6	2.5	4	3	1	10.2	3.9	2.5	8.4	3.0	4.1	2.0	1.2	4.7	1.9	1.6
8	15	89	8	75.1	204	237	220	4.9	3.4	2.2	4	3	1	9.1	4.7	3.7	7.9	4.2	6.5	2.5	2.1	4.6	2.6	3.5
8	14	89	9	78.4	206	228	210	5.1	3.4	2.4	4	3	1	8.8	4.9	3.9	7.8	4.1	7.3	2.7	2.0	4.2	2.4	3.7
10	25	89	15	72.8	171	259	292	3.3	2.8	2.7	2	2	2	8.5	7.3	6.4	10.8	7.0	6.7	3.5	3.2	5.7	4.1	3.4
9	1	89	15	79.8	236	212	148	6.0	6.1	6.6	2	2	2	8.4	6.7	6.6	8.5	6.2	6.4	1.7	1.5	2.0	1.8	1.7
10	26	89	19	70.4	219	212	302	3.4	1.5	2.0	6	6	6	8.3	6.1	3.9	13.4	6.3	5.8	6.2	3.5	12.8	3.5	4.4

SITE #5 - 34th/12th

Mo	Dy	Yr	Hr BEG	TAVG F	WDM1 deg	WDM2 deg	WSM1 mph	WSM2 mph	SC1	SC2	Obs ppm	Regulatory Default C3Q ppm	GIM ppm	TEX ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	GIM ppm	TEX ppm	IMM ppm	CAL ppm
11	2	89	19	52.8	336	339	2.4	2.3	6	6	15.5	9.2	5.3	11.5	7.2	11.3	7.3	4.4	9.4	6.1	7.8
10	11	89	20	56.1	301	300	4.6	5.0	6	6	14.6	8.4	4.2	8.6	4.2	8.6	1.4	1.1	3.6	1.2	2.7
11	9	89	15	57.7	257	253	4.5	5.0	4	4	10.4	11.5	8.7	12.9	8.5	12.0	4.3	2.4	6.7	3.1	5.6
10	25	89	16	68.8	259	250	3.3	3.6	3	3	9.9	10.3	8.5	12.3	8.2	10.1	4.5	3.2	7.2	4.0	4.9
10	25	89	15	71.9	345	341	3.5	2.8	2	2	9.3	11.4	8.6	12.1	8.5	11.9	4.4	3.3	6.5	4.5	6.8
10	26	89	13	72.7	352	335	4.2	3.2	3	2	8.9	10.5	6.9	11.7	5.1	11.5	4.2	2.2	6.4	2.8	6.0
10	27	89	15	71.0	350	353	5.1	4.1	3	3	8.7	10.7	8.5	12.7	9.8	11.7	3.7	2.7	5.5	3.5	5.1
10	27	89	14	72.5	350	349	4.3	3.8	3	2	8.4	11.6	7.7	13.2	6.4	12.2	4.2	2.7	6.9	3.3	6.3
11	22	89	16	34.3	309	304	5.1	5.3	4	4	7.6	15.1	11.7	17.4	11.8	14.2	4.0	2.9	5.8	3.1	4.0
10	26	89	15	71.7	1	1	5.7	4.2	3	3	7.4	10.8	8.8	12.3	8.1	11.4	3.4	2.6	5.4	3.3	5.2

Note: TAVG = average temperature over all monitors; WDM<1 2 3> = wind direction at monitor 1, 2 or 3; WSM<1 2 3> = wind speed at monitor 1, 2, or 3; SC<1 2 3> = stability class at monitor 1, 2, or 3; Obs = Observed; C3Q = CAL3QHC; TEX = TEXIN2; CAL = CALINE4

Wind Speed = 1 m/s
Stability Class = D
Sigma-Theta = 25°
Observed Temperature
"Worst Case" Wind Direction Angle (determined using ten degree increments)

Meteorological data measured at either two or three locations at each site are also listed in the table. The peak concentrations obtained through the use of the measured meteorological data make use of the meteorological data nearest the receptor at which the peak concentration is predicted.

As expected, the predicted concentrations found using the regulatory default meteorology are nearly always greater than those obtained with the measured meteorology. At Site #1, where the highest observed CO concentration unpaired in time or space is 10.6 ppm, TEXIN2 overpredicts by more than a factor of two with a predicted concentration of 23.1 ppm. CALINE4 also overpredicts with a concentration of 13.6 ppm. CAL3QHC, with a maximum predicted concentration of 10.4 ppm, nearly matches the maximum observed concentration, unpaired in time or space. Using the observed meteorology, TEXIN2 also overpredicts the maximum observed concentration with a predicted concentration of 14.5 ppm. The model with the next highest concentration (8.1 ppm) is CAL3QHC.

At Site #2, the highest observed CO concentration is 11.5 ppm. Using the default meteorology, only TEXIN2 produces a concentration in excess of 11.5 ppm, with a maximum predicted concentration of 13.4 ppm. The model with the next highest concentration (8.0 ppm) is CAL3QHC. Using the observed meteorology, TEXIN2 also overpredicts the maximum observed concentration with a predicted value of 12.8 ppm. CAL3QHC, the model with the next highest concentration, underpredicts with a concentration of 6.2 ppm.

The highest observed CO concentration at Site #5 is 15.5 ppm. As found at Site #2, only TEXIN2 produces a maximum value (17.4 ppm) in excess of the observed peak, when the default meteorology is used. All the other models tested underpredict the maximum concentration, with CAL3QHC most closely matching the maximum observed concentration with a predicted value of 15.1 ppm. Using the observed meteorology, all five models underpredict.

These results may underestimate the ability of CALINE4 and CAL3QHC to produce peak concentrations in excess of the peak observed concentration, when the default meteorological conditions are employed. Only those hours associated with the ten highest observed concentrations have been considered here. These hours may not coincide with those hours in which the peak predicted concentrations are found (using the measured meteorology). Larger predicted concentrations can be anticipated if the entire data set is modeled with the default meteorological assumptions.

6.2.4 Scoring Scheme Results

The method for aggregating component results of model performance into a single performance measure proposed by Cox and Tikvart (1990) (discussed in Section 5.2.2) was used to compare the overall performance of the five models evaluated at three intersection sites. The bootstrap resampling technique (Efron, 1982) was used to determine the significance of differences in composite performance between models.

Estimates of the robust highest concentration (RHC) for one-hour averages are shown in Table 28 along with the corresponding fractional bias for each model evaluated at the three intersections. In general, the RHCs are largest using the operational (or entire) dataset for each site. The FB in RHC is displayed in Figure 51 with confidence limits for each model and site. The solid horizontal line represents a perfect fit and the dashed horizontal lines represent a factor of two. The upper and lower values correspond to the estimated 95% confidence limits on the fractional bias. The confidence interval is estimated from the standard deviation of the bootstrap outcomes, and the student-t parameter. An ideal model will produce an FB equal to zero. As shown in Figure 51, this "real" evaluation produces non-zero values. By estimating confidence intervals for these results, the significance of these non-zero values may be quantified. If the 95% confidence interval about the FB measure should overlap zero, then one may conclude that there is not sufficient evidence to suggest any model bias. In Figure 51, CALINE4 performs best at Site #1 and TEXIN2 performs best at Sites #2 and 5. Note that only the confidence interval associated with TEXIN2 overlaps zero.

Among the three diagnostic components in Table 28, estimates of RHC are lowest for the higher wind speed category (> 6 mph). Each diagnostic FB category is displayed with confidence limits in Figures 52 through 54, for each site. Of the three diagnostic categories, the highest RHC values and best model performance are found for lower wind speeds (≤ 6 mph) and neutral/stable conditions (diagnostic component 1). This category is the most important for regulatory applications. The best value of FB in diagnostic component 1 is found for CALINE4 at Site #1, CAL3QHC at Site #2, and TEXIN2 at Site #5.

The fractional bias in the RHC for each of the three diagnostic components can be combined into a single measure that is called the diagnostic fractional bias. The mechanics for doing this are similar to those discussed in Section 5.2, Equation 10. In essence, the diagnostic FB is a weighted average of the three diagnostic components in which component #1 (low wind speed; neutral/stable) receives a weight equal to the combined weight of the other two components. Confidence intervals are found by means of the bootstrap technique, and the results are presented in Figure 55. Here, CALINE4 performs best at Site #1 and TEXIN2 performs best at Sites #2 and #5. Only the confidence intervals associated with TEXIN2 overlap zero. A measure that includes both the diagnostic and the operational fractional bias is constructed by averaging these two components. Again, the resulting measure is computed for many bootstrap outcomes in order to estimate the confidence limits. Figure 56 presents the results, which are similar to those presented earlier. The qualitative features seen in Figures 51 (operational FB), 55 (diagnostic FB), and 56 (combined FB) are nearly identical.

TABLE 28

ROBUST HIGHEST CONCENTRATIONS AND FRACTIONAL BIAS BY OPERATIONAL/DIAGNOSTIC COMPONENT

SITE #1

Component	Observed	Robust Highest Concentration 1h Averages (PPM) CAL3QHC	IMM	TEXIN2	GIM	CALINE4	Fractional Bias CAL3QHC	IMM	TEXIN2	GIM	CALINE4
Operational	10.0	7.2	6.4	17.4	4.7	8.2	0.33	0.44	-0.54	0.72	0.20
Diagnostic 1 (u ≤ 6 mph, nuetral/stable)	9.4	6.8	6.7	17.5	4.4	7.1	0.32	0.33	-0.61	0.73	0.28
Diagnostic 2 (u ≤ 6 mph, unstable)	10.0	5.9	5.1	14.4	3.8	8.4	0.52	0.65	-0.37	0.90	0.17
Diagnostic 3 (u > 6mph)	7.4	4.7	4.2	10.2	2.5	7.3	0.46	0.55	-0.32	0.98	0.02

SITE #2

Component	Observed	Robust Highest Concentration 1h Averages (PPM) CAL3QHC	IMM	TEXIN2	GIM	CALINE4	Fractional Bias CAL3QHC	IMM	TEXIN2	GIM	CALINE4
Operational	12.1	9.3	6.1	14.1	5.8	6.0	0.26	0.65	-0.16	0.70	0.68
Diagnostic 1 (u ≤ 6 mph, nuetral/stable)	10.3	9.3	5.7	14.3	5.4	5.7	0.10	0.57	-0.32	0.63	0.58
Diagnostic 2 (u ≤ 6 mph, unstable)	11.2	4.9	6.4	7.2	4.8	5.6	0.78	0.55	0.44	0.79	0.67
Diagnostic 3 (u > 6 mph)	8.4	4.9	5.3	6.0	4.2	3.6	0.53	0.45	0.34	0.68	0.81

SITE #5

Component	Observed	Robust Highest Concentration 1h Averages (PPM) CAL3QHC	IMM	TEXIN2	GIM	CALINE4	Fractional Bias CAL3QHC	IMM	TEXIN2	GIM	CALINE4
Operational	14.8	9.1	6.6	12.9	6.4	9.5	0.47	0.76	0.14	0.79	0.43
Diagnostic 1 (u ≤ 6 mph, nuetral/stable)	13.8	9.5	5.9	12.3	6.7	8.3	0.37	0.80	0.11	0.70	0.50
Diagnostic 2 (u ≤ 6 mph, unstable)	11.1	6.0	6.3	9.6	4.0	9.3	0.60	0.56	0.15	0.95	0.18
Diagnostic 3 (u > 6 mph)	7.4	3.1	2.7	4.9	2.5	4.5	0.81	0.92	0.40	0.99	0.48

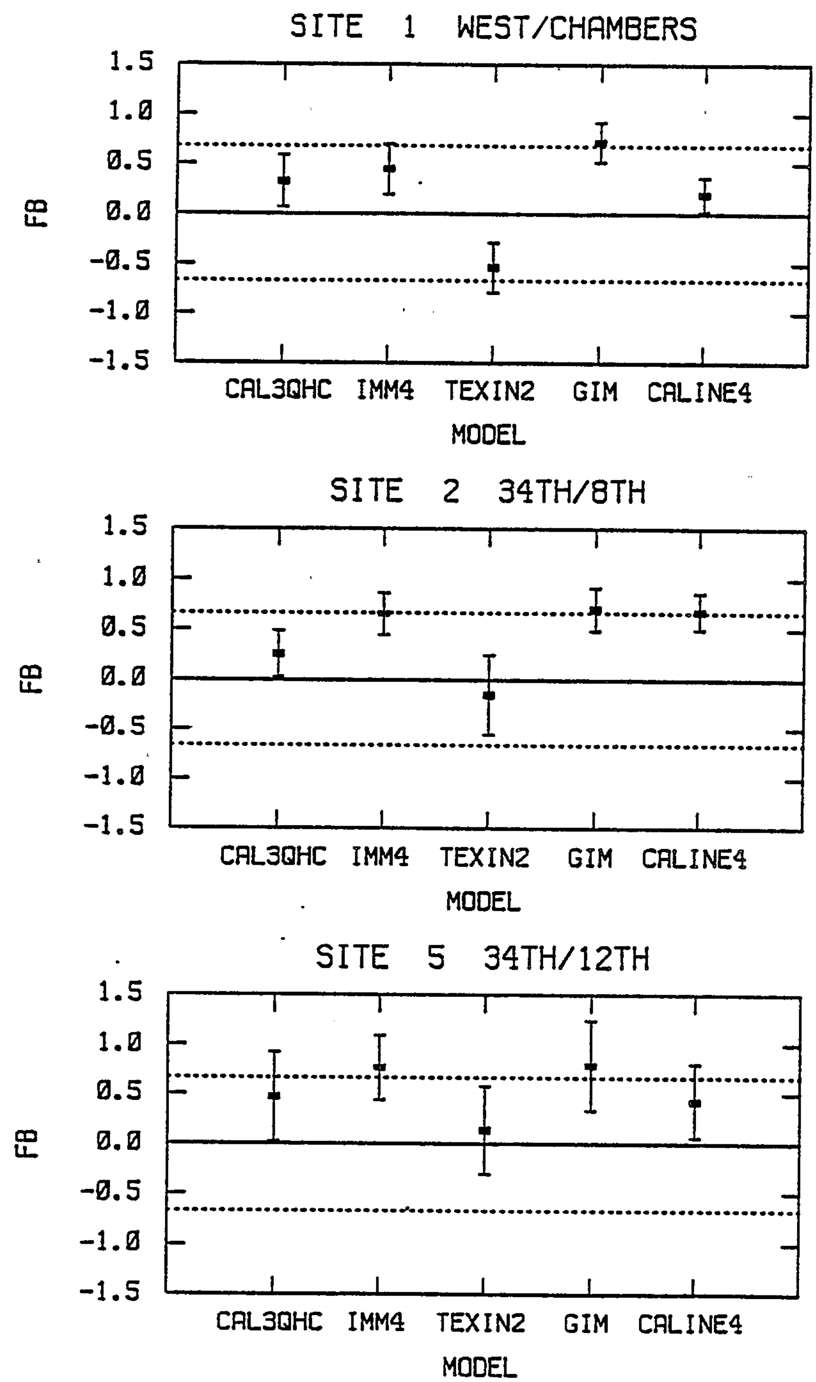


Figure 51. The operational fractional bias (FB) with 95% confidence limits for each model as a function of site.

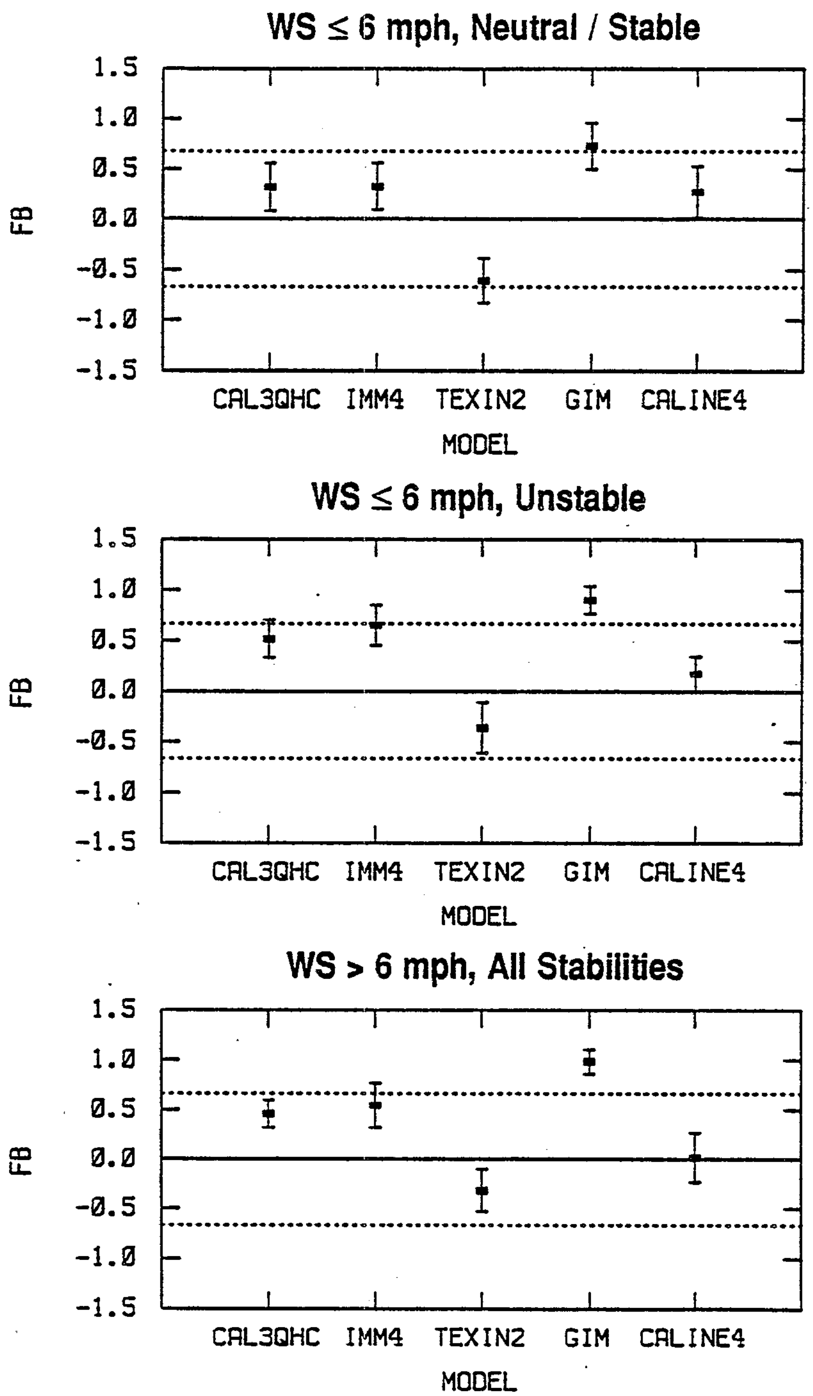


Figure 52. The three diagnostic FB components with 95% confidence limits for each model at Site #1.

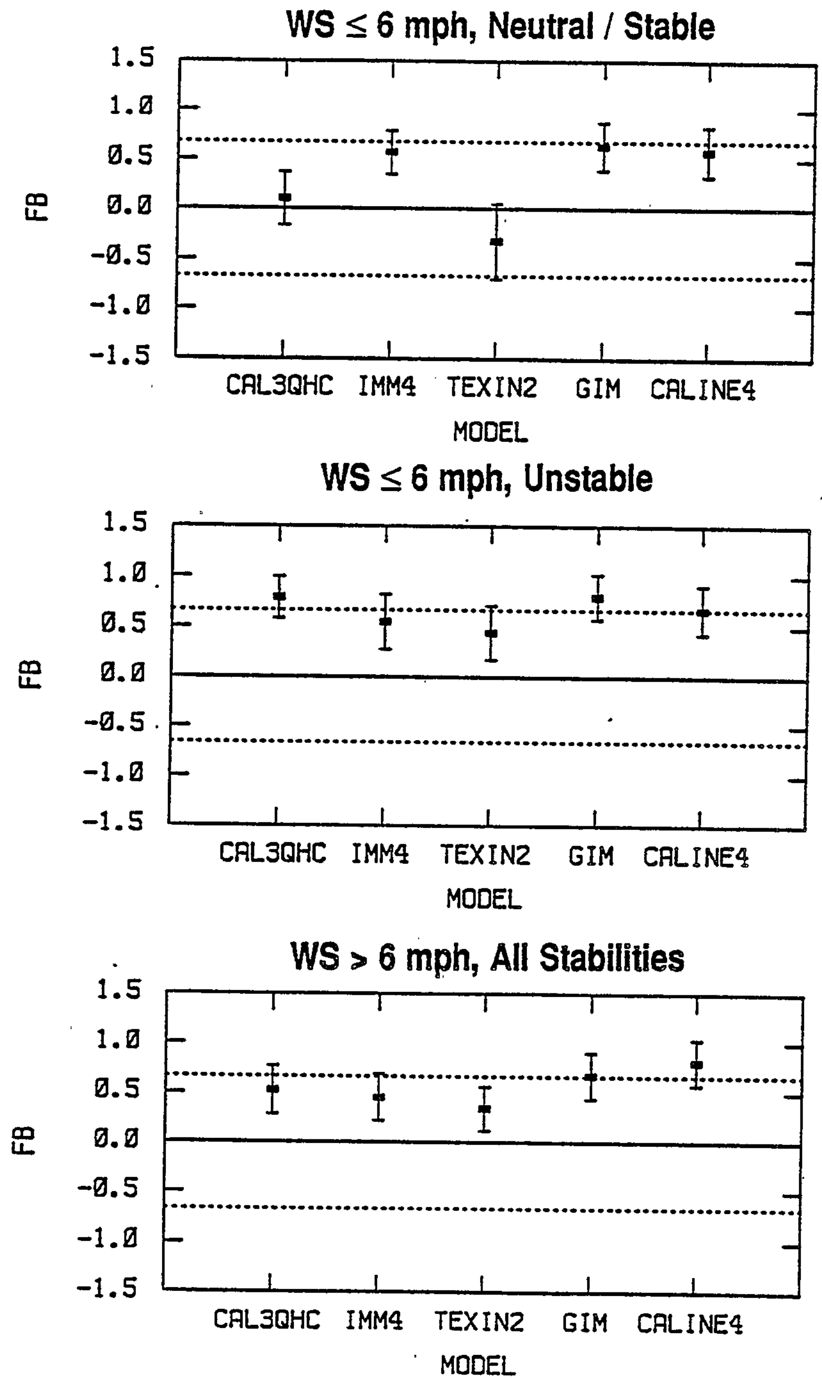


Figure 53. The three diagnostic FB components with 95% confidence limits for each model at Site #2.

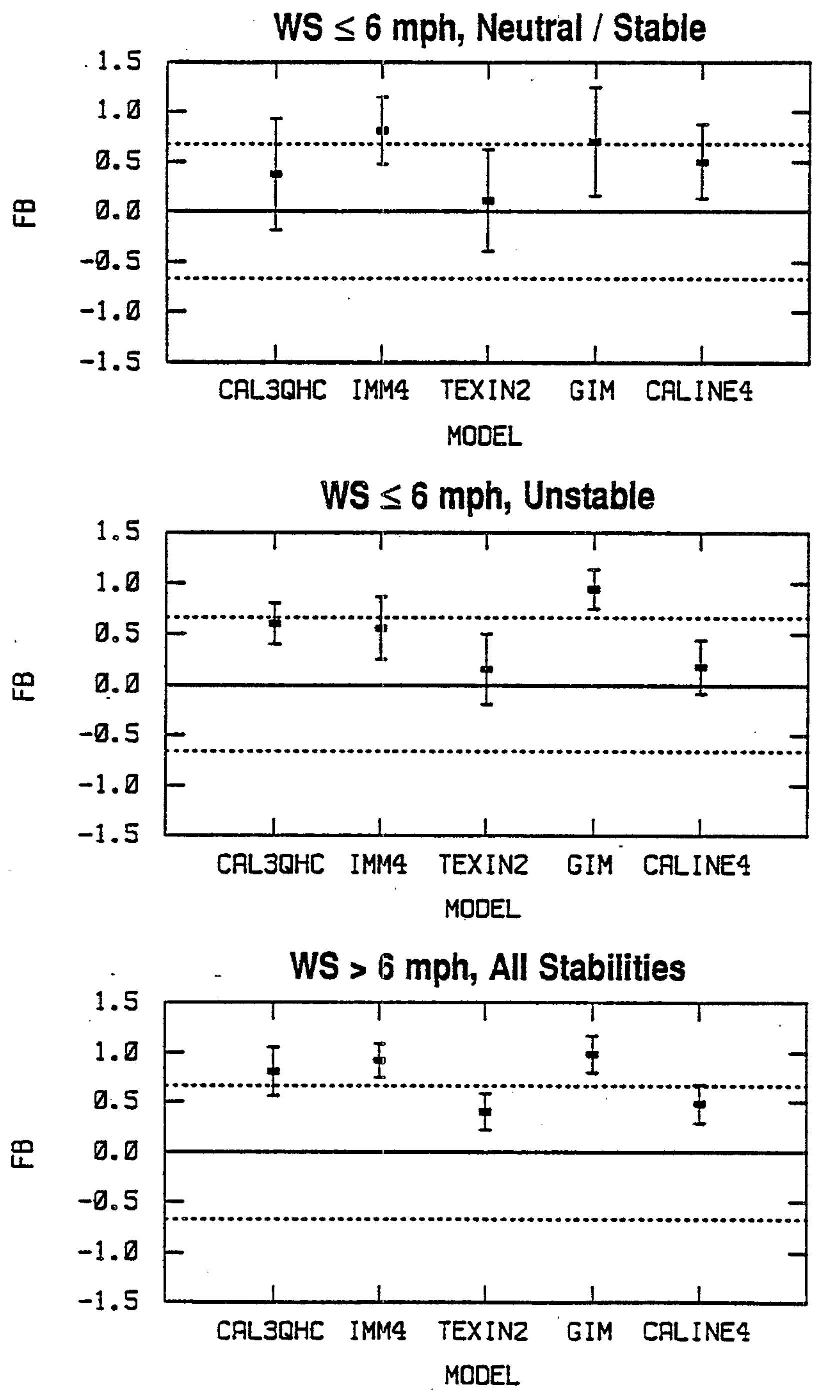


Figure 54. The three diagnostic FB components with 95% confidence limits for each model at Site #5.

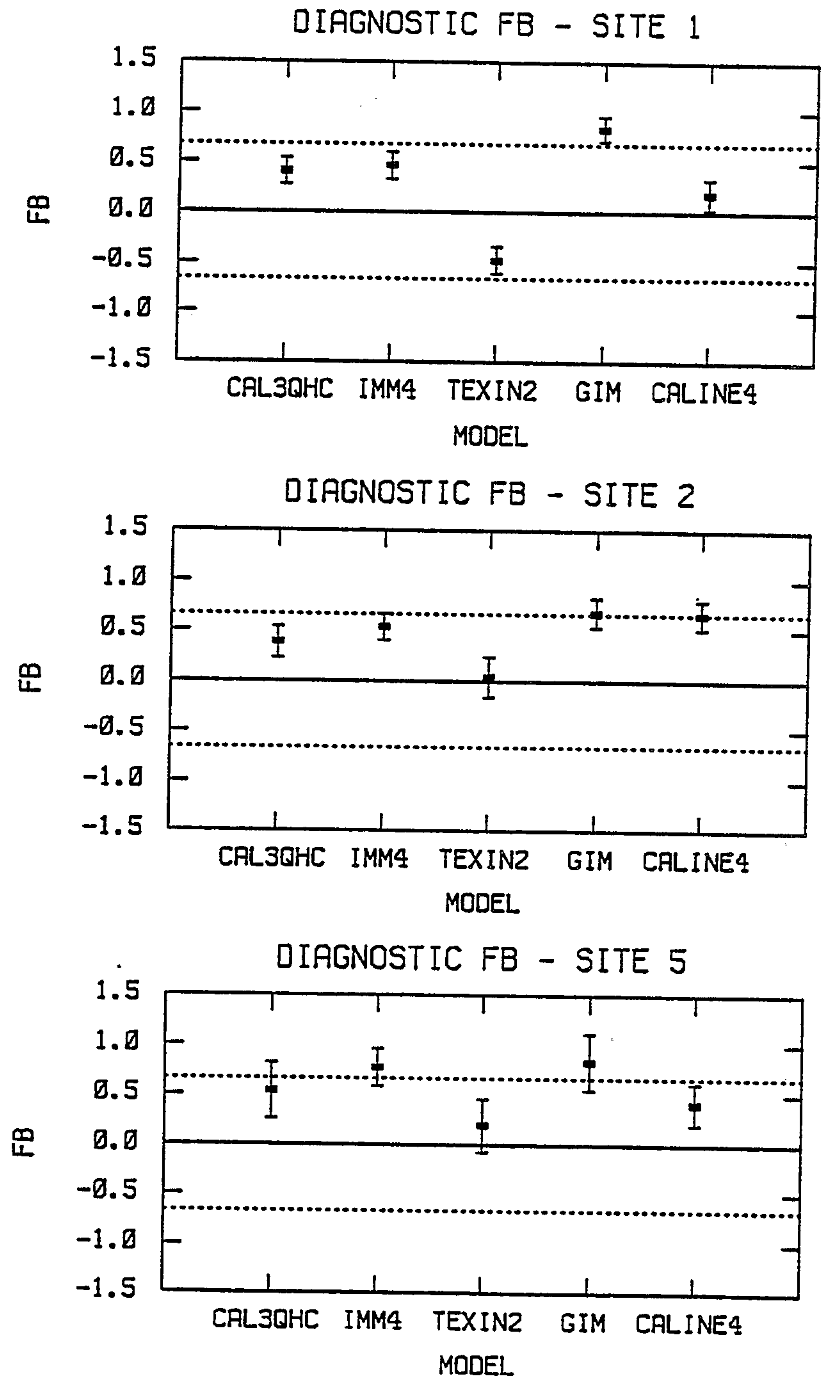


Figure 55. The combined diagnostic FB with 95% confidence limits for each model as a function of site.

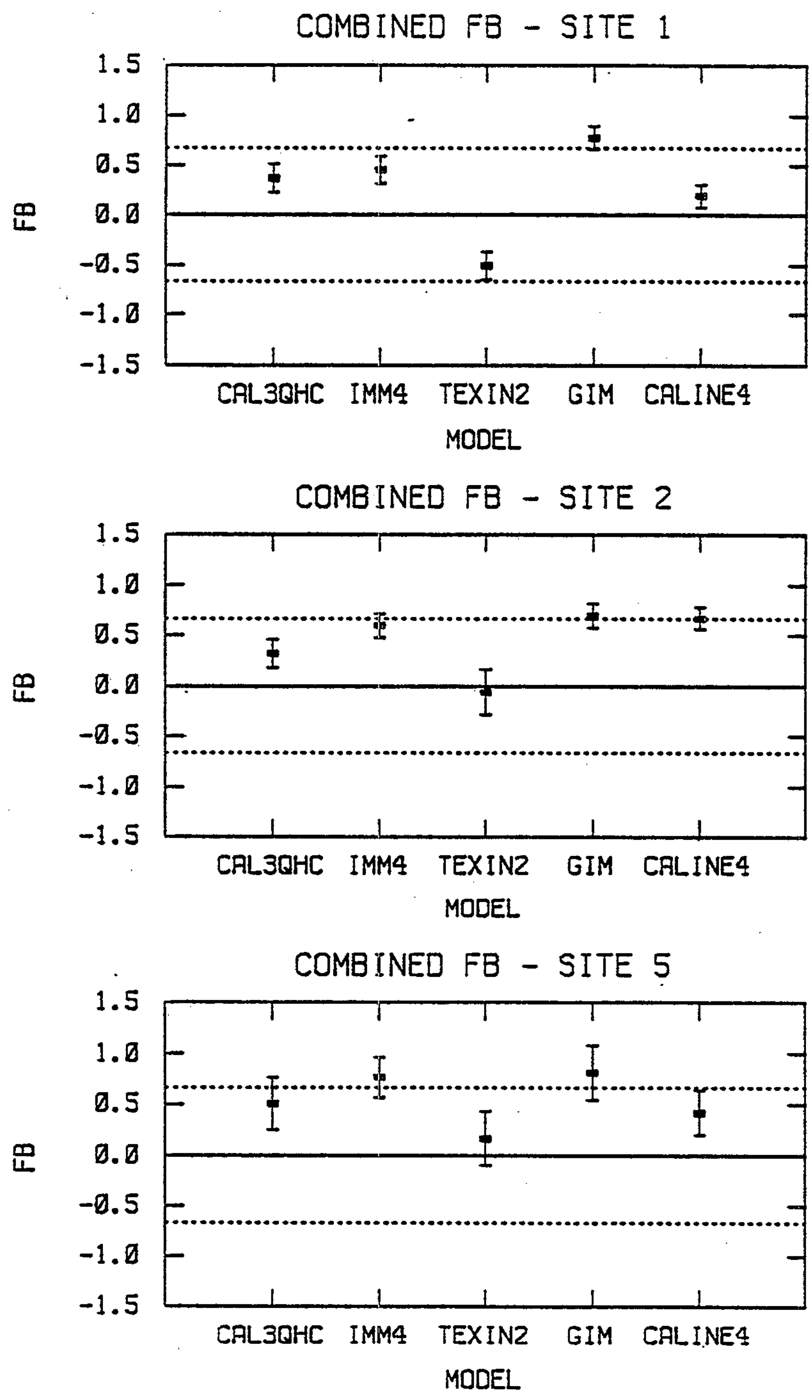


Figure 56. The combined operational and diagnostic FB with 95% confidence limits for each model as a function of site.

Because the fractional bias is a signed measure, small values may be obtained when several values with opposite signs are combined. In characterizing the overall performance of these models, we also wish to use a measure that avoids such "cancellation" effects. This is accomplished by using the absolute fractional bias, AFB. In particular, a composite performance measure (CPM) for the models is formed as a weighted linear combination of the individual absolute fractional bias components (see Equations 9 and 10 in Section 5.2.2). The CPM values with 95% confidence limits are presented in Figure 57. The smaller the CPM value, the better the overall performance of the model. Results for CAL3QHC, IMM, GIM, and CALINE4 are the same as those found for the combined FB in Figure 56. This is due to the fact that none of the models produce an FB that is negative, so there is no difference between AFB and FB. TEXIN2 does produce FBs of both sign, so the characteristics of its AFB are different from those of its FB. At Site #2 for example, FB for TEXIN2 is not significantly different from zero, whereas the corresponding CPM is significantly different from zero.

A further combination is made in order to construct a performance measure across all three sites. This is the composite model comparison measure (CM), which is made up of the CPM values calculated at each site (see Equation 18 in Section 5.2.2). The results, shown in Figure 58, indicate that the best performing models are TEXIN2, CALINE4, and CAL3QHC, with TEXIN2 having the lowest overall CM value using the CPM statistics. Similarly, the AFB from diagnostic category 1 ($u \leq 6$ mph, neutral/stable) can also be combined over all three sites into a single CM. As shown in Figure 59, CAL3QHC has the lowest CM by a factor of two from the next best model (TEXIN2). As mentioned earlier, this category is typically most important in terms of regulatory applications.

So far, all of the performance measures presented in this section quantify the performance of each model in reproducing the RHC that is observed. When comparing these performance measures, one would like to know if differences are significant. Therefore, as discussed in Section 5.2.2, two separate difference measures have been formed and the 95% confidence intervals about them have been estimated. The first difference measure evaluated is DFB or the difference in FB between two models denoted as A and B (ΔFB(A,B)). Figures 60 through 62 present the ΔFB or DFB statistics with 95% confidence limits for each pair of models for each site. As discussed in subsection 5.2, the method of Cleveland and McGill (1984) was used to calculate simultaneous confidence intervals for each pair of models in order to ensure an adequate confidence level and to protect against falsely concluding that two models are different. Using the ΔFB statistics, it may be concluded that at Site #1, TEXIN2 is significantly different from the other models. However, at Site #2, TEXIN2 is not significantly different from CAL3QHC, and it is not significantly different from either CAL3QHC or CALINE4 at Site #5.

Differences in combined measures were also calculated. As discussed in Section 5.2.2, the CPM or composite performance measure was used to calculate pairs of differences between the models because the purpose of the analysis is to contrast the overall performance among the models. The difference in CPM values between one model and another model is the model comparison measure (MCM). The MCM is used to judge the statistical significance of the apparent superiority of any one model over another. The MCM statistics with

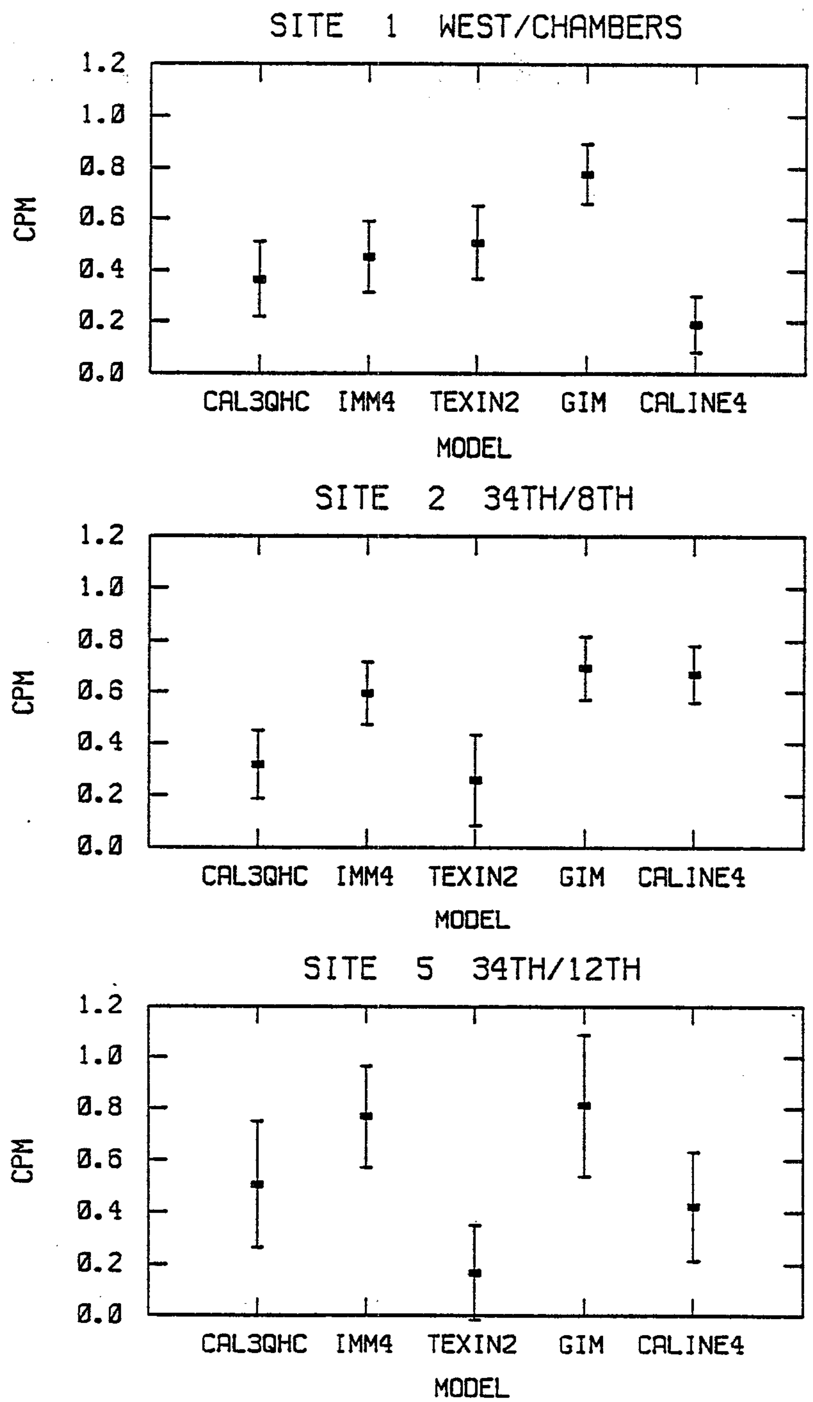


Figure 57. The composite performance measure (CPM) with 95% confidence limits for each model as a function of site.

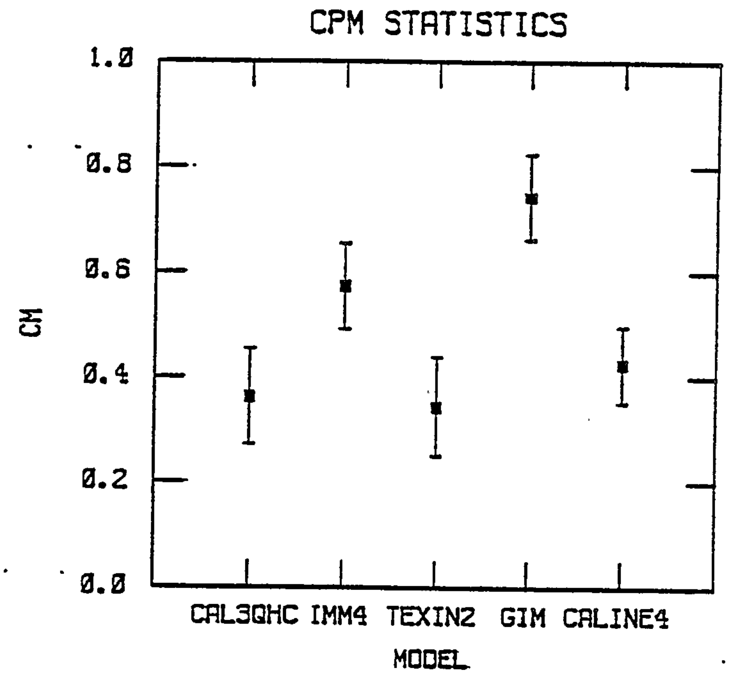


Figure 58. The composite model comparison measure (CM) with 95% confidence limits using CPM statistics.

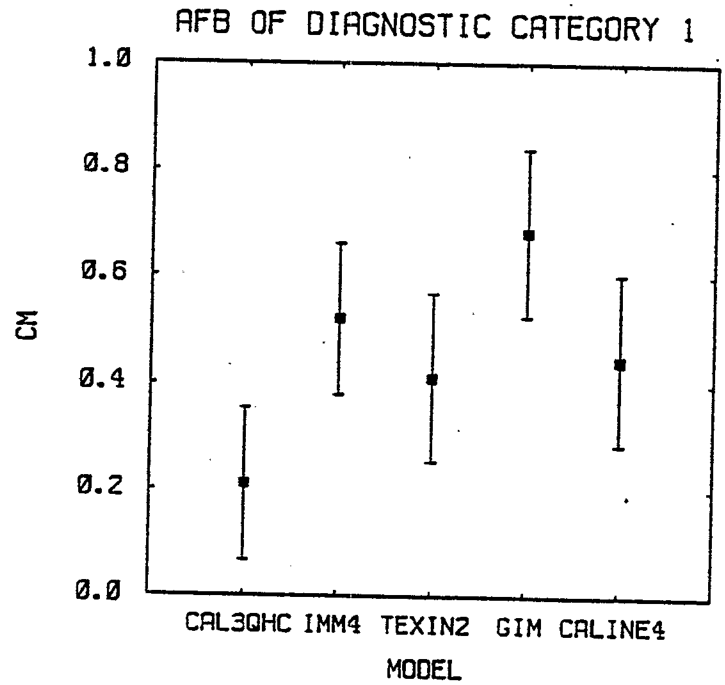


Figure 59. The composite model comparison measure (CM) with 95% confidence limits using the AFB of diagnostic category 1 ($U \leq 6$mph, neutral/stable) statistics.

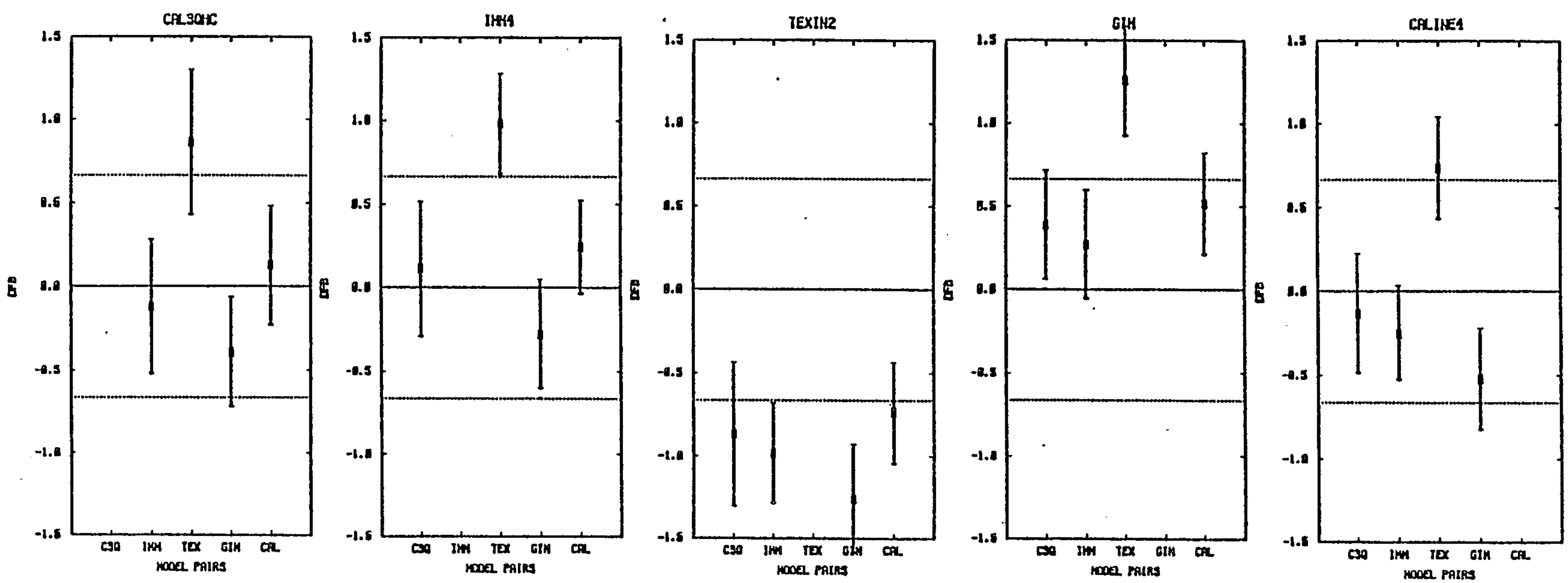


Figure 60. The ΔFB (DFB) with 95% confidence limits for each model pair at Site #1.

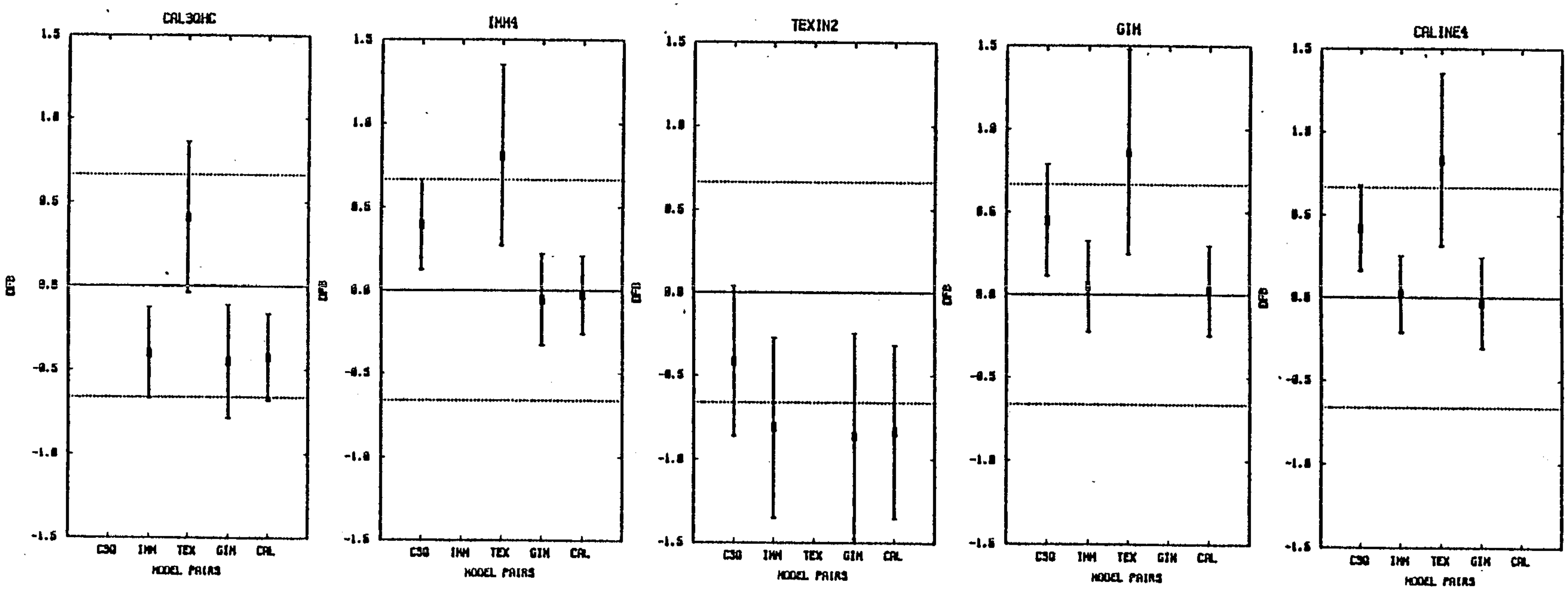


Figure 61. The ΔFB (DFB) with 95% confidence limits for each model pair at Site #2.

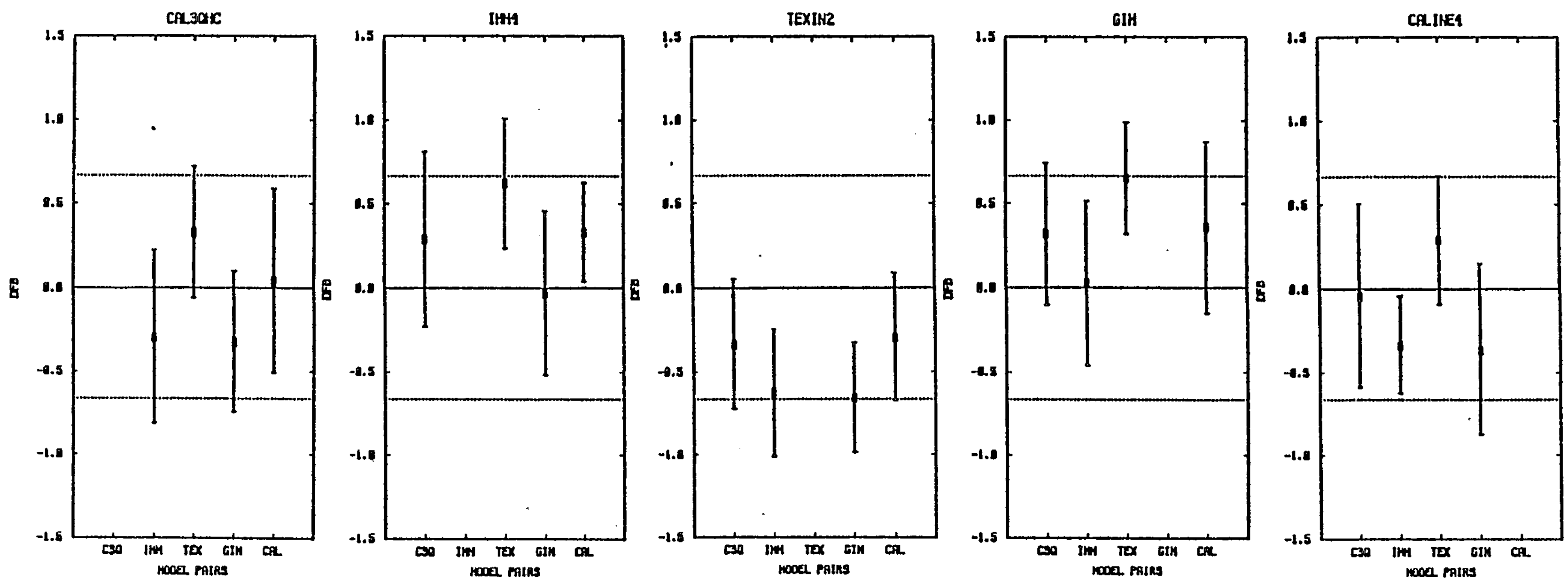


Figure 62. The ΔFB (DFB) with 95% confidence limits for each model pair at Site #5.

simultaneous 95% confidence limits for each model pair are presented in Figures 63 through 65 for each site. Since TEXIN2 had the best composite model performance measure when using the CPM statistics, it is important to test if this model is significantly different from all other models evaluated. As shown in Figure 63, at Site #1, TEXIN2 is not significantly different from CAL3QHC, IMM, and GIM. At Site #2 (see Figure 64), TEXIN2 is not significantly different from CAL3QHC and IMM. At Site #5 (see Figure 65), TEXIN2 is not significantly different from CALINE4. Furthermore, when the MCM statistics from each site are combined into one composite model comparison measure (CM), TEXIN2 is not significantly difference from either CAL3QHC or CALINE4 (see Figure 66). A summary of the CM statistics including the standard error (S) and the ratio of CM to S is presented in Table 29 for each pair of models. Also included in Table 29 is the composite value of c for CPM over each site that ensures an adequate confidence level and protects against falsely concluding that two models are different. If the ratio of CM/S is greater than ±c, then it may be concluded with 95% confidence that the two models are significantly different. As shown in Table 29, the following model pairs are not significantly different with 95% confidence: CAL3QHC/TEXIN2 and TEXIN2/CALINE4.

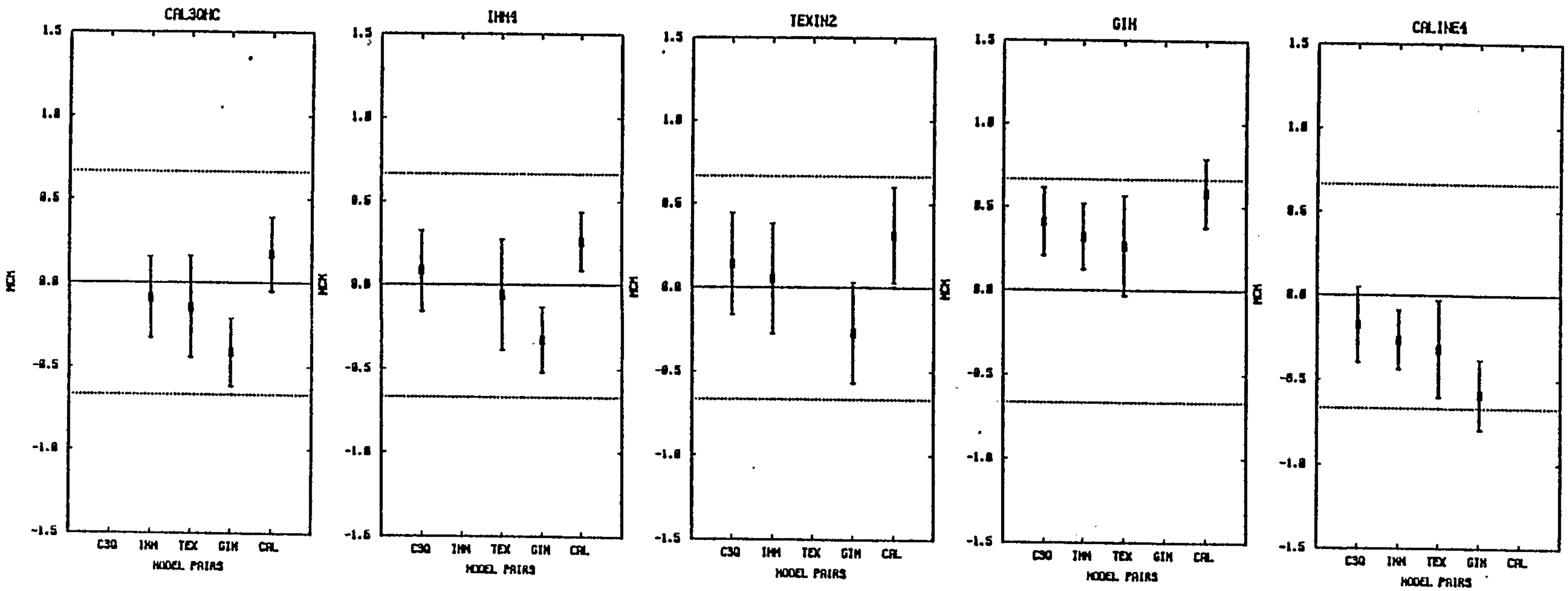


Figure 63. The model comparison measure (MCM) with 95% confidence limits for each model pair at Site #1.

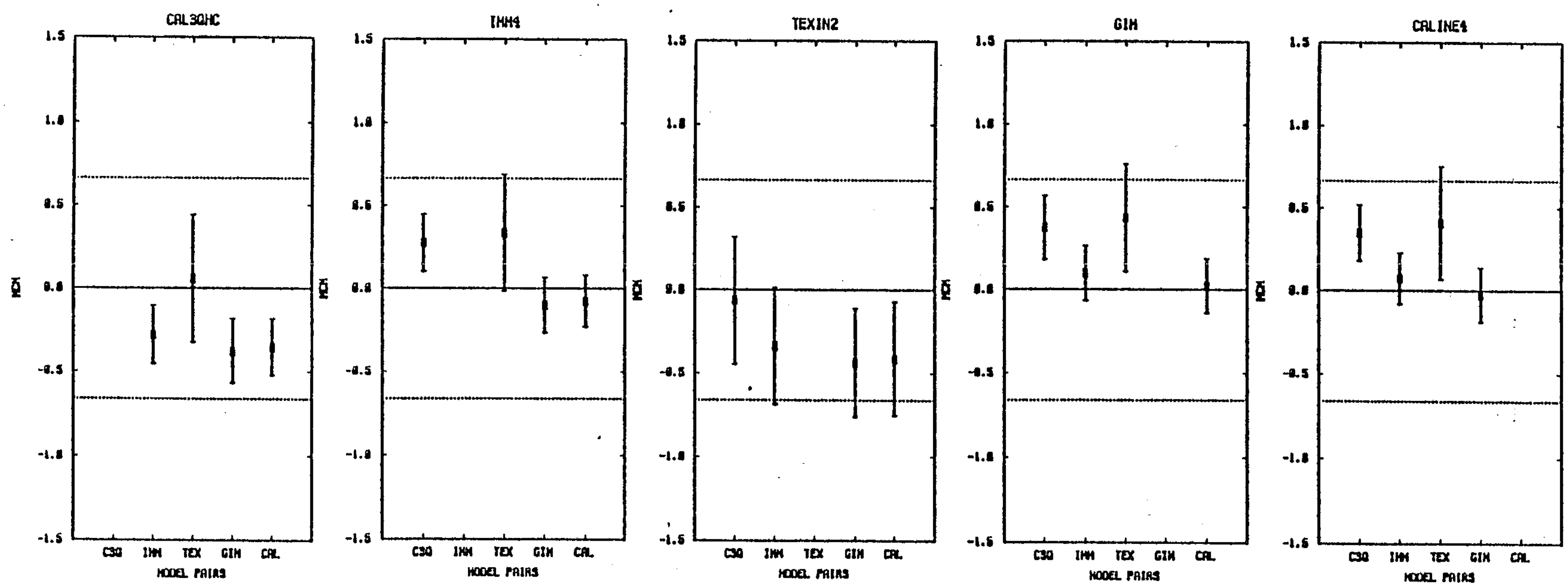


Figure 64. The model comparison measure (MCM) with 95% confidence limits for each model pair at Site #2.

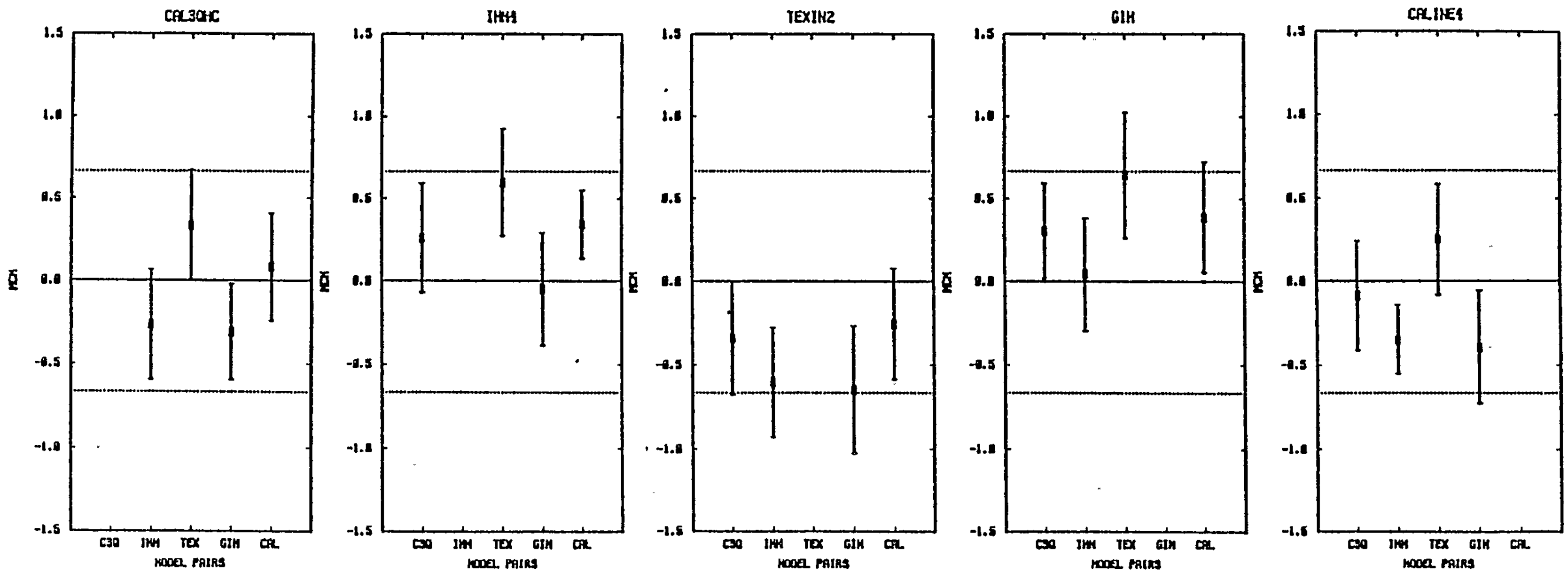


Figure 65. The model comparison measure (MCM) with 95% confidence limits for each model pair at Site #5.

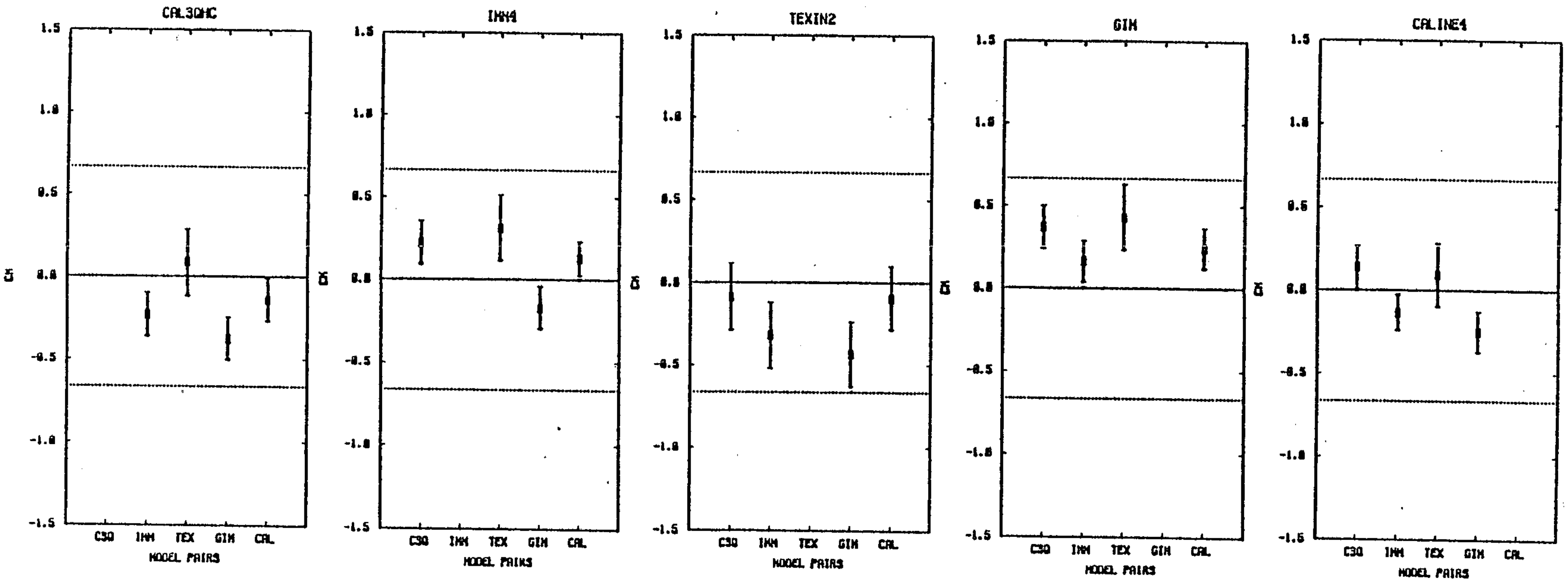


Figure 66. The composite model comparison measure (CM) with 95% confidence limits for each model pair using MCM statistics.

TABLE 29

SUMMARY OF THE COMPOSITE MODEL COMPARISON MEASURES (CM) OF DIFFERENCES BETWEEN MODEL PERFORMANCE AS MEASURED BY THE ABSOLUTE FRACTIONAL BIAS IN PREDICTING ROBUST HIGHEST CONCENTRATIONS FOR MCM STATISTICS

Model 1	Model 2	CM	S	c	CM/S
CAL3QHC	IMM4	-0.226	0.044	2.99	-5.07
CAL3QHC	TEXIN2	0.087	0.067	2.99	1.29
CAL3QHC	GIM	-0.374	0.044	2.99	-8.59
CAL3QHC	CALINE4	-0.137	0.043	2.99	-3.19
IMM4	TEXIN2	0.316	0.067	2.99	4.74
IMM4	GIM	-0.166	0.041	2.99	-4.02
IMM4	CALINE4	0.132	0.035	2.99	3.80
TEXIN2	GIM	-0.432	0.066	2.99	-6.54
TEXIN2	CALINE4	-0.092	0.063	2.99	-1.45
GIM	CALINE4	0.245	0.041	2.99	5.94

Notes: S = standard error in CM based on bootstrap outcomes.

c = factor for the 95% simultaneous confidence interval.

The hypothesis that there is no difference in model performance can be rejected with 95% confidence if $|CM/S| > c$.

7.0 SUMMARY AND CONCLUSIONS

An evaluation of performance of eight modeling techniques (CAL3QHC, FHWAINT, GIM, EPAINT, CALINE4, VOL9MOB4, TEXIN2, and IMM) in simulating concentrations of CO at the six intersections monitored as part of the Route 9A Reconstruction Project in New York City is presented in this report. A phase I study evaluated the performance of all eight modeling techniques at all six intersections. Estimates of the emission rate of CO were obtained from MOBILE4.0. A new version of this model, MOBILE4.1, was released as the phase I study was completed. Results obtained during phase I were used to identify a subset of modeling techniques and intersections for a phase II study in which estimates of the emission rate of CO were obtained from MOBILE4.1. Of the three EPA intersection models evaluated in Phase I (EPAINT, VOL9MOB4, and CAL3QHC), CAL3QHC performed best. Of the two models utilizing the FHWA advocated average speed approach rather than explicit queuing (FHWAINT and GIM), GIM performed better. Therefore, the phase II study with MOBILE4.1 was performed for five models: CAL3QHC, GIM, IMM, TEXIN2, and CALINE4. A uniform wind analysis conducted for each site indicated that Sites #5 (34th/12th) and #1 (West/Chambers) are best in terms of unhindered approach wind flows and wind field uniformity. The best quality assurance procedures were followed at Sites #1 and #2 (34th/8th) when collecting and compiling the New York City database. Therefore, the phase II MOBILE4.1 study was performed for three intersections (Sites #1, 2, and 5).

Two types of statistical evaluations of differences between observed and modeled CO concentrations are performed. First, the EPA Model Evaluation Support System (MESS) is used to calculate a standard set of performance measures and statistical estimators. Second, a scoring scheme is used to aggregate the component results of model performance into a single performance measure used to compare the overall performance of the models and the boot-strap resampling technique is used to determine the significance of differences in composite performance between models.

The phase I results using eight models with MOBILE4.0 emissions at six sites indicate that, on average, FHWAINT and VOL9MOB4 display the largest bias. When time-paired comparisons are made, TEXIN2 has the bias nearest zero at four of the six sites and all eight modeling techniques indicate underpredictions at Sites #1 through #5. When the average residuals are based on concentrations paired by location only, TEXIN2 performs best at Sites #1, 2, and 5; GIM performs best at Site #3, CAL3QHC performs best at Site #4; and CALINE4 performs best at Site #6. The average residuals based on the highest unpaired 25 predicted and observed concentrations indicate that no one model consistently outperforms all other models. In fact, when the fractional bias of the mean and standard deviation of the highest 25 predicted CO concentrations relative to the mean and standard deviation of the 25 highest observed concentrations is used as an indicator of performance, none of the models produces fractional biases less than or equal to 0.67 in absolute value across all of the sites.

Sites #1, 2, and 5 appear qualitatively different from the other three sites in that the relative performance of the models is independent of whether the residuals are obtained from paired or unpaired concentrations, or whether all data are used or just the "top 25." In contrast, the ordering of the models in terms of how near zero their bias becomes, changes at Sites #3, 4, and 6 when concentrations are no longer paired in time. This behavior might indicate the presence at these sites of factors that are not properly resolved in the data, or that are not properly addressed in the model. Recall that Sites #1, 2, and 5 are the least complex sites in the group.

The phase II study indicates that the performance of the five models when MOBILE4.1 is used is qualitatively similar to the performance seen in phase I when MOBILE4.0 is used. Key points discovered in this evaluation include the following:

1. Effect of Using MOBILE4.1 Relative to MOBILE4.0

   Larger CO concentrations are generally predicted by all models at all sites. TEXIN2 exhibits the greatest change in bias, apparently due to the use of correction factors to emissions during idle conditions.

2. Mean Bias Exhibited by Each Model

   When the observed and predicted concentrations are paired in time and location, TEXIN2 exhibits the smallest average bias at all three sites. For the paired in time only residuals, all models underpredict the highest observed concentrations at all three sites, except TEXIN2 at Site #1. When paired by station only, CALINE4 displays the smallest average bias at Site #1 and TEXIN2 displays the smallest bias at Sites #2 and #5. All of the models underpredict the highest-25 concentrations at all three sites except for TEXIN2 at Site #1.

3. Influence of Meteorology on Model Performance

   CAL3QHC performs better at lower wind speeds. Relative performance among the other models does not change in a consistent manner as a function of the meteorology. Hence, differences between models are primarily related to how emissions are determined and allocated to the links used to describe each intersection.

4. Model Performance with "Regulatory Default Meteorology"

   The predicted concentrations found using the regulatory default meteorology are nearly always greater than those obtained with the measured meteorology. At Site #1, TEXIN2 overpredicts the maximum observed concentration by more than a factor of two; whereas, CAL3QHC nearly matches the maximum observed concentration, unpaired in time or space. At Site #2, TEXIN2 overpredicts while CAL3QHC, the next highest modeled concentration, underpredicts. At Site #5, TEXIN2 also overpredicts the maximum observed concentration, while CAL3QHC nearly matches it.

5. Fractional Bias of the Robust Highest Concentrations (RHC)

   The analysis of the fractional bias (FB) of the robust highest concentration (RHC) for all one-hour averages indicates that CALINE4 performs best at Site #1, and TEXIN2 performs best at Sites #2 and 5. The confidence interval associated with TEXIN2 indicates that its FB is not significantly different from zero at the 95% confidence level at Sites #2 and 5.

6. Diagnostic Evaluation of Performance for the RHC

   When performance is evaluated for three diagnostic categories, the best model performance is found for light wind and neutral/stable conditions. This category is most important for regulatory applications. The best value of FB for this diagnostic category is found for CALINE4 at Site #1, CAL3QHC at Site #2, and TEXIN2 at Site #5. When results for these sites are combined by forming a comparison measure (CM) based on the absolute FB(AFB), the CM indicates that CAL3QHC performs best for the category containing light winds and neutral/stable dispersion.

7. Overall Evaluation of AFB in RHC

   An analysis of the weighted linear combination of the individual AFB components (operational and diagnostic) or composite performance measure (CPM) indicates that when the results from all three sites are combined into one composite model performance measure (CM), TEXIN2 performs best and the performance of CAL3QHC is very close to that of TEXIN2.

8. Significance of Performance Results

   The model comparison measure (MCM), which is the difference in CPM values between one model and another model, is used to judge the statistical significance of the apparent superiority of any one model over another. Since TEXIN2 has the best composite model performance measure when using the CPM statistics, it is important to test if its performance is significantly different from all other models evaluated. At Site #1, TEXIN2 is not significantly different from CAL3QHC, IMM, and GIM. At Site #2, TEXIN2 is not significantly different from CAL3QHC and IMM. At Site #5, TEXIN2 is not significantly different from CALINE4. When the MCM statistics from each intersection are combined, TEXIN2 is not significantly different from either CAL3QHC or CALINE4 with 95% confidence.

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APPENDIX A

ADDITIONAL PHASE I MOBILE4.0 ANALYSES

TABLE A-1

ALL OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) PAIRED IN TIME AND LOCATION USING MOBILE4.0

SITE #1

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	1057	3.5	2.6	2.5	2.7	1.7	1.6
FHWAINT	1053	3.5	2.9	2.8	3.0	1.7	1.6
CALINE4	1069	3.4	1.7	1.6	1.8	1.7	1.7
CAL3QHC	1056	3.5	2.4	2.3	2.5	1.7	1.6
VOL9MOB4	1051	3.5	2.9	2.8	3.0	1.7	1.6
TEXIN2	1071	3.4	0.7	0.6	0.9	2.3	2.2
GIM	1058	3.5	2.5	2.4	2.6	1.7	1.6
IMM4	1058	3.5	2.1	2.0	2.2	1.6	1.6

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	1.8	3.1	2.6	0.413	6.427	5.696	7.251
FHWAINT	1.8	3.3	2.9	0.467	16.386	14.519	18.492
CALINE4	1.8	2.4	1.9	0.455	1.875	1.663	2.114
CAL3QHC	1.8	2.9	2.5	0.420	3.275	2.902	3.695
VOL9MOB4	1.8	3.4	2.9	0.382	13.432	11.901	15.160
TEXIN2	2.4	2.4	1.9	0.409	0.670	0.594	0.755
GIM	1.7	3.0	2.5	0.453	6.307	5.590	7.116
IMM4	1.7	2.7	2.3	0.482	3.369	2.986	3.801

SITE #2

MODEL	NUMBER OF EVENTS	AVERAG OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	1098	3.9	3.0	2.9	3.1	1.6	1.5
FHWAINT	1098	3.9	3.5	3.4	3.6	1.6	1.5
CALINE4	1098	3.9	3.0	2.9	3.1	1.6	1.6
CAL3QHC	1098	3.9	3.0	2.9	3.1	1.7	1.6
VOL9MOB4	1098	3.9	3.2	3.1	3.3	1.6	1.5
TEXIN2	1098	3.9	2.7	2.5	2.8	1.8	1.7
GIM	1098	3.9	2.9	2.8	3.0	1.6	1.5
IMM4	1098	3.9	2.8	2.7	2.9	1.7	1.6

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	1.7	3.4	3.0	0.355	2.993	2.659	3.369
FHWAINT	1.7	3.9	3.5	0.309	22.750	20.209	25.610
CALINE4	1.7	3.4	3.0	0.330	2.702	2.401	3.042
CAL3QHC	1.7	3.4	3.0	0.332	2.431	2.160	2.737
VOL9MOB4	1.6	3.6	3.2	0.363	6.163	5.475	6.938
TEXIN2	1.8	3.2	2.8	0.342	1.422	1.263	1.601
GIM	1.6	3.3	2.9	0.370	3.238	2.877	3.645
IMM4	1.7	3.3	2.8	0.340	2.089	1.856	2.351

TABLE A-1 (continued)

ALL OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) PAIRED IN TIME AND LOCATION USING MOBILE 4.0

SITE #3

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	481	3.8	1.5	1.2	1.7	2.9	2.7
FHWAINT	479	3.8	2.7	2.5	2.9	2.1	2.0
CALINE4	483	3.7	0.8	0.5	1.0	3.1	2.9
CAL3QHC	479	3.8	1.4	1.1	1.8	3.5	3.3
VOL9MOB4	478	3.8	1.9	1.7	2.2	2.7	2.5
TEXIN2	480	3.8	1.6	1.4	1.9	3.0	2.8
GIM	481	3.8	1.2	0.9	1.4	2.8	2.7
IMM4	481	3.8	1.6	1.3	1.8	2.6	2.4

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	3.1	3.2	2.6	-0.011	0.800	0.669	0.957
FHWAINT	2.2	3.4	2.9	-0.019	4.640	3.877	5.552
CALINE4	3.3	3.2	2.5	-0.088	0.721	0.603	0.862
CAL3QHC	3.8	3.8	2.9	-0.079	0.439	0.367	0.525
VOL9MOB4	2.9	3.3	2.7	-0.016	0.989	0.826	1.183
TEXIN2	3.2	3.4	2.8	-0.007	0.696	0.582	0.832
GIM	3.0	3.1	2.5	0.009	0.807	0.675	0.966
IMM4	2.8	3.0	2.5	-0.022	1.205	1.007	1.441

SITE #4

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	436	3.9	2.0	1.7	2.2	2.4	2.2
FHWAINT	436	3.9	2.9	2.7	3.0	1.8	1.7
CALINE4	437	3.9	1.6	1.4	1.9	2.6	2.4
CAL3QHC	436	3.9	2.0	1.7	2.2	2.5	2.4
VOL9MOB4	436	3.9	2.4	2.2	2.6	2.1	1.9
TEXIN2	437	3.9	1.6	1.4	1.9	2.6	2.5
GIM	436	3.9	1.6	1.3	1.8	2.6	2.5
IMM4	436	3.9	2.4	2.2	2.6	2.0	1.9

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	2.5	3.1	2.6	0.056	0.874	0.724	1.055
FHWAINT	2.0	3.4	2.9	0.081	3.555	2.945	4.291
CALINE4	2.8	3.0	2.5	0.060	0.649	0.538	0.784
CAL3QHC	2.7	3.2	2.7	0.055	0.681	0.564	0.822
VOL9MOB4	2.2	3.2	2.7	0.064	1.523	1.261	1.838
TEXIN2	2.8	3.1	2.6	0.073	0.602	0.499	0.726
GIM	2.8	3.1	2.5	0.059	0.602	0.499	0.727
IMM4	2.2	3.1	2.6	0.014	2.083	1.726	2.515

TABLE A-1 (continued)

ALL OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) PAIRED IN TIME AND LOCATION USING MOBILE 4.0

SITE #5

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	586	3.8	2.8	2.7	3.0	1.9	1.8
FHWAINT	585	3.8	3.0	2.9	3.2	1.8	1.7
CALINE4	587	3.8	1.9	1.7	2.1	2.2	2.1
CAL3QHC	586	3.8	2.8	2.6	2.9	2.0	1.9
VOL9MOB4	585	3.8	3.1	2.9	3.2	1.9	1.8
TEXIN2	587	3.8	1.7	1.5	1.9	2.3	2.1
GIM	587	3.8	2.7	2.6	2.9	1.9	1.8
IMM4	586	3.8	2.6	2.4	2.7	2.0	1.9

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	2.0	3.4	2.9	0.245	3.643	3.097	4.284
FHWAINT	1.9	3.5	3.0	0.303	6.242	5.306	7.342
CALINE4	2.4	2.9	2.3	0.244	1.195	1.016	1.406
CAL3QHC	2.1	3.4	2.9	0.256	2.657	2.259	3.125
VOL9MOB4	2.0	3.6	3.1	0.215	4.886	4.154	5.747
TEXIN2	2.4	2.8	2.1	0.274	1.046	0.890	1.230
GIM	2.0	3.3	2.8	0.255	3.358	2.856	3.949
IMM4	2.1	3.3	2.7	0.182	3.248	2.762	3.820

SITE #6

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	263	2.1	0.5	0.3	0.7	1.7	1.6
FHWAINT	264	2.1	0.8	0.6	1.0	1.6	1.4
CALINE4	268	2.1	0.7	0.5	0.9	1.7	1.6
CAL3QHC	263	2.1	0.8	0.6	1.0	1.9	1.7
VOL9MOB4	263	2.1	1.0	0.8	1.1	1.3	1.2
TEXIN2	273	2.0	-0.8	-1.1	-0.4	3.0	2.8
GIM	265	2.1	0.7	0.5	0.9	1.5	1.4
IMM4	263	2.1	0.8	0.6	0.9	1.5	1.4

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	1.9	1.8	1.4	0.527	0.502	0.394	0.640
FHWAINT	1.7	1.7	1.4	0.416	0.939	0.737	1.197
CALINE4	1.9	1.9	1.5	0.239	1.107	0.870	1.407
CAL3QHC	2.0	2.0	1.6	0.379	0.581	0.455	0.740
VOL9MOB4	1.4	1.6	1.3	0.551	1.183	0.928	1.508
TEXIN2	3.3	3.1	2.2	0.275	0.224	0.176	0.284
GIM	1.7	1.7	1.3	0.492	0.814	0.639	1.036
IMM4	1.6	1.7	1.3	0.511	0.832	0.653	1.060

TABLE A-2

HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM)
EVENT BY EVENT (PAIRED IN TIME) USING MOBILE4.0

SITE#1

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
EPAINT	142	5.8	4.0	3.8	4.2	1.0	0.9	1.2
FHWAINT	142	5.8	4.8	4.6	4.9	1.0	0.9	1.1
CALINE4	142	5.8	2.2	2.0	2.4	1.3	1.2	1.5
CAL3QHC	142	5.8	3.3	3.1	3.5	1.2	1.1	1.4
VOL9MOB4	142	5.8	4.6	4.4	4.8	1.0	0.9	1.1
TEXIN2	142	5.8	0.6	0.2	1.0	2.4	2.2	2.7
GIM	142	5.8	4.0	3.8	4.2	1.1	1.0	1.2
IMM4	142	5.8	3.2	3.0	3.5	1.2	1.1	1.4

SITE #2

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
EPAINT	143	6.6	4.2	3.9	4.5	1.6	1.4	1.8
FHWAINT	143	6.6	5.6	5.4	5.8	1.2	1.1	1.4
CALINE4	143	6.6	3.9	3.7	4.2	1.4	1.3	1.6
CAL3QHC	143	6.6	3.8	3.6	4.1	1.6	1.5	1.9
VOL9MOB4	143	6.6	5.0	4.7	5.2	1.4	1.2	1.5
TEXIN2	143	6.6	3.0	2.7	3.3	2.0	1.8	2.2
GIM	143	6.6	4.0	3.8	4.3	1.5	1.4	1.7
IMM4	143	6.6	3.6	3.3	3.8	1.5	1.4	1.7

SITE #3

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
EPAINT	66	5.9	1.1	0.3	1.9	3.3	2.8	4.0
FHWAINT	66	5.9	3.7	3.4	4.1	1.4	1.2	1.7
CALINE4	66	5.9	0.3	-0.5	1.0	3.0	2.6	3.7
CAL3QHC	66	5.9	0.5	-0.7	1.6	4.7	4.0	5.7
VOL9MOB4	66	5.9	1.6	0.9	2.4	3.0	2.6	3.7
TEXIN2	66	5.9	0.6	-0.2	1.5	3.4	2.9	4.1
GIM	66	5.9	0.6	-0.0	1.3	2.7	2.3	3.2
IMM4	66	5.9	1.5	0.8	2.2	2.8	2.4	3.4

TABLE A-2 (continued)

HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) EVENT BY EVENT (PAIRED IN TIME) USING MOBILE4.0

SITE #4

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
EPAINT	74	5.7	2.0	1.4	2.6	2.5	2.2	3.0
FHWAINT	74	5.7	3.8	3.4	4.1	1.6	1.3	1.9
CALINE4	74	5.7	1.2	0.5	1.8	2.7	2.4	3.3
CAL3QHC	74	5.7	1.5	0.8	2.2	3.0	2.6	3.5
VOL9MOB4	74	5.7	3.1	2.6	3.5	2.0	1.7	2.4
TEXIN2	74	5.7	0.6	0.0	1.2	2.6	2.2	3.1
GIM	74	5.7	1.1	0.4	1.8	3.0	2.6	3.6
IMM4	74	5.7	3.1	2.7	3.5	1.8	1.6	2.2

SITE #5

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
EPAINT	75	6.2	3.9	3.5	4.4	2.1	1.8	2.5
FHWAINT	75	6.2	4.8	4.3	5.3	2.0	1.7	2.4
CALINE4	75	6.2	1.9	1.4	2.4	2.3	1.9	2.7
CAL3QHC	75	6.2	3.3	2.8	3.8	2.2	1.9	2.6
VOL9MOB4	75	6.2	4.6	4.1	5.1	2.1	1.8	2.5
TEXIN2	75	6.2	1.5	0.9	2.0	2.4	2.0	2.8
GIM	75	6.2	4.0	3.5	4.5	2.1	1.8	2.5
IMM4	75	6.2	3.7	3.3	4.2	2.0	1.7	2.4

SITE #6

MODEL	NUMBER OF EVENTS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT	UPPER LIMIT
EPAINT	75	4.0	-0.2	-0.7	0.2	1.8	1.6	2.2
FHWAINT	75	4.0	1.2	0.8	1.6	1.7	1.5	2.1
CALINE4	75	4.0	1.0	0.6	1.3	1.7	1.4	2.0
CAL3QHC	75	4.0	0.5	-0.1	1.0	2.3	2.0	2.8
VOL9MOB4	75	4.0	1.1	0.8	1.4	1.3	1.2	1.6
TEXIN2	75	4.0	-2.4	-3.1	-1.7	3.0	2.6	3.6
GIM	75	4.0	0.6	0.2	1.0	1.7	1.5	2.0
IMM4	75	4.0	0.5	0.2	0.8	1.3	1.1	1.6

TABLE A-3

HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) PAIRED BY STATION USING MOBILE4.0

SITE #1

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV.OF RESIDUAL	LOWER LIMIT
EPAINT	8	8.4	4.9	3.6	6.3	1.5	1.0
FHWAINT	8	8.4	6.0	4.9	7.2	1.3	0.9
CALINE4	8	8.4	2.6	0.9	4.4	2.0	1.3
CAL3QHC	8	8.4	3.8	2.4	5.3	1.6	1.1
VOL9MOB4	8	8.4	5.7	4.5	6.9	1.3	0.9
TEXIN2	8	8.4	-1.1	-4.1	1.9	3.4	2.2
GIM	8	8.4	5.1	3.7	6.5	1.6	1.0
IMM4	8	8.4	4.0	2.8	5.1	1.3	0.8

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	2.0	5.1	4.9	0.136	1.369	0.274	6.838
FHWAINT	2.7	6.2	6.0	-0.229	11.953	2.393	59.707
CALINE4	4.0	3.2	2.6	-0.473	1.254	0.251	6.263
CAL3QHC	3.3	4.1	3.8	0.152	0.897	0.180	4.481
VOL9MOB4	2.7	5.8	5.7	0.277	1.421	0.284	7.097
TEXIN2	6.8	3.3	2.7	-0.246	0.181	0.036	0.905
GIM	3.2	5.3	5.1	-0.252	2.533	0.507	12.651
IMM4	2.6	4.1	4.0	0.079	5.501	1.101	27.477

SITE #2

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	8	8.6	5.4	3.3	7.5	2.4	1.6
FHWAINT	8	8.6	7.2	5.6	8.9	1.8	1.2
CALINE4	8	8.6	5.3	3.1	7.5	2.5	1.6
CAL3QHC	8	8.6	5.4	3.2	7.6	2.4	1.6
VOL9MOB4	8	8.6	5.9	4.1	7.7	2.0	1.3
TEXIN2	8	8.6	3.7	1.1	6.3	2.9	1.9
GIM	8	8.6	5.6	3.9	7.3	1.9	1.3
IMM4	8	8.6	4.7	2.8	6.5	2.1	1.4

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	4.8	5.8	5.4	0.202	1.070	0.214	5.344
FHWAINT	3.7	7.4	7.2	0.297	15.341	3.071	76.629
CALINE4	5.1	5.8	5.3	0.331	0.649	0.130	3.243
CAL3QHC	5.0	5.9	5.4	0.268	0.801	0.160	4.003
VOL9MOB4	4.2	6.2	5.9	0.167	2.796	0.560	13.964
TEXIN2	6.0	4.6	3.7	0.309	0.428	0.086	2.137
GIM	3.9	5.9	5.6	0.292	2.526	0.506	12.618
IMM4	4.2	5.1	4.7	0.155	2.506	0.502	12.519

TABLE A-3 (continued)

HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) PAIRED BY STATION USING MOBILE4.0

SITE #3

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	8	8.5	-1.0	-6.6	4.5	6.2	4.1
FHWAINT	8	8.5	5.1	3.4	6.7	1.9	1.2
CALINE4	8	8.5	-1.0	-4.5	2.5	3.9	2.6
CAL3QHC	8	8.5	-4.3	-13.9	5.3	10.8	7.1
VOL9MOB4	8	8.5	-0.8	-5.5	4.0	5.3	3.5
TEXIN2	8	8.5	-0.3	-4.2	3.5	4.3	2.9
GIM	8	8.5	-0.0	-2.5	2.5	2.8	1.8
IMM4	8	8.5	0.5	-3.0	3.9	3.8	2.5

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	12.6	5.9	4.6	0.389	0.027	0.005	0.136
FHWAINT	3.8	5.4	5.1	-0.336	0.764	0.153	3.816
CALINE4	8.0	3.8	2.8	0.442	0.063	0.013	0.316
CAL3QHC	22.0	11.0	7.3	0.353	0.009	0.002	0.046
VOL9MOB4	10.8	5.0	3.9	0.355	0.037	0.007	0.185
TEXIN2	8.8	4.1	3.1	-0.034	0.067	0.013	0.335
GIM	5.7	2.6	2.2	0.082	0.162	0.032	0.810
IMM4	7.8	3.6	3.2	0.288	0.072	0.014	0.361

SITE #4

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	6	8.3	0.9	-1.6	3.4	2.2	1.4
FHWAINT	6	8.3	4.3	2.0	6.5	2.0	1.2
CALINE4	6	8.3	-0.4	-3.8	3.0	3.0	1.8
CAL3QHC	6	8.3	0.3	-4.2	4.9	4.0	2.5
VOL9MOB4	6	8.3	2.1	0.7	3.5	1.2	0.8
TEXIN2	6	8.3	1.0	-3.3	5.2	3.7	2.3
GIM	6	8.3	-1.1	-4.2	2.0	2.7	1.7
IMM4	6	8.3	2.0	-0.5	4.5	2.1	1.3

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	5.4	2.2	1.1	-0.239	0.321	0.045	2.297
FHWAINT	4.9	4.6	4.3	-0.365	0.491	0.069	3.510
CALINE4	7.3	2.7	2.2	-0.494	0.175	0.024	1.249
CAL3QHC	9.8	3.6	3.0	0.198	0.059	0.008	0.420
VOL9MOB4	3.0	2.4	2.1	0.155	1.209	0.169	8.637
TEXIN2	9.0	3.5	2.5	-0.158	0.084	0.012	0.601
GIM	6.5	2.7	2.1	-0.060	0.166	0.023	1.189
IMM4	5.3	2.8	2.3	-0.598	0.485	0.068	3.462

TABLE A-3 (continued)

HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) PAIRED BY STATION USING MOBILE4.0

SITE #5

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	8	9.4	4.6	1.7	7.4	3.2	2.1
FHWAINT	8	9.4	5.4	3.1	7.7	2.6	1.7
CALINE4	8	9.4	3.5	0.2	6.8	3.7	2.4
CAL3QHC	8	9.4	4.3	0.9	7.7	3.8	2.5
VOL9MOB4	8	9.4	4.7	1.8	7.5	3.2	2.1
TEXIN2	8	9.4	1.9	-1.1	4.9	3.4	2.2
GIM	8	9.4	4.1	1.1	7.2	3.4	2.3
IMM4	8	9.4	5.3	2.0	8.6	3.7	2.4

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	6.6	5.5	4.5	-0.075	3.388	0.678	16.924
FHWAINT	5.2	5.9	5.4	0.406	3.000	0.601	14.983
CALINE4	7.5	4.9	3.5	-0.416	3.057	0.612	15.268
CAL3QHC	7.6	5.6	4.3	0.045	1.042	0.209	5.206
VOL9MOB4	6.5	5.6	4.7	0.165	1.625	0.325	8.118
TEXIN2	6.8	3.7	2.8	0.124	1.431	0.287	7.150
GIM	7.0	5.2	4.1	0.048	1.605	0.321	8.019
IMM4	7.5	6.3	5.3	-0.869	6.741	1.350	33.673

SITE #6

MODEL	NUMBER OF DATA PAIRS	AVERAGE OBSERVED VALUE	AVERAGE DIFFERENCE	LOWER LIMIT	UPPER LIMIT	STANDARD DEV. OF RESIDUAL	LOWER LIMIT
EPAINT	4	4.3	-0.5	-2.5	1.4	1.1	0.6
FHWAINT	4	4.3	-1.7	-6.7	3.3	2.7	1.6
CALINE4	4	4.3	0.3	-1.1	1.8	0.8	0.4
CAL3QHC	4	4.3	-0.5	-2.8	1.8	1.2	0.7
VOL9MOB4	4	4.3	1.1	-0.0	2.3	0.6	0.4
TEXIN2	4	4.3	-7.3	-13.4	-1.2	3.3	1.9
GIM	4	4.3	-0.4	-1.7	1.0	0.7	0.4
IMM4	4	4.3	0.4	-2.0	2.9	1.4	0.8

MODEL	UPPER LIMIT	ROOT MEAN SQ ERROR	AVERAGE ABSOLUTE RESIDUAL	PEARSON CORR. COEF.	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	4.1	1.1	0.7	0.989	0.536	0.035	8.277
FHWAINT	10.2	2.9	1.7	0.684	0.515	0.033	7.955
CALINE4	2.9	0.8	0.5	0.997	1.946	0.126	30.038
CAL3QHC	4.6	1.2	0.9	0.987	0.501	0.032	7.732
VOL9MOB4	2.4	1.3	1.1	0.980	1.407	0.091	21.716
TEXIN2	12.3	7.8	7.3	0.970	0.211	0.014	3.260
GIM	2.8	0.7	0.5	0.990	0.662	0.043	10.219
IMM4	5.1	1.3	1.1	0.909	2.572	0.167	39.711

TABLE A-4

25 HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) UNPAIRED IN TIME OR LOCATION USING MOBILE4.0

SITE #1

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	8.1	3.1	5.0	4.6	5.4	1.946	0.857	4.412
FHWAINT	8.1	2.0	6.1	5.7	6.4	6.654	2.931	15.088
CALINE4	8.1	5.8	2.2	1.8	2.7	1.684	0.742	3.819
CAL3QHC	8.1	4.2	3.8	3.4	4.3	1.674	0.738	3.797
VOL9MOB4	8.1	2.3	5.8	5.3	6.2	1.573	0.693	3.567
TEXIN2	8.1	9.8	-1.8	-2.3	-1.2	0.616	0.271	1.397
GIM	8.1	3.1	4.9	4.6	5.3	4.778	2.105	10.834
IMM4	8.1	4.1	3.9	3.5	4.3	3.249	1.431	7.367

SITE #2

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	8.6	4.5	4.0	3.4	4.6	1.662	0.732	3.769
FHWAINT	8.6	1.6	6.9	6.5	7.4	15.989	7.044	36.257
CALINE4	8.6	4.5	4.1	3.5	4.7	1.788	0.787	4.054
CAL3QHC	8.6	4.9	3.7	3.1	4.3	1.285	0.566	2.913
VOL9MOB4	8.6	3.0	5.5	5.0	6.0	4.875	2.148	11.055
TEXIN2	8.6	6.7	1.9	1.1	2.7	0.418	0.184	0.949
GIM	8.6	4.1	4.5	4.0	5.0	5.339	2.352	12.107
IMM4	8.6	4.6	4.0	3.5	4.5	5.071	2.234	11.499

SITE #3

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	7.8	8.9	-1.1	-2.6	0.4	0.084	0.037	0.190
FHWAINT	7.8	3.5	4.2	3.7	4.7	2.340	1.031	5.307
CALINE4	7.8	9.5	-1.8	-2.8	-0.8	0.216	0.095	0.490
CAL3QHC	7.8	11.5	-3.8	-6.2	-1.3	0.031	0.013	0.069
VOL9MOB4	7.8	7.8	-0.1	-1.4	1.3	0.102	0.045	0.231
TEXIN2	7.8	9.0	-1.3	-2.3	-0.2	0.199	0.088	0.452
GIM	7.8	8.7	-0.9	-1.7	-0.2	0.499	0.220	1.132
IMM4	7.8	7.8	0.0	-1.0	1.1	0.191	0.084	0.434

TABLE A-4 (continued)

25 HIGHEST OBSERVED AND PREDICTED CO CONCENTRATIONS (PPM) UNPAIRED IN TIME OR LOCATION USING MOBILE4.0

SITE #4

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	7.4	7.1	0.3	-0.3	0.8	0.694	0.306	1.575
FHWAINT	7.4	3.6	3.8	3.3	4.3	0.840	0.370	1.904
CALINE4	7.4	8.3	-0.9	-1.5	-0.3	0.510	0.225	1.157
CAL3QHC	7.4	8.1	-0.7	-1.5	0.2	0.196	0.086	0.443
VOL9MOB4	7.4	5.4	2.0	1.5	2.5	0.938	0.413	2.126
TEXIN2	7.4	8.2	-0.8	-1.6	-0.0	0.245	0.108	0.555
GIM	7.4	8.3	-0.9	-1.7	-0.1	0.210	0.093	0.477
IMM4	7.4	4.6	2.8	2.2	3.4	0.411	0.181	0.932

SITE #5

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	8.8	3.9	4.8	3.9	5.8	3.085	1.359	6.997
FHWAINT	8.8	3.0	5.8	4.8	6.7	3.446	1.518	7.815
CALINE4	8.8	6.4	2.4	1.5	3.3	6.936	3.056	15.728
CAL3QHC	8.8	4.6	4.1	3.1	5.2	2.150	0.947	4.876
VOL9MOB4	8.8	3.5	5.3	4.3	6.4	1.671	0.736	3.789
TEXIN2	8.8	7.0	1.8	0.8	2.8	2.081	0.917	4.720
GIM	8.8	4.0	4.8	3.7	5.8	1.905	0.839	4.319
IMM4	8.8	3.9	4.9	4.0	5.7	14.677	6.466	33.282

SITE #6

MODEL	AVERAGE OBSERVED VALUE	AVERAGE PREDICTED VALUE	DIFFERENCE OF AVERAGES	LOWER LIMIT	UPPER LIMIT	VARIANCE COMPARISON	LOWER LIMIT	UPPER LIMIT
EPAINT	4.9	6.4	-1.4	-2.1	-0.7	0.810	0.357	1.836
FHWAINT	4.9	4.5	0.5	-0.4	1.3	0.421	0.186	0.956
CALINE4	4.9	4.4	0.5	-0.1	1.1	1.311	0.577	2.972
CAL3QHC	4.9	6.2	-1.2	-2.0	-0.4	0.515	0.227	1.167
VOL9MOB4	4.9	4.1	0.9	0.3	1.4	2.234	0.984	5.066
TEXIN2	4.9	9.3	-4.4	-5.6	-3.1	0.166	0.073	0.376
GIM	4.9	4.9	0.0	-0.7	0.8	0.679	0.299	1.540
IMM4	4.9	4.9	0.1	-0.5	0.6	2.319	1.022	5.258

TABLE A-5

A COMPARISON OF TOP-TEN OBSERVED CONCENTRATIONS WITH PREDICTED CONCENTRATIONS USING REGULATORY DEFAULT AND OBSERVED METEOROLOGY USING MOBILE4.0

SITE #1

Mo	Dy	Yr	Hr Beg	TAVG F	WDM1 deg	WDM2 deg	WSM1 mph	WSM2 mph	SC1	SC2	Regulatory Default Obs ppm	C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm
3	29	89	18	68.2	299	339	1.9	1.5	3	3	10.6	6.4	3.0	4.4	9.0	4.1	2.8	5.9	9.2	4.6	2.8	3.8	7.6	3.6	2.7	4.0	6.7
3	29	89	17	70.5	301	338	2.6	2.2	3	3	9.1	8.2	4.0	5.4	14.1	5.5	3.2	7.1	12.1	4.4	2.9	3.0	9.4	3.7	1.6	3.8	7.3
3	15	89	17	66.6	162	181	4.1	4.8	4	4	9.0	7.6	3.5	5.0	13.6	5.4	2.9	6.8	11.8	1.7	1.1	1.7	5.2	1.4	1.2	1.9	3.9
4	3	89	19	57.8	130	134	2.9	3.7	6	6	8.6	6.2	2.9	3.0	7.9	3.8	2.1	4.9	6.3	6.7	4.2	3.4	6.1	4.5	1.5	3.6	4.0
5	24	89	17	61.2	322	334	5.4	5.3	4	4	8.2	8.8	4.2	5.6	9.8	5.8	2.9	7.0	12.3	3.7	1.5	2.2	4.6	2.3	1.0	2.6	5.9
4	14	89	6	38.6	306	315	4.2	4.1	4	4	7.8	7.3	4.7	5.2	16.5	5.2	3.2	7.2	7.9	2.6	1.2	2.5	9.8	2.2	1.5	3.2	3.5
4	4	89	14	69.0	131	142	4.2	5.5	2	2	7.6	8.8	5.0	5.7	14.0	5.5	4.2	8.2	10.1	1.4	0.9	1.3	4.0	1.2	1.1	2.9	3.4
3	29	89	16	70.7	315	338	4.7	3.8	3	2	7.5	8.1	4.4	5.6	14.3	5.5	4.3	8.2	12.6	2.8	1.3	1.8	6.2	2.1	1.3	2.5	5.5
5	9	89	6	50.8	313	324	2.9	2.5	3	3	7.5	7.3	3.9	5.1	17.1	4.8	3.1	6.2	8.5	3.6	1.8	2.7	11.2	2.8	1.6	3.4	5.9
3	29	89	15	69.6	323	342	5.6	4.7	3	3	7.4	8.3	4.8	5.6	14.4	5.5	4.3	7.8	12.7	2.5	1.4	1.6	5.5	1.8	1.0	2.4	5.5

SITE #2

Mo	Dy	Yr	Hr Beg	TAVG F	WDM1 deg	WDM2 deg	WDM3 deg	WSM1 mph	WSM2 mph	WSM2 mph	SC1	SC2	SC3	Regulatory Default Obs ppm	C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm
8	13	89	16	77.5	221	232	208	4.8	4.2	3.4	2	2	1	11.5	4.8	2.9	4.2	5.6	3.9	1.3	4.0	4.6	1.8	0.8	1.3	2.1	1.4	0.5	2.3	2.0
10	26	89	11	68.7	72	137	303	4.0	4.3	3.2	2	2	2	10.5	7.0	3.4	6.7	7.5	5.7	2.0	6.1	5.9	2.3	1.2	2.4	2.7	1.9	0.8	2.9	2.0
10	25	89	16	71.5	175	236	282	3.4	2.9	2.9	3	3	3	10.4	6.0	3.6	5.7	8.1	5.0	2.0	5.5	5.7	3.7	2.1	3.8	4.9	3.3	1.2	3.7	3.0
9	12	89	14	78.5	194	267	299	4.2	4.2	4.2	2	2	2	10.2	6.3	3.5	6.3	6.6	5.2	1.9	5.5	5.9	2.1	1.2	2.2	2.4	1.8	0.8	2.7	1.8
8	14	89	8	76.1	199	235	213	5.0	3.6	2.5	4	3	1	10.2	3.5	1.5	2.4	8.1	2.8	1.4	2.9	4.0	1.8	0.8	1.2	4.5	1.4	0.7	1.9	1.6
8	15	89	8	75.1	204	237	220	4.9	3.4	2.2	4	3	1	9.1	4.2	2.9	3.7	7.4	3.7	1.6	2.9	6.3	2.3	1.5	2.1	4.3	1.9	0.9	2.5	3.3
8	14	89	9	78.4	206	228	210	5.1	3.4	2.4	4	3	1	8.8	4.5	2.7	3.7	7.1	3.7	1.6	4.0	7.1	2.5	1.3	1.9	3.8	2.0	0.8	2.3	3.6
10	25	89	15	72.8	171	259	292	3.3	2.8	2.7	2	2	2	8.5	6.3	3.8	6.2	8.7	5.3	2.2	5.9	6.1	3.0	1.8	3.1	4.7	2.6	1.2	3.5	3.1
9	1	89	15	79.8	236	212	148	6.0	6.1	6.6	2	2	2	8.4	6.2	4.1	6.5	7.7	5.6	2.3	6.0	6.3	1.6	1.1	1.5	1.7	1.4	0.5	1.8	1.6
10	26	89	19	70.4	219	212	302	3.4	1.5	2.0	6	6	6	8.3	5.3	3.0	3.7	11.0	4.7	2.0	5.9	5.4	5.4	4.3	3.3	10.3	4.3	2.0	2.9	4.1

SITE #3

Mo	Dy	Yr	Hr Beg	TAVG F	WDM1 deg	WDM2 deg	WSM1 mph	WSM2 mph	SC1	SC2	Regulatory Default Obs ppm	C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm
12	19	89	9	25.7	340	329	2.3	1.3	3	3	10.2	9.0	7.5	11.2	10.1	9.2	5.7	8.9	10.5	6.6	5.4	8.9	5.6	7.1	4.3	7.9	6.3
12	18	89	9	24.3	218	327	3.3	1.3	3	3	9.0	8.7	7.8	9.9	9.9	7.8	3.9	9.2	9.5	2.8	2.8	4.1	3.4	2.8	1.6	2.3	4.7
1	29	90	12	41.5	7	12	3.8	2.8	4	4	9.0	6.4	4.4	6.6	7.4	4.9	2.6	6.3	6.2	2.7	2.7	2.9	2.4	2.8	1.4	3.8	2.1
12	18	89	10	26.4	350	338	3.6	2.1	2	2	8.8	9.1	7.5	10.8	9.0	8.1	4.4	9.5	8.1	3.3	3.1	4.1	2.8	3.5	1.7	5.5	3.3
11	1	89	23	57.7	209	207	1.9	1.8	6	6	8.2	7.6	5.2	6.2	8.6	6.7	2.1	6.7	9.7	4.2	3.2	4.6	7.1	3.4	2.5	3.0	5.7
12	11	89	9	45.7	212	332	2.1	0.9	3	3	7.3	7.4	6.1	9.3	8.7	7.3	4.0	7.4	8.4	3.9	3.5	5.6	4.7	3.7	2.7	2.7	4.9
12	5	89	8	34.2	209	321	4.0	1.3	3	3	7.2	9.6	7.7	11.4	10.4	9.6	5.9	9.1	9.4	2.7	2.9	4.1	3.1	2.8	2.3	2.9	3.7
12	19	89	10	26.6	11	306	2.9	1.6	2	2	7.0	8.8	7.5	10.5	9.3	7.6	4.5	8.7	8.0	3.2	3.4	4.3	2.5	3.4	1.9	4.6	3.0
12	20	89	10	28.8	211	335	3.2	1.4	2	2	6.9	8.5	8.6	9.1	9.2	7.4	3.7	8.7	7.7	2.8	2.2	3.4	3.3	2.5	1.6	3.0	4.4
12	17	89	15	34.9	214	328	4.1	1.4	4	3	6.8	10.0	7.2	9.3	9.6	8.7	3.6	10.5	9.9	5.7	5.3	3.8	3.6	5.0	1.6	3.8	6.8

Note: TAVG = average temperature over all monitors; WDM<1 2 3> = wind direction at monitor 1, 2 or 3; WSM<1 2 3> = wind speed at monitor 1, 2, or 3; SC<1 2 3> = stability class at monitor 1, 2, or 3; Obs = Observed; C3Q = CAL3QHC; V9M = VOL9MOB4; TEX = TEXIN2; EPA = EPAINT; FHW = FHWAINT; CAL = CALINE4

TABLE A-5 (continued)

A COMPARISON OF TOP-TEN OBSERVED CONCENTRATIONS WITH PREDICTED CONCENTRATIONS USING REGULATORY DEFAULT AND OBSERVED METEOROLOGY USING MOBILE4.0

SITE #4

Mo	Dy	Yr	Hr Beg	TAVG F	WDM1 deg	WDM2 deg	WSM1 mph	WSM2 mph	SC1	SC2	Regulatory Default Obs ppm.	C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm
11	14	89	17	73.7	236.0	224.0	1.8	5.1	6	5	9.6	3.8	2.4	4.2	5.0	3.2	1.6	3.0	4.7	3.6	2.3	2.6	5.9	3.1	1.1	1.7	2.7
11	9	89	9	64.9	31.0	31.0	4.3	4.7	4	4	8.9	4.7	2.9	4.9	5.7	3.8	1.8	3.8	5.2	3.0	2.2	4.0	6.5	2.9	2.1	2.3	3.4
11	13	89	10	50.0	35.0	9.0	6.0	6.5	3	3	8.6	4.8	2.8	5.2	5.9	3.9	1.9	3.7	4.9	1.7	1.1	2.6	3.1	1.6	1.1	2.4	1.9
1	17	90	12	61.0	131.0	87.0	5.6	2.7	3	2	8.3	4.0	3.1	4.6	5.8	3.9	3.4	3.6	5.2	1.1	0.6	1.3	1.9	1.0	1.3	0.7	1.5
11	9	89	8	64.1	52.0	20.0	1.1	3.1	4	4	8.2	4.8	3.0	5.4	5.9	4.3	2.1	4.4	5.4	11.8	6.7	11.4	12.1	8.9	6.1	5.0	9.2
1	17	90	7	54.4	122.0	99.0	6.9	4.7	6	6	7.5	3.7	2.6	4.9	5.2	3.4	1.8	3.3	5.1	0.8	0.6	0.9	3.3	0.7	0.7	1.1	2.0
12	31	89	17	51.4	9.0	27.0	2.9	6.7	4	4	7.3	6.7	4.3	6.3	6.8	5.6	3.0	4.7	7.2	7.2	5.3	9.4	8.9	6.5	4.0	4.9	9.8
11	9	89	7	61.4	67.0	28.0	0.9	2.5	4	4	7.1	3.9	3.1	5.0	5.5	3.6	1.9	3.5	5.4	11.4	4.6	11.8	10.3	7.4	5.1	3.5	9.3
11	8	89	16	63.7	44.0	29.0	4.7	8.3	4	4	7.0	3.0	1.5	2.6	3.6	2.5	0.9	1.8	3.2	2.6	1.6	2.3	3.9	2.5	1.0	1.3	2.0
1	17	90	19	60.4	296.0	283.0	8.1	4.7	4	5	6.9	4.8	2.2	3.9	6.1	3.8	1.9	3.3	7.1	5.4	3.7	6.1	7.8	5.0	2.6	2.8	5.8

SITE #5

Mo	Dy	Yr	Hr BEG	TAVG F	WDM1 deg	WDM2 deg	WSM1 mph	WSM2 mph	SC1	SC2	Regulatory Default Obs ppm	C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm
11	2	89	19	52.8	336	339	2.4	2.3	6	6	15.5	7.8	3.7	5.2	10.5	5.5	3.0	6.0	10.9	5.4	2.2	4.2	8.6	4.0	2.3	5.1	7.4
10	11	89	20	56.1	301	300	4.6	5.0	6	6	14.6	7.2	3.2	4.2	8.1	4.9	1.8	3.4	8.2	1.2	1.0	1.1	3.4	1.6	0.6	1.1	2.5
11	9	89	15	57.7	257	253	4.5	5.0	4	4	10.4	9.9	7.1	8.4	10.9	7.9	4.7	7.3	11.2	3.9	2.1	2.4	5.6	2.9	1.7	2.6	5.2
10	25	89	16	68.8	259	250	3.3	3.6	3	3	9.9	8.4	6.5	8.2	10.3	7.3	5.2	6.7	9.3	4.0	2.5	3.1	6.0	3.2	2.4	3.2	4.5
10	25	89	15	71.9	345	341	3.5	2.8	2	2	9.3	9.5	7.9	8.1	10.2	8.3	5.7	6.9	10.9	3.9	2.4	3.0	5.3	3.0	2.5	3.7	6.2
10	26	89	13	72.7	352	335	4.2	3.2	3	2	8.9	9.0	6.0	6.6	10.3	6.8	3.7	4.3	10.6	3.8	1.8	2.2	5.7	2.5	1.4	2.3	5.6
10	27	89	15	71.0	350	353	5.1	4.1	3	3	8.7	9.3	7.0	8.0	10.6	7.5	4.9	8.1	10.8	3.3	2.0	2.5	4.5	2.3	2.0	2.9	4.7
10	27	89	14	72.5	350	349	4.3	3.8	3	2	8.4	9.4	8.1	7.4	11.2	12.1	5.1	5.2	11.2	3.7	2.4	2.6	5.8	2.9	1.9	2.7	5.8
11	22	89	16	34.3	309	304	5.1	5.3	4	4	7.6	13.1	11.9	11.4	13.4	7.8	7.4	9.8	13.3	3.7	2.5	2.9	4.3	2.8	2.2	2.7	3.8
10	26	89	15	71.7	1	1	5.7	4.2	3	3	7.4	9.5	7.9	8.3	10.5	7.8	4.7	6.8	10.5	3.1	1.8	2.5	4.6	2.2	1.8	2.9	4.9

SITE #6

Mo	Dy	Yr	Hr Beg	TAVG F	WDM1 deg	WSM1 mph	SC1	Regulatory Default Obs ppm	C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm	Measured Meteorology C3Q ppm	V9M ppm	GIM ppm	TEX ppm	EPA ppm	FHW ppm	IMM ppm	CAL ppm
2	16	90	15	42.4	263	2.5	4	8.1	12.3	7.4	10.9	13.4	12.2	12.8	7.0	10.6	6.8	3.8	4.5	5.7	6.5	3.6	5.3	3.5
1	3	90	16	44.5	244	2.2	3	7.5	11.7	6.9	10.0	13.0	11.5	9.2	6.8	9.8	5.9	3.9	4.6	5.8	6.7	3.0	5.9	2.9
2	16	90	16	43.4	274	2.2	4	7.0	9.9	6.0	8.0	10.1	10.2	9.7	7.3	9.8	7.4	4.3	4.8	5.7	7.4	4.3	6.1	4.0
1	24	90	17	56.2	207	2.5	4	7.0	10.6	6.0	9.0	12.9	10.3	8.7	6.2	9.0	3.5	5.0	5.0	8.2	7.6	2.8	3.9	2.6
2	13	90	19	49.4	221	3.5	6	5.0	7.2	4.9	5.3	11.2	6.5	4.8	4.3	7.2	1.0	2.1	2.0	4.8	3.2	1.1	2.5	2.1
1	31	90	17	45.9	223	2.7	3	4.8	11.6	6.8	9.8	13.1	11.4	9.1	6.7	9.8	4.1	4.1	4.6	6.3	6.9	2.7	5.3	2.8
2	1	90	16	52.6	71	3.4	3	4.8	8.8	5.0	7.2	10.1	8.4	6.2	6.0	9.3	3.1	1.7	2.8	5.3	3.1	3.2	3.3	3.1
2	16	90	17	42.0	249	2.5	4	4.8	11.3	6.3	9.2	12.5	10.2	7.3	5.8	9.6	2.6	3.6	4.0	5.3	5.5	2.3	4.5	3.3
1	25	90	17	52.8	74	3.4	4	4.8	8.7	5.0	7.0	10.5	8.5	6.7	6.3	8.8	3.4	1.9	2.9	5.4	3.4	3.4	3.8	2.8
1	31	90	16	47.0	229	3.0	3	4.6	11.2	6.4	9.8	13.5	10.7	9.3	6.2	9.7	2.9	3.6	4.0	5.8	5.7	2.4	4.3	2.7

Note: TAVG = average temperature over all monitors; WDM<1 2 3> = wind direction at monitor 1, 2 or 3; WSM<1 2 3> = wind speed at monitor 1, 2, or 3; SC<1 2 3> = stability class at monitor 1, 2, or 3; Obs = Observed; C3Q = CAL3QHC; V9M = VOL9MOB4; TEX = TEXIN2; EPA = EPAINT; FHW = FHWAINT; CAL = CALINE4

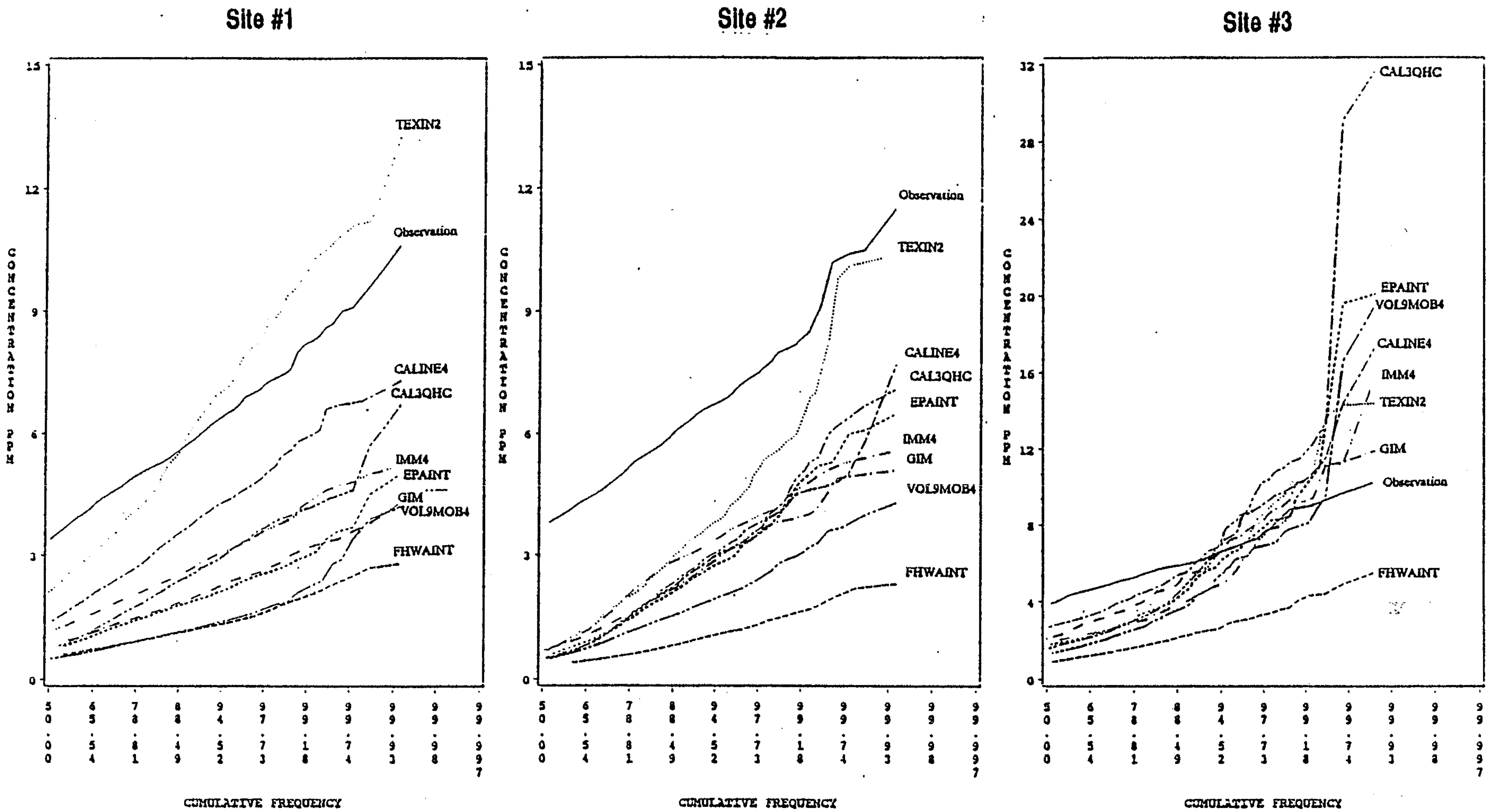


Figure A-1 The cumulative frequency of observed and predicted concentrations for each model evaluated using MOBILE4.0 emissions at Sites #1, 2, and 3.

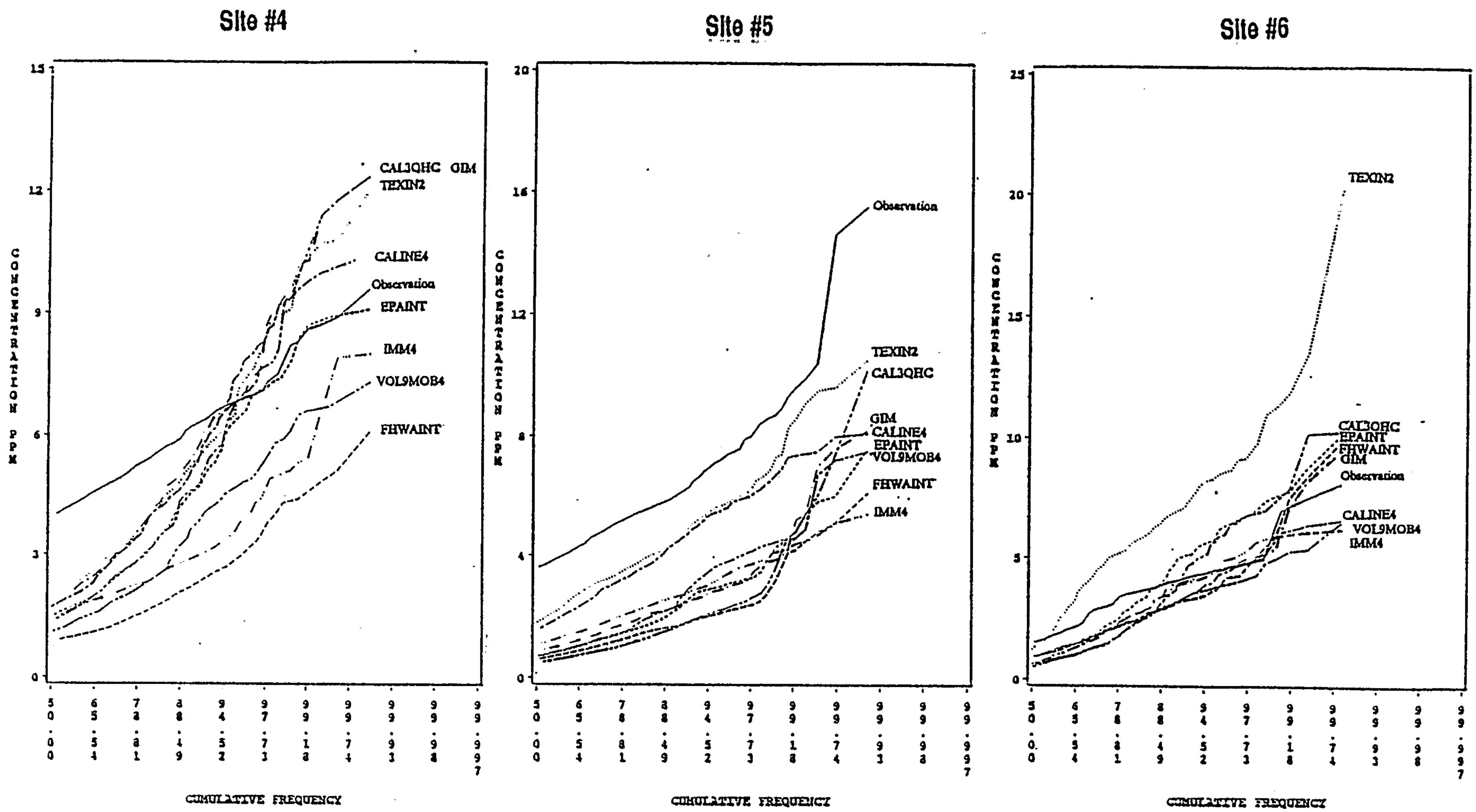


Figure A-2 The cumulative frequency of observed and predicted concentrations for each model evaluated using MOBILE4.0 emissions at Site #4, 5, and 6.

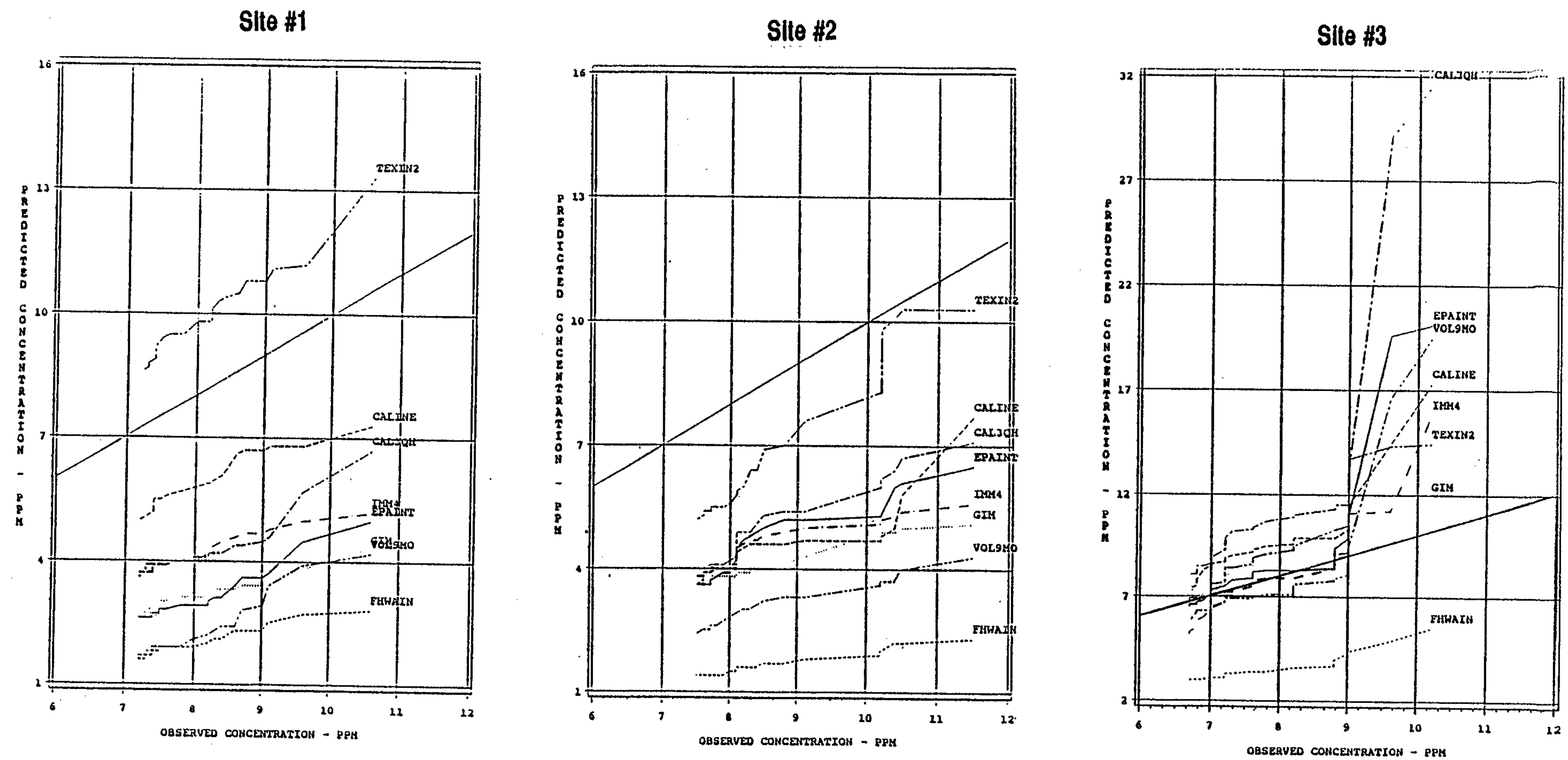


Figure A-3 The 25-highest observed versus predicted concentrations for each model evaluated using MOBILE4.0 emissions at Sites #1, 2, and 3. The solid, unmarked line is the 1:1 perfect fit.

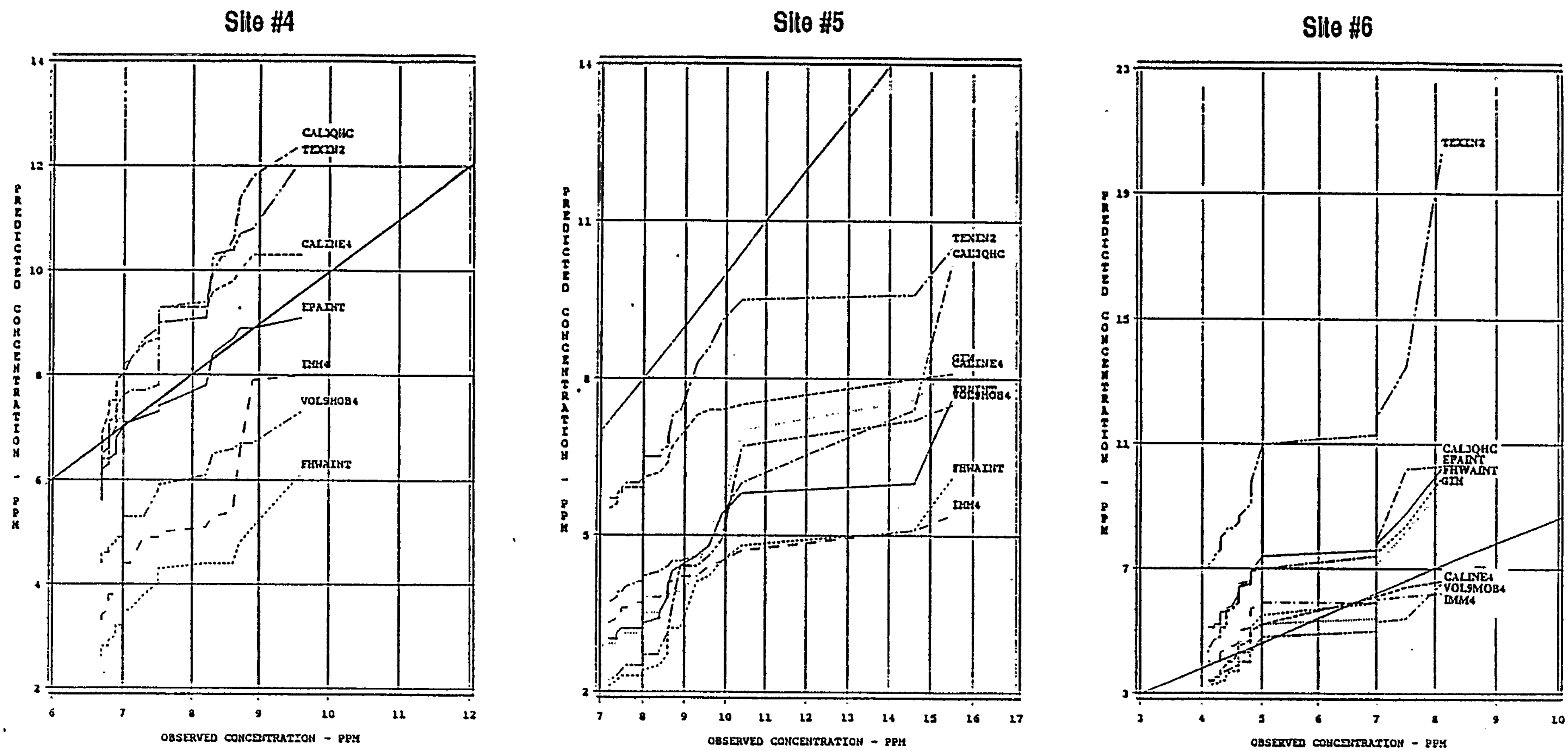
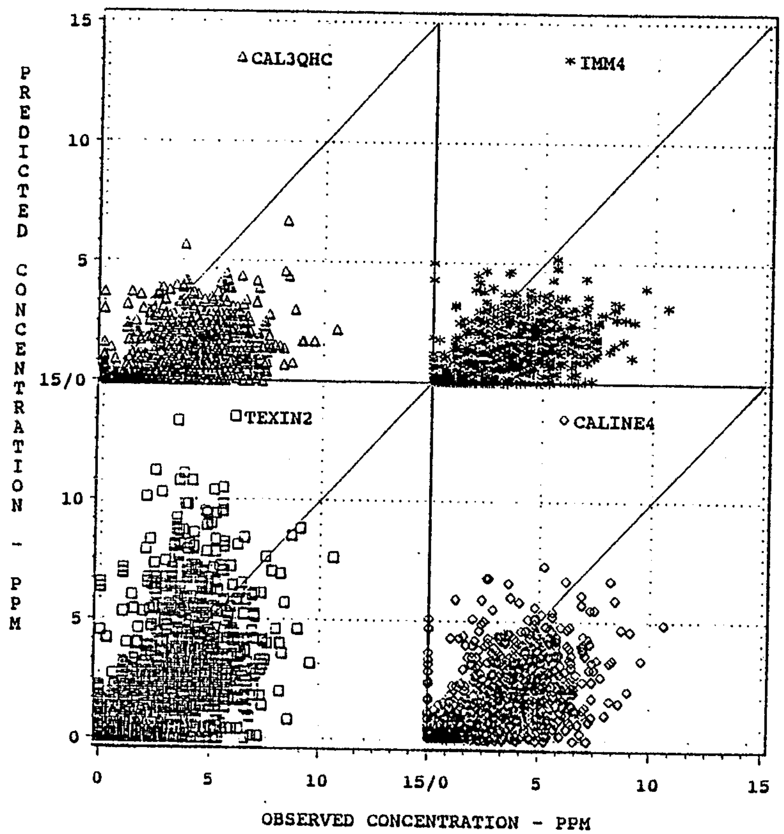


Figure A-4 The 25-highest observed versus predicted concentrations for each model evaluated using MOBILE4.0 emissions at Sites #4, 5, and 6. The solid, unmarked line is the 1:1 perfect fit.

SITE 1 – ALL DATA



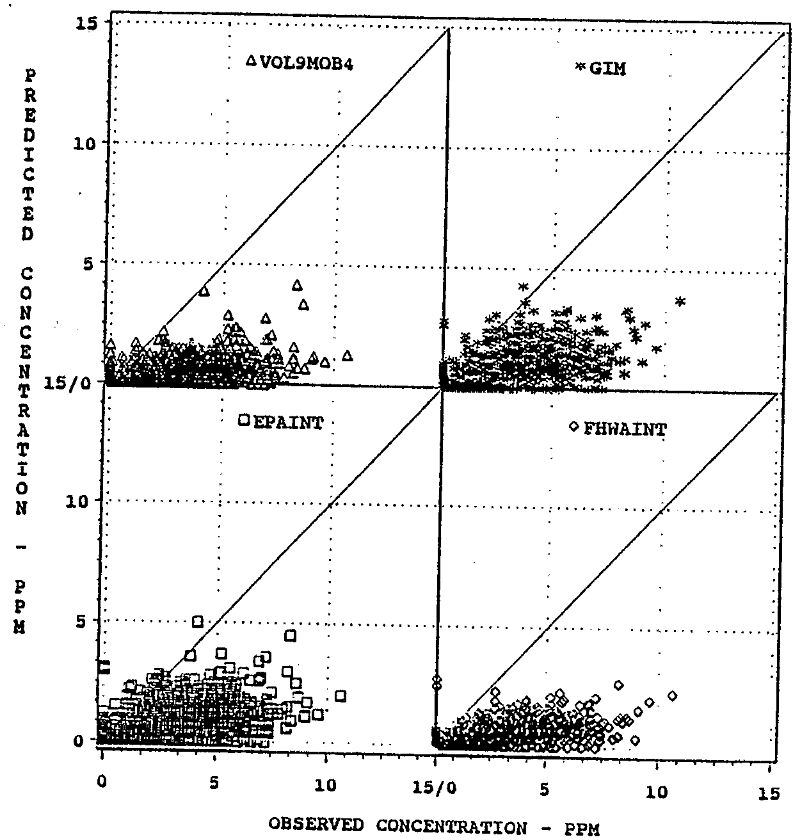


Figure A-5 Scatterplots of observed versus predicted concentrations for each model evaluated using MOBILE4.0 emissions at Site #1.

SITE 2 – ALL DATA

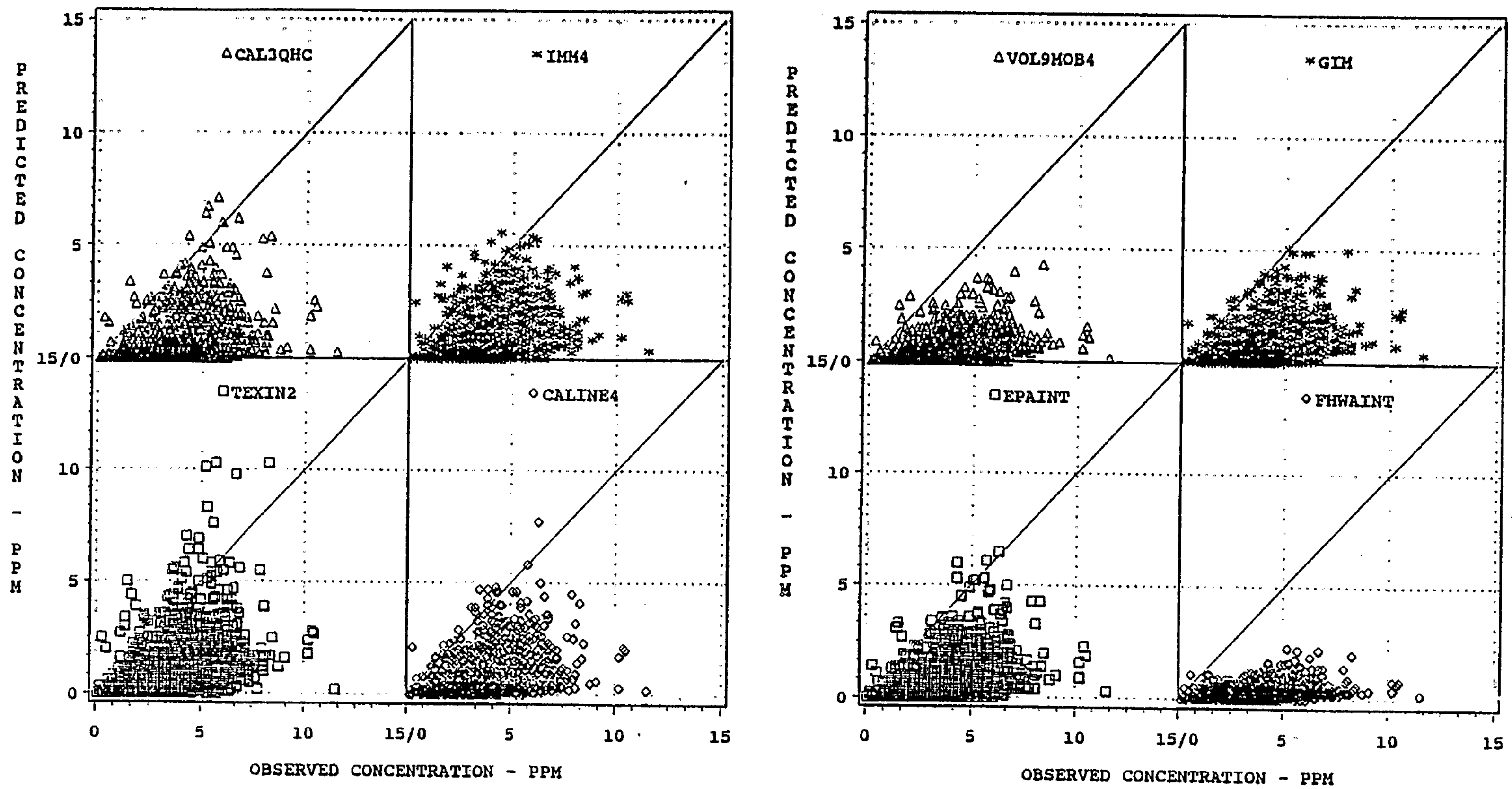


Figure A-6 Scatterplots of observed versus predicted concentrations for each model evaluated using MOBILE4.0 emissions at Site #2.

SITE 3 – ALL DATA

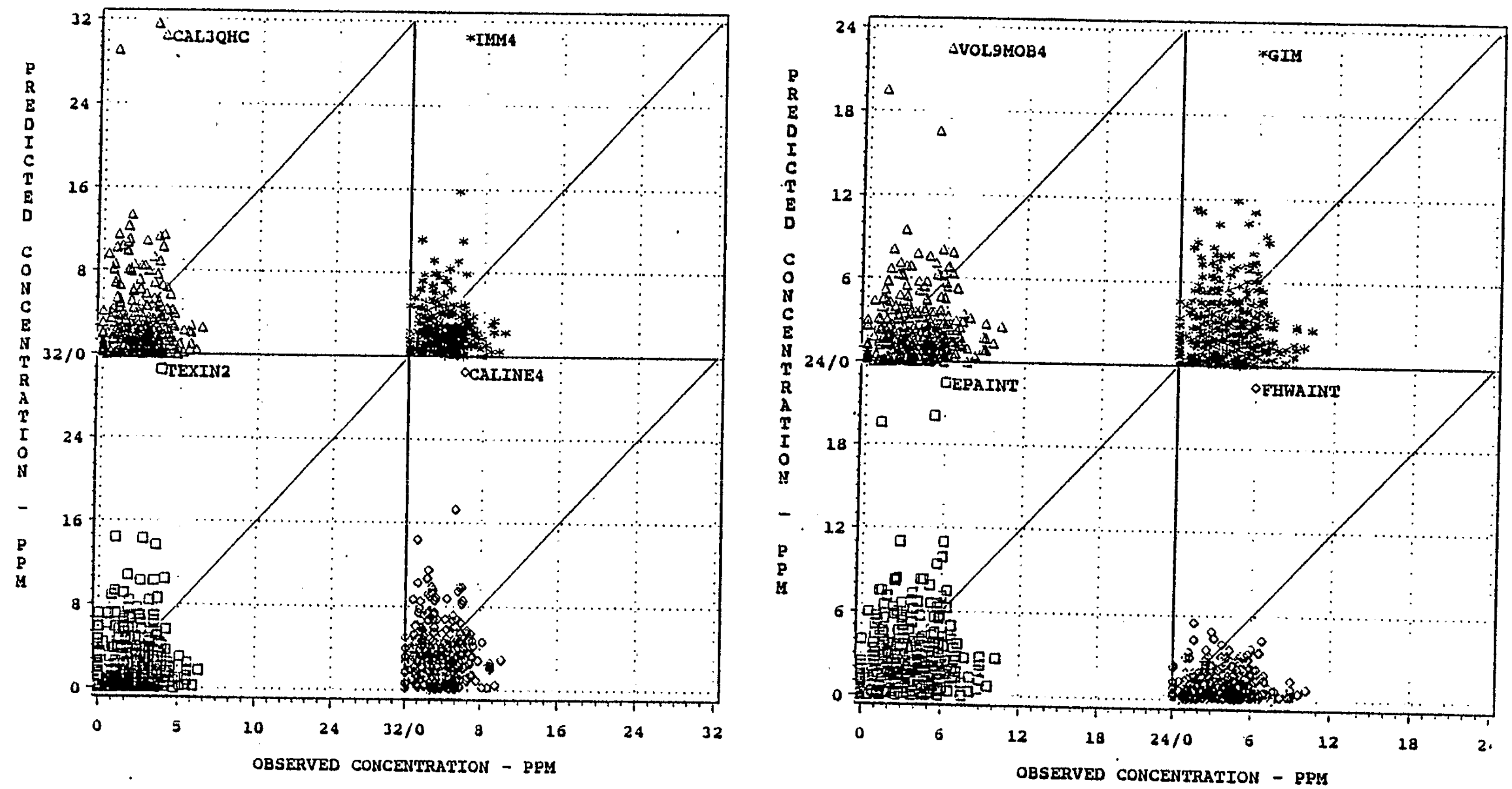


Figure A-7 Scatterplots of observed versus predicted concentrations for each model evaluated using MOBILE4.0 emissions at Site #3.

SITE 4 – ALL DATA

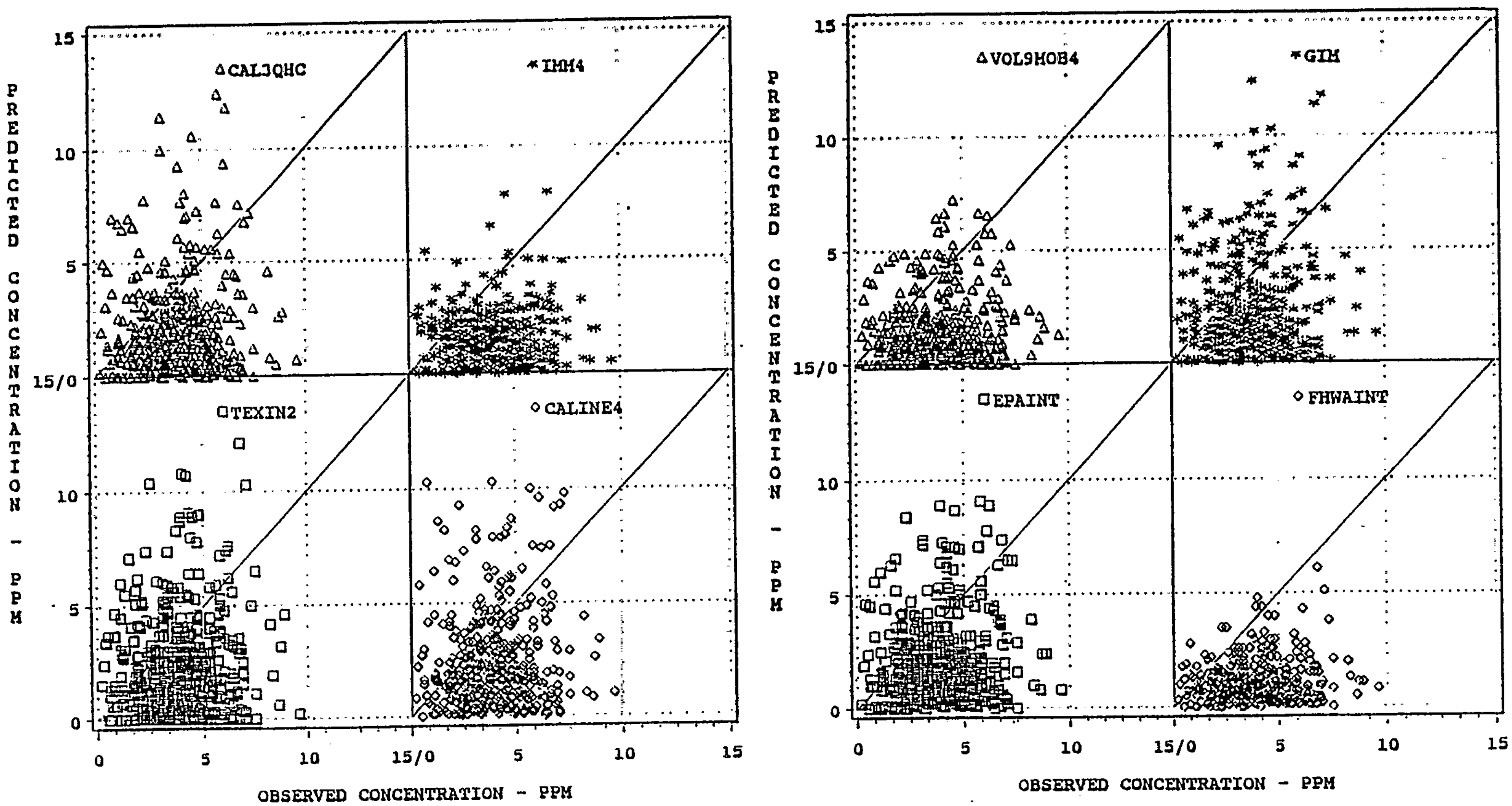


Figure A-8 Scatterplots of observed versus predicted concentrations for each model evaluated using MOBILE4.0 emissions at Site #4.

SITE 5 – ALL DATA

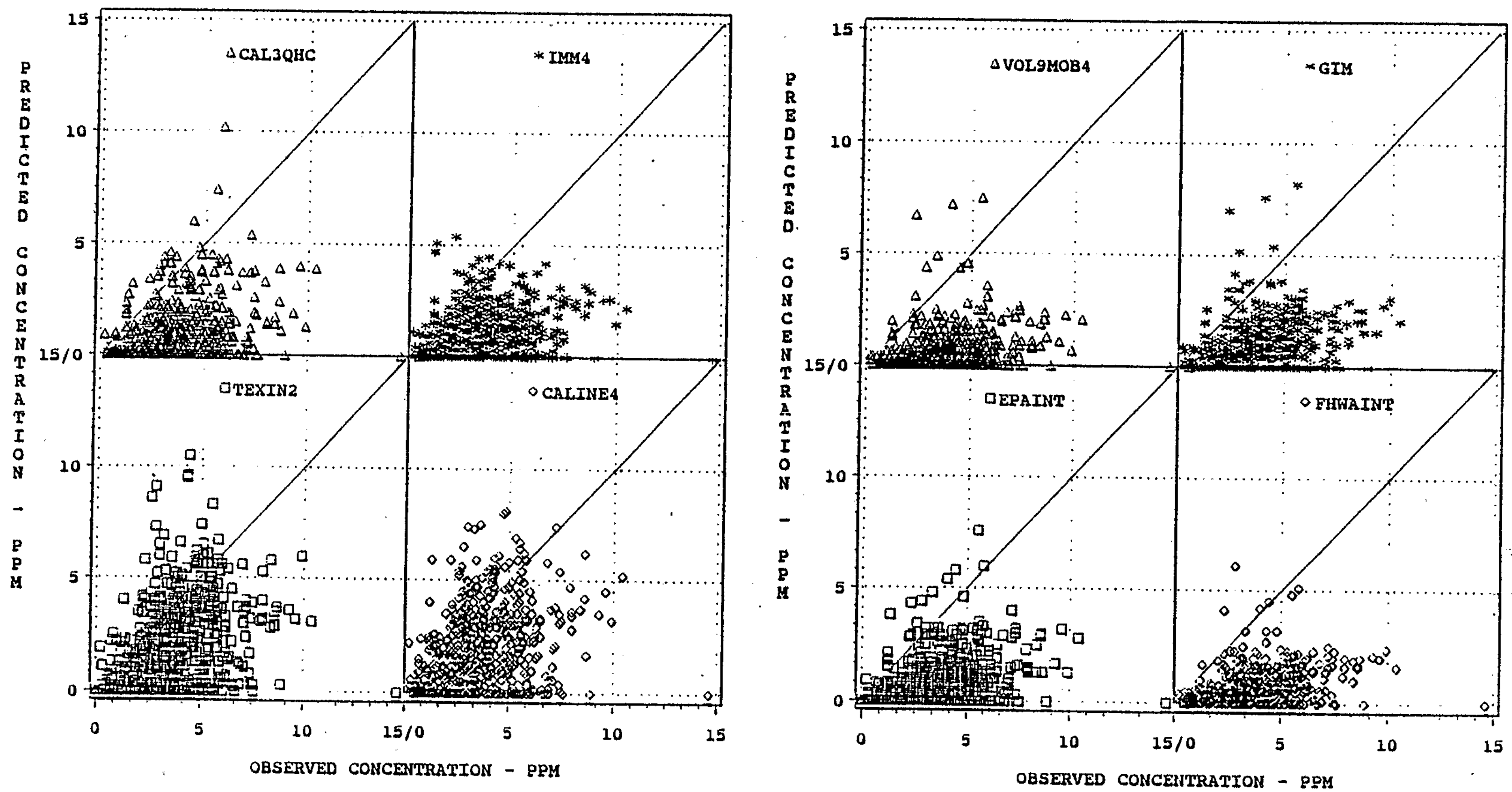


Figure A-9 Scatterplots of observed versus predicted concentrations for each model evaluated using MOBILE4.0 emissions at Site #5.

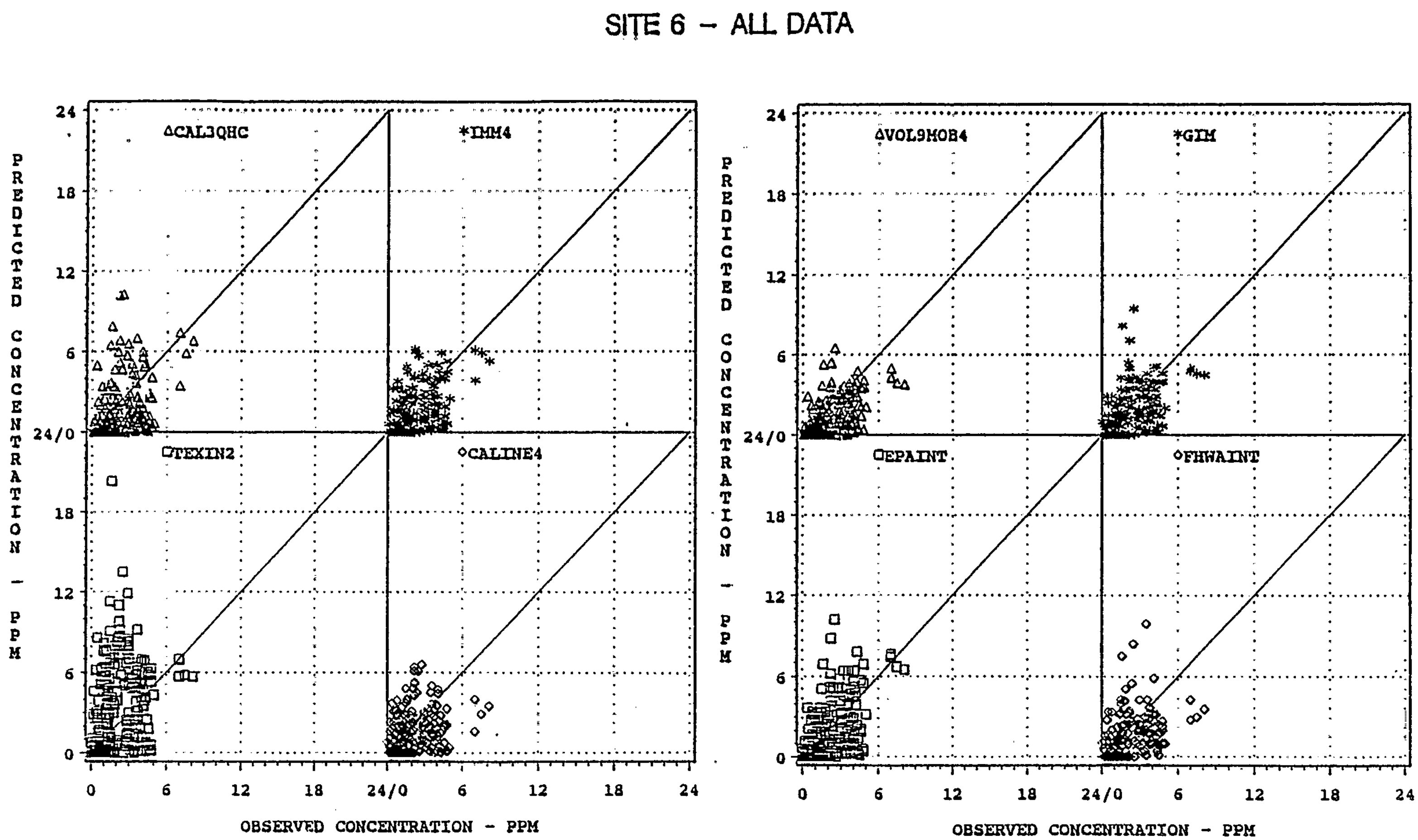


Figure A-10 Scatterplots of observed versus predicted concentrations for each model evaluated using MOBILE4.0 emissions at Site #6.

APPENDIX B

RESIDUAL PLOTS USING MOBILE4.1 EMISSIONS

SITE 1

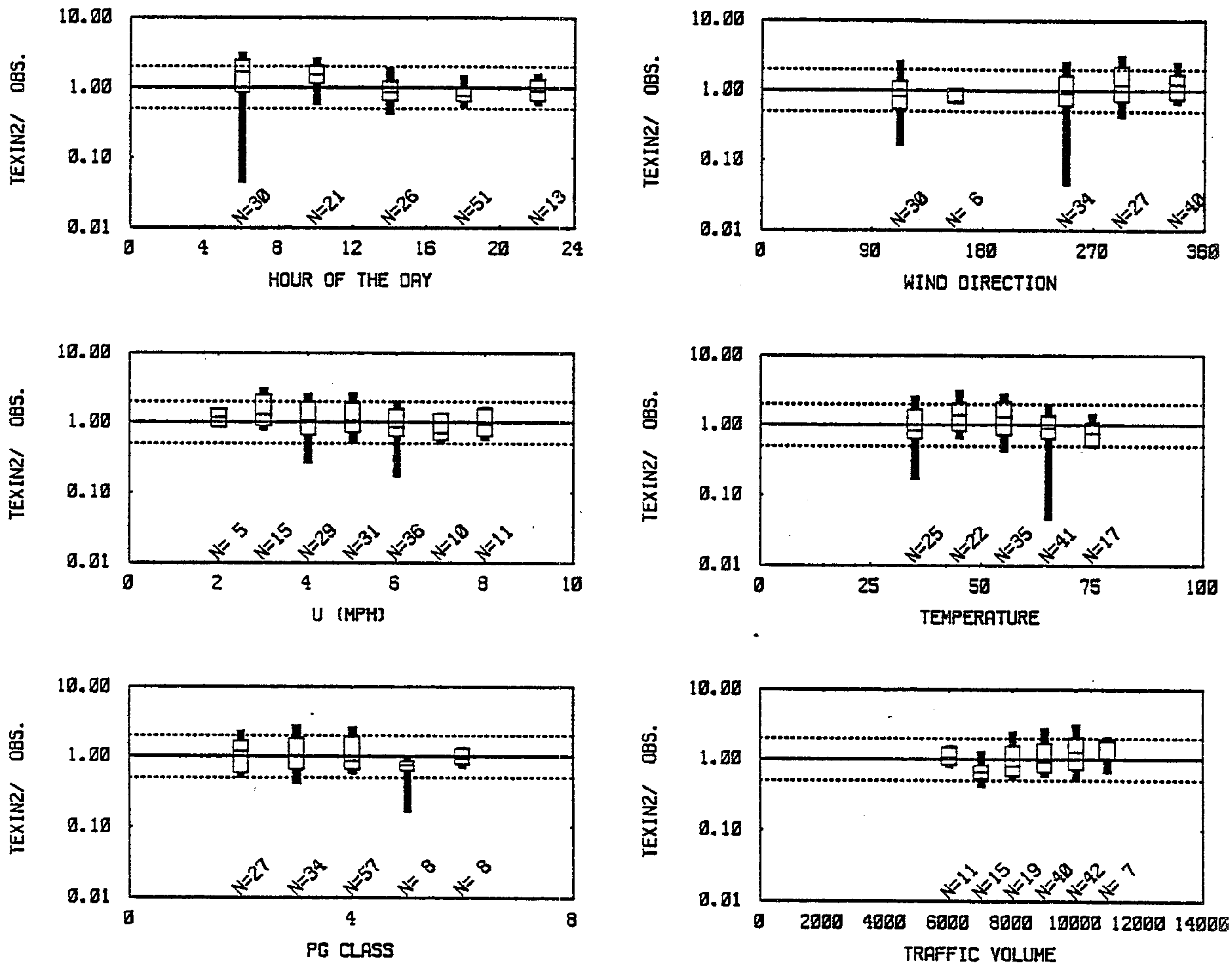


Figure B-1. The residual or ratio of the predicted to observed concentration using the TEXIN2 model with MOBILE4.1 emissions at Site #1 plotted versus the hour of the day, wind direction, wind speed (u), ambient temperature, Pasquill-Gifford (PG) stability class, and traffic volume. Significant points on each box plot represent the 2nd, 16th, 50th, 84th, and 98th percentiles. The number of observations used in each box are also labelled near the bottom as "N = #." The dashed lines represent the factor of two lines.

SITE 1

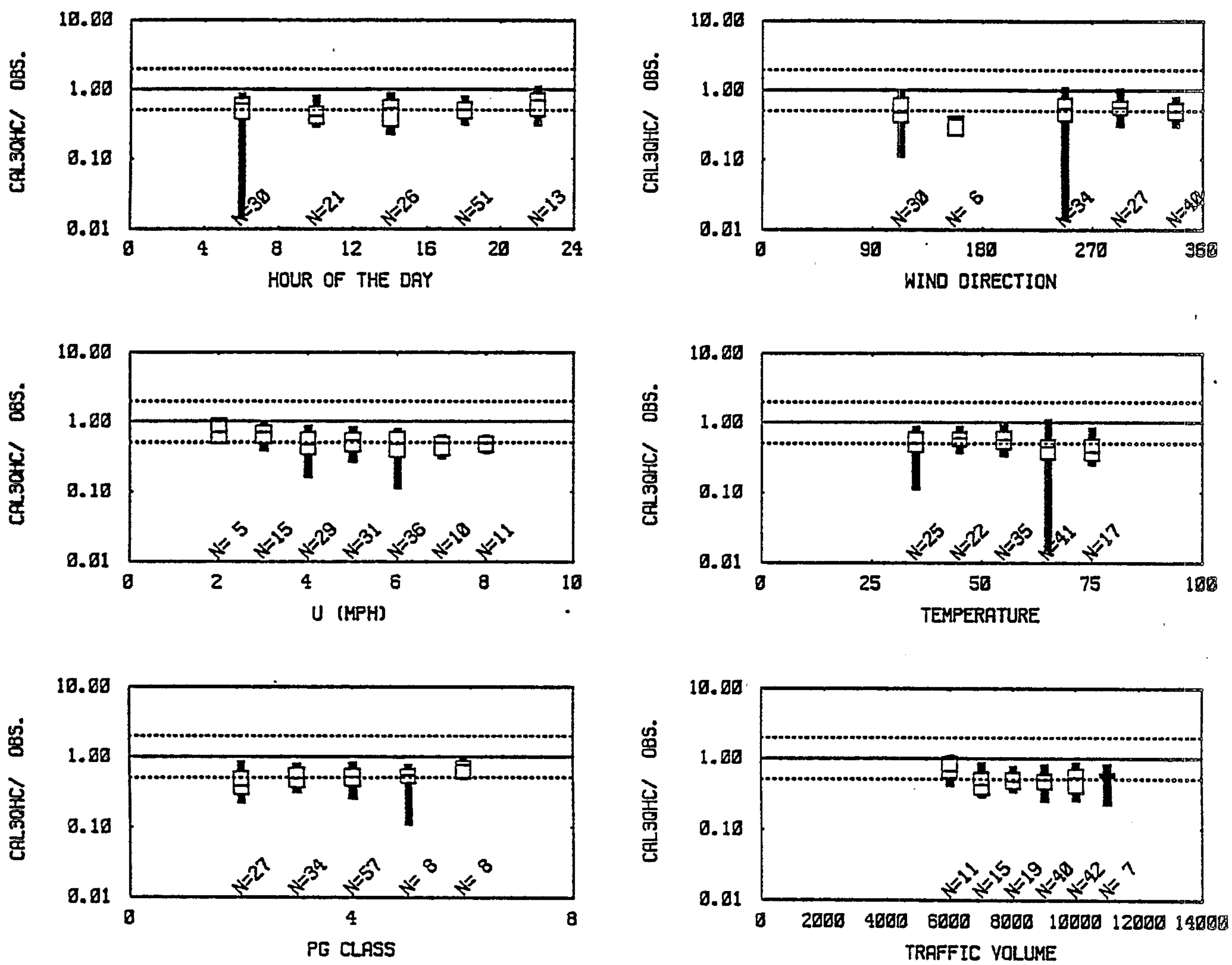


Figure B-2. Same as Figure B-1 except for the CAL3QHC model.

SITE 1

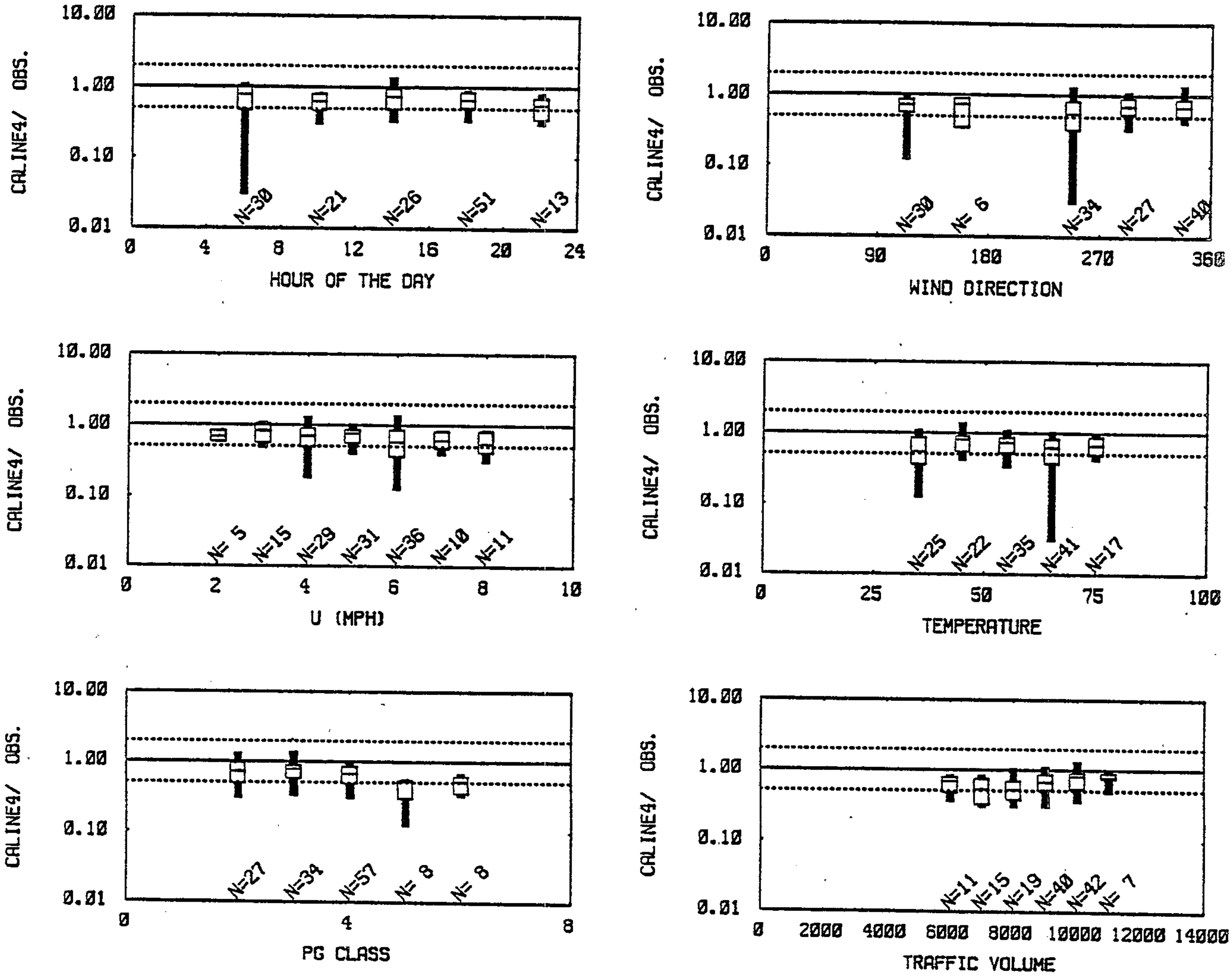


Figure B-3. Same as Figure B-1 except for the CALINE4 model.

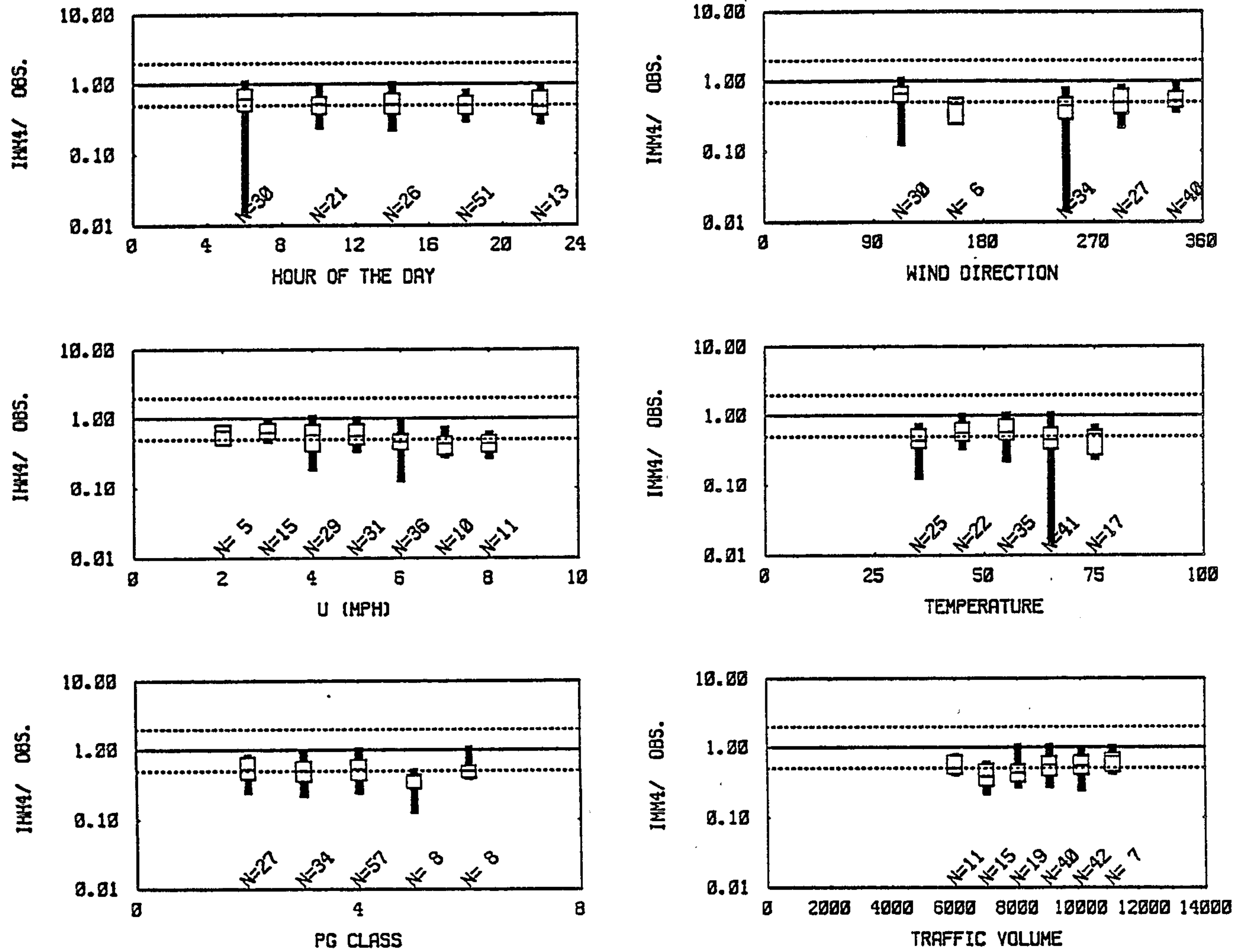


Figure B-4. Same as Figure B-1 except for the IMM model.

SITE 1

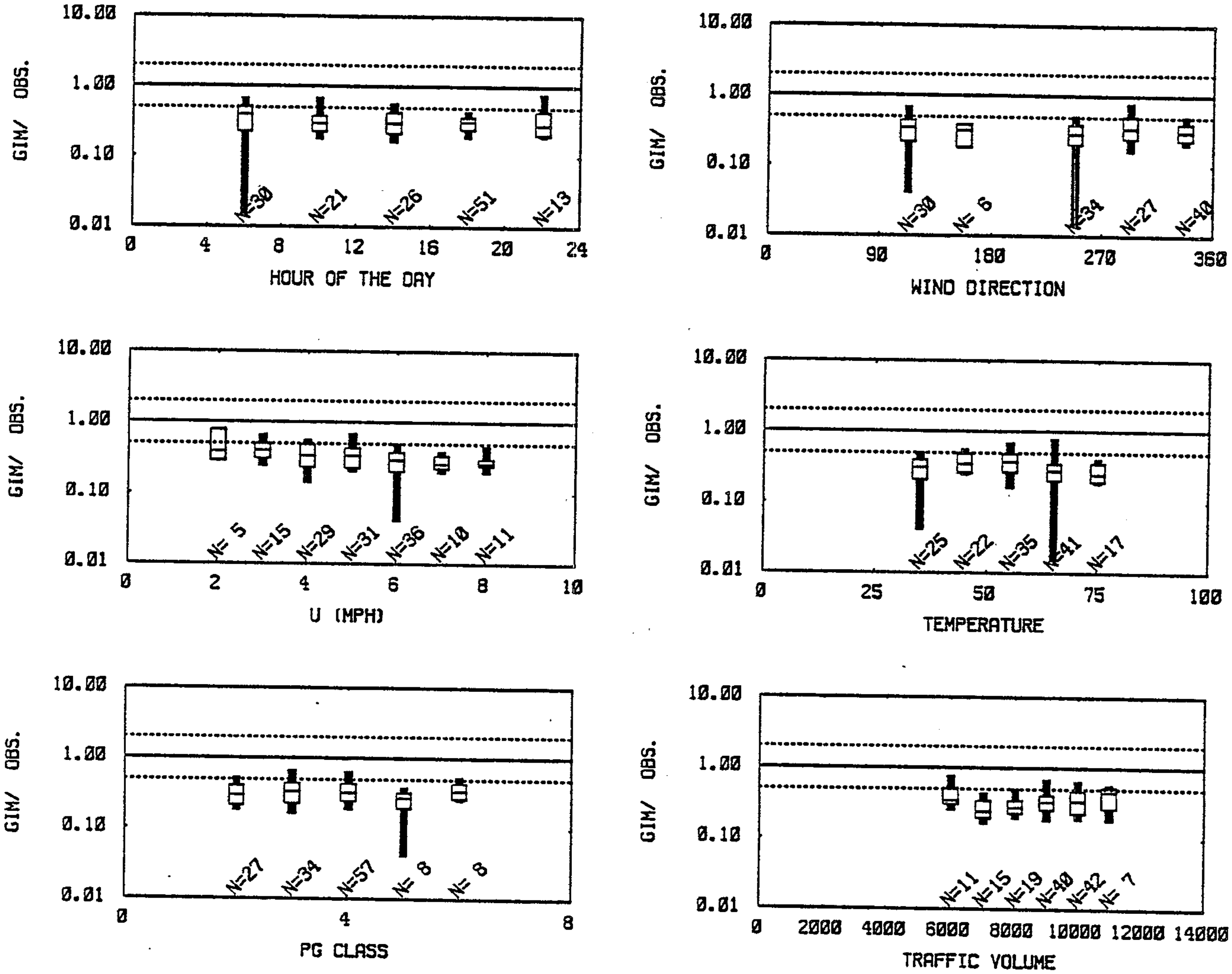


Figure B-5. Same as Figure B-1 except for the GIM model.

SITE 2

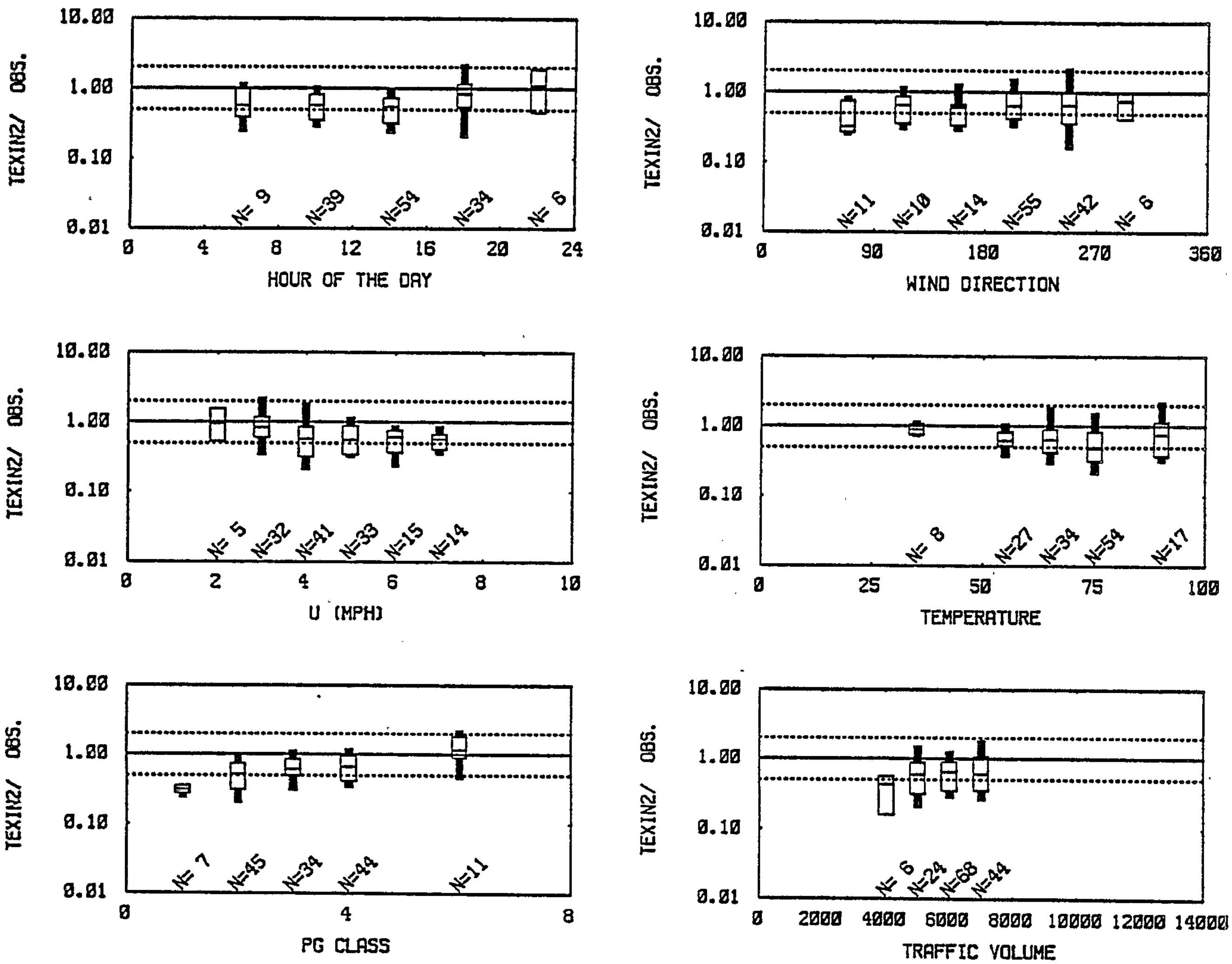


Figure B-6. Same as Figure B-1 except for the TEXIN2 model at Site #2.

SITE 2

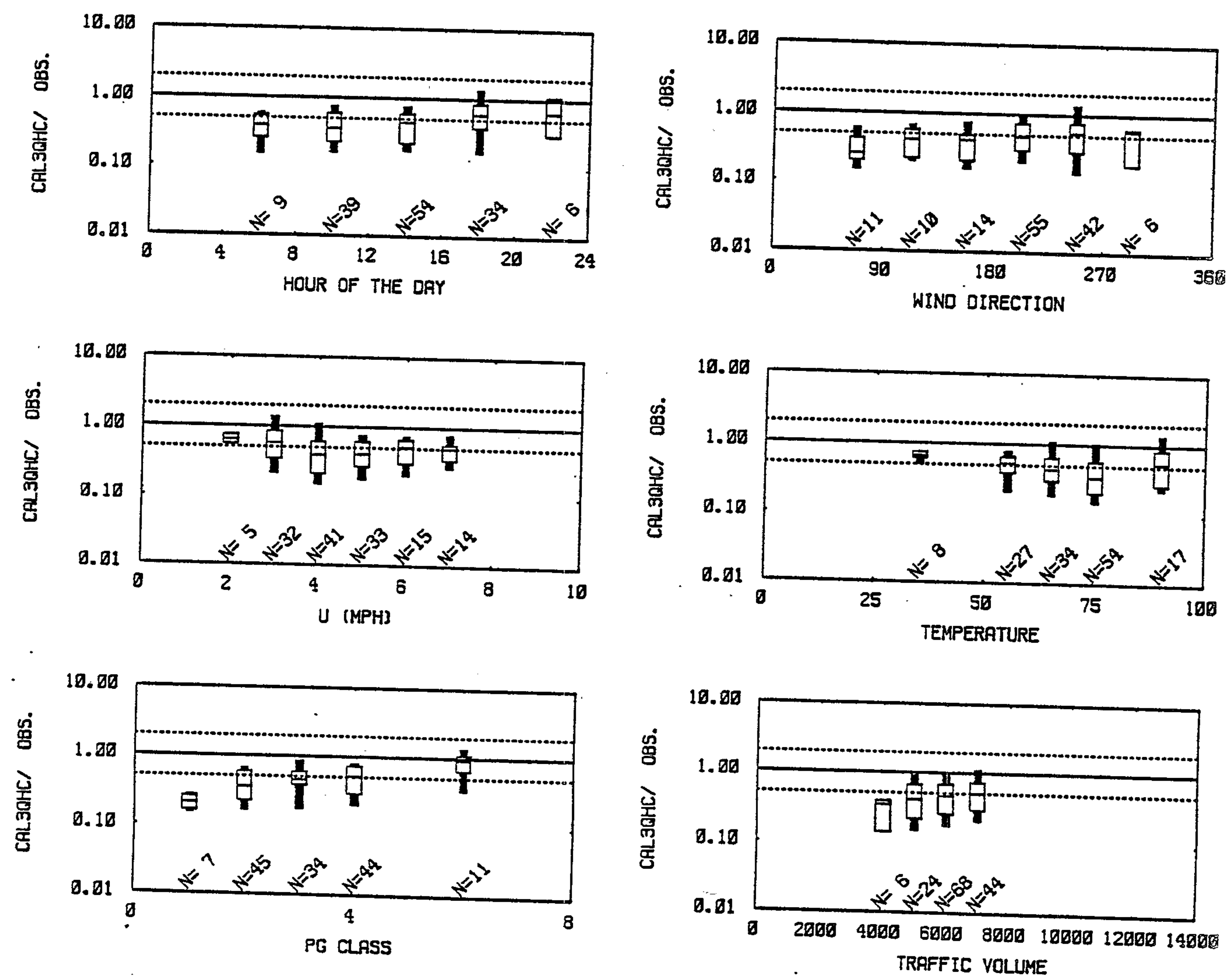


Figure B-7. Same as Figure B-1 except for the CAL3QHC model at Site #2.

SITE 2

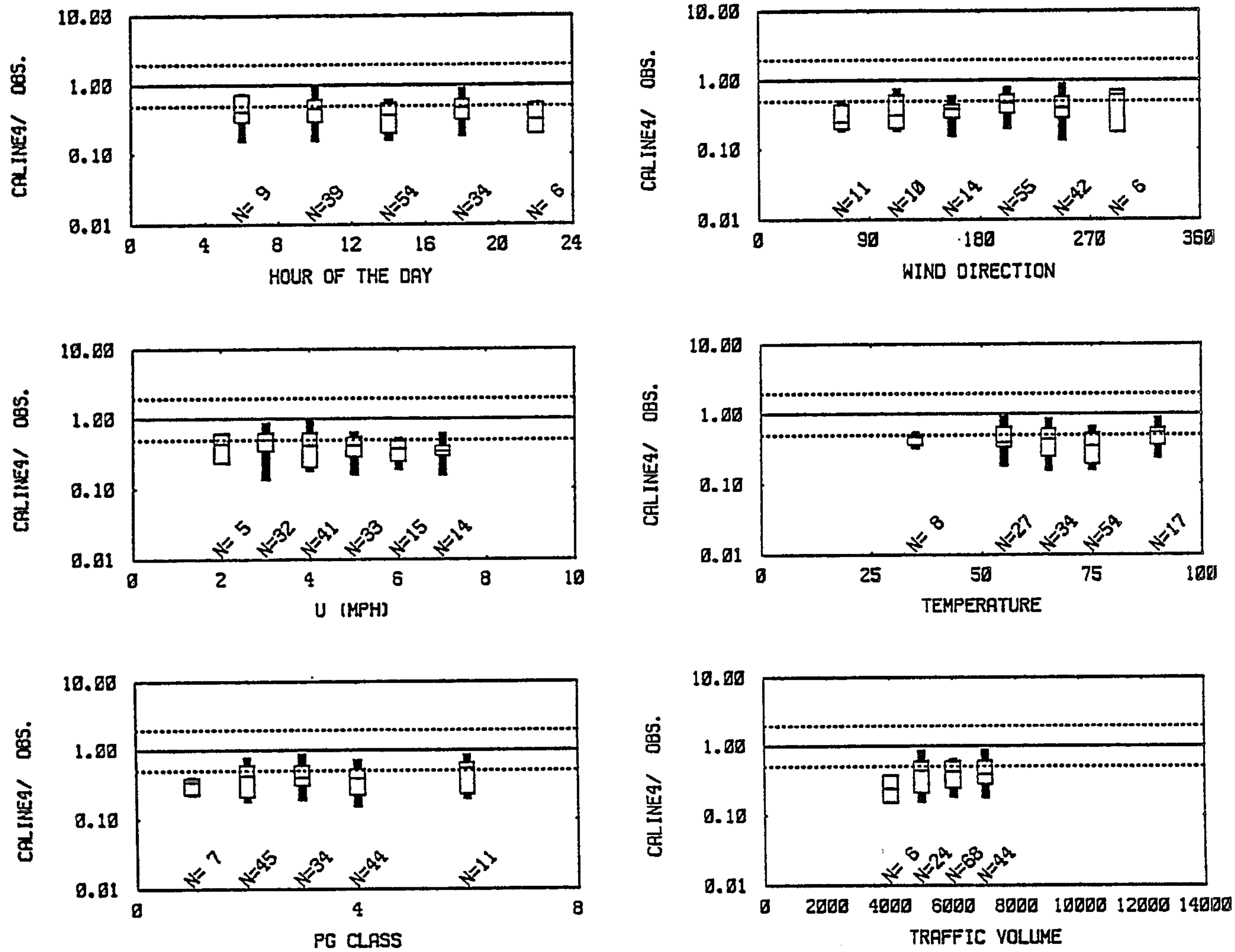


Figure B-8. Same as Figure B-1 except for the CALINE4 model at Site #2.

SITE 2

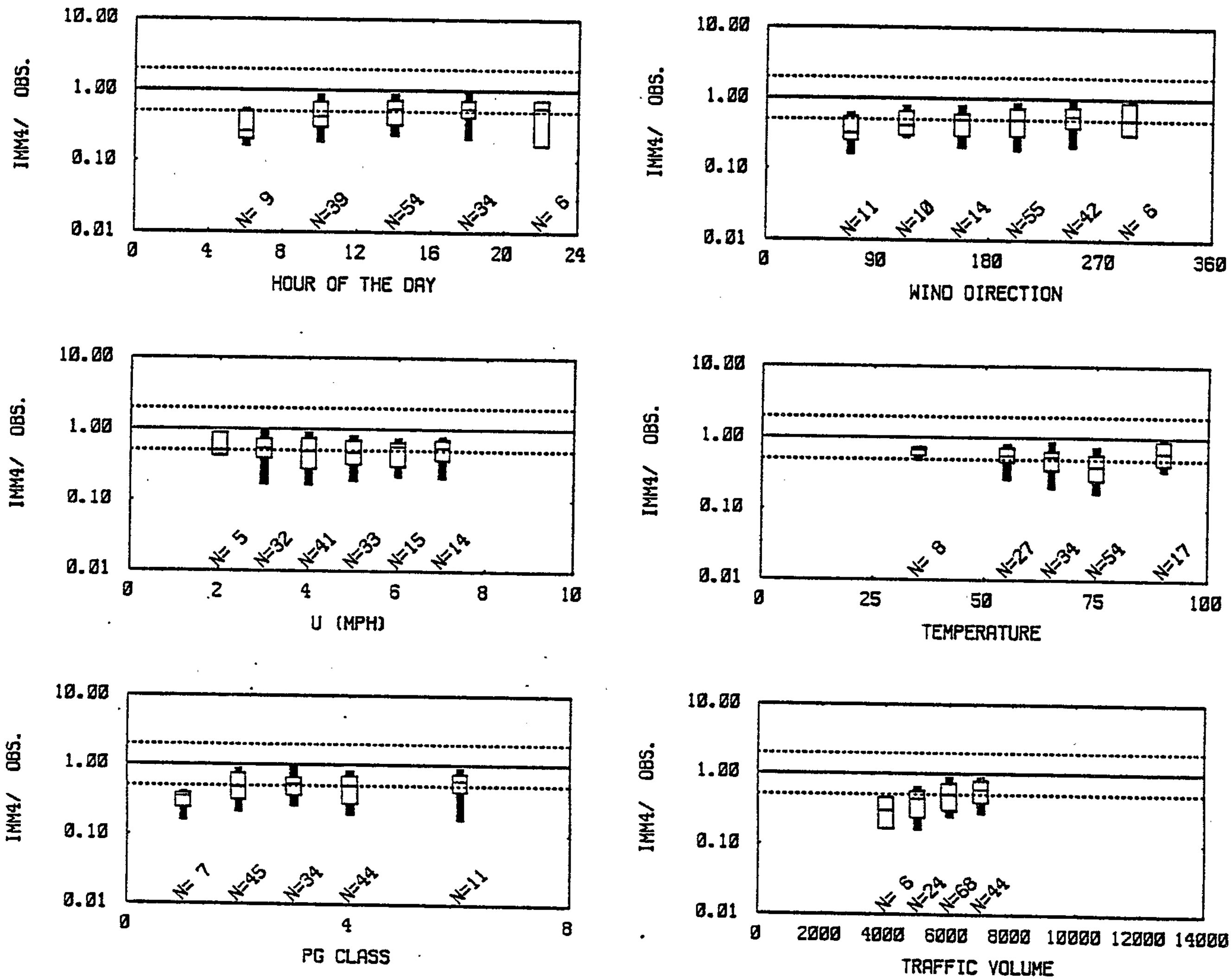


Figure B-9. Same as Figure B-1 except for the IMM model at Site #2.

SITE 2

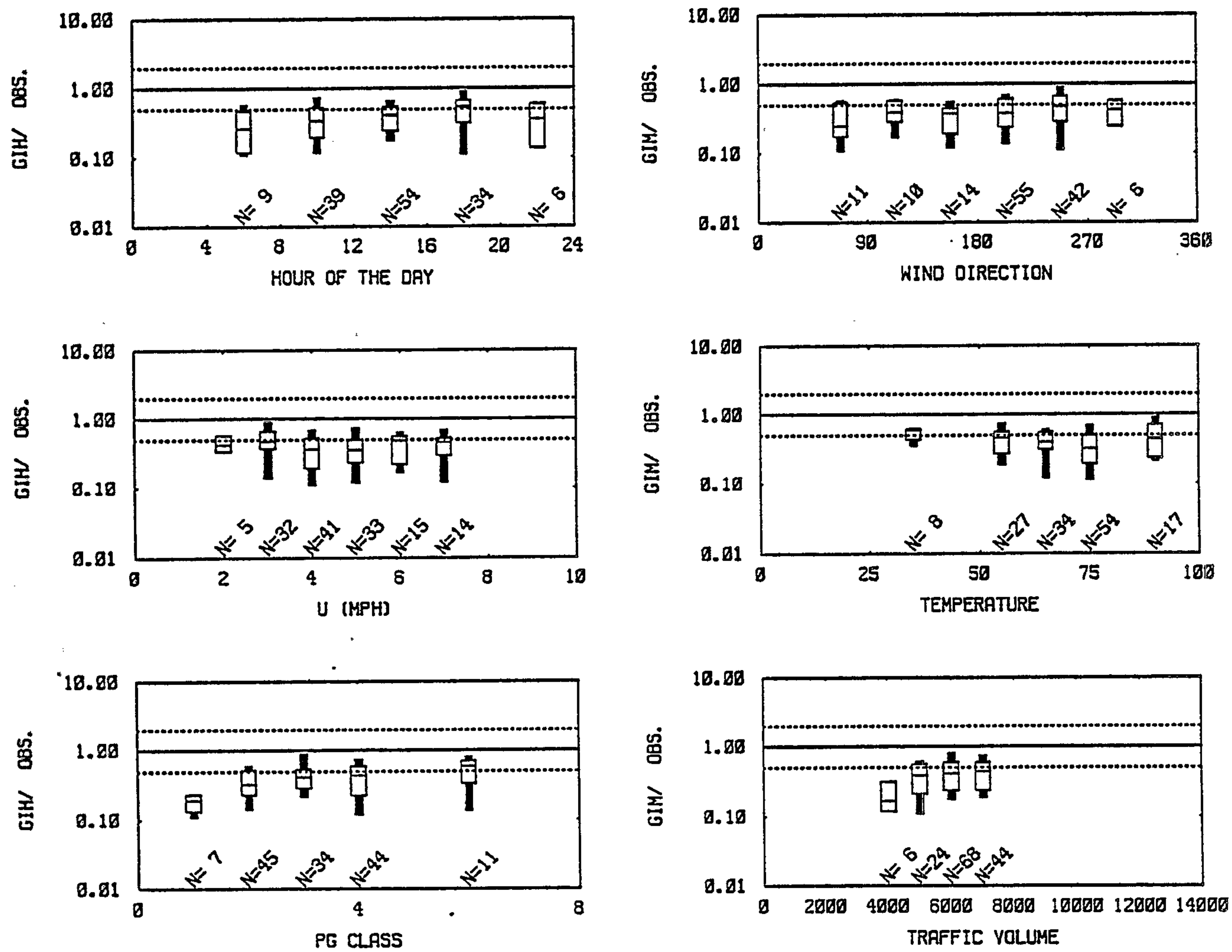


Figure B-10. Same as Figure B-1 except for the GIM model at Site #2.

SITE 5

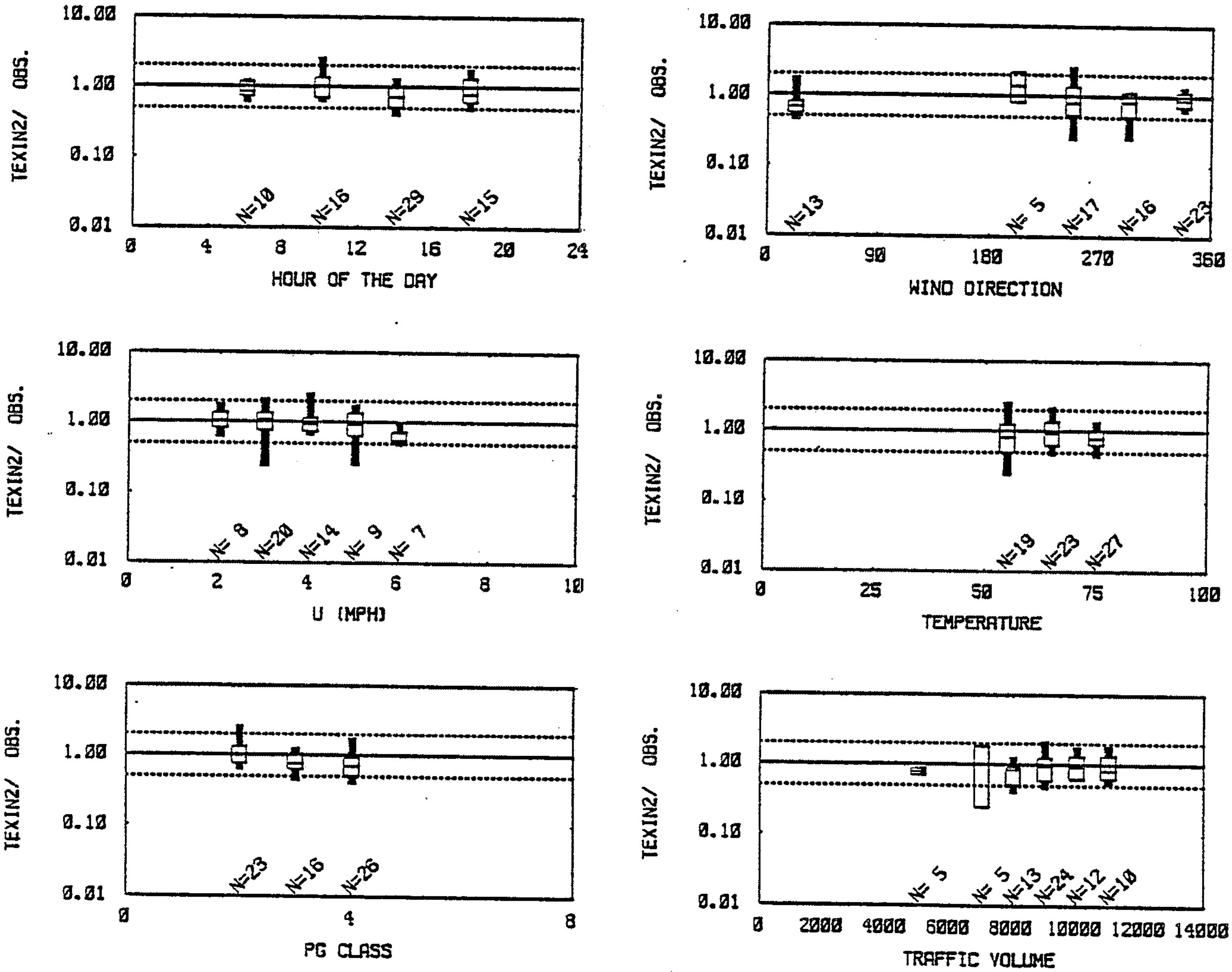


Figure B-11. Same as Figure B-1 except for the TEXIN2 model at Site #5.

SITE 5

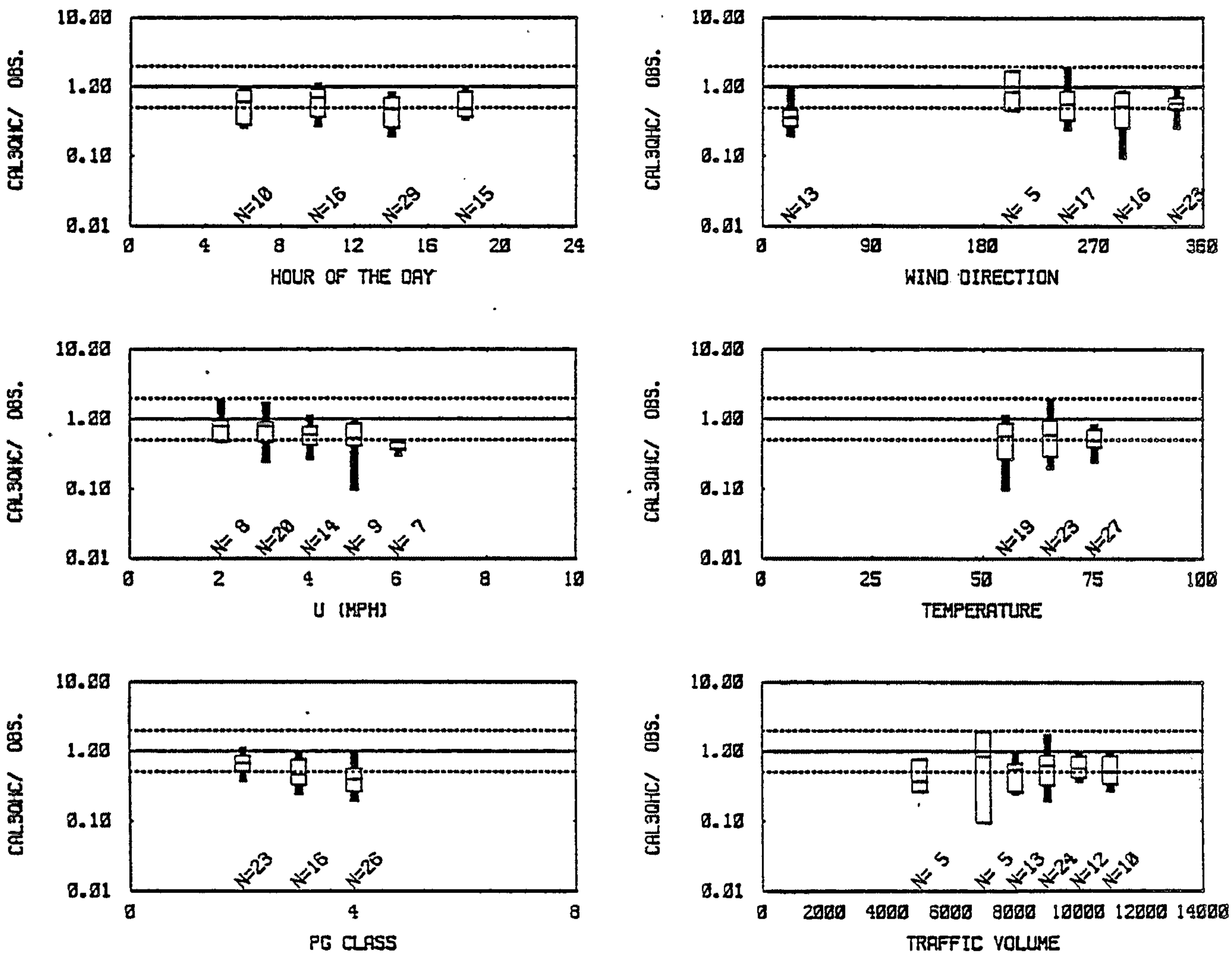


Figure B-12. Same as Figure B-1 except for the CAL3QHC model at Site #5.

SITE 5

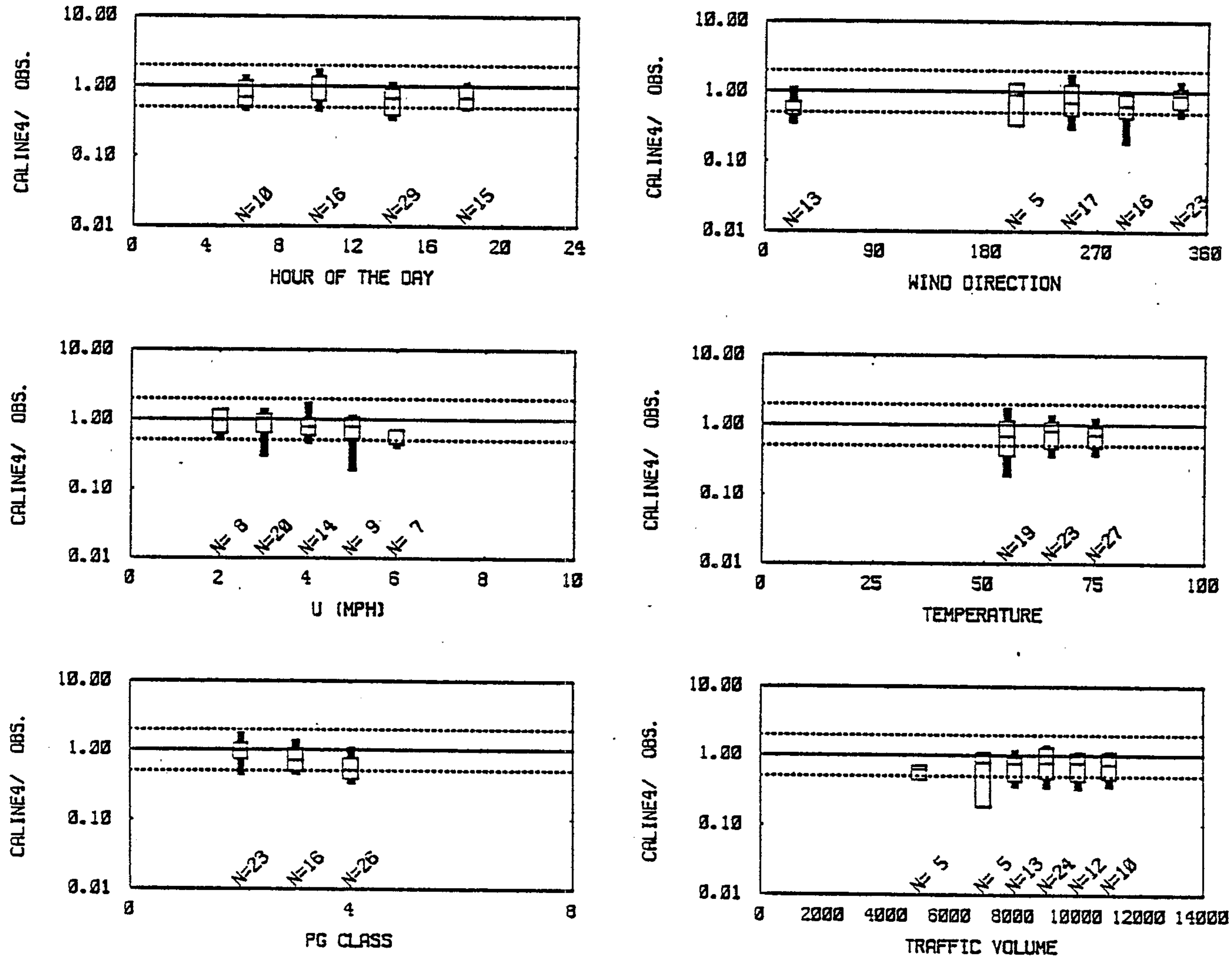


Figure B-13. Same as Figure B-1 except for the CALINE4 model at Site #5.

SITE 5

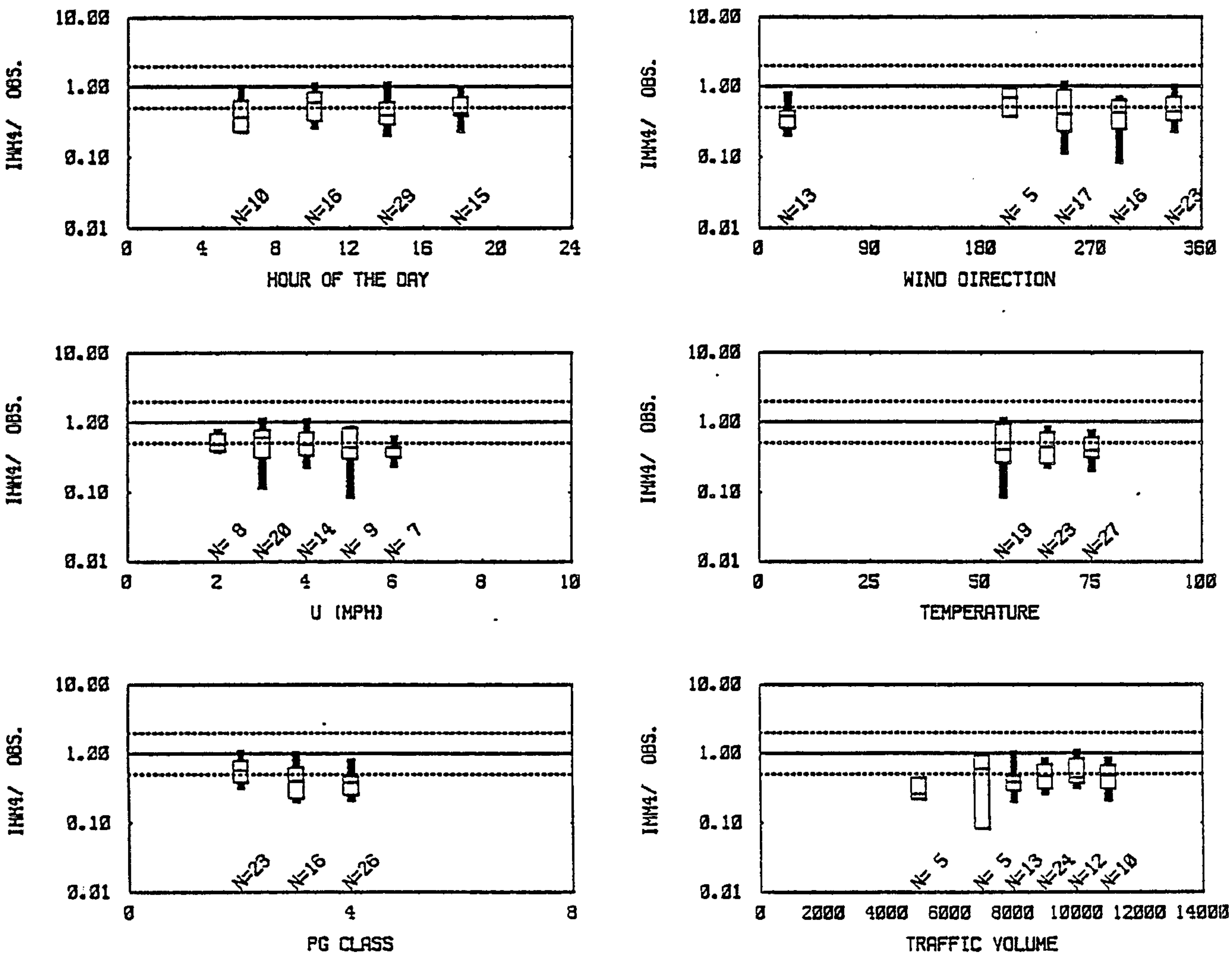


Figure B-14. Same as Figure B-1 except for the IMM model at Site #5.

SITE 5

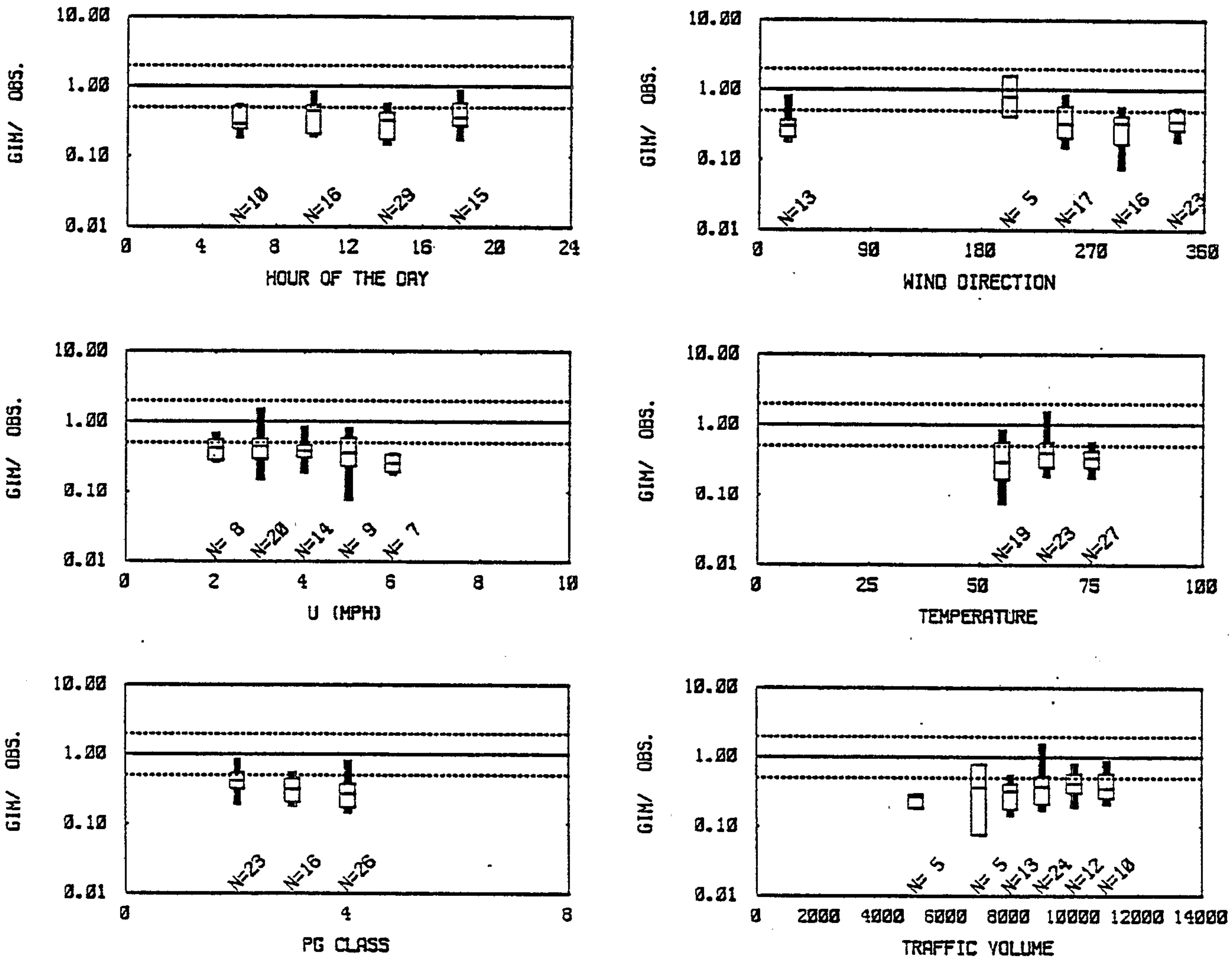


Figure B-15. Same as Figure B-1 except for the GIM model at Site #5.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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16. ABSTRACT

A New York City database has been used to evaluate eight intersection modeling techniques in simulating CO concentrations. The database consists of 1990 monitored meteorological, CO air quality, and traffic data collected at six intersection sites. The modeling techniques evaluated are CAL3QHC, FHWAINT, GIM, EPAINT, CALINE4, IMM, VOL9MOB4, and TEXIN2. A phase I evaluation was conducted for all eight modeling techniques using MOBILE4 emissions at the six intersection sites. Then, a phase II evaluation was conducted using MOBILE4.1 emissions for a subset of intersection models (CAL3QHC, GIM, IMM, TEXIN2, and CALINE4) at the three intersection sites with the best data quality. This report provides the results of the performance evaluation.

17. KEY WORDS AND DOCUMENT ANALYSIS

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