

# Carbon Monoxide Categorical Hot-Spot Finding Technical Document

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**FINAL**

**Prepared For:  
Federal Highway Administration**



U.S. Department of Transportation  
**Federal Highway Administration**

**Prepared By:**

**Volpe National Transportation Systems Center**



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# 1. Introduction

## 1.1 Purpose of this Document

The purpose of this technical document is to describe the modeling process and analysis used to support the Federal Highway Administration (FHWA) carbon monoxide (CO) categorical hot-spot finding for intersections using MOVES2010b as described in later sections of this document. The modeling does not apply to California which uses EMFAC for its emissions model. The modeling process described in this document includes the input determination process, use of guidance materials, MOVES emission modeling, and CAL3QHC dispersion modeling. This document only covers the modeling process that was used to support FHWA's CO categorical hot-spot finding and is not intended to describe the implementation of results. FHWA's CO categorical hot-spot finding and the MOVES2010b and CAL3QHC files are available on FHWA's [CO categorical hot-spot finding website](#).

## 1.2 Regulatory Background for the CO Categorical Hot-Spot Finding

A CO categorical hot-spot finding was included in the January 24, 2008 final conformity rule amendments at 40 CFR 93.123(a)(3) and explained in the preamble at 73 FR 4432-4434. This provision allows the U.S. Department of Transportation (USDOT), in consultation with the Environmental Protection Agency (EPA) to make a categorical hot-spot finding that the requirements in 40 CFR 93.116(a) are met without any further hot-spot analysis for applicable FHWA and FTA projects in CO nonattainment or maintenance areas. This finding must be based on "appropriate modeling" and may consider current air quality circumstances for a given CO nonattainment or maintenance area\*.

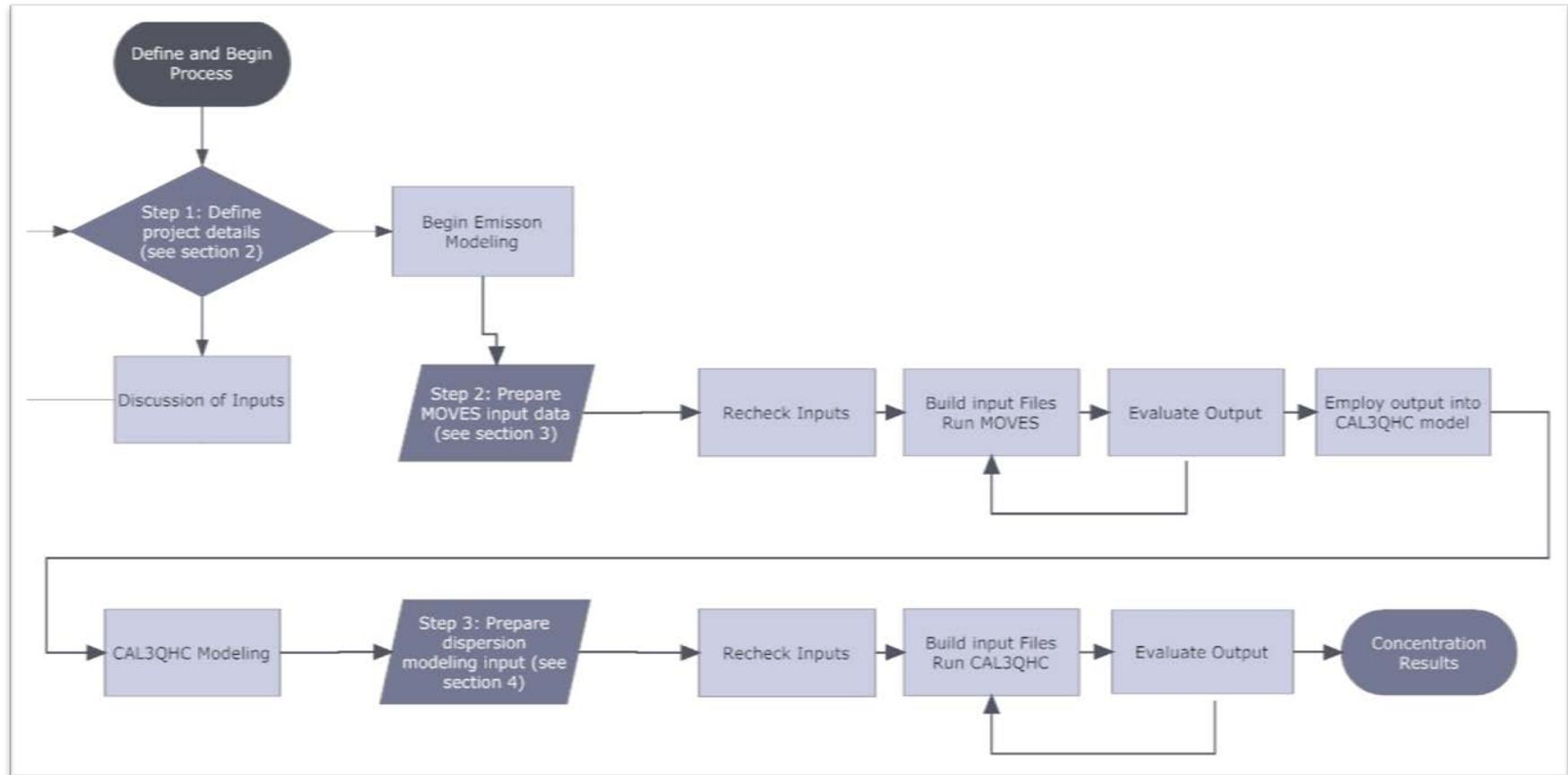
## 1.3 Overview of Modeling Approach

In order to meet the requirements in 40 CFR 93.123(a)(3), FHWA, in consultation with the EPA, conducted a screening analysis of a large intersection operating at capacity using MOVES2010b and CAL3QHC so that projects meeting the finding's parameters would not produce a CO concentration higher than what was modeled and, when combined with background concentrations, would not violate the NAAQS for CO. In other words, the goal of the analysis was to ensure the analysis was applicable to as many intersection projects in CO maintenance areas as possible. The analysis conducted here met all the conformity requirements for a CO hot-spot analysis including 40 CFR 93.110, 93.111, 93.116(a), and 93.123(a) and (c) by using the latest versions of appropriate models; MOVES2010b<sup>1</sup> and CAL3QHC<sup>2</sup>; and consistent with EPA's guidance: "Guideline for Modeling Carbon Monoxide from Roadway Intersections"<sup>3</sup> (1992 CO Guideline) and "Using MOVES in Project Level Carbon Monoxide Analyses"<sup>5</sup> (2010 CO MOVES Guidance). In accordance with the Highway Capacity Manual<sup>4</sup> (HCM2010), we relied on the HCM2010 Software to develop our traffic volumes and speeds (HCM2010, pg. 18-31). As noted in section 1.1 above, the MOVES-based analysis conducted here cannot be used in California.

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\* EPA's "[Greenbook](#)" states that, "As of September 27, 2010, all carbon monoxide areas have been redesignated to maintenance areas"

Figure 1 presents an overview of the modeling process. Reference to sections where the description of work occurs is included in the figure.



## **2. Step 1: Define Project Details**

### **2.1 Defining Project Scope**

The goal of the analysis was to model a large intersection using MOVES2010b and CAL3QHC operating at capacity so that projects meeting the finding's parameters would not produce a CO concentration higher than what was modeled and, when combined with background concentrations, would not violate the NAAQS for CO. It is important to note that background concentration would be a function of the particular project and will be provided by a project sponsor following the 1992 CO Guideline<sup>3</sup>. Section 2.2 provides a summary of the intersection project that was analyzed for the categorical hot-spot finding.

### **2.2 Intersection**

A large urban, signalized intersection was analyzed. The symmetrical intersection was modeled with each of the approaches and departures at 90 degree angles. The intersection included four approach lanes in each direction, four departure lanes in each direction, and two left turn lanes for each approach. The right lane in each direction was assumed to include both through and right turn movements. Lanes were assumed to be 12 feet wide in all cases. The intersection geometry modeled is shown graphically in Figure 2.

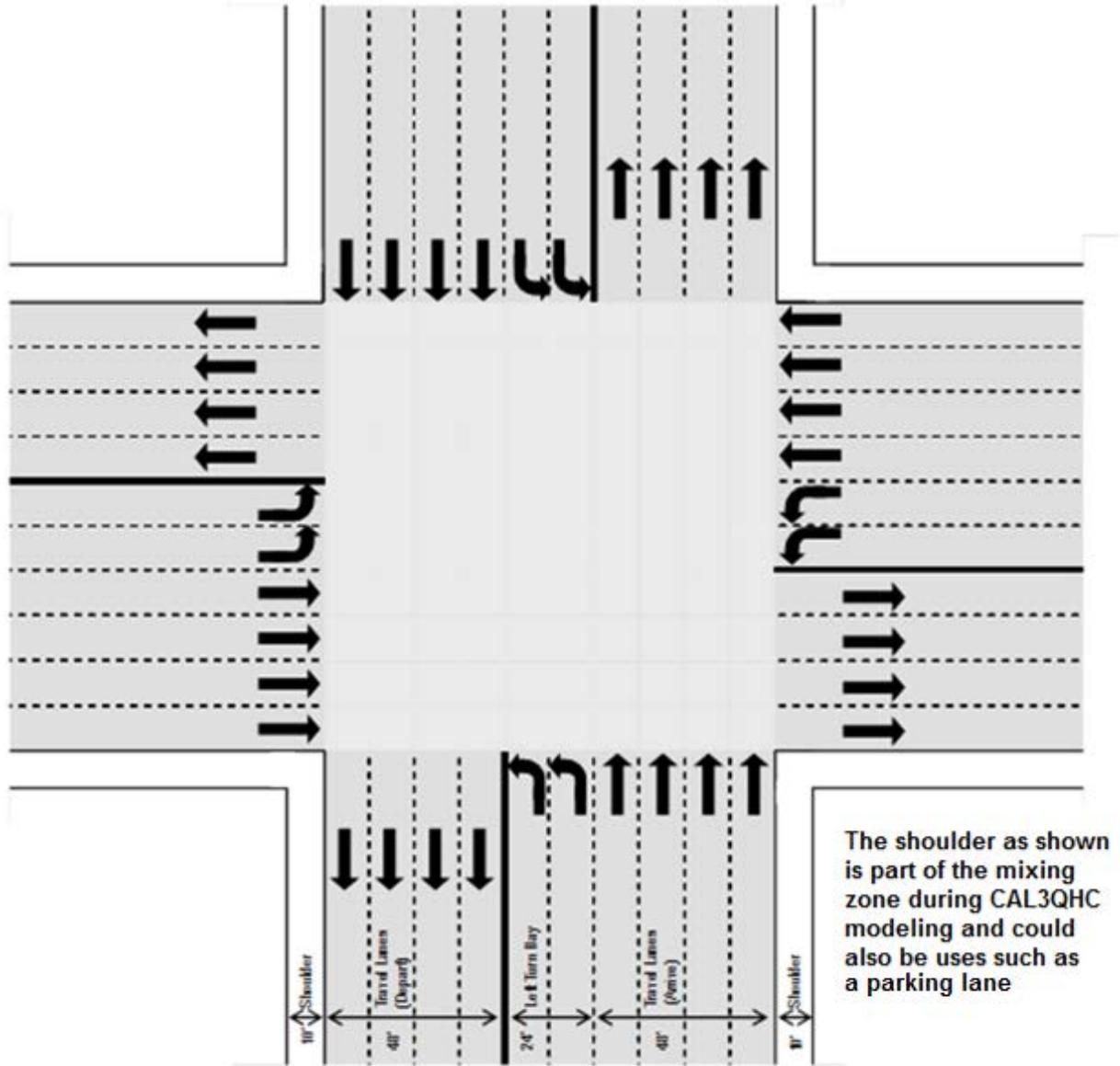


Figure 2. Geometry of Intersection Analyzed

Using the Highway Capacity Software, the HCM2010<sup>4</sup> provides a methodology to calculate the approach volumes for a signalized intersection approaching LOS F (defined as an average control delay greater than 80 seconds per vehicle). It was assumed that all approaches would have equal demand to represent a maximum total intersection throughput.

The assumptions made regarding the operation of the intersection approaching LOS F included allowing for a separate through and left-turn phases for each roadway for the total cycle length, and “green time” was allocated proportionately for each selected movement based on the demand. Given these assumptions and the roadway geometry shown in Figure 2, the Highway Capacity Software calculated a design flow rate of 2640 vehicles per hour for each approach leg. Of that total, 396 vehicles were assigned to the left-turn lanes and the remaining 2244 vehicles were assigned to the through lanes, including the shared through-right turn lane.

Directly related to the volume of an intersection is the signal timing. Based on the HCM2010<sup>4</sup>, signal times were determined to be 130 seconds for the total cycle (red to red for one direction), an average green time of 41 seconds for the through and right turn movements occurring at the same time for opposing approaches, and 14 seconds for the average left turn movement concurrent in opposing directions.

The average approach and departure speeds were established as recommended in the 1992 CO Guideline<sup>3</sup>. The speed was selected as 25 miles-per-hour per Table 4.2 in the 1992 CO Guideline<sup>3</sup>. While a range of 25 to 30 mph was given in Table 4.2, using 25 mph results in a greater emission rate when using MOVES. Idle emission rates were also determined using MOVES and more detail is included in Section 3. Queue lengths were determined internally by the CAL3QHC model during the modeling process which will be discussed in Section 4.

Because severe grades may pose a safety hazard and are not generally expected for intersections of this size, a more typical grade condition was selected. In this configuration, one approach and corresponding departure were assumed to be on an uphill grade of 2% while the parallel approach and departure were assumed to be on a downhill grade of 2%. The perpendicular approaches and departures were modeled with no grade (0%).

Table 1 lists the final geometric and traffic parameters used in the modeling.

Table 1. Final Geometric and Traffic Characteristics for the Intersection

Component	Description
Lane configuration	<ul style="list-style-type: none"> <li>• 4 through lanes and 2 left turn lanes per approach and 4 departure lanes per each leg of the intersection</li> <li>• Perpendicular approach angles</li> </ul>
Lane width	12 feet
Signalization	<ul style="list-style-type: none"> <li>• Cycle length of 130 seconds with average green time length of 14 seconds for the left turn and average green time length for the right/through traffic of 41 seconds</li> <li>• Average intersection control delay is 78.5 seconds per vehicle during the peak hour</li> </ul>
Turning movements	15% left turn and 5% right turn
Median width	None
Traffic volume	<ul style="list-style-type: none"> <li>• 2640 vehicles per hour on each approach during the peak hour</li> <li>• On each approach: 2244 are through traffic or turning right; remaining 396 vehicles turn left</li> </ul>
Level of service	E
Grade	±2% on one cross street and 0% on the other cross street
Heavy-duty trucks	5%
Peak hour average approach speed	25 mph

### 3. Step 2: Prepare MOVES Input Data

The MOVES2010b<sup>1</sup> model was used for this analysis. Each MOVES input is discussed in the following sections and is consistent with 2010 CO MOVES Guidance<sup>5</sup>. The MOVES2010b files used in this analysis can be found on FHWA’s [CO categorical hot-spot finding website](#) in the folder titled “MOVES Files.”

#### 3.1 Run Specification (RunSpec) Inputs

##### Description

The MOVES inputs described in the RunSpec and Project Data Manager sections were used to model the Intersection scenario.

## Scale

The CO hot-spot analysis is a project-level analysis using the project domain and Inventory calculation type. The inventory calculation was selected because it provides the information needed, when post processed (via EPA's scripts), to get the emission rates needed for CAL3QHC.

## Time Spans

- Year - 2015

2015 was chosen for the year of analysis because CO emission rates decline steadily in future years and 2015 represents the design year in which the highest CO emission rates will occur. Any design year after 2015 would yield lower CO emission rates.

- Month – January

Following the 1992 CO Guideline<sup>3</sup> and the 2010 CO MOVES Guidance<sup>5</sup>, the month of January was selected. Refer to the Meteorology discussion within the Project Data Manager sub-section for more details.

- Day – Weekday

MOVES requires either a weekday or weekend to be chosen for project-level modeling. Since either choice would not impact modeling results, the analysis was conducted for a weekday.

- Hour - 08:00 to 08:59 a.m.

MOVES requires a specific hour to be chosen for project-level modeling; since only one hour is being modeled for this analysis and all project data is being provided for that hour, 8:00- 8:59 am was selected to represent peak hour data for the intersection.

## Geographic Bounds

- Custom Domain

A custom domain was chosen utilizing national defaults for Barometric Pressure, Vapor Adjustment, Spill Adjustment, and the Geographic Phase-In Area (GPA) fraction parameters and is listed in Table 2. Vapor and Spill Adjustment parameters are not applicable to the Running Exhaust and Crankcase Running Exhaust processes and therefore not included in the analysis.

Table 2. Geographic Bounds Generic County Parameters

<b>Generic County Parameters</b>	
StatelD	99

CountyID	1
GPA Fraction	0
Barometric Pressure	28.94
Vapor Adjustment	0
Spill Adjustment	0

### Vehicles/Equipment

Since all MOVES vehicle types were assumed to be operating in the project area, in accordance with the 2010 CO MOVES Guidance<sup>5</sup> all 13 MOVES source use types were selected for the analysis. Table 3 lists the vehicle and fuel type combinations utilized in this analysis.

Table 3. Vehicles and Equipment Fuel Combinations

<b>Source Use Types</b>	<b>Fuel Type(s)</b>
Motorcycle	Gasoline
Passenger Car	Diesel Fuel and Gasoline
Passenger Truck	Diesel Fuel and Gasoline
Light Commercial Truck	Diesel Fuel and Gasoline
Refuse Truck	Diesel Fuel and Gasoline
Motor Home	Diesel Fuel and Gasoline
School Bus	Diesel Fuel and Gasoline
Transit Bus	Diesel Fuel, Gasoline, and CNG
Intercity Bus	Diesel Fuel
Single Unit Short-haul Truck	Diesel Fuel and Gasoline
Single Unit Long-haul Truck	Diesel Fuel and Gasoline
Combination Short-haul Truck	Diesel Fuel and Gasoline
Combination Long-haul Truck	Diesel Fuel

### Road Type

The Urban Unrestricted Access road type was used to represent all Intersection links.

## Pollutants and Processes

The intersection scenario required the Running Exhaust and Crankcase Running Exhaust emissions processes for CO to be selected.

## Manage Input Data Sets

The input database utilized is titled CO\_CATFi\_Final\_08012013\_in. The entire database can be found on FHWA's [CO categorical hot-spot finding website](#) in the folder titled "MOVES Files."

## Strategies

There were no changes made to the Alternative Vehicle Fuels and Technologies (AVFT) or On-Road Retrofit strategies<sup>†</sup>.

## Output

The output database utilized is titled CO\_CATFi\_Final\_08012013\_out. This database can be found on FHWA's [CO categorical hot-spot finding website](#) in the folder titled "MOVES Files." Table 4 lists the General Output selections and Table 5 lists the Output emissions detail selections used for this analysis.

Table 4. General Output Selections

<b>Heading</b>	<b>Selection(s)</b>
Database	CO_CaftFi_Final1_out
Units	Mass Units = Grams
	Energy Units = Million Btu
	Distance Units = Miles
Activity	Distance Traveled
	Source Hours Operating
	Population

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<sup>†</sup> AVFT input has been relocated from the Run Specification Panel to the 'Fueltype and Technologies' tab within Project Data Manager for MOVES2010b

Table 5. Output Emissions Detail

Heading	Selection(s)
Always	Time (link and hour)
	Location (link and hour)
	Pollutant (link and hour)
For all Vehicle/Equipment Categories	No Selections
On Road/Off Road	Selected
On Road	No Selections
Off Road	No Selections

### Advanced Performance Features

No Advanced Performance Features were utilized for the analysis

## 3.2 Project Data Manager

### Meteorology Data

Following the 1992 CO Guideline<sup>3</sup> and the 2010 CO MOVES Guidance<sup>5</sup>, and since this analysis is intended to apply to all the CO maintenance areas (except in CA), the analysis utilized an average January temperature of -10° Fahrenheit in order to permit wide applicability of the finding. "Relative humidity" was set at 100%. These values result in higher CO emission rates than an area with a higher average January temperature, but a lower relative humidity. It is important to note that CO emission rates for diesel or gasoline vehicle types are not sensitive to temperature and relative humidity when temperature values are below 60° F for Running and Crankcase exhaust processes<sup>6</sup>.

### Age Distribution

The 2010 CO MOVES Guidance<sup>5</sup> allows for default age distribution from MOVES to be used when no other state or local data is available. Because this analysis is not focused on a specific area, the national default age distribution representing the 2015 analysis year was used.

### Fuel

The 2010 CO MOVES Guidance<sup>5</sup> recommends that the default MOVES fuel supply and fuel formulation data be utilized representing the project specific area. However, for the CO categorical hot-spot finding analysis a fuel type with specific parameters that would yield high CO emission rates was used to have wide applicability.

- Fuel Supply Data

Based upon a literature review of MOVES documentation on the MOVES fuel adjustments<sup>7</sup> and discussions with EPA, Fuel Formulation ID 3812 was chosen to analyze gasoline vehicle types. Fuel Formulation ID 20011 was used to analyze diesel vehicle types and is the only diesel fuel formulation available after 2012. It is also important to note that diesel parameters do not affect CO emission rates. Fuel Formulation ID 30 was chosen to analyze CNG transit buses.

- Fuel Formulation Data

Fuel formulation parameters can significantly affect the CO emission rates. Gasoline Fuel parameters that can affect CO emission rates include Reid Vapor Pressure (RVP), Sulfur Content, Ethanol (ETOH), and E200/E300 (percent of fuel evaporated at 200° and 300° Fahrenheit). The EPA recommended that Fuel Formulation ID 3812 be utilized for this analysis because this yields higher CO emission rates compared to other fuel formulations. Table 6 lists the fuel formulation used for this analysis.

Table 6. Fuel Formulation Parameters

<b>Fuel Type</b>	<b>fuelFormulationID</b>	<b>RVP</b>	<b>Sulfur Content (ppm)</b>	<b>ETOHVolume</b>	<b>e200</b>	<b>e300</b>	<b>T50</b>	<b>T90</b>
Diesel	20011	0	11	0	0	0	-	-
Gasoline	3812	15.7	28	10	58.1352	94.8717	183.214	275.447
CNG	30	0	0	0	0	0	0	0

## Inspection and Maintenance (I/M) Programs

No I/M program was modeled in the analysis due to the variation in I/M programs across the CO maintenance areas. Also, including an I/M program would yield lower CO emission rates.

## Link Source Types

The Source Type Distribution used was the national default for the year 2015, obtained from a National Scale MOVES run for that year. Utilizing the vehicle miles traveled (VMT) information from the 'movesactivityoutput' table within the output database the Source Type Distributions for Urban Unrestricted Road Type was obtained and transformed into a Source Type Hour Fraction for the intersection scenario. The Source Type Hour Fraction based upon the national default was adjusted as described below to reflect a higher proportion of vehicles that have higher CO emission rates:

- Gasoline vehicle types typically have higher CO emission rates compared to diesel vehicle types within MOVES. FHWA analyzed states which had the lowest heavy-duty diesel truck percentage in their urban area and determined that states like Maine represented the lowest percentage of these vehicle types with approximately 5% of their urban vehicle fleet mix being heavy-duty diesel trucks.
- The national default Source Type Hour Fractions for the Urban Unrestricted Access Road Type was adjusted by reducing Combination and Single-Unit Trucks to represent 5% of the total fleet mix. All other MOVES source types were proportionally adjusted to reflect the overall reduction in the heavy-duty diesel truck percentage.
- Passenger Trucks have the highest CO emission rates compared to all of the other MOVES source types. Also, Passenger Cars make up the largest fraction of the total vehicle mix and Passenger Trucks are the second largest fraction of the total vehicle mix. Therefore, the Source Type Hour Fraction was adjusted to reflect a 50/50 proportional split between Passenger Car and Passenger Truck source types.

Table 7 lists the Link Source Type utilized for the intersection scenario.

Table 7. Urban Unrestricted Access Link Source Type

SourceTypeID	Description	SourceTypeHourFraction
11	Motorcycle	0.00462922
21	Passenger Car	0.42403
31	Passenger Truck	0.42403
32	Light Commercial Truck	0.0940995
41	Intercity Bus	0.000696839
42	Transit Bus	0.000192628
43	School Bus	0.000777021
51	Refuse Truck	0.000306255
52	Single Unit Short-haul Truck	0.0239796
53	Single Unit Long-haul Truck	0.00341864
54	Motor Home	0.00123829
61	Combination Short-haul Truck	0.00917038
62	Combination Long-haul Truck	0.0134314

### Links

The intersection scenario was modeled using the Urban Unrestricted Access Road Type, as noted under Road Type above, with an average free flow speed of 25 mph at grades of +2%, -2%, and 0% (see Section 2.2 for discussion of grade). Idle conditions were also modeled for the intersection scenario.

CO emission rates in grams per vehicle mile (grams/veh-mile) were obtained for each link with exception of the idle link where CO emission rates are in grams-per-vehicle-hour (grams/veh-hour). During emission modeling, each link length was set to a 1 mile segment with a volume of 1000 vehicles per hour to allow ease in extracting the appropriate data. This is different from the dispersion links that will be described later in this report. Table 8 lists the characteristics and definitions associated with each link used in the analysis.

Table 8. Links Characteristics

<b>linkID</b>	<b>Road Type</b>	<b>Link Length (mile)</b>	<b>Volume</b>	<b>Average Speed (mph)</b>	<b>Grade (%)</b>	<b>Link Definition</b>
525	Urban Unrestricted Access	1	1000	25	0	Free flow
5225	Urban Unrestricted Access	1	1000	25	2	Free flow (approach/departure)
50225	Urban Unrestricted Access	1	1000	25	-2	Free flow (approach/departure)
500	Urban Unrestricted Access	1	1000	0	0	Queue (idle)

### Link Drive Schedule

User-defined Link Drive Schedules were not utilized for this analysis.

### Operating Mode Distribution

User-defined Operating Mode Distributions were not utilized for this analysis.

### Off-Network

Off-Network links were not included in this analysis.

### Fuel Type and Technologies

As previously discussed under the Strategies section, AVFT and On-Road Retrofits were not included in this analysis.

## **3.3 MOVES Output**

The analysis utilized the Inventory approach in obtaining MOVES output consistent with the 2010 CO MOVES Guidance<sup>5</sup>. The CO emission rates for each link were obtained by executing the EPA provided CO\_CAL3QHC\_EF.sql script in MOVES2010b which provided CO emission rates in grams per vehicle-mile. LinkID 500 represented a queue link at idle condition and the CO emission rate in grams per vehicle-hour was calculated by dividing the total emissions of the link by the 1000 vehicles assigned to the link over the hour modeled. Table 9 lists the emissions rates for the links associated with the intersection scenario and used with CAL3QHC for air quality dispersion modeling.

Table 9. MOVES Link Based Emission Rates

<b>linkID</b>	<b>Road Type</b>	<b>Average Speed (mph)</b>	<b>Grade</b>	<b>CO Rate (g/veh-mile)</b>
525	Urban Unrestricted Access	25	0%	9.52
5225	Urban Unrestricted Access	25	2%	12.32
50225	Urban Unrestricted Access	25	-2%	7.635
500	Urban Unrestricted Access	0	0	53.19 (g/veh-hr)

## 4. Step 3: Prepare Dispersion Modeling (CAL3QHC) Input

Dispersion modeling was completed using the recommended CAL3QHC model, Version 2.0<sup>2</sup> and for CO screening analyses of highway-only projects as discussed in the 1992 CO Guideline<sup>3</sup>. The CAL3QHC files used in this analysis can be found on FHWA's [CO categorical hot-spot finding website](#) in the folder titled "CAL3QHC Files." The following discussion describes the inputs specific for CAL3QHC used in this analysis.

### 4.1 Intersection Inputs

#### Dispersion Links

Dispersion links were extended out to 3000 feet from the intersection so that midblock receiver locations at 2500 feet from the center of the intersection could be evaluated without end effects occurring. Figure 2 previously presented the geometry in the immediate vicinity of the intersection.

#### Receptors

Receptors were placed in a grid configuration in each quadrant of the intersection to make sure the maximum concentration was estimated for the analysis. Receptors were located according to the 1992 CO Guideline<sup>3</sup> at no closer than 10 feet (3 meters) to the roadway edge to account for the mixing zone. The example receptor locations as described in the 1992 CO Guideline are shown in Figure 3<sup>3</sup>. Receptors extending away from the intersection up to midblock conditions were used. Additional receptors beyond the guideline examples were also added in a grid configuration in each quadrant of the intersection to make sure the maximum concentration was evaluated as shown in Figure 4. The grid configuration resulted in receptors being located at the closest point to both roadways (10 feet from each roadway), then along each roadway maintaining the 10 foot distance from the pavement edge to account for the mixing zone out to a distance of 500 feet. To account for possible midblock concentrations, receptors were placed at 2500 feet from the intersection and 10 feet from the edge of the roadway. Finally, rows of receptors at varying distances from the roadway were included to form a grid in each quadrant. Receptors were all placed at a height of 6 feet.

It should be noted that CAL3QHC, Version 2.0<sup>2</sup> can only model 60 receptor locations in a single run. Each of the four quadrants modeled required modeling 484 receptor locations for a total of 1936 receptors. To accomplish this, each of the four quadrants were broken down by rows of receptors and 11 model runs performed per quadrant for a total of 44 input/output file combinations. All roadways and vehicles were modeled in each run so that only the receptor locations changed permitting all receptor locations to be analyzed for all traffic and all wind angles.

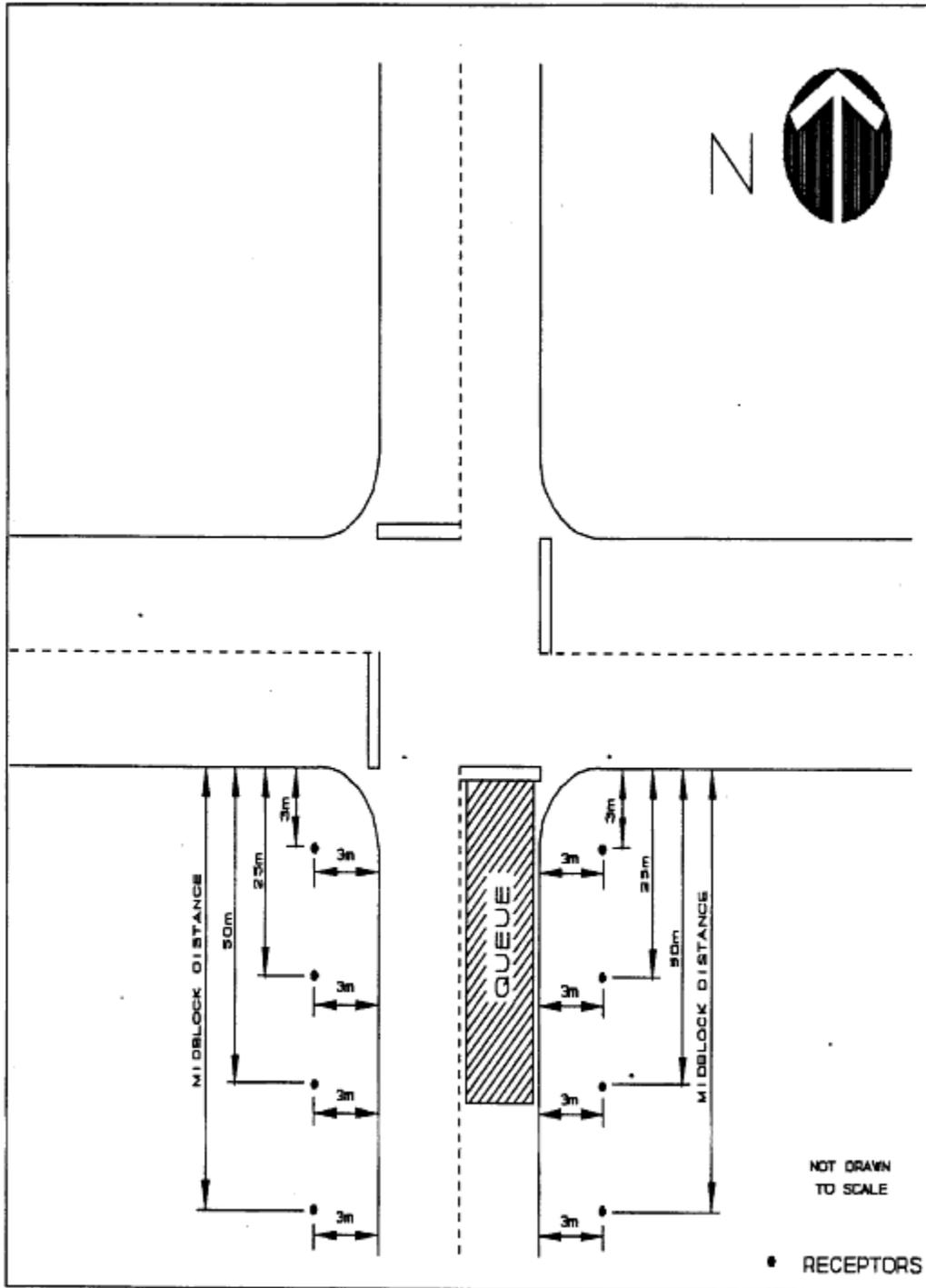
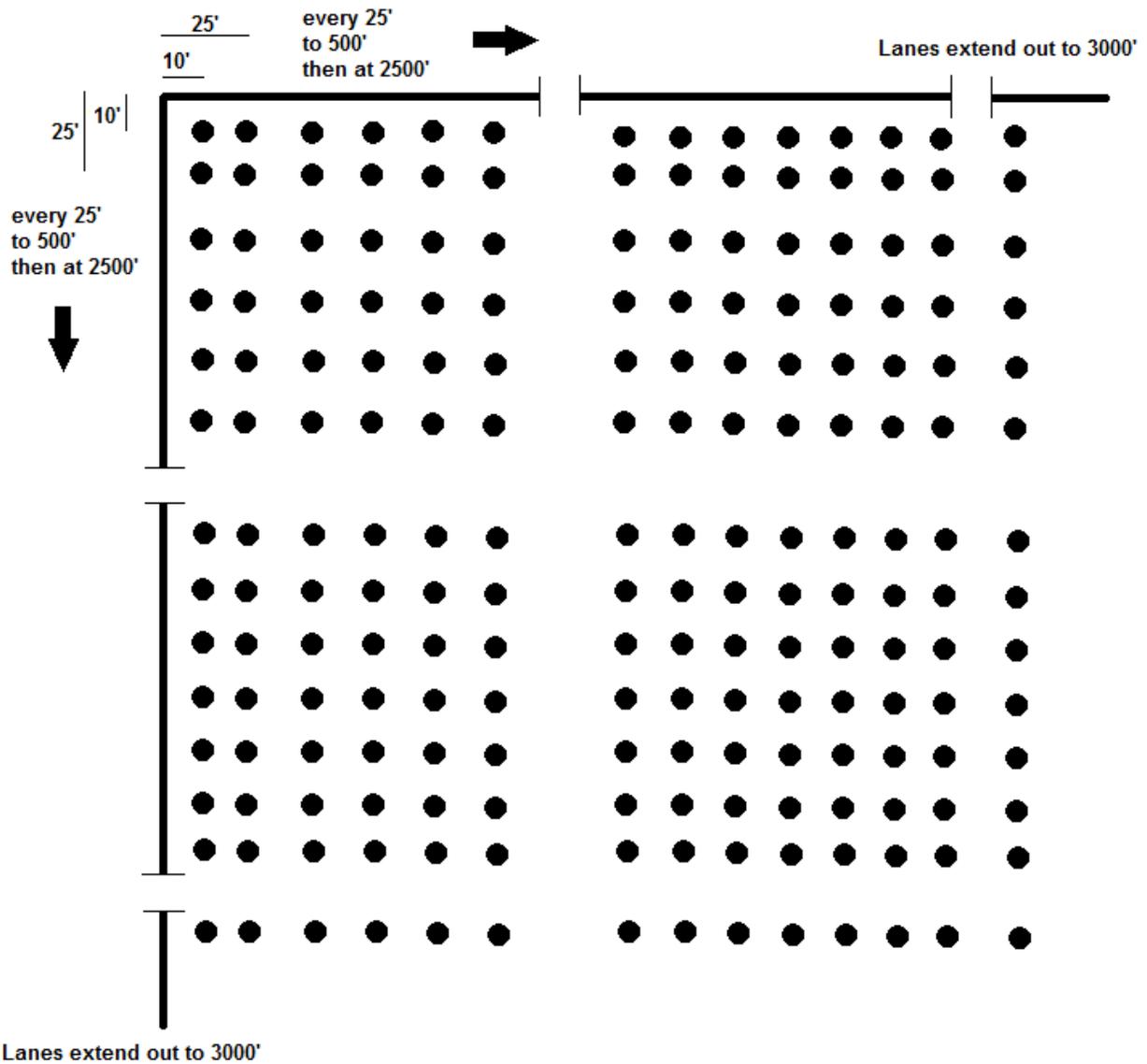


Figure 3. Receptor Locations as Defined by the 1992 CO Guidelines<sup>3</sup>

Figure 4. Receptor Grid Used in Modeling (only the Southeast quadrant shown, gaps indicate continuation of the same pattern)



### Traffic Volume

The approach volume of 2640 vehicles per hour during the peak hour was used for this analysis as previously discussed in Section 2.2.

### Vehicle Movements at Intersection

As mentioned in Section 2.2, movements were assumed to be 15% for left turns and 5% for right turns. This results in a high fraction of left turns and considerable idle time. Additionally, right turns were assumed to come to a complete stop and not proceed until a green signal phase occurred.

The total cycle length used was 130 seconds and developed based on traffic principles. Again, based on traffic principles, an average green time of 14 seconds was allocated for left turns and 41 seconds of green time for the right and through traffic. The lost time at the intersection was assumed to be 2 seconds per phase. This resulted in an average intersection delay of 78.5 seconds per vehicle, which corresponds to LOS E conditions approaching LOS F (which is defined as delay greater than 80 seconds per vehicle). Accordingly, the modeled intersection is theoretically functioning just before breakdown into a LOS F condition and represents the greatest delay of a functioning intersection.

### Approach/Departure Speeds

Based on the 1992 CO Guideline<sup>3</sup>, a signalized approach/departure speed of 25 mph for urban conditions was used as described in Section 2.2. The appropriate emission factor was used as previously described in Section 3.

### Meteorology

*Wind.* The worst case surface meteorology as prescribed in the 1992 CO Guidelines<sup>3</sup> was used. Wind speed was assumed to be 1.0 meters-per-second resulting in the greatest predicted level when using the CAL3QHC model. The wind direction was again evaluated every 10 degrees from 0 to 360 degrees to insure the maximum concentration was predicted for the array of receptors accounting for the full range of possible wind directions.

*Stability and Mixing Height.* An urban worst case stability class of D and a mixing height of 1000 meters were utilized, consistent with the 1992 CO Guideline<sup>3</sup>.

### Surface Characteristics

A surface roughness of 108 centimeters, corresponding to a single family residential condition, was used. This is based on the 1992 CO Guideline<sup>3</sup> and the paper by Auer<sup>8</sup> that explains that the use of the smallest value of surface roughness in an urban area allows prediction of greater CO concentrations.

## CAL3QHC Output

A 1-hour averaging time was used. This resulted in 1-hour concentrations at the selected receptor locations being predicted. 8-hour concentrations were predicted using the EPA recommended persistence factor of 0.7, described in detail below in Section 6, Persistence Factor.

## Summary of CAL3QHC Inputs

Table 10 summarizes the final input parameters used for modeling the intersection.

Table 10. Summary of CAL3QHC Inputs Used for the Intersection Modeling

<b>Component</b>	<b>Description</b>
Traffic and Geometric Design	See Table 1
Receptor Locations	In a grid for each quadrant (see Figure 4) beginning at the edge of mixing zone (10 feet from roadway edge) and extending out to 2500 along roadway for midblock location
Meteorology	Wind speed = 1 m/s Wind direction = every 10 degrees from 0 to 350 degrees Mixing height = 1000 meters Stability class = D (urban) Surface roughness = 108 cm (single family residential)
Emission Factors	12.32 grams-per-vehicle-mile for the 25 mph increasing grade (2%) and 7.635 grams-per-vehicle-mile for the down-grade. The emission factor for the level roadway was 9.52 grams-per-vehicle mile. The idle emission factor used was 53.19 grams-per-hour.
Output from CAL3QHC	Parts-per-million for 1-hour concentration

## **5. Background Concentration Values**

No background concentration values were included in the modeling since this will be a function of the project location and will be determined on a project-specific basis using the appropriate methodology such as described in the 1992 CO Guideline<sup>3</sup>.

## 6. Persistence Factor

The CO NAAQS consists of both 1-hour and 8-hour standards. To allow comparison to both the 1-hour and the 8-hour NAAQS for CO, the 1992 CO Guideline<sup>3</sup> recommends using a persistence factor to convert peak 1-hour predicted concentrations to peak 8-hour estimations. Use of this persistence factor allows for the changes in traffic volumes and meteorological conditions over the 8-hour period as compared to the 1-hour period. If a local persistence factor based on monitoring data is unavailable, the 1992 CO Guideline<sup>3</sup> recommends using a default persistence factor of 0.7.

For the intersection analysis the 1-hour concentration was first predicted using CAL3QHC. Then, using the procedure described above, the predicted 1-hour concentration was multiplied by the default persistence factor of 0.7 to allow estimation of the 8-hour concentration.

## 7. Results

As presented in Section 3, the emission factors for the urban intersection were 12.32 grams-per-vehicle-mile for the 25 mph increasing grade (2%) and 7.635 grams-per-vehicle-mile for the down-grade (-2%). The emission factor for the level roadway was 9.52 grams-per-vehicle mile. The idle emission factor was 53.19 grams-per-hour. This resulted in predicted concentrations of 5.5 parts-per-million for the 1-hour concentration and using the 0.7 persistence factor, 3.9 parts-per-million for the 8-hour concentration. These values can be compared to the NAAQS of 35 ppm and 9 ppm for the 1-hour and 8-hour standards, respectively. Table 11 includes a summary of the key results of the analysis.

Table 11. Summary of Key Modeling Results for Carbon Monoxide (CO)

<b>Facility Type</b>	<b>1-Hour Predicted Concentration (ppm)</b>	<b>8-Hour Predicted Concentration (ppm)</b>
Intersection	5.5	3.9

## 8. Summary

This document summarizes the technical information and methodology used to support FHWA's categorical hot-spot finding for CO. Emission and dispersion modeling using MOVES2010b<sup>1</sup> and CAL3QHC Version 2.0<sup>2</sup>, respectively, are described in detail and the key results presented. Only urban cases were analyzed, since CO maintenance areas mainly cover these areas. A large intersection (4 through/right turn approaches and 2 left turn lanes) was evaluated. The predicted emission factors were used as input for dispersion modeling to determine the 1-hour predicted concentrations. The 8-hour concentrations were determined using the 1-hour predictions and the use of a 0.7 persistence factor. The analysis was intentionally performed in a way to allow results to reflect predicted concentrations greater than expected for most projects

## 9. References

- <sup>1</sup> U.S. Environmental Protection Agency, [Motor Vehicle Emission Simulator 2010b \(MOVES2010b, database dated 10/30/2012\)](#), Office of Transportation and Air Quality.
- <sup>2</sup> U.S. Environmental Protection Agency, [CAL3QHC, Version 2.0 with a date of 04244](#), Technology Transfer Network, Support Center for Regulatory Atmospheric Modeling.
- <sup>3</sup> U.S. Environmental Protection Agency, [Guideline for Modeling Carbon Monoxide from Roadway Intersections](#), EPA-454/R-92-005, Office of Air Quality Planning and Standards, November, 1992.
- <sup>4</sup> [Highway Capacity Manual](#), Transportation Research Board, Washington, D.C., 2010.
- <sup>5</sup> U.S. Environmental Protection Agency, [Using MOVES in Project-Level Carbon Monoxide Analyses](#), EPA-420-B-10-041, Transportation and Regional Programs Division, Office of Transportation and Air Quality, December, 2010.
- <sup>6</sup> Choi, D., M. Beardsley, D. Brzezinski, J. Koupal, and J. Warila, [MOVES Sensitivity Analysis: The Impacts of Temperature and Humidity on Emissions](#), Environmental Protection Agency, OTAQ, Ann Arbor, MI, no date specified.
- <sup>7</sup> U.S. Environmental Protection Agency, [MOVES2010 Fuel Adjustment and Air Toxic Emission Calculation Algorithm – Development and Results](#), EPA-420-R-11-009, July, 2011.
- <sup>8</sup> Auer, A.H., Jr., "Correlation of Land Use and Cover with Meteorological Anomalies", [Journal of Applied Meteorology](#), 1978.