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AIR QUALITY ANALYSIS OF A MULTILEVEL COMPLEX INTERCHANGE: CASE STUDY USING THE IMPROVED TSC/EPA MODEL

Eugene M. Darling, Jr.
David S. Prerau
Paul J. Downey
Jeffrey D. Garlitz

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

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FINAL REPORT

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16. Abstract

As requested by the Region 3 Federal Highway Administrator and in keeping with the program goal of promoting liaison and coordination within the U.S. Department of Transportation, Operating Administrations, the Transportation Systems Center prepared a detailed computer analysis of air quality for a complex multilevel interchange in Baltimore consisting of elevated road, at-grade roads, and ascending and descending ramps.

An in-house version of the Environmental Protection Agency Gaussian Highway Line Source model as modified by the Transportation Systems Center, was used. These analyses showed that the levels of air pollution near this interchange would not exceed national standards in either year in question, 1980 or 1995.

This analysis is treated as a case study, illustrative of a method that is useful for computing air-pollution levels associated with many highway configurations. The individual ingredients of the analysis are described in detail, including the handling of road geometry, the calculation of emissions, the estimation of meteorological parameters and the selection of receptor locations. A complete listing of the computer program used in these studies is included.

It is concluded that the method of air-quality analysis developed for this case is an easy to-use, straightforward procedure of general applicability. Within the limitations of the model and subject to the accuracy of the input data, the approach can produce reasonable estimates of worst-case pollutant concentrations for comparison with national ambient air-quality standards.

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PREFACE

In response to Federal legislation requiring that each department of the U.S. Government take steps carefully and systematically to consider the environmental effects of its actions, the Office of the Secretary of Transportation initiated the Technology for Environmental Analysis program at the Transportation Systems Center in FY72. The objection of the program was to develop unified technological capabilities in air-pollution control as part of a family of techniques and capabilities necessary to support the development in the Office of the Secretary and in its Operating Administrations, of planning procedures related to the environmental effects of transportation systems and facilities.

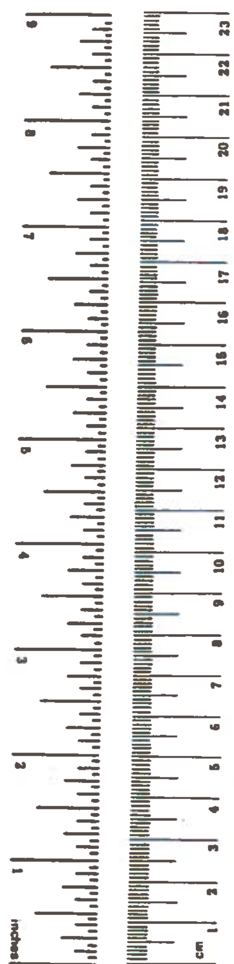
An aspect of this program was for the Transportation Systems Center to promote liaison with, and coordination among, these Operating Administrations, the Environmental Protection Agency, and such other organizations which are concerned with transportation-generated air pollution. The work reported here was performed as part of this combined effort made in a joint request by the Federal Highway Administration and the U.S. Department of Justice.

The authors are members of the Data Technology Branch, Information Sciences Division, Technology Directorate of the Transportation Systems Center. In this report, all references to work by the Transportation Systems Center pertain to the accomplishments of this Branch.

METRIC CONVERSION FACTORS

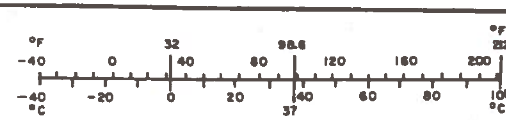
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ILLUSTRATIONS (CONTINUED)

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1. INTRODUCTION

1.1 BACKGROUND

This report describes a case study of an air quality analysis prepared by the U.S. Department of Transportation (DOT), Transportation Systems Center (TSC). The site analyzed was the proposed I-83/I-95 interchange in Baltimore, Maryland. This interchange is part of the 3-A System of highways in Baltimore, comprising several segments which have already been completed and other segments which are in various stages of approval.

TSC originally became involved in air quality analyses of the 3-A System in April 1973 when the first author was asked by the Federal Highway Administration (FHWA) and the U.S. Department of Justice to appear as an air quality expert witness for the Government in the trial of a citizen suit which attempted to block construction of a part of the System. His testimony related to the adequacy of the air-quality analysis which had been prepared by the Maryland analysis which had been prepared by the Maryland Department of Transportation for the Franklin-Mulberry Corridor. Included in his testimony, was a discussion of an air quality analysis which had been performed by TSC [1]. This analysis indicated that the national primary ambient air quality standards for carbon monoxide (CO) concentrations would not be exceeded in the year 1978 if this section of the 3-A System were built or not. However, the TSC estimates of CO concentrations were slightly higher for the latter case not to build. These findings were cited in the Court's decision favoring the Government position in this case to build.

1.2 THIS REPORT

The present analysis was requested by the FHWA Region 3 Administrator [Appendix A]. In preparing this study, TSC was assisted by T. H. Hamer, Chief, Environmental Section, Interstate Division for Baltimore City, Maryland, who provided both engineering diagrams of the interchange and traffic projections for the years 1980 and 1995.

Section 2 describes the proposed I-83/I-95 interchange.

Section 3 discusses TSC modifications which had to be incorporated in the original Environmental Protecting Agency (EPA) highway air-pollution-dispersion model to analyze this interchange.

In Section 4, the details of the air quality analysis for the years 1980 and 1995 are presented.

Section 5 discusses additional air quality analyses of the site using maximum-seeking methods.

Section 6 contains the summary and conclusions.

2. PROPOSED I-83/I-95 INTERCHANGE

The proposed I-83/I-95 interchange is part of the 3-A System of Roadways.

2.1 DESCRIPTION OF 3-A SYSTEM

The proposed 3-A System for Baltimore consists of the 22.7 miles of expressways and boulevards shown (as dashed lines) in Figure 2.1. The following road segments comprise the system:

a. The extension of I-83 south to the Inner Harbor, then east, connecting the I-95 at an interchange north of the Harbor Tunnel entrance.

b. I-95 from the southwest City Line, across South Baltimore, across the Harbor at Fort McHenry, turning northeastward and connecting with the existing I-95 at the eastern City Line.

c. I-70N from the western City Line, through Leaking Park, turning southeastward and connecting with I-95 in southwest Baltimore.

d. I-170, an expressway spur from I-70N to City Boulevard west of the City Center.

e. I-395, an expressway spur from I-95 northeastward to City Boulevard south of the City Center.

f. City Boulevard, a semi-circle running from the south side of the Inner Harbor and connecting with I-83 north of the City Center.

The 3-A System was designed by the Urban Design Concept Team, a multidisciplinary group of leading architects, planners, and designers. This approach to the planning of the System was approved by the U.S. Department of Transportation on September 24, 1967. In mid-January 1969, the Bureau of Public Roads selected the 3-A System from a group of three candidates proposed by the Concept Team.

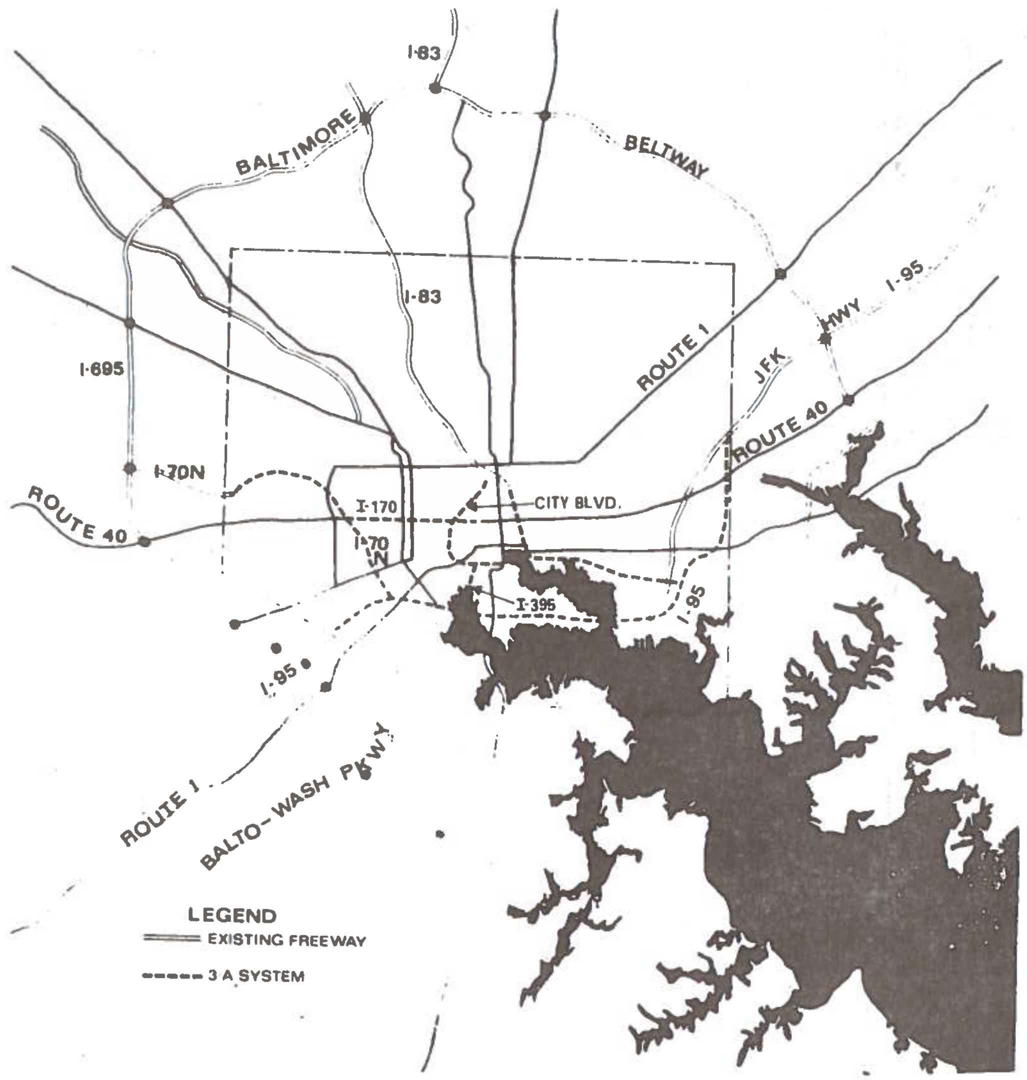

FIGURE 2.1. 3-A SYSTEM

2.2 SITE DESCRIPTION

Figure 2.2 is a diagram of the proposed I-83/I-95 Interchange which consists of five elevated roads. Three at-grade roads, and seven ramps of which four are ascending and three are descending. In addition, the site contains numerous existing roadways. The approximate dimensions of the interchange are 1.0 mile north-south and 0.8 mile east-west.

The site is mainly occupied by a tank farm, by warehouses, and by utility buildings of the Baltimore Highway Department. There are three cemetaries to the east of the proposed I-95 location. The main residential areas are in the northern and eastern positions of the site. The existing Harbor Tunnel Thruway runs north-south through the center of the site.

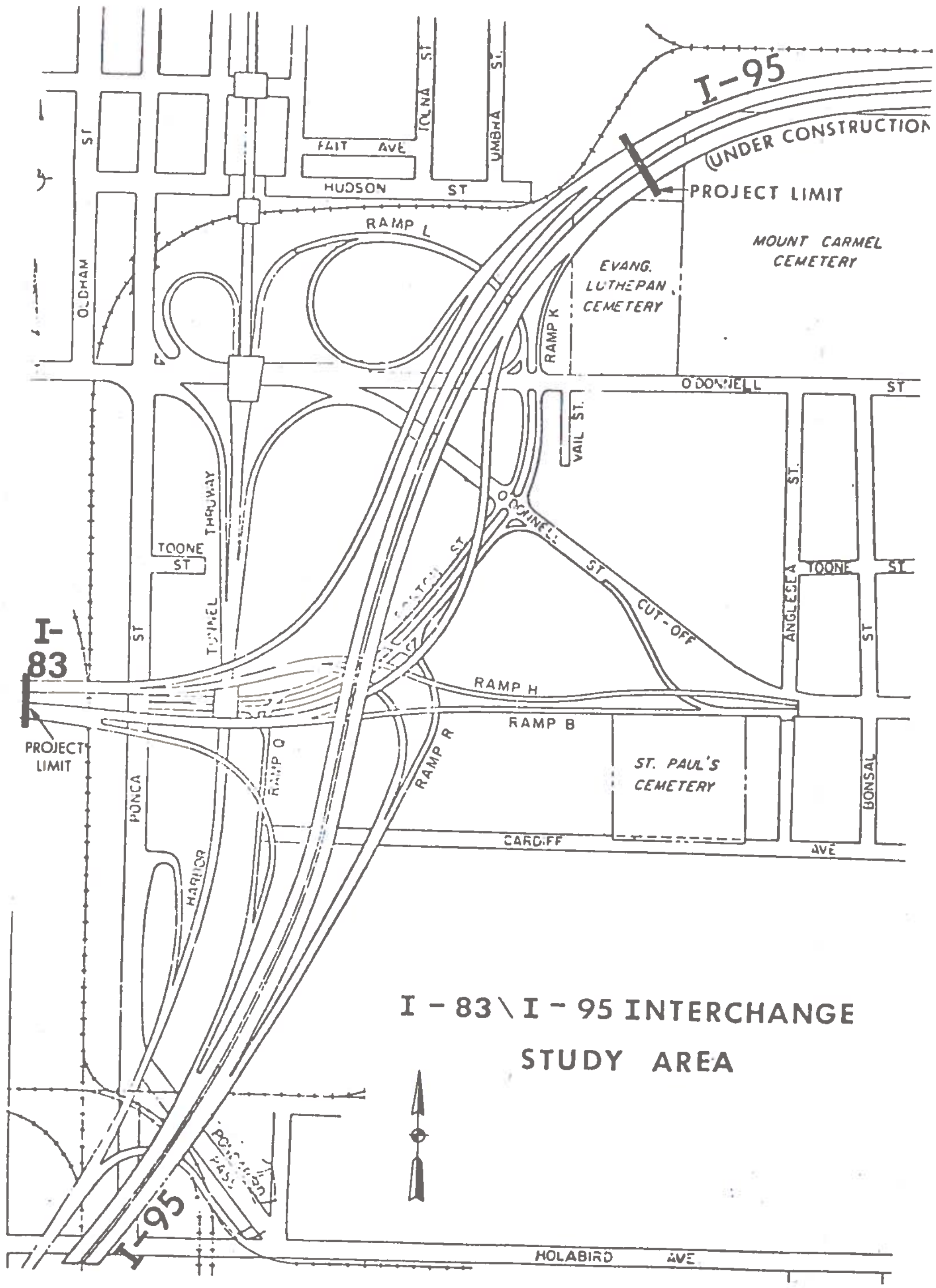

FIGURE 2.2 I-83/I-95 INTERCHANGE

3. TSC/EPA HIGHWAY LINE SOURCE MODEL

The air quality analysis for the proposed I-83/I-95 interchange was performed with a modified version of the TSC/EPA highway line-source model. The original TSC/EPA model (Reference 1) is discussed below and the modifications incorporated for the present analysis are described in subsequent sections. Appendix A contains the improved model program, including the modification.

3.1 ORIGINAL TSC/EPA HIGHWAY LINE SOURCE MODEL

The TSC/EPA Highway Line-Source Model is an air-pollution-dispersion model of the Gaussian type. The computer program for this model was originally written by J. Zimmerman, EPA National Environmental Research Center, Research Triangle Park, North Carolina. Major modifications to the original model were subsequently made at TSC by the second and third authors. The model program is written in FORTRAN IV. Examples of the use of the original TSC/EPA Model for analyzing highways, streets, or complex interchanges are discussed in Reference 1.

3.1.1 Model Description

The model can calculate the pollutant concentration at any number of receptors that is produced by any number of straight-line read-segment sources. Each road segment may consist of one or more lanes, with or without a center strip. A complex set of roadways; e.g., an interchange, can be modeled by a large set of such road-segment sources.

The model first calculates the location of uniform-emission line sources to represent each lane of each road segment, based on the location of the centerline of the road, the road width, and the width of the center strip. Then, it calculates the concentration of each receptor because of each line source. Finally, it sums the contributions of each receptor caused by each lane of each road segment to produce the final computed concentration.

The concentration of a single line source at a receptor is given by:

$$C(R) = \int_{o}^{L} Q_s \; P_R(\ell) d\ell$$

where C(R) is the concentration at receptor R,

L is the length of the line source,

Q_s is the line-source strength, and

$P_r(\ell)$ is the concentration produced at receptor R by a unit-strength point source located a distance ℓ from the end of the line source.

To compute the integral, the model divides the line source into small line-source segments and sums the contributions of each segment of the pollutant concentration at the receptor. The line source is divided into a progressively greater number of smaller line-source segments until successive calculated values of pollutant concentration at the receptor. The line source is divided into a progressively greater number of smaller line-source segments until successive calculated values of pollutant concentration seems to have converged. The contribution from each small line-source segment is calculated by the trapezoidal rule, which approximates the contribution to the integral by a small line-source segment as the average of the contributions of point sources located at each each of the segment. Thus, the above equation becomes:

$$C(R) = \frac{Q_s}{N} \left[\frac{P_R(0) + P_R\left(\frac{L}{N}\right)}{2} + \frac{P_R\left(\frac{2L}{N}\right) + P_R\left(\frac{L}{N}\right)}{2} + \ldots \right] + E_N$$

$$= \frac{Q_s}{N} \left[\frac{1}{2} P_R(0) + \sum_{i=1}^{N=1} P_R\left(\frac{iL}{N}\right) + \frac{1}{2} P_R(L) \right] + E_N \quad ,$$

where: N is the number of line-source segments of $\frac{L}{N}$ into which the line source has been divided, and

E_N is the error term (which decreases as N increases).

Thus, each step in the calculation of the concentration, because of the line source, is reduced to the calculation of the concentration at the receptor caused by N point sources. N is continually doubled until a convergence criterion is met.

To calculate the concentration at a receptor of a point source, the TSC/EPA Model uses the following equation adapted from Reference 2:

$$P_R(x,y,x,H) = \frac{1}{2\pi U\sigma_y\sigma_z} \exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left[\exp\left(\frac{-(z-H)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H)^2}{2\sigma_z^2}\right) + \sum_{N=1}^{J} A(N)\right],$$

$$A(N) \triangleq \exp\left(\frac{-(z-H-2NM)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H-2NM)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-z-H+2NM)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H+2NM)^2}{2\sigma_z^2}\right),$$

where: P_R is a concentration point at receptor R which is located at point (x,y,z) because of a unit point source of pollution located at point (0, 0, H). [x is the downwind distance; y is the crosswind distance, z is the vertical distance, and H is the source height.],

U is the windspeed,

σ_y, a function of x, is the standard deviation of concentration in the crosswind direction,

σ_z, a function of x, is the standard deviation of concentration in the vertical direction,

M is the height of the mixing layer, and

J is chosen, such that N=J is the first value of N, so that A(N) is less than a given small constant.

The equation is a form of the standard Gaussian plume model of air-pollution dispersion. The first exponential accounts for cross-wind dispersion. The first z exponential gives the contribution of pollution directly from the source. The second z exponential gives the contribution of pollution which was reflected from the ground. The A(N) terms account for multiple eddy reflections from both the ground and the stable layer.

The TSC/EPA Model considers multiple wind directions, rather than a single wind direction, and computes principal wind direction concentrations by sector-averaging. It is possible for the worst-case traffic and meteorological conditions to occur for any wind direction. Since the wind direction is a variable of primary importance in the determination of the pollutant concentration produced at a given receptor by a given road configuration, it is desirable to consider many wind directions for each situation considered. Therefore, the model iterates on wind direction so that results for several wind directions can be produced sequentially in one model run. From these results, the worst-case wind direction can be chosen for each receptor, and thus, the worst-case results can be used. In general, the worst-case wind direction will be different for each receptor.

Because of the known variability of wind direction at the low wind-speeds usually considered in worst-case computations, a sector-averaged pollutant computation of the following form is used:

$$C_{SA} = \frac{1}{4}\left[C(\theta_n - 22.5°) + 2C(\theta_n) + C(\theta_n + 22.5°)\right],$$

where: C_{SA} is the sector-average pollutant concentration for a principal wind direction,

$C(\theta)$ is the calculated concentration for wind direction, and

θ_n is the nominal angle for the principal wind direction.

Using the multiple wind-direction capability, 16 different runs are made using wind directions every 22.5 degrees. The model then automatically computes the pollutant concentration at each receptor for each principal wind direction, using sector-averaging.

3.1.2 Inputs

The model accepts the following inputs:

a) Endpoints of the centerline of each road segment,

b) Width of each road segment,

c) Width of the center strip of each road segment, if any,

d) Height of emissions for each road segment,

e) Emission strength of each lane of each road segment,

f) Wind directions to be used,

g) Wind speed,

h) Height of the mixing layer, and

i) Coordinates of the receptors.

3.1.3 Outputs

The output of the model contains all of the above input parameters in addition to the predicted pollution concentration at each receptor for each wind direction considered.

3.2 MODIFICATIONS TO ORIGINAL TSC/EPA MODEL

Two modifications had to be incorporated into the original TSC/EPA highway line-source model to deal with the complexities of the I-83/I-95 interchange: (a) provisions for entering the heights of both endpoints of each road segment to accommodate ascending and descending roadways, and (b) subdividing total pollutant concentration at each receptor into the components; namely, the separate contributions from ascending, descending, and horizontal road segments(done to permit the introduction of separate emission factors for these three types of road segments).

3.2.1 Modification to Accommodate Ascending and Descending Roadways

This modification was accomplished by introducing as input parameters the heights of the two endpoints of each road segment. The z-values along the line segment which are required in the emissions computations are then calculated by interpolation.

3.2.2 Modification to Subdivide Predicted Pollution into Contributions from Sloping and Horizontal Road Segments

TSC had intended to use separate emission factors for each sloping road segment which would be a function of the direction (up or down) and inclination of the segment. However, conversations with knowledgeable personnel of EPA at both Raleigh and Durham, North Carolina, and Ann Arbor, Michigan, revealed that no work had been done on estimating emission factors for sloping roads.

To obtain a rough estimate of this effect, TSC made several runs with a computer model of vehicle performance which TSC had developed. Using this model, a standard automobile was run through the EPA 7.5-mile urban-drive cycle for 4 road inclinations: 0 (horizontal), 2, 4, and 6 degrees all ascending. (A 6 degree incline is the maximum planned for the I-83/I-95 interchange.) The model computes the total fuel consumption for the cycle. As expected, it was found that fuel consumption is nearly a linear function of road inclination, so that compared to the amount of fuel consumed at 0 degrees, the percent increases at 2, 4, and 6 degrees were 9, 20 and 30 percent respectively. Similar decreases in fuel consumption could be anticipated for descending roads of the same slopes. (These computations were not made.)

It would be reasonable to assume that the percentage change in an emission factor caused by road slope would be the same as the corresponding percentage change in fuel consumption. Since these estimated changes of slope are relatively small, it was decided not to modify the model to incorporate separate emission factors for sloping road segments. Instead, the model was altered to output separately the contributions of ascending, descending, and horizontal road segments to the total pollution at each receptor. By subdividing the results in this way, it will be possible to analyze if the use of separate emission factors for inclined roads is desirable.

3.3 MODEL VALIDATION

Because of the unavailability of reliable air quality data suitable for model validation, the TSC/EPA Model has not, as yet, been fully validated. However, it was one of 13 air-pollution-dispersion models whose model predictions were compared in a recent study (Reference 2). The outputs of the 13 models were compared against each other for the same set of input data to determine how closely the model predictions agreed with one another. The TSC/EPA model and four other models (two Gaussian and two Conservation of Mass) emerged as Consensus Models, yielding results agreeing closely with one another. Although it is impossible, in the absence of validation data, to determine if the predictions of these Consensus Models no more accurate than those of the other models, none of the Consensus Models are likely to harbor theoretical or programming errors since their results agree closely with each other. Furthermore, since the set of Consensus Models contains models based upon two different theoretical formulations, this lends further credence to the validity of these models, including that of the TSC/EPA Model.

4. TSC AIR QUALITY ANALYSIS OF PROPOSED I-95/I-83 MULTILEVEL INTERCHANGE

4.1 ROAD SEGMENTATION

An overall view of the proposed I-83/I-95 interchange can be seen in Figure 2.2. The first step in the TSC air quality analysis was to break this complex interchange up into 21 separate roadways and ramps. These 21 roadways and ramps were then divided into 133 straightline segments of roadway for use with the improved TSC/EPA Model. A typical roadway, I-95 Northbound, is shown in Figure 4.1, with its eight segments indicated. The complete set of 21 roadways with 133 segments is shown in Appendix B. Appendix C shows the endpoints of each segment and segment width and number of lanes.

4.2 EMISSION CALCULATION

The emissions for each roadway segment are found in the program for the segment data and from the number of vehicles per hour on the segment, the traffic speed on the segment, and the emissions factor. The projected traffic densities and speeds for I-95 Northbound and Southbound for a 1980 peak hour case are shown in Table 4.1. The project densities and speeds for all segments are shown in Appendix D. Appendix D.1 shows the 1980 peak-hour data; Appendix D.2, the 1980 off-peak-hour data; Appendix D.3, the 1995 peak-hour data; and Appendix D.4, the 1995 off-peak-hour data. The emission factors used are shown in Table 4.2.

4.3 RECEPTION LOCATION

Eleven receptors were used in this air quality analysis. They were positioned at the points of expected maximum pound-level pollution concentrated. Their positions are shown with the stars in Figure 4.2. They are listed in Table 4.3.

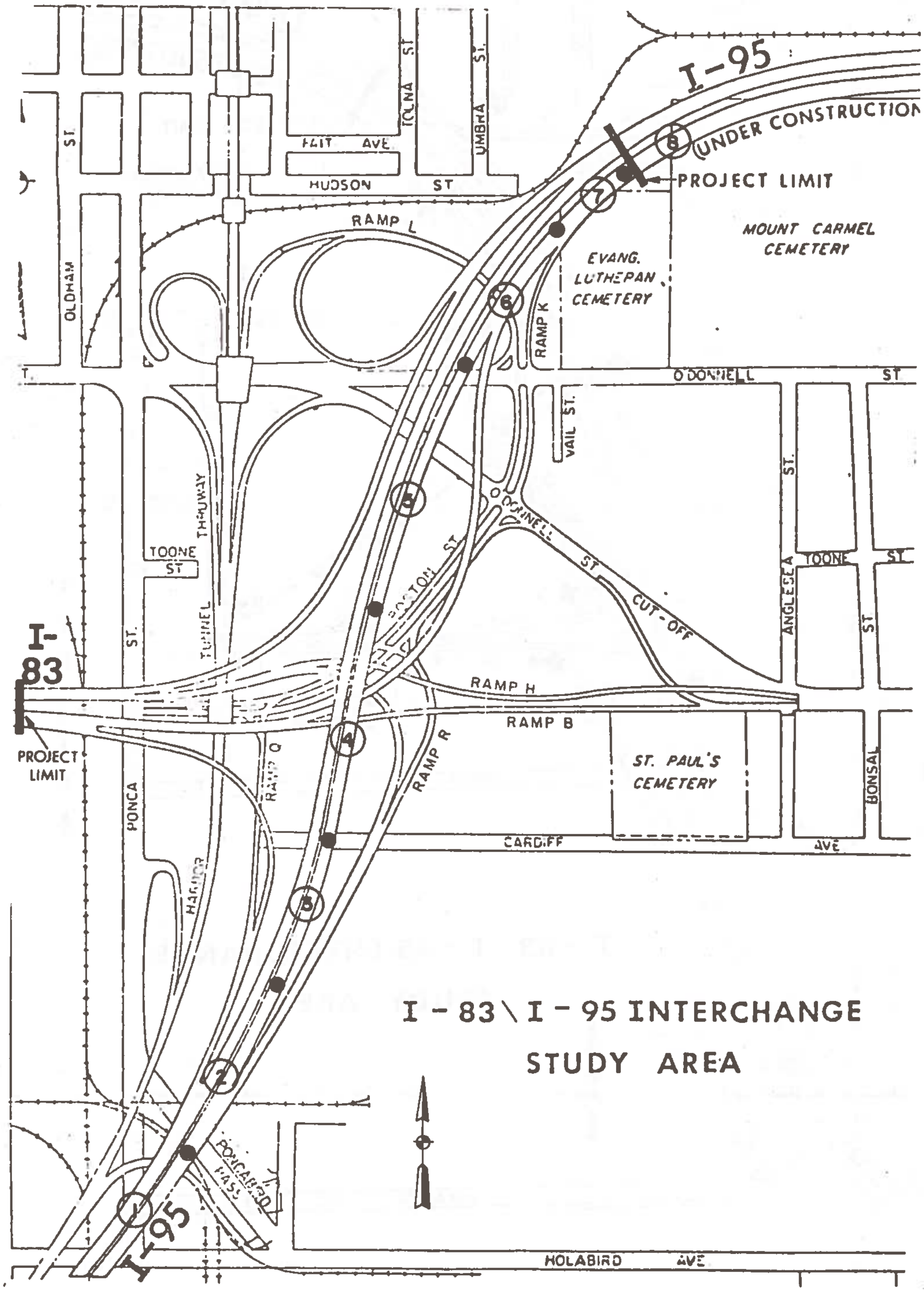

FIGURE 4.1 I-95 NORTHBOUND WITH ITS SEGMENTS

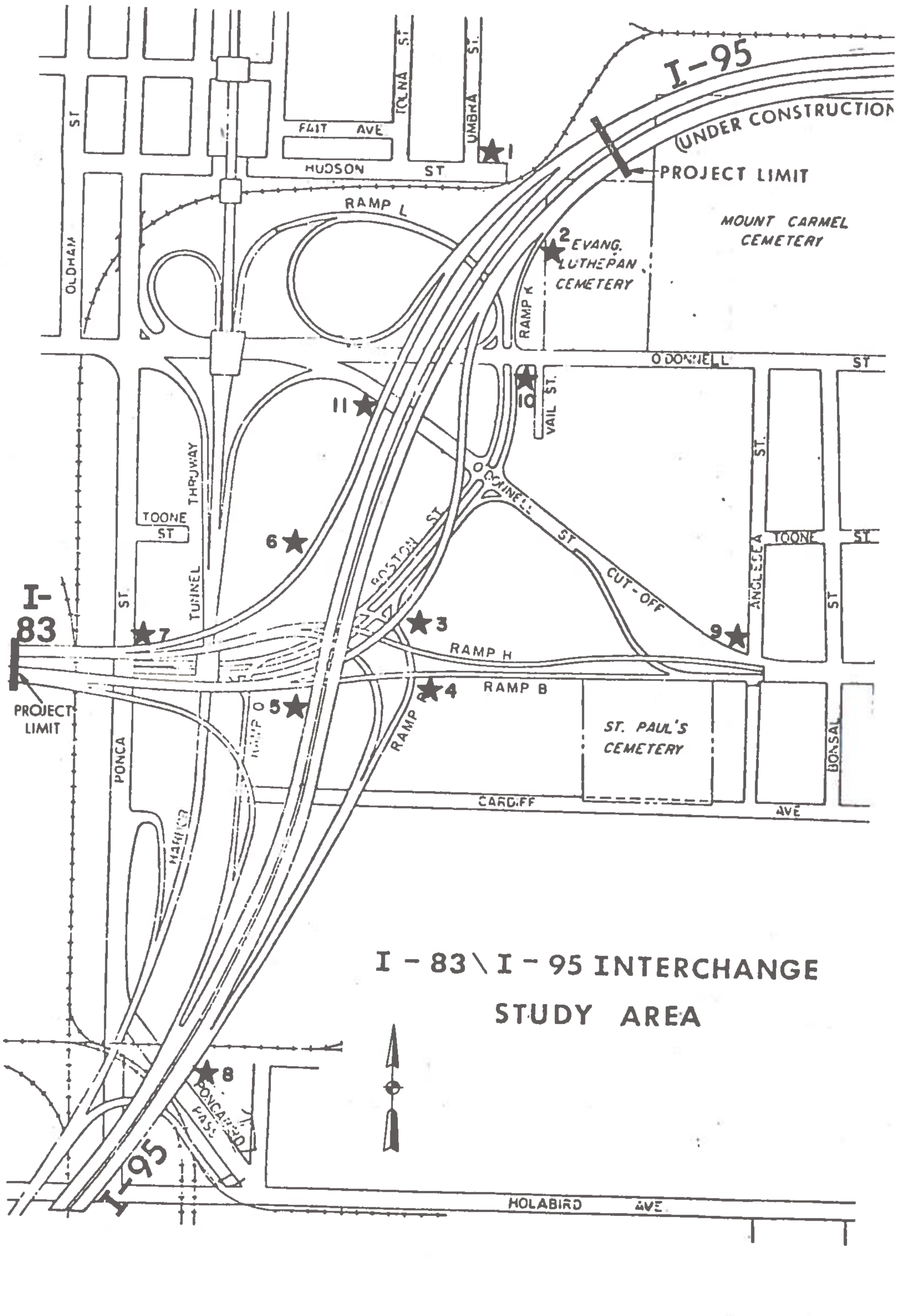

FIGURE 4.2 PROPOSED I-83/I-95 INTERCHANGE WITH RECEPTOR LOCATIONS

TABLE 4.1 EMISSIONS FOR I-95 NORTHBOUND (NB) AND SOUTHBOUND (SB)

1980 Peak Hour = 50% at 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only

I-83 and Others - 5%

	HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	1980 EMISSION FACTOR for CO & HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
				MPG	11%		
NB	1	6100	1525	50	11		
	2	6100	1525	50	11		
	3	4400	1100	50	11		
	4	4400	1100	50	11		
	5	4400	1100	50	11		
	6	4400	1100	50	11		
	7	6350	1270	50	11		
	8	6950	1160	50	11		
SB	10	3750	938	50	11		
	11	1950	650	50	11		
	12	1950	650	50	11		
	13	1950	650	50	11		
	14	1950	650	50	11		
	15	1950	650	50	11		
	16	1950	650	50	11		
	17	1950	650	50	11		

TABLE 4.2 CARBON MONOXIDE EMISSION FACTORS
(Grams Per Mile)

Year	Speed	Heavy Duty Vehicle, Percent 17	11	9	5
1980	50	12.52	10.12	9.3	7.61
	40	13.82	11.05	0.0	0.0
	20			15.37	11.9
	10			21.08	15.95
1995	50	9.78	7.19	6.30	4.48
	40	10.88	7.95	0.0	0.0
	20			10.43	6.75
	10			14.33	8.90

TABLE 4.3 RECEPTORS

RECEPTOR NUMBER	(FEET) X	Y	Z
1	8670	4800	5
2	8945	4580	5
3	8530	3080	5
4	8545	2660	5
5	8100	2420	5
6	7900	3200	5
7	7400	2890	5
8	7765	1000	5
9	9800	2900	5
10	8810	4000	5
11	8100	3800	5

4.4 CALCULATED CONCENTRATIONS FOR 1980

The computed concentration for the 1980 peak-hour case can be found in Table 4.4. The maximum peak-hour concentration of 7.02 parts per million (ppm) occurs at receptor 9 with winds from a westernly direction. This value is far below the national one-hour primary ambient air quality standard for CO, which is 35 ppm.

The 1980 off peak hour results are shown in Table 4.5. The maximum concentration found was 2.45 ppm occurring at receptor 9 with the wind from the west. This value is also far below the national one-hour primary ambient air quality standard.

All peak-hour and off-peak-hour concentrations are less than the national eight-hour average primary ambient air quality standard of 9 ppm for CO. Thus, any combination of eight hours will clearly be below the national standard.

4.5 CALCULATED CONCENTRATIONS FOR 1995

The computed concentrations for the 1995 peak-hour case are presented in Table 4.6. The maximum peak-hour concentration of 5.00 ppm occurs at receptor 9 with winds from the westerly direction. This value is far below the national ambient air quality standard.

The results for the off-peak-hour case in 1995 are shown in Table 4.7. The maximum concentration found was 2.15 ppm at receptor 9 with wind from the west. This value is far below the national primary ambient-air-quality standard.

As for 1980, all 1995 peak-hour and off-peak hour concentrations are considerably below the national eight-hour average standard. Thus, any eight-hour average will satisfy the standard.

4.6 USE OF ASCENDING AND DESCENDING ROAD-EMISSION FACTORS

It will be noted that the air-pollution levels associated with this interchange are low at all receptors, the maximum being only 7.02 ppm for the peak hour in 1980. In most cases, the contributions of the ascending and descending roads to the total

TABLE 4.4 PEAK HOUR CONCENTRATIONS (Parts Per Million)

RECEPTOR NUMBER	WIND DIRECTION							
	N	NE	E	SE	S	SW	W	NW
1	0.00	0.35	1.43	0.67	3.26	2.17	0.60	0.04
2	1.41	0.49	0.00	0.23	2.24	3.43	1.20	0.36
3	2.77	0.89	0.91	0.68	1.16	3.21	2.00	1.50
4	2.49	1.11	0.40	0.00	0.01	1.24	2.53	1.82
5	2.17	2.13	0.75	0.08	0.46	0.97	1.02	1.68
6	0.63	0.98	1.25	1.25	1.59	1.12	0.26	0.36
7	0.22	1.56	2.60	1.71	1.77	1.24	0.44	0.00
8	2.05	0.74	0.00	0.00	0.00	0.08	0.15	0.38
9	0.19	0.06	0.73	2.52	2.32	3.45	7.02	2.67
10	0.89	0.10	0.00	0.25	2.80	2.89	1.27	1.11
11	1.00	2.11	1.31	1.57	1.35	0.90	0.37	1.28

TABLE 4.5 OFF-PEAK HOUR CONCENTRATIONS
(Parts Per Million)

RECEPTOR NUMBER	WIND DIRECTION N	NE	E	SE	S	SW	W	NW
1	0.00	0.13	0.44	0.22	1.20	0.89	0.28	0.02
2	0.39	0.12	0.00	0.08	0.79	1.22	0.51	0.14
3	0.98	0.32	0.33	0.25	0.36	1.09	0.72	0.59
4	0.86	0.40	0.15	0.00	0.00	0.48	0.88	0.66
5	0.76	0.73	0.27	0.03	0.16	0.38	0.38	0.62
6	0.28	0.36	0.45	0.43	0.53	0.40	0.09	0.17
7	0.10	0.52	0.92	0.60	0.63	0.41	0.14	0.00
8	0.82	0.26	0.00	0.00	0.00	0.04	0.07	0.16
9	0.04	0.02	0.24	0.90	0.84	1.26	2.45	0.88
10	0.27	0.02	0.00	0.10	0.97	1.01	0.50	0.45
11	0.41	0.63	0.47	0.57	0.46	0.33	0.17	0.58

TABLE 4.6 1995 PEAK HOUR CONCENTRATIONS
(Parts Per Million)

RECEPTOR NUMBER	N	NE	E	SE	S	SW	W	NW
	WIND DIRECTION							
1	0.00	0.23	1.03	0.47	2.31	1.62	0.49	0.04
2	1.07	0.39	0.00	0.16	1.65	2.54	0.91	0.26
3	1.96	0.62	0.64	0.49	0.84	2.34	1.44	1.10
4	1.78	0.79	0.29	0.00	0.01	0.96	1.88	1.32
5	1.55	1.50	0.53	0.06	0.35	0.81	0.82	1.31
6	0.46	0.68	0.88	0.87	1.18	0.83	0.19	0.31
7	0.18	1.14	1.85	1.28	1.34	0.86	0.31	0.00
8	1.64	0.52	0.00	0.00	0.00	0.07	0.13	0.30
9	0.15	0.04	0.52	1.79	1.65	2.50	5.00	1.93
10	0.64	0.08	0.00	0.18	1.99	2.06	0.95	0.81
11	0.74	1.57	0.91	1.10	0.98	0.67	0.32	1.06

TABLE 4.7 1995 OFF-PEAK HOUR CONCENTRATIONS (Parts Per Million)

RECEPTOR NUMBER	WIND DIRECTION N	NE	E	SE	S	SW	W	NW
1	0.00	0.12	0.40	0.20	1.07	0.82	0.26	0.02
2	0.36	0.11	0.00	0.07	0.70	1.10	0.47	0.13
3	0.86	0.27	0.29	0.23	0.28	0.91	0.63	0.52
4	0.76	0.35	0.13	0.00	0.00	0.40	0.75	0.57
5	0.67	0.63	0.22	0.02	0.13	0.34	0.33	0.55
6	0.25	0.31	0.39	0.36	0.46	0.37	0.08	0.16
7	0.10	0.47	0.80	0.51	0.57	0.36	0.13	0.00
8	0.73	0.22	0.00	0.00	0.00	0.04	0.06	0.14
9	0.04	0.02	0.21	0.79	0.74	1.11	2.15	0.78
10	0.24	0.02	0.00	0.08	0.84	0.88	0.46	0.41
11	0.38	0.57	0.42	0.50	0.40	0.30	0.16	0.55

pollution was considerably less than the contribution of the at-grade roads. Thus in view of the overall low-pollution levels, it was deemed unnecessary to use separate emission factors for the ascending and descending roads of this analysis. At such time as EPA promulgates emission factors for such situations, it will be a simple matter to incorporate them in the TSC/EPA model.

5. ADDITIONAL ANALYSIS

In the air-quality analysis described in Section 4, the receptor locations were chosen in the standard manner were to be those points which were accessible and which expected to have the highest pollutant concentrations. In this section, an improved method of determining receptor locations will be discussed.

The points of maximum pollutant concentration near an at-grade road are easily found to be the accessible ground-level points which were closest to the roadway. For an elevated highway, if one confines interest to ground-level receptors, theoretical values of the approximate location of maximum pollutant concentration (given the height of the elevated roadway) can be found. These maximum points will be at a distance from the road, which is dependent upon the roadway height.

However, for a complex multilevel interchange such as the one analyzed in this report, the location of the maximum concentration points is not so clear. Each at-grade roadway will yield its maximum ground-level pollution as close to the roadway as is accessible, but the elevated road sections will produce maximum ground-level pollution at distances from the roadway increasing with increasing height of the sections. The combination of several at-grade road sections and several elevated sections of various (and varying) heights, with each section having different geometry and emissions levels, is much too complex to allow a simple determination of the points of maximum ground-level concentrations. The use of engineering judgment is guess the location of maximum pollutant concentrations (as was done in Section 4) is a reasonable method. However, methods of maximum seeking can be used to find better locations for these maximum points.

5.1 MAXIMUM GROUND-LEVEL POLLUTION POINTS FOR SINGLE ROADWAYS

Using the Gaussian formulation for an infinite line source, the concentration at a ground-level receptor can be written as (1):

$$C = (2Q/(SQRT(2pi)\ U\ SIGz))\ (EXP\ (-H**2/2SIGz(X)), \qquad (1)$$

where C = the concentration at a point at distance X from the line source,

Q = the emission per unit length,

U = the average windspeed,

H = the height above the ground of the line source, and

SIGz = the vertical dispersion coefficient, a function of X.

This can be written as:

$$C(X) = A/SIGz(X)\ \ (FXP(-H**2/2SIGz(X)), \qquad (2)$$

where A = 2Q / U (SORT(2pi)).

For an at-grade line source, (H=0), Equation (2) becomes

$$C(X) = A/SIGz(X). \qquad (3)$$

Thus, C(X) is maximum when SIGz is at a minimum. Figure 5-1 shows SIGz versus X, from Reference 2. It can be seen that for all stabilities, SIGz monotonically increases with X. Therefore, it is clear that SIGz(X) will be minimum (and C(X) maximum) for the smallest possible value of X. This would correspond to the closest accessible point to the road.

For an elevated infinite line source, to get the maximum ground-level pollution, Equation (2) is differentiated and set to zero, yielding:

$$SIGz(Xmax) = H. \qquad (4)$$

Thus, the maximum ground-level pollution from an infinite line source of elevation H will occur at that distance Xmax such that SIGz(Xmax) equals the road height. A table of Xmax values for elevated roadways of 30, 40, and 50 feet is shown in Table 5-1. Note that the point of maximum ground-level pollution is at some distance from the roadway, in some cases over a quarter of a mile. The value of maximum ground-level pollution concentration is:

$$C(Xmax) = A/H\ (EXP\ -1/2),$$

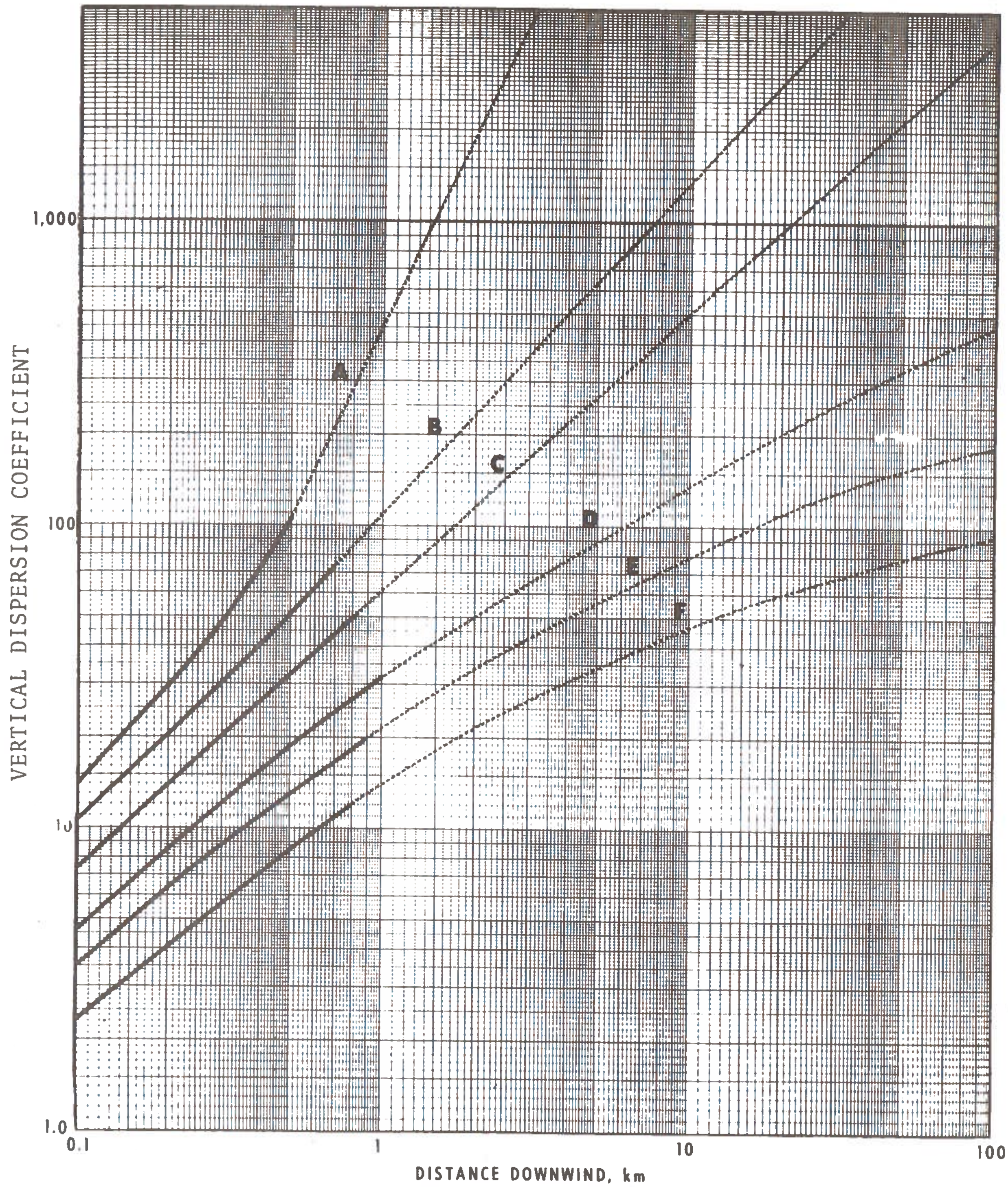

FIGURE 5.1 ESTIMATED CONCENTRATIONS OF VERTICAL DISPERSION OF AIR POLLUTION

which is, interestingly, independent of stability.

The TSC/EPA Model was run for a very long (i.e., "infinite") road which was at a 50-foot elevation. For each stability, a ground-level receptor was plaeced every 100 feet from the road. The receptor with the maximum pollution for each stability is shown in Table 5-2. These distances compare well with the ground-level maximum concentration distances for a 50-foot-high roadway, as shown in Table 5-1.

5.2 MAXIMUM GROUND-LEVEL POLLUTION POINTS FOR COMPLEX MULTILEVEL INTERCHANGES

As discussed above, for a given stability, elevated roadways of different heights will have maximum ground-level pollutant points at different locations remote from the highway, and ground-level roadways will produce maximum ground-level pollutant values as near as possible to the roadway. Therefore for a complex multilevel interchange with many road segments of different height, orientation, traffic volume and speed, the locations of the points of maximum ground-level pollutant concentrations are not obvious.

A two-dimensional stepwise maximum-seeking technique can be used to find such points. Such techniques are often used to find extremes of functions in a two-dimensional plane, and can be applied to the present situation.

One method, which might be called the one-dimensional search method, involves the following steps:

a. Choose a reasonable set of initial ground-level receptors.

b. Find the wind angle that produces the largest ground-level pollutant concentration at the receptor because of the interchange.

c. Search along a line through the receptor point and parallel to the maximum wind direction. Find the point of maximum pollution.

The search can be accomplished by trying a set of receptors along with line, each a certain distance (e.g., 100 feet) apart and finding the one with the highest pollution.

TABLE 5.1 DISTANCE TO MAXIMUM GROUND-LEVEL POLLUTION FROM INFINITE ELEVATED LINE SOURCE

STABILITY	(feet) HEIGHT OF INFINITE LINE SOURCE		
	30	40	50
A	223	289	361
B	282	384	482
C	417	574	725
D	705	1010	1312
E	1033	1549	3018
F	1788	2641	3773

TABLE 5.2 MAXIMUM GROUND-LEVEL POLLUTION FROM 50-FOOT HIGH INFINITE LINE SOURCE AS CALCULATED BY TSC/EPA MODEL

STABILITY	(feet) DISTANCE FROM ROAD OF RECEPTOR WITH MAXIMUM POLLUTANT CONCENTRATION
A	300
B	400
C	700
D	1200
E	2000
F	4100

ROAD ENDPOINT NO. 1:	(-5000,0,50)
ROAD ENDPOINT NO. 2:	(5000,0,50)
VEHICLES PER HOUR:	10,000, 5 percent HDV
SPEED:	40 MPH
MIXING HEIGHT:	20,000 ft.
WIND:	0. 1 MPS

The one-dimensional search method was applied to the I-83/I-95 interchange, using as initial points the receptors of Section 4. The results are shown in Table 5-3.

As might be expected, the maximum value found using this method still occurs at receptor 9. The value 8.77 ppm found at this receptor is still quite below the ambient-air-quality standard.

Other methods of maximum-seeking can be used. For example, a two-dimensional grid search method would consist of the following steps.

a) Choose a reasonable set of initial ground-level receptors.

b) For each initial receptor (Xo,Yo), find the pollution at the four surrounding points: (Xo+D,Yo), (Xo-D,Yo), (Xo,Yo+D), and (Xo,Yo-D).

c) Move each receptor to that one of the four surrounding points with the highest pollution concentration.

d) Repeat steps (2 and 3) until a relative maximum is found for each initial receptor.

This technique has not as yet been applied by TSC to the I-83/I-95 interchange since the technique involves a much greater amount of computational time than the one-dimensional search method.

TABLE 5.3 MAXIMUM GROUND-LEVEL CONCENTRATIONS USING ONE-DIMENSIONAL SEARCH METHOD

RECEPTOR NUMBER	INITIAL RECEPTOR	POLLUTION CONCENTRATION P.P.M.	STAB.	MAXIMUM WIND ANGLE (DEGREES)	MAXIMUM RECEPTOR	POLLUTION CONCENTRATION (P.P.M.)
1	8670,4800	1.29	A	202.5	8860,4860	2.21
		2.21	B	202.5	8860,4860	4.03
		3.06	C	202.5	8860,4860	5.00
		4.10	D	202.5	8860,4860	6.60
		4.47	E	202.5	8860,4860	6.81
		4.56	F	202.5	8955,4890	6.14
2	8945,4580	0.71	A	202.5	8945,4580	.71
		1.46	B	202.5	8945,4580	1.46
		2.23	C	202.5	8945,4580	2.23
		3.93	D	202.5	8945,4580	3.93
		5.10	E	202.5	8945,4580	5.10
		5.99	F	202.5	9040,4610	6.61
3	8530,3080	1.39	A	247.5	8890,3560	1.69
		2.18	B	247.5	8890,3560	2.18
		2.72	C	247.5	8890,3560	2.78
		3.77	D	247.5	8530,3080	3.77
		4.52	E	247.5	8530,3080	4.52
		5.57	F	247.5	8530,3080	5.57
4	8545,2660	1.21	A	270.0	8545,2860	1.61
		1.82	B	270.0	8545,2860	2.58
		2.27	C	270.0	8545,2860	3.07
		3.15	D	270.0	8545,2860	3.97
		3.60	E	270.0	8545,2760	4.81
		3.58	F	270.0	8545,2760	6.16
5	8100,2420	0.99	A	22.5	7625,2345	1.61
		1.55	B	22.5	7625,2345	2.20
		1.99	C	22.5	7625,2345	2.64
		2.77	D	22.5	7815,2375	3.62
		3.42	E	22.5	7720,2360	4.39
		4.52	F	22.5	7815,2375	5.34
6	7900,3200	0.96	A	180.0	8400,3200	1.38
		1.44	B	180.0	8100,3200	1.82
		1.86	C	180.0	8100,3200	2.02
		2.22	D	180.0	8400,3200	2.24
		2.22	E	180.0	8400,3200	2.62
		1.79	F	180.0	8400,3200	3.30
7	7400,2890	1.29	A	90.0	7400,2690	2.17
		1.98	B	90.0	7400,2690	2.86
		2.35	C	90.0	7400,2690	3.31
		3.06	D	90.0	7400,2690	3.80
		3.66	E	90.0	7400,2790	4.31
		4.64	F	90.0	7400,2790	5.61
8	7765,1000	1.24	A	0.0	7765,1000	1.24
		1.90	B	0.0	7765,1000	1.90
		2.16	C	0.0	7765,1000	2.16
		2.63	D	0.0	7565,1000	3.40
		3.14	E	0.0	7665,1000	4.48
		3.59	F	0.0	7665,1000	6.76

TABLE 5.3 MAXIMUM GROUND-LEVEL CONCENTRATIONS USING ONE-DIMENSIONAL SEARCH METHOD (CONTINUED)

RECEPTOR NUMBER	INITIAL RECEPTOR	POLLUTION CONCENTRACTION P.P.M.	STAB.	MAXIMUM WIND ANGLE (DEGREES)	MAXIMUM RECEPTOR	POLLUTION CONCENTRATION (P.P.M.)
9	9800,2900	2.90	A	270.0	9800,2900	2.90
		3.84	B	270.0	9800,2900	3.84
		4.84	C	270.0	9800,2900	4.84
		6.68	D	270.0	9800,2900	6.68
		7.72	E	270.0	9800,2900	7.72
		8.77	F	270.0	9800,2900	8.77
10	8810,4000	1.07	A	202.5	8100,4000	1.07
		2.18	B	202.5	8100,4000	2.18
		3.15	C	202.5	8100,4000	3.15
		5.44	D	202.5	8100,4000	5.44
		7.05	E	202.5	8100,4000	7.05
		8.56	F	202.5	8100,4000	8.57
11	8100,3800	0.84	A	112.5	8280,2945	1.16
		1.23	B	112.5	8280,2945	1.39
		1.44	C	112.5	8280,2945	1.60
		2.14	D	112.5	8100,3800	2.14
		2.87	E	112.5	8100,3800	2.87
		4.15	F	112.5	8100,3800	4.15

6. SUMMARY AND CONCLUSIONS

In this report, a case study on the computer analysis of air pollution produced by a multilevel complex interchange has been presented. This study is concerned with a series of air-quality analyses performed by TSC for the proposed I-83/I-95 interchange in Baltimore, Maryland, at the request of the Federal Highway Administration, Region 3. The analyses showed that the national primary standards for air pollution would not be exceeded in either 1980 or 1995, for both the peak and the off-peak hours.

The air-quality analysis for the I-83/I-95 site is treated in this report as a case study, exemplifying the TSC air-quality-analysis methodology. This methodology consists of five steps: (a) Road Segmentation -- dividing the road configuration into a set of homogenous straight segments; (b) Emissions Calculation -- using traffic volume and speed estimates to calculate the pollutant emissions of each segment; (c) Receptor Location -- positioning the points at which concentrations will be calculated at strategic locations; (d) Peak-Hour-Concentration Calculation -- calculating pollutant concentrations for a peak-hour traffic situation; and (e) Off-Peak Concentration Computation -- calculating pollutant concentrations for off-peak-hour traffic situations. The procedure for each step is described in this report. A set of standard tables are used for data entry in carrying out the five-step process.

The above methodology was used to calculate pollutant concentrations for the interchange. The site includes elevated highways, streets, and ramps, both ascending and descending. The complete standard tables for each air-quality analysis are shown in the report.

TSC methodology is based upon the use of the TSC-modified version of the EPA Highway Line-Source Model. The original EPA model is a Gaussian plume air pollution-dispersion model, specifically tailored for calculating air-pollution dispersion from a single highway-line source. This model was modified for use in the five-step procedure. The modifications allow for:

(a) the input of ascending and descending roadways; and (b) the subdivision of predicted pollution into contributions from sloping and horizontal road segments.

TSC five-step approach to the computer analysis of vehicle-source air pollution (as shown in this case study) is an easy-to-use, straightforward procedure which can be followed in the performance of future air quality analyses. Within the limitations of the model and the traffic estimates used, it can produce reasonable estimates of worst-case pollutant concentrations for comparison with the EPA national ambient air quality standards or other one-hour and eight-hour standards. Use of an improved or expanded model would allow for a greater variety of applications and for improved accuracy of results.

APPENDIX A. LISTING OF UPGRADED TSC/EPA MODEL PROGRAM

```
C          THIS PROGRAM CALCULATES THE CONCENTRATION FROM A LINE SOURCE
C           AT EACH OF A NUMBER OF RECEPTORS. SUBROUTINE RELCO
C           IS CALLED WHICH IN TURN CALLS SUBROUTINE SIGMA.
      DIMENSION XVZ(6),XVY(6),GLS(24),HEAD(20),SS(16,7)
      DIMENSION AR(16,7)
      DIMENSION XPRR(30),YPRR(30),ZPRR(30)
      DIMENSION ANGL(17),EMIS(40),POLL(30,20),SCLS(30)
      DIMENSION XRD2(140),YRD2(140),ZRD2(140)
      DIMENSION CONTR(133,11)
      DIMENSION XRD1(140),YRD1(140),ZRD1(140)
      DIMENSION I1XNL(140),XWIDTH(140)
      DIMENSION ITYP(140),ISCT(140),C(11,16,7)
      DIMENSION JSECT(140),NCAR(140),NSPLT(140),ISPD(140),
     1  JHEV(140)
      COMMON /A/ GY(6),GZ(6,6)
      DATA XVZ/0.012,0.012,0.017,0.027,0.035,0.058/
      DATA XVY/.009,.013,.020,.032,.044,.044/
      DO 777 I=1,11
      DO 777 J=1,16
       DO 777 K=1,7
      C(I,J,K)=0.0
  777 CONTINUE
      JRD=9
      ANGL(1)=0.0
      DO 1 I=2,16
      ANGL(I)=ANGL(I-1)+22.5
    1 CONTINUE
      IRD=10
      NANG=16
      NRECP=2
```

```
      NCASE=133
      IWRI=12
      IWRR=6
      LLR=14
      LU=11
      XMET=.3048
      HL=1000.0*XMET
      H=3.0*XMET
      CNTR=0.0
C     READ THE RECEPTORS
      READ(LLR,401) (YPRR(I),XPRR(I),ZPRR(I),I=1,NRECP)
 2050 CONTINUE
      WRITE(IWRI,433) (XPRR(I),YPRR(I),ZPRR(I),I=1,NRECP)
 401  FORMAT(F6.1,F7.1,1X,F4.1)
 433  FORMAT(F7.1,F6.1,1X,F4.1)
   72 FORMAT(I2,1X,I1)
   71 FORMAT(5I5)
C     READ YEAR AND WIND SPEED
      READ(JRD,72)IYR,IU
      WRITE(IWRI,72) IYR,IU
      U=IU
C      READ EMISSION DATA
      READ(JRD,71)(JSECT(I),NCAR(I),NSPLT(I),ISPL(I),JHDV(I)
     1  ,I=1,NCASE)
C      READ ALL ROAD SEGMENT DATA
      READ(IRD,177)(ISCT(I),XRD1(I),YRD1(I),ZRD1(I),XRD2(I),
     1 YRD2(I),ZRD2(I),XWIDTH(I),IIXNL(I),ITYP(I),I=1,NCASE)
  177 FORMAT(1X,I4,7F7.1,2I3)
    7 FORMAT(2F9.3,I2,F10.3)
      JK=0
```

```
C       CHECK TO SEE IF ROAD DATA AND
C       EMISSION DATA ARE PROPERLY LINED UP
      DO 703 J=1,NCASE
      TEMP=XRD1(J)
      XRD1(J)=YRD1(J)
      YRD1(J)=TEMP
      STO=XRD2(J)
      XRD2(J)=YRD2(J)
      YRD2(J)=STO
  703 CONTINUE
      DO 508 I=1,NCASE
      IF(ISCT(I).EQ.JSECT(I))GO TO 508
      JK=JK+1
  508   CONTINUE
      IF(JK.EQ.0) GO TO 609
       WRITE(IWRI,503) JK
 503   FORMAT(1X,'NUMBER OF DISCREPANCIES IS ',1X,I4)
 609  CONTINUE
 88   FORMAT(I4)
    9 FORMAT(8F10.4)
   10 FORMAT(2F10.3)
   11 FORMAT(I2)
   12 FORMAT(4F10.3,I3,2F10.3)
   13 FORMAT(8F10.3)
   14 FORMAT(20A4)
   15 FORMAT(1H0, 20A4)
   16 FORMAT(1X, 28HWIDTH OF AT-GRADE HIGHWAY IS ,F10.3,3H  M /
     1 1X,24HWIDTH OF CENTER STRIP IS , F10.3  )
   17 FORMAT(1X, 37HEMISSION RATE (GRAMS/SECOND*METER) OF ,I4,
     1  8H LANE(S) )
```

```
   18 FORMAT(1H ,36HTHE SCALE OF THE COORDINATE AXES IS ,F10.4,4H KM. )
   19 FORMAT(1H0,51HCOORDINATES OF THE ENDPOINTS OF THE LINE SOURCE ARE
     1F10.3,1H,,F10.3,7H  AND  ,F10.3,1H,,F10.3)
   20 FORMAT(1H0,17HWIND DIRECTION IS,F7.0,25H  DEGREES   WIND SPEED IS
     1F7.1,11H METERS/SEC/19H STABILITY CLASS IS,I2,1X,
     2 25HHEIGHT OF LIMITING LID IS,F8.1,6HMETERS   )
   23 FORMAT(1X, 18HEMISSION HEIGHT IS , F8.3, 7H METERS   )
   28 FORMAT(1H0,52H  RECEPTOR LOCATION         RECEPTOR    CONCENTRATIO
     1/6X,2HRR,10X,29HSR          HEIGHT(M)       PPM       )
   30 FORMAT(1H ,3(F10.4,2X),E15.5)
   31 FORMAT(1H1)
   34 FORMAT(F10.3,3X,I2,I5,3X,I2)
 35    CONTINUE
       KST=6
        XPRR(1)=9800.0
             YPRR(1)=2900.0
C      READ NUMBER OF CASES
C      READ(IRD ,88)NCASE
       DO 3050 LY=1,NANG
       DO 8 J=1,NRECP
       SCLS(J)=0.0
 8     CONTINUE
       DO 1000 IDOW=1,NCASE
 8888  CONTINUE
       THETA =ANGL(LY)
       KTY=ITYP(IDOW)
C      READ(IRD ,12) REP1,SEP1,REP2,SEP2,IXNL,CNTR,WIDTH
       IXNL=IIXNL(IDOW)
       XNL=IXNL
C      READ  NUMBER OF RECEPTORS FOR THIS CASE
```

```
C      READ (IRD ,11) NRECP
C      READ(IRD ,34) H,NHDV,NVEH,NSPEED
       ISP=ISPD(IDOW)
       IHDV=JHDV(IDOW)
       NVEH=NCAR(IDOW)
       CALL FINDBG(IYR,ISP,IHDV,NVEH,G)
C      READ(IRD ,7) THETA,U,KST,HL
       B=Q/XNL
       DO 5002 I=1,IXNL
       QLS(I)=B
 5002  CONTINUE
       REP1=XRD1(IDOW)*XMET
       REP2=XRD2(IDOW)*XMET
       SEP1=YRD1(IDOW)*XMET
       SEP2=YRD2(IDOW)*XMET
       WIDTH=XWIDTH(IDOW)*XMET
       CNTR=CNTR*XMET
C         REP1,SEP1 ARE THE COORDINATES OF AN END POINT OF THE LINE
C           SOURCE IN SOURCE COORDINATES.
C         REP2,SEP2 ARE THE COORDINATES OF THE OTHER END POINT OF THE
C           LINE SOURCE IN SOURCE COORDINATES.
C         H IS THE EFFECTIVE EMISSION HEIGHT OF THE SOURCE IN METERS.
C      CNTR IS THE WIDTH OF THE CENTER STRIP (M)
C         WIDTH IS THE HIGHWAY WIDTH  (M) FOR AT GRADE
C         XNL IS THE NUMBER OF LANES FOR THE AT-GRADE HIGHWAY.
       NL=XNL
       IF(XNL.GT.1.) XNL=XNL-1.
       DELW=(WIDTH-CNTR)/XNL
C      WRITE(IWRI,19)REP1,SEP1,REP2,SEP2
C      WRITE(IWRI,23)H
```

```
C       WRITE(IWRI,17)NL
 1921 FORMAT(8F11.5)
C           QLS IS THE LINE SURCE STRENGTH (GRAMS/SECOND*METER)
C       WRITE (IWRI,2)(QLS(I),I=1,NL)
     2 FORMAT(8F12.6)
       CUT=0.0
C           XNDL IS THE NUMBER OF LINE SOURCES REPRESENTING THE TOP OF THE
C            CUT SECTION.
C       WIDTC IS THE WIDTH OF THE TOP OF THE CUT(M)
       IF(CUT.EQ.0.)GOTO0101
C           DQLS IS THE CUT SECTION SOURCE STRENGTH
       DQLS=0.
       DO 40 I=1,NL
    40 DQLS=DQLS+QLS(I)
       NL=XNDL
       IF(XNDL.GT.1.) XNDL=XNDL-1.
       DOWNL=NL
       DQLS = DQLS/DOWNL
       DELW=WIDTC/XNDL
C      WRITE(IWRI,29)WIDTC
    29 FORMAT(32H WIDTH OF TOP OF CUT SECTION IS ,F10.3,3H M   )
       DO100I=1,NL
   100 QLS(I)=DQLS
       GOTO102
  101  CONTINUE
C 101  WRITE(IWRI,16)WIDTH,CNTR
  102  CONTINUE
C          THETA IS THE WIND DIRECTION IN DEGREES.
C          U IS THE WIND SPEED IN METERS PER SECOND.
C          KST IS THE STABILITY CLASS
```

```
C          HL IS THE HEIGHT OF THE LIMITING LID
C       WRITE (IWRI,20) THETA,U,KST,HL
        GS=.001
C          GS IS THE MEASURE BETWEEN COORDINATES (KM).
C       WRITE(IWRI,18) GS
C       WRITE(IWRI,28)
C            CONVERT COORDINATE SYSTEM SO THAT HIGHWAY
C             IS ORIENTATED ALONG ZERO DEGREES (MATH SYSTEM)
        X1=REP1
        Y1=SEP1
        X2=REP2
        Y2=SEP2
C       WRITE(IWRI,9000) X1,Y1,X2,Y2
        DX=X2-X1
        DY=Y2-Y1
        CALL ATH(DX,DY,ANGH,DANG)
        REP1=Y1*SIN(ANGH)+X1*COS(ANGH)
        SEP1=Y1*COS(ANGH)-X1*SIN(ANGH)
        REP2=Y2*SIN(ANGH)+X2*COS(ANGH)
        SEP2=Y2*COS(ANGH)-X2*SIN(ANGH)
C       WRITE(IWRI,9000) REP1,SEP1,REP2,SEP2
C           CONVERT WIND DIRECTION WRT HIGHWAY
        THETA=THETA+DANG
        IF(THETA.LT.0.)THETA=THETA+360.
        IF(THETA.GE.360.)THETA=THETA-360.
        T =THETA/57.2958
C           T IS THE WIN DIRECTION IN RADIANS
        SINT=SIN(T)
        COST=COS(T)
C           SINT AND COST ARE THE SINE AND COSINE OF THE WIND DIRECTION
```

```
C          P IS THE LENGTH OF THE LINE SOURCE
      P=(((REP2-REP1)*(REP2-REP1)+(SEP2-SEP1)*(SEP2-SEP1))**0.5)*GS
      Z1=ZRD1(IDOW)*XMET + H
      Z2=ZRD2(IDOW)*XMET+ H
      DZ=Z2-Z1
C     WRITE(IWRI,171)Z1,Z2,DX,P
 171  FORMAT(1X,'Z',4E14.5)
      DO  975  JDOW = 1,NRECP
      XXRR=XPRR(JDOW)* XMET
      XXSR=YPRR(JDOW)*XMET
C      WRITE(IWRI,9000) XXRR,XXSR
      Z=ZPRR(JDOW) *  XMET
C          XXRR,XXSR ARE THE COORDINATES OF THE RECEPTOR
C          Z IS THE RECEPTOR HEIGHT IN METERS
      IF(XXRR.EQ.9999.)GO1035
      CNTS=0.
      CLS=0.
C          CONVERT RECEPTOR COORDINATES WRT HIGHWAY
      XRR=XXSR*SIN(ANGH)+XXRR*COS(ANGH)
      XSR=XXSR*COS(ANGH)-XXRR*SIN(ANGH)
      RR=XRR
5051  FORMAT(1X,I4,2X,4E20.7)
      DO600IL=1,NL
      DOWIL= IL-1
      IF(CUT.NE.0.)GOTO76
      IF(IL.GT.NL/2.AND.IL.NE.1)CNTS=CNTR
  76  IF(THETA.GT.90.0 .AND. THETA.LE.270.0 ) GO TO 77
      SR =  XSR - DELW * DOWIL -CNTS + WIDTH/2.0
      GOTO78
  77  SR =  XSR + DELW * DOWIL +CNTS - WIDTH/2.0
```

```
   78 ESTD=0.
      WRITE(IWRI,9000)SR,DANG,ANGH
         CALCULATE DOWNWIND AND CROSSWIND DISTANCES OF RECEPTOR IR,IS
          FOR THE ENDPOINTS OF THE LINE SOURCE
      R1=(REP1-RR)*GS
      S1=(SEP1-SR)*GS
      R2=(REP2-RR)*GS
      S2=(SEP2-SR)*GS
      X1=R1*SINT+S1*COST
      Y1=S1*SINT-R1*COST
      X2=R2*SINT+S2*COST
      Y2=S2*SINT-R2*COST
 9000 FORMAT(4E15.5)
 6897 FORMAT(1X,3I6)
      WRITE(IWRI,6897)IDCW,JDCW,LY
      DIS=(X2-X1)**2+(Y2-Y1)**2
      DIS=SQRT(DIS)
  172  FORMAT(1X,'DIS',5E12.5)
 5052 FORMAT(1X,8E15.5)
 5054 FORMAT(1X,3E16.7)
         X1,Y1 ARE THE DOWNWIND AND CROSSWIND DISTANCES (KM)
          OF RECEPTOR IR,IS FROM ENDPOINT REP1,SEP1 OF THE LINE SOURCE
         X2,Y2 ARE THE DOWNWIND AND CROSSWIND DISTANCES (KM)
          OF RECEPTOR IR,IS FROM ENDPOINT REP2,SEP2 OF THE LINE SOURCE
         TEST FOR AT LEAST ONE ENDPOINT UPWIND OF RECEPTOR - OTHERWISE,
          CONCENTRATION  = 0.
         CHECK FOR RECEPTOR DOWNWIND OF SOURCE.  IF NOT, SET CONC. = 0.
      IF (X1)  4402,105,4403
 4403 IF (X2) 4404,110,110
 4404 CONTINUE
```

```
      Y2=Y2-((Y2-Y1)/(X2-X1)) * X2
      X2=0.0
      P=((X2-X1)**2 + (Y2-Y1)**2)**.5
      Z2=Z1+(P/DIS) * DZ
      GO TO 110
 4402 IF (X2) 500,500,4405
 4405 CONTINUE
      Y1= Y1-((Y2-Y1)/(X2-X1))* X1
      X1 = 0.0
      P=((X2-X1)**2 + (Y2-Y1)**2)**.5
      Z1=Z2-(P/DIS) * DZ
      GO TO 110
  105 IF(X2) 500,110,110
C         CHECK FOR RECEPTOR BETWEEN CENTERLINE OF PLUMES FROM ENDPOINTS.
C          IF IT IS DIVIDE SOURCE INTO TWO SEGMENTS (INDX=2), GO TO 150.
  110 IF(Y1) 112,120,112
  112 IF(Y2) 115,120,115
  115 Y3=SIGN(Y1,Y2)
      IF(Y3-Y1) 150,120,150
  120 XA=X1
      XB=X2
      YA=Y1
      YB=Y2
      PP=P
      INDX=1
      GO TO 210
  150 XA=X1
      YA=Y1
      XP=X1+(X2-X1)*ABS(Y1)/(ABS(Y1)+ABS(Y2))
      XB=XP
```

```
      YB=0.
      PP=P*ABS(Y1)/(ABS(Y1)+ABS(Y2))
      ZOLD=Z2
      Z2=Z1+(PP/DIS)*DZ
      INDX=2
  210 M=0
  91  FORMAT(1X,I1,6E10.3)
      DX=XB-XA
      DY=YB-YA
      DZ=Z2-Z1
      XZA=XA+XVZ(KST)
      XZB=XB+XVZ(KST)
      XYA=XA+XVY(KST)
      XYB=XB+XVY(KST)
      ESTF=0.0
      CALL RELCO(U,Z,Z1,HL,XZA,XYA,YA,KST,AN,RC1,XVZ,XVY)
      CALL RELCO(U,Z,Z2,HL,XZB,XYB,YB,KST,AN,RC2,XVZ,XVY)
      CURR=(RC1+RC2)*PP/2.
  178 FORMAT(1X,4E14.4)
      IF(CURR) 215,215,220
  215 ESTC=0.0
      GO TO 300
  220 PREV=CURR
      SUBT=0.0
      M=2*M+1
      DX=DX/2.
      DY=DY/2.
      DZ=DZ/2.0
      DO 250 K=1,M,2
      DOWK = K
```

```
      X =  XA + DOWK * DX
      Y =  YA + DOWK * DY
      XZ=X+XVZ(KST)
      XY=X+XVY(KST)
      ZNEW=Z1+DOWK*DZ
      CALL RELCO(U,Z,ZNEW,HL,XZ,XY,Y,KST,AN,RC,XVZ,XVY)
  250 SUBT=SUBT+RC
      DOWM  = M+1
      CURR  =  PREV/2.0 + SUBT * PP/DOWM
      ESTC=(4.*CURR-PREV)/3.
      IF(ESTC) 215,215,255
C         ESTC AND ESTP ARE CURRENT AND PREVIOUS RICHARDSON'S
C          EXTRAPULATIONS.
  255 RAT=ABS((ESTC-ESTP)/ESTC)
C         RAT IS A COMPARISON BETWEEN THE CURRENT AND PREVIOUS VALUES.
C          WHEN RAT BECOMES LESS THAN 0.02 THE CURRENT VALUE IS ACCEPT
C          FOR THE VALUE OF THE INTEGRAL.
      IF (ABS(ESTC) .LT.        .000001 ) GO TO 300
      IF(RAT-0.005) 300,260,260
  260 ESTP=ESTC
      GO TO 220
  300 ESTD=ESTC+ESTD
      IF(INDX-1) 500,500,310
  310 XA=XP
      YA=0.
      XB=X2
      YB=Y2
      PP=P*ABS(Y2)/(ABS(Y1)+ABS(Y2))
      Z1=Z2
      Z2=ZOLD
```

```
      INDX=1
      GO TO 210
  500 CLSS=ESTD*QLS(IL)*1000.
 3890 FORMAT(1X,I3,6E10.3)
  600 CLS=CLSS+CLS
      CONVERT TO PPM
      CLS=  CLS * 870.0
      WRITE(IWRR,8161)ANGL(LY),IDOW,JDOW,CLS
 8161 FORMAT(1X,F6.1,3X,2I5,E15.5)
      SCLS(JDOW)=SCLS(JDOW)+CLS
      WRITE(IWRI,30) XXRR,XXSR,Z,CLS
      C(JDOW,LY,KTY)=C(JDOW,LY,KTY)+CLS
      C(JDOW,LY,4)=C(JDOW,LY,4)+CLS
      IF(ZRD1(IDOW).GT. 10.0 .OR.ZRD2(IDOW).GT.10.0) GO TO 8172
      C(JDOW,LY,6)=C(JDOW,LY,6)+CLS
      GO TO 8173
 8172 C(JDOW,LY,7)=C(JDOW,LY,7)+CLS
 8173 CONTINUE
      IF(IDOW.LT.116)GO TO 974
      C(JDOW,LY,5)=C(JDOW,LY,5)+CLS
  974 CONTR(IDOW,JDOW)=CLS
      TEMP=0.0
  975 CONTINUE
 1000 CONTINUE
      DO 387 J=1,NRECP
      IF(SCLS(J).GT.TEMP) GO TO 386
      GO TO 387
  386 TEMP=SCLS(J)
      K=J
  387 CONTINUE
```

```
C       WRITE(IWRI,345) ANGL(1),KST,K,YPRR(K),TEMP
 345    FORMAT(1X,F5.1,1X,I2,1X,I2,1X,F12.4,1X,E13.5)
 428    FORMAT(1X,F6.1,1X,I3)
C       WRITE(IWRR,2593)
C       WRITE(IWRR,2592) (I,(CONTR(I,J),J=1,NRECP),I=1,NCASE)
 2592   FORMAT(1X,I3,1X,11E10.2)
 2593   FORMAT(1H1)
        DO 1055 I=1,NRECP
        POLL(I,LY)=SCLS(I)
C       WRITE(IWRR,1050)  I,SCLS(I)
 1050   FORMAT(1X ,I3,2X,E16.5)
 1055   CONTINUE
 3050   CONTINUE
 3051    CONTINUE
4071    FORMAT(1X,F5.1,7(1X,F6.2))
4072    FORMAT(1X,'RECPT.',I3,5X,3F7.1)
4070    CONTINUE
        DO 8330 L=1,NRECP
        DO 8310 K=1,7
        DO 8320 J=1,NANG
        IF(J.EQ.1) GO TO 8300
        IF(J.EQ.16) GO TO 8295
        SS(J,K)=(C(L,J-1,K)+2.0*C(L,J,K)+C(L,J+1,K))/4.0
        GO TO 8320
 8300   SS(J,K)=(C(L,16,K)+2.0*C(L,1,K)+C(L,2,K))/4.0
        GO TO 8320
 8295   SS(J,K)=(C(L,15,K)+2.0*C(L,16,K)+C(L,1,K))/4.0
 8320   CONTINUE
 8310   CONTINUE
        WRITE(IWRI,4072) L,XPRR(L),YPRR(L),ZPRR(L)
```

```
      DO 4050 IA=1,NANG
      WRITE(IWRI,4071) ANGL(IA),(SS(IA,J),J=1,7)
4050  CONTINUE
 8330 CONTINUE
5000  CONTINUE
      RETURN
      END
      SUBROUTINE RELCO(U,Z,H,HL,X,XY,Y,KST,AN,RC,XVZ,XVY)
      DIMENSION XVZ(6),XVY(6)
      COMMON /A/ GY(6),GZ(6,6)
C        SUBROUTINE RELCO CALCULATES CHI/Q CONCENTRATION VALUES, RELCO
C         CALLS UPON SUBROUTINE SIGMA TO OBTAIN STANDARD DEVIATIONS.
C        THE INPUT VARIABLES ARE....
C         U     WIND SPEED (M/SEC)
C         Z     RECEPTOR HEIGHT (M)
C         H     EFFECTIVE STACK HEIGHT (M)
C         HL=L  HEIGHT OF LIMITING LID (M)
C         X     DOWNWIND DISTANCE FOR CALCULATING SIGMAZ (KM)
C         XY    DOWNWIND DISTANCE FOR CALCULATING SIGMAY (KM)
C         Y     DISTANCE RECEPTOR IS CROSSWIND FROM SOURCE (KM)
C         KST   STABILITY CLASS
C        THE OUTPUT VARIABLES ARE....
C         AN    THE NUMBER OF TIMES THE SUMMATION TERM IS EVALUATED
C                AND ADDED IN.
C         RC    RELATIVE CONCENTRATION (SEC/M**3)
C        THE FOLLOWING EQUATION IS SOLVED --
C          RC = (1/(2*PI*U*SIGMA Y*SIGMA Z))* (EXP(-0.5*(Y/SIGMA Y)**2))
C            (EXP(-0.5*((Z-H)/SIGMA Z)**2) + EXP(-0.5*((Z+H)/SIGMA Z)**2)
C              PLUS THE SUM OF THE FOLLOWING 4 TERMS K TIMES (N=1,K) --
C                TERM 1- EXP(-0.5*((Z-H-2NL)/SIGMA Z)**2)
```

```
C             TERM 2- EXP(-0.5*((Z+H-2NL)/SIGMA Z)**2)
C             TERM 3- EXP(-0.5*((Z-H+2NL)/SIGMA Z)**2)
C             TERM 4- EXP(-0.5*((Z+H+2NL)/SIGMA Z)**2)
C       THE ABOVE EQUATION IS SIMILAR TO EQUATION (5.8) P 36 IN
C        WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES WITH THE ADDITI
C        OF THE EXPONENTIAL INVOLVING Y.
C       IWRI IS CONTROL CODE FOR OUTPUT
      IWRI = 12
C       IF X IS LESS THAN ZERO,    SET RC=0. AND RETURN.  THIS AVOIDS
C        PROBLEMS OF INCORRECT VALUES NEAR THE SOURCE.
      IF(X-XVZ(KST))30,30,5
    5 IF(XY-XVY(KST))30,300,300
C       CALL SIGMA TO OBTAIN VALUES FOR SY AND SZ
  300 CALL SIGMA (X,XY,KST,SY,SZ)
C         SY = SIGMA Y, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C         Y-DIRECTION (M)
C         SZ = SIGMA Z, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C         Z-DIRECTION (M)
C       INITIAL VALUE OF AN SET = 0.
      AN=0.
C       IF THE RECEPTOR IS ABOVE THE LID, WRITE THAT OUT, SET RC = 0
C        AND RETURN.
      IF(Z-HL)10,10,20
   20 WRITE(IWRI,1)
    1 FORMAT(1X,'RECEPTOR HIGHER THAN LID')
   30 RC=0.
      RETURN
C       IF THE SOURCE IS ABOVE THE LID, SET RC = 0., AND RETURN.
   10 IF(H-HL)40,40,30
C       YD IS CROSSWIND DISTANCE IN METERS.
```

```
C          STATEMENTS 40 TO 250 CALCULATE RC, THE RELATIVE CONCENTRATION,
C           USING THE EQUATION DISCUSSED ABOVE.  SEVERAL INTERMEDIATE
C           VARIABLES ARE USED TO AVOID REPEATING CALCULATIONS.
C           CHECKS ARE MADE TO BE SURE THAT THE ARGUMENT OF THE
C           EXPONENTIAL FUNCTION IS NEVER GREATER THAN 50 (OR LESS THAN
C           -50).  IF 'AN' BECOMES GREATER THAN 45, A LINE OF OUTPUT IS
C           PRINTED INFORMING OF THIS.
   40 YD = 1000.*Y
      C1 = 0.5*(YD/SY)*(YD/SY)
      IF(C1-50.)50,30,30
   50 A1=1./(6.28318*U*SY*SZ*EXP(C1))
      C2=2.*SZ*SZ
      CA = Z-H
      CB = Z+H
      C3 = CA*CA/C2
      C4 = CB*CB/C2
      IF(C3-50.)60,70,70
   60 A2=1./EXP(C3)
      GO TO 80
   70 A2=0.
   80 IF(C4-50.)90,100,100
   90 A3=1./EXP(C4)
      GO TO 110
  100 A3=0.
  110 SUM=0.
      THL = 2.* HL
  120 AN=AN+1.
      C5 = AN*THL
      CC = CA-C5
      CD = CB-C5
```

```
      CE = CA+C5
      CF = CB+C5
      C6 = CC*CC/C2
      C7 = CD*CD/C2
      C8 = CE*CE/C2
      C9 = CF*CF/C2
      IF(C6-50.)130,140,140
  130 A4=1./EXP(C6)
      GO TO 150
  140 A4=0.
  150 IF(C7-50.)160,170,170
  160 A5=1./EXP(C7)
      GO TO 180
  170 A5=0.
  180 IF(C8-50.)190,200,200
  190 A6=1./EXP(C8)
      GO TO 210
  200 A6=0.
  210 IF(C9-50.)220,230,230
  220 A7=1./EXP(C9)
      GO TO 240
  230 A7=0.
  240 T=A4+A5+A6+A7
      SUM=SUM+T
      IF(T-0.01)250,260,260
  260 IF(AN-45.)120,270,270
  270 WRITE(IWRI,2)X,Y,H,T,SUM
    2 FORMAT(1X,'N GREATER THAN 45',/,6X,'X = ',F7.0,5X,'Y = ',F7.0,5X,
     1'H = ',F5.1,5X,'T = ',F7.3,5X,'SUM = ',F7.3)
  250 RC=A1*(A2+A3+SUM)
```

```
      RETURN
      END
      SUBROUTINE SIGMA(X,XY,KST,SY,SZ)
      COMMON /A/ GY(6),GZ(6,6)
      AZ=X*1000.
      AY=XY*1000.
      IF(AZ-5000.)641,643,640
 640  IZ=1
      GOTO644
 641  IF(AZ.GE.500.) GOTO643
      IZ=3
      GOTO644
 643  IZ=2
 644  SZ=GZ(IZ,KST)*AZ**GZ(IZ+3,KST)
      SY=GY(KST)*AY**0.903
      RETURN
      END
      SUBROUTINE ATH(DX,DY,ANGH,DANG)
      RAD=57.2958
      IF(DX)5,6,7
    5 IF(DY.EQ.0.)GOTO9
      ANGH=ATAN(DY/DX)*RAD+180.
      GOTO16
    9 ANGH=180.
      GOTO16
    6 IF(DY)10,11,12
   10 ANGH=270.
      GOTO16
   11 ANGH=0.
      GOTO16
```

```
12 ANGH=90.
   GOTO16
 7 IF(DY)13,14,15
13 ANGH=ATAN(DY/DX)*RAD+360.
   GOTO16
14 ANGH=360.
   GOTO16
15 ANGH=ATAN(DY/DX)*RAD
16 DANG=ANGH
   ANGH=ANGH/RAD
   RETURN
   END
   BLOCK DATA
   COMMON /A/ GY(6),GZ(6,6)
   DATA GY/0.4,0.205,0.2,0.13,0.098,.066/
   DATA GZ/2*0.0002539,0.0385,2*2.0886,1.2812,2*0.04936,0.1393,
  A2*1.1137,0.9467,0.1154,0.1014,0.112,0.9109,0.926,0.91,0.7368,
  B0.2591,0.0856,0.5642,0.6869,0.665,1.2969,0.2527,0.0618,
  C0.4421,0.6341,0.8155,1.5763,.2017,.0545,.3606,.6020,.0124/
   END
   SUBROUTINE FINDBQ(IYR,ISP,IHDV,NVEH,G)
   DIMENSION GM(8,4)
   DATA GM/12.52,13.82,0.0,0.0,9.78,10.88,0.0,0.0,
  1        10.12,11.05,0.0,0.0,7.19,7.95,0.0,0.0,
  2         9.3,0.0,15.37,21.06,6.30,0.0,10.43,14.33,
  3         7.61,0.0,11.9,15.95,4.48,0.0,6.75,8.90/
   LU=12
   IF(IYR.EQ.80) GO TO 5
   IF(IYR.EQ.95) GO TO 6
   WRITE(LU,1) IYR
```

```
1     FORMAT(1X,I4,2X,'WAS A VERY BAD YEAR')
      RETURN
5     I=1
      GO TO 7
6     I=5
7     IF(ISP.EQ.50) GO TO 8
      IF(ISP.EQ.40) I=I+1
      IF(ISP.EQ.20) I=I+2
      IF(ISP.EQ.10) I=I+3
8     IF(IHDV.EQ.17) J=1
      IF(IHDV.EQ.11) J=2
      IF(IHDV.EQ.9) J=3
      IF(IHDV.EQ.5) J=4
      XNV=NVEH
      Q=XNV*GM(I,J)/5793660.0
      RETURN
      END
```

APPENDIX B. TWENTY-ONE ROADWAYS AND THEIR SEGMENTS

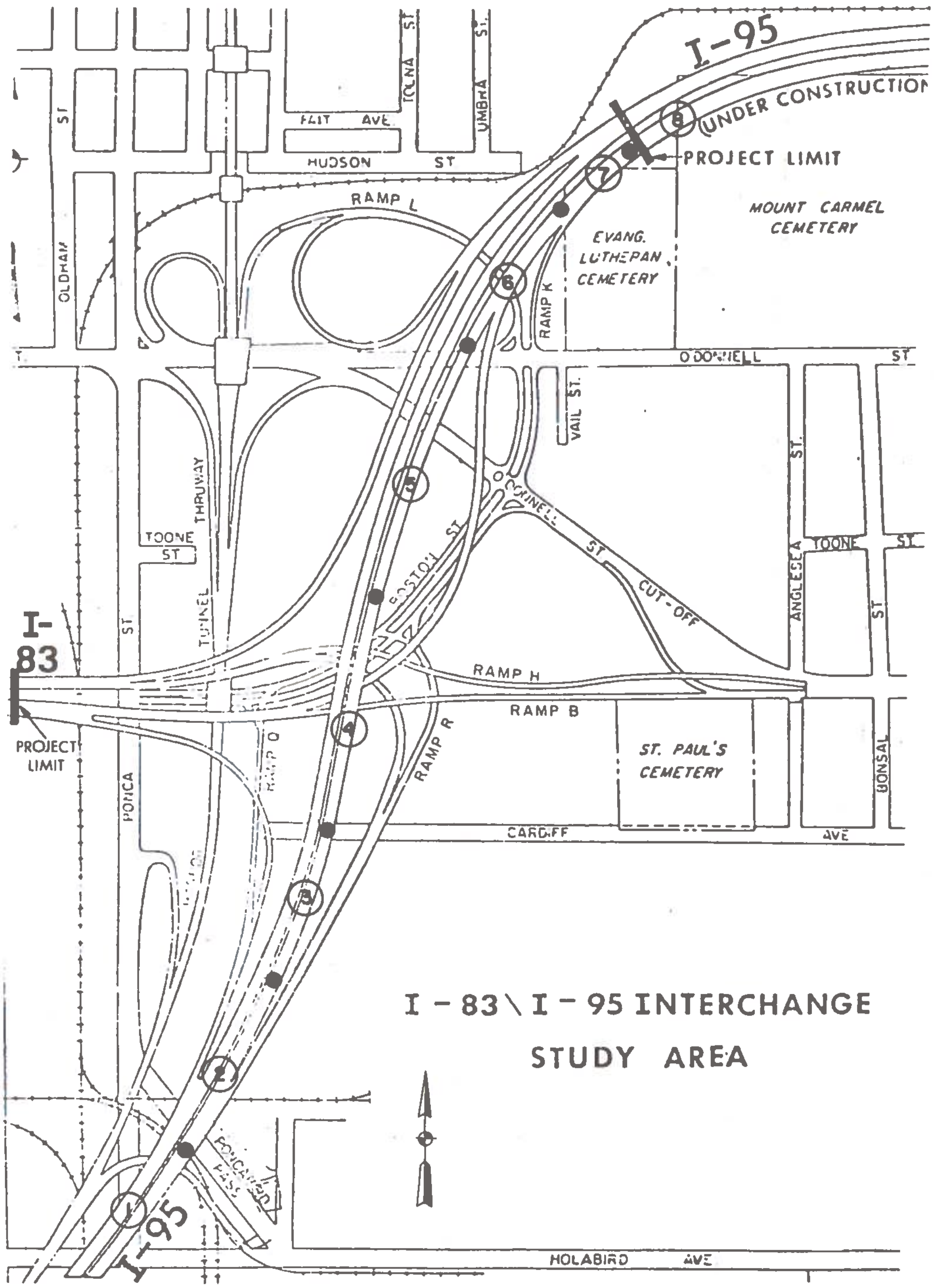

FIGURE B.1 I-95 NORTHBOUND

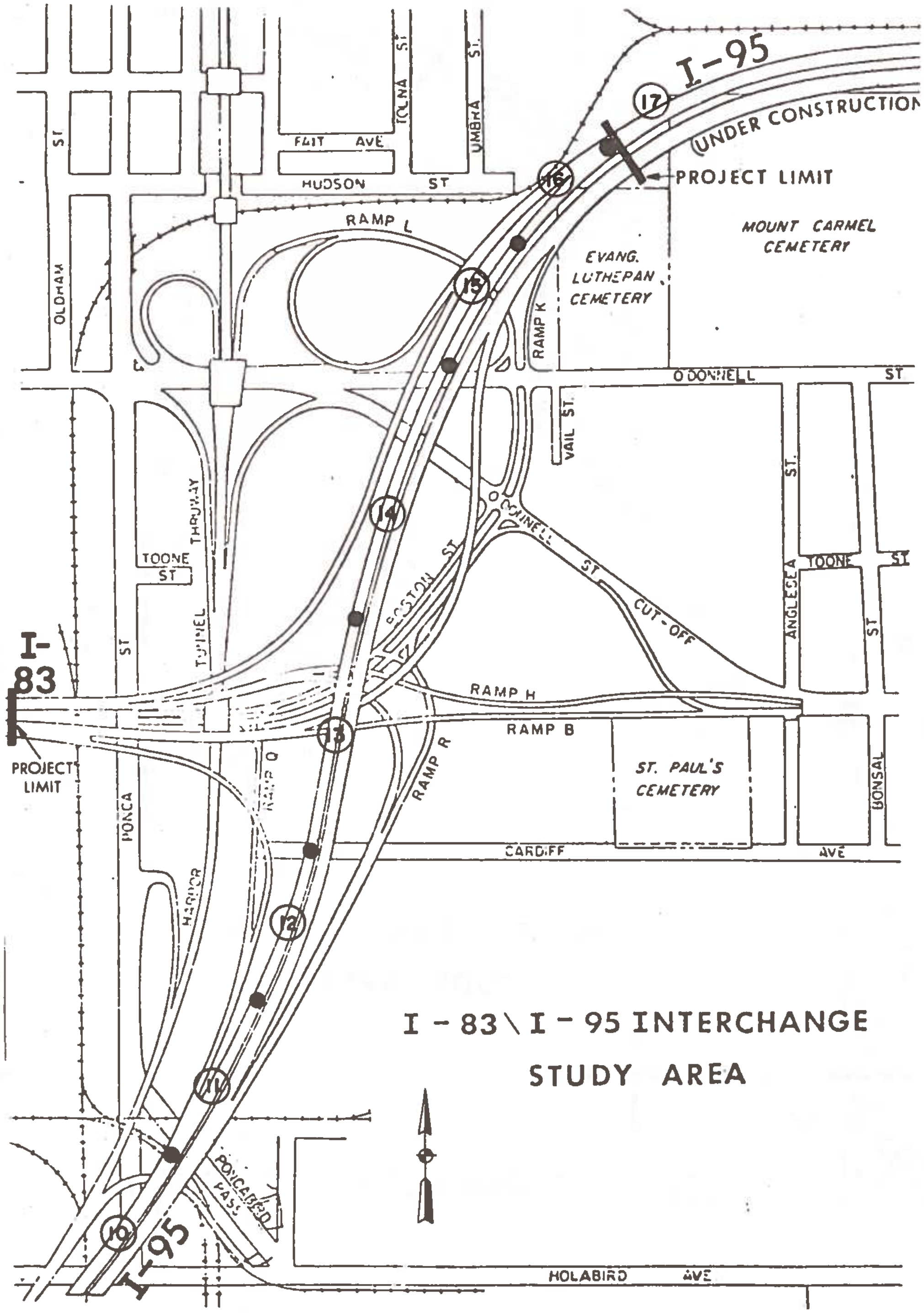

FIGURE B.2 I-95 SOUTHBOUND

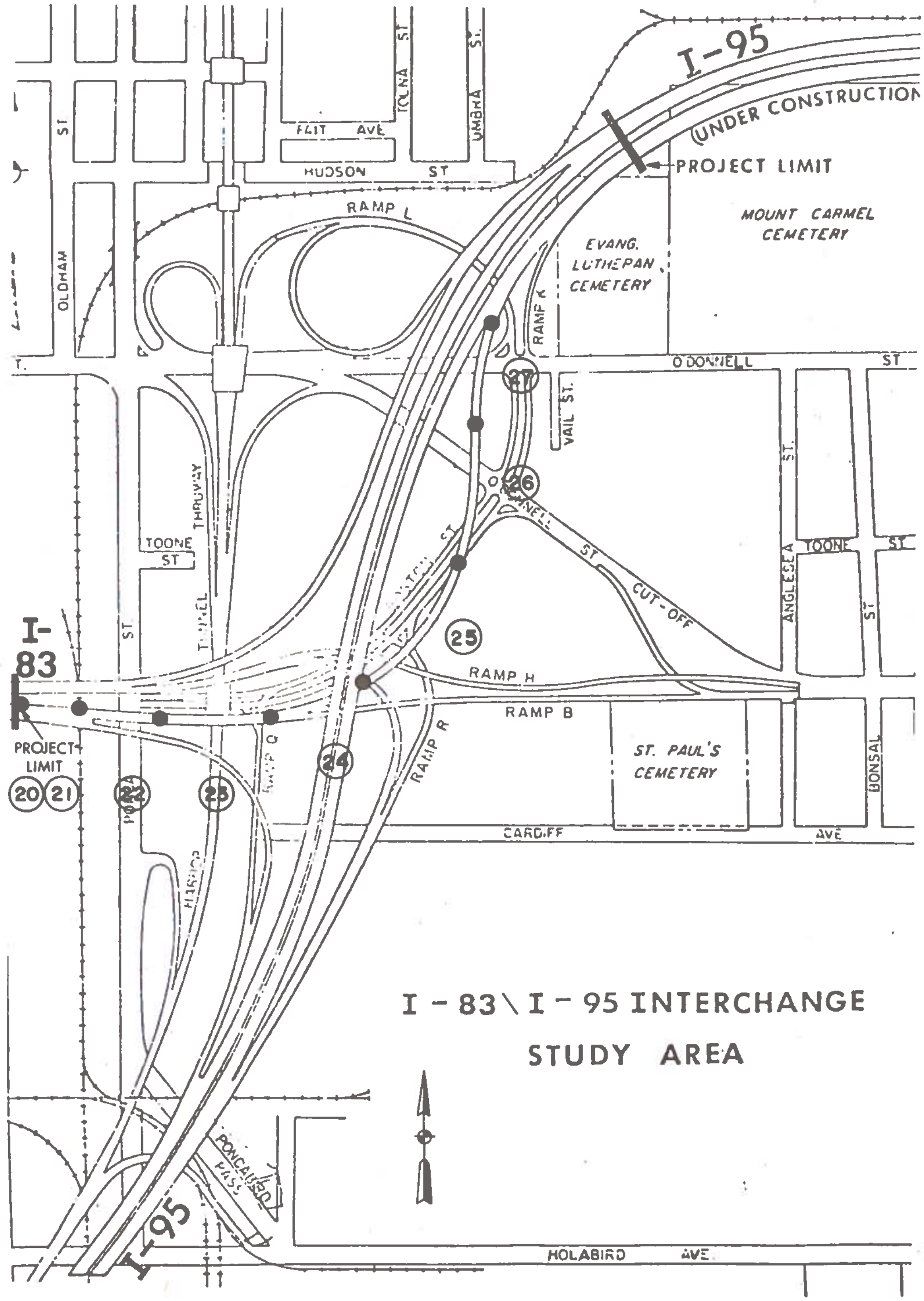

FIGURE B.3 I-83 SOUTHBOUND TO I-95 NORTHBOUND

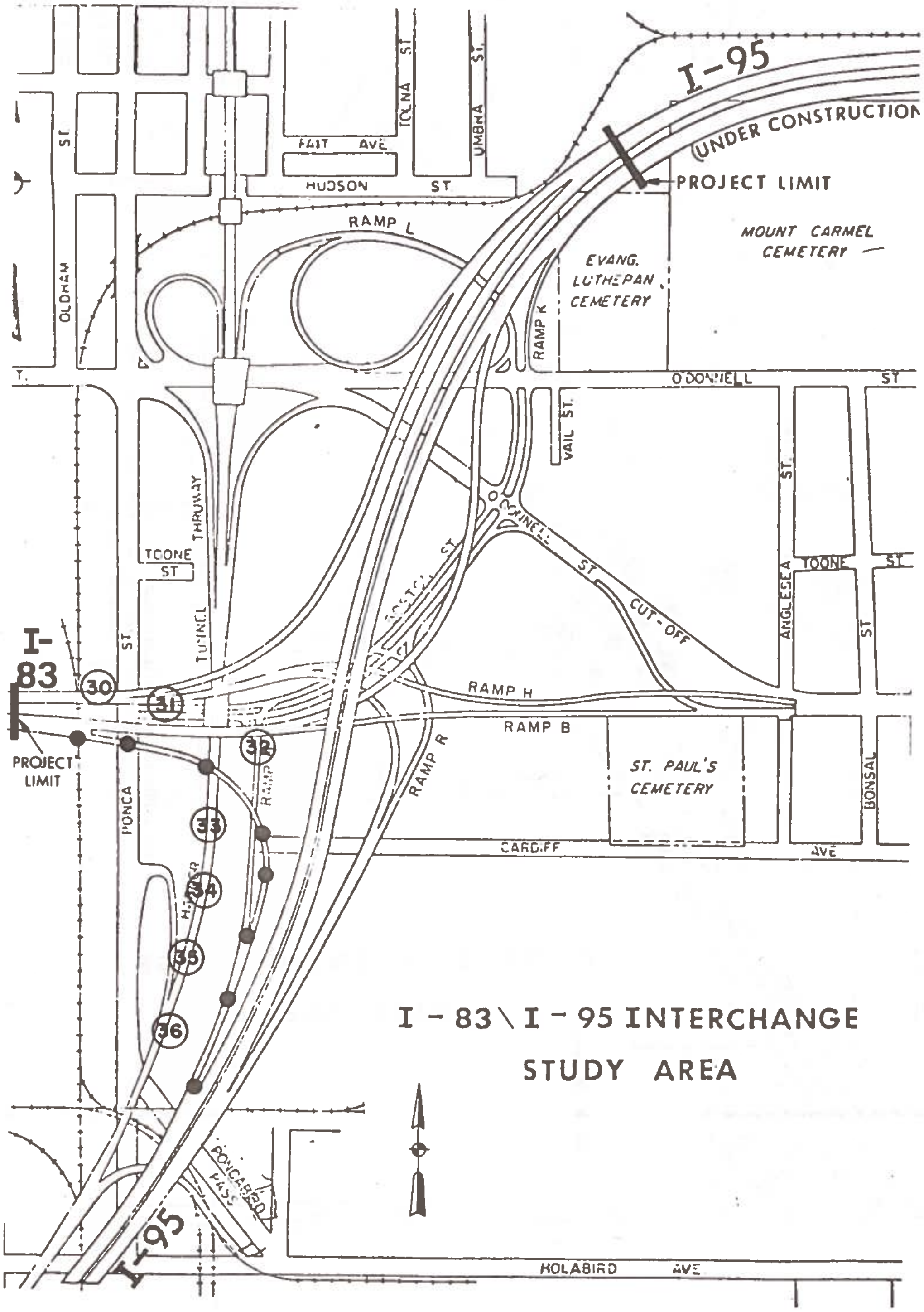

FIGURE B.4 I-83 SOUTHBOUND TO I-95 SOUTHBOUND

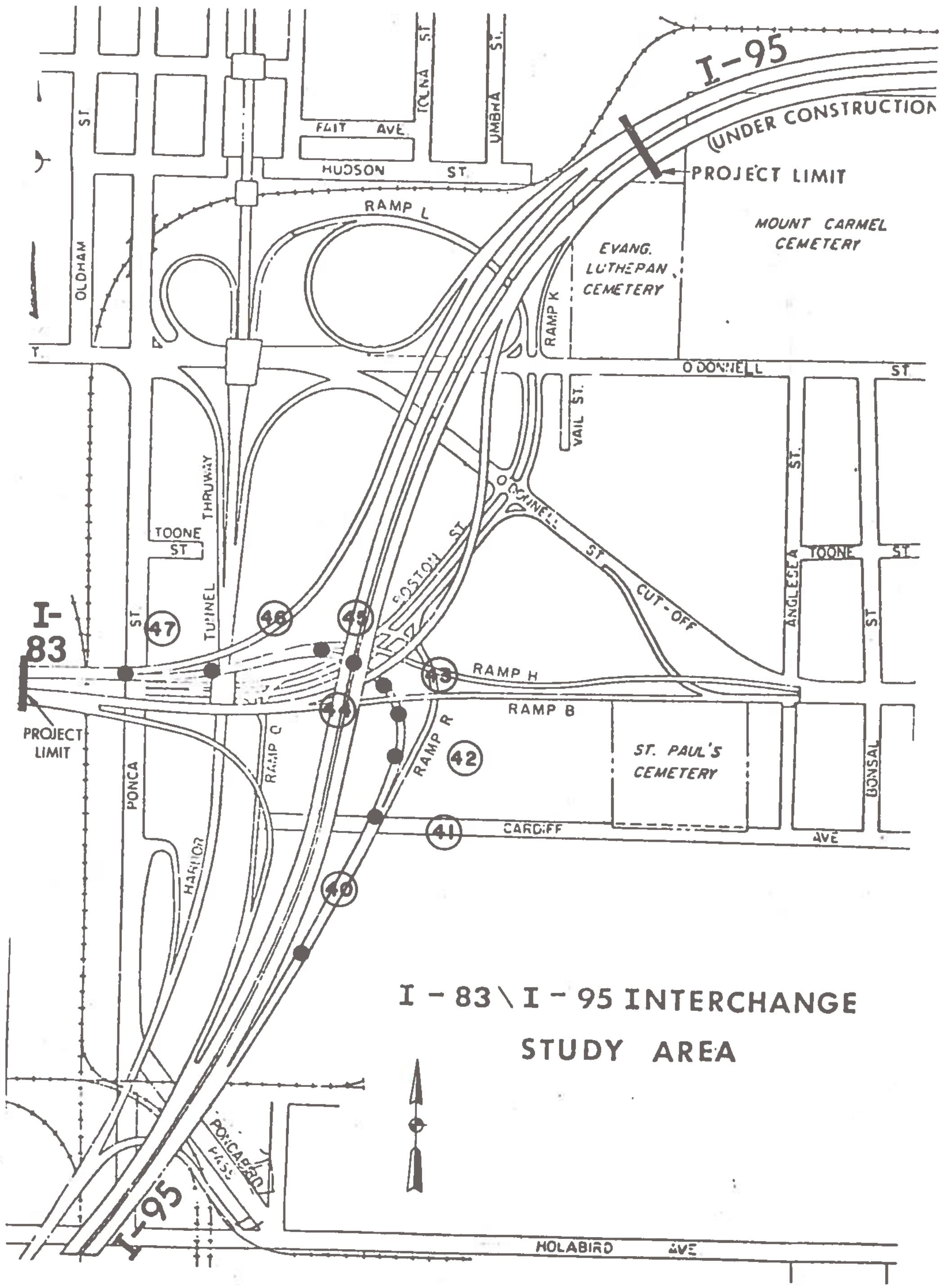

FIGURE B.5 I-95 NORTHBOUND TO I-83 NORTHBOUND

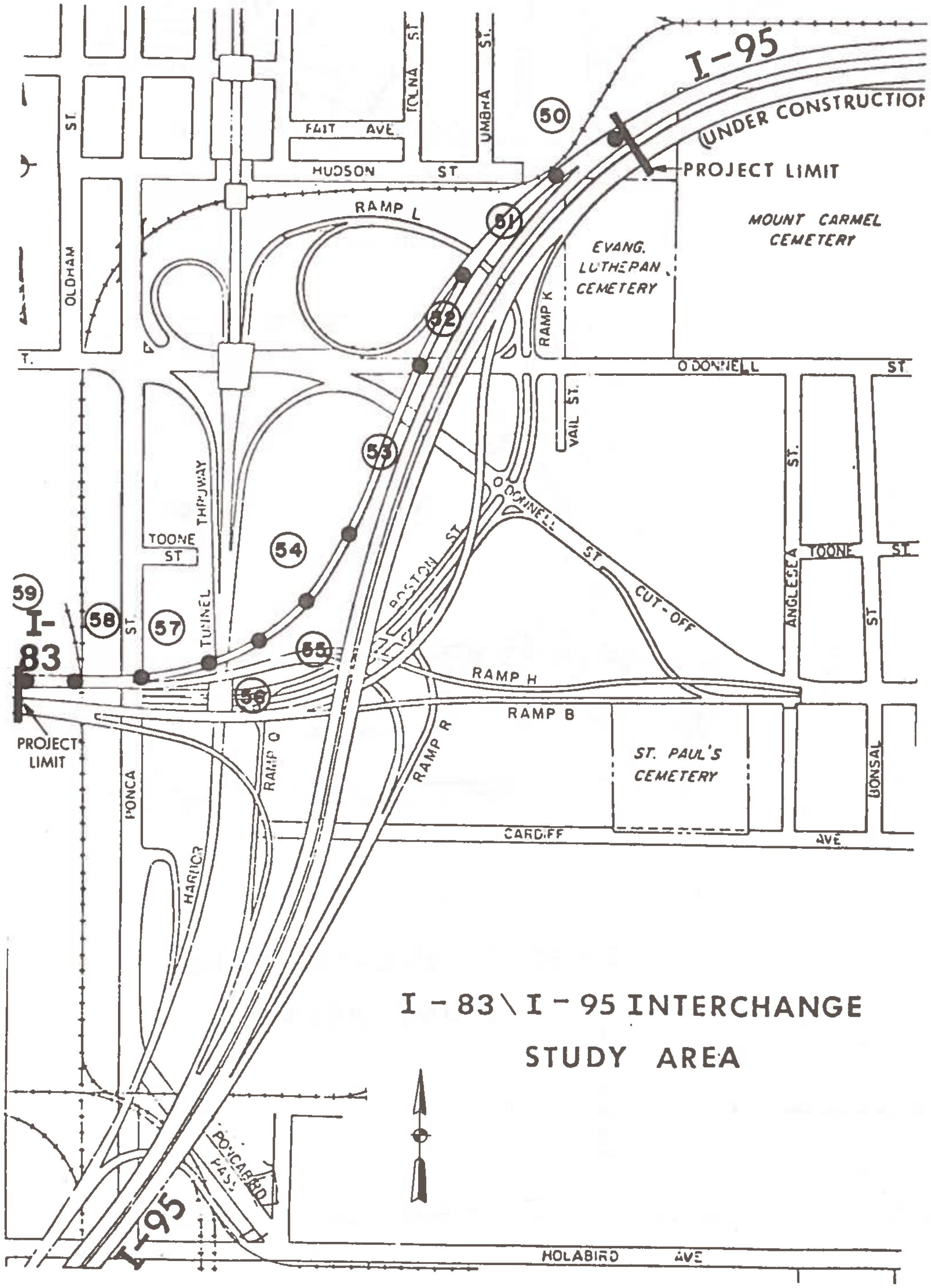

FIGURE B.6 I-95 SOUTHBOUND TO I-83 NORTHBOUND

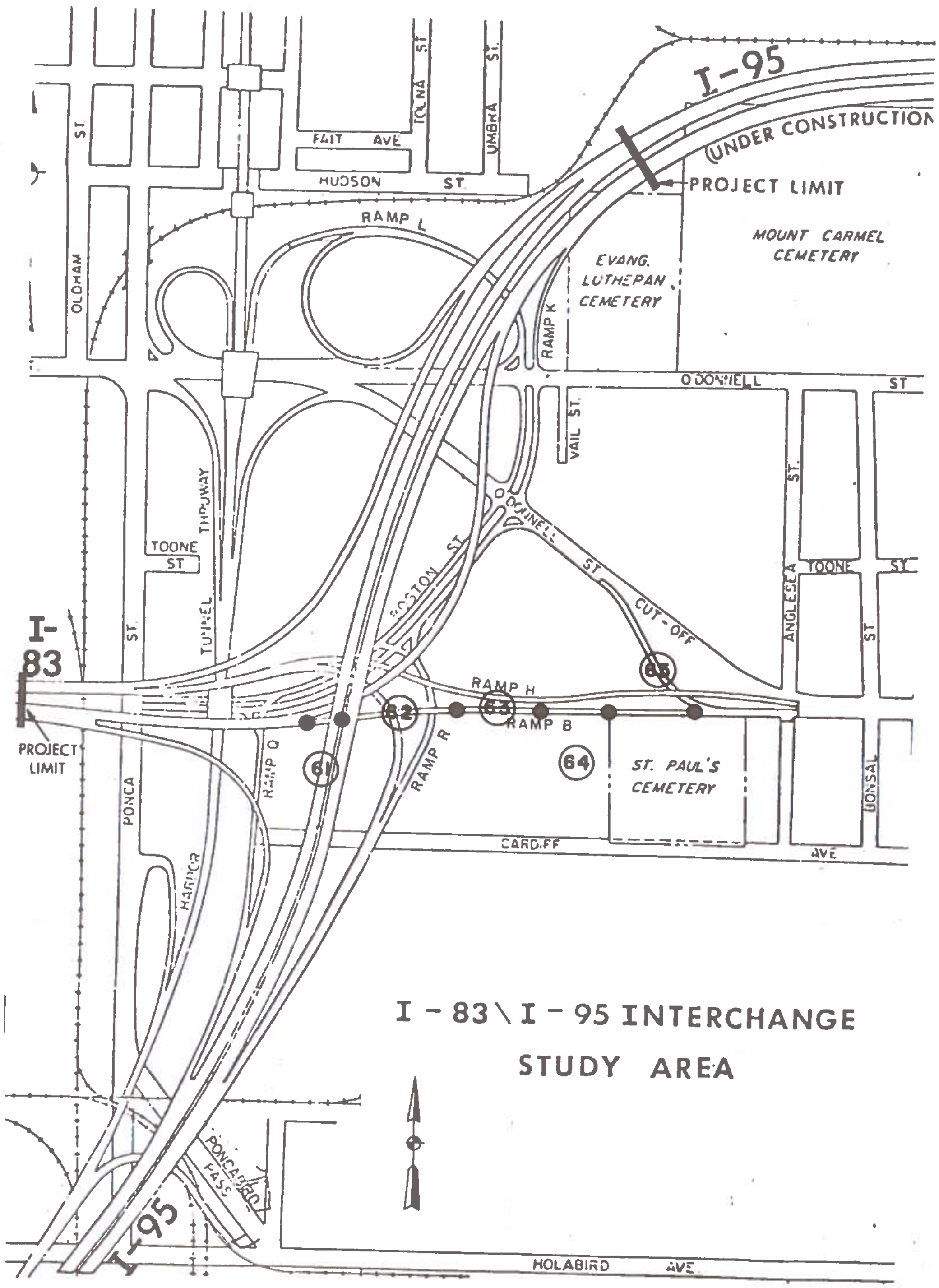

FIGURE B.7 RAMP G

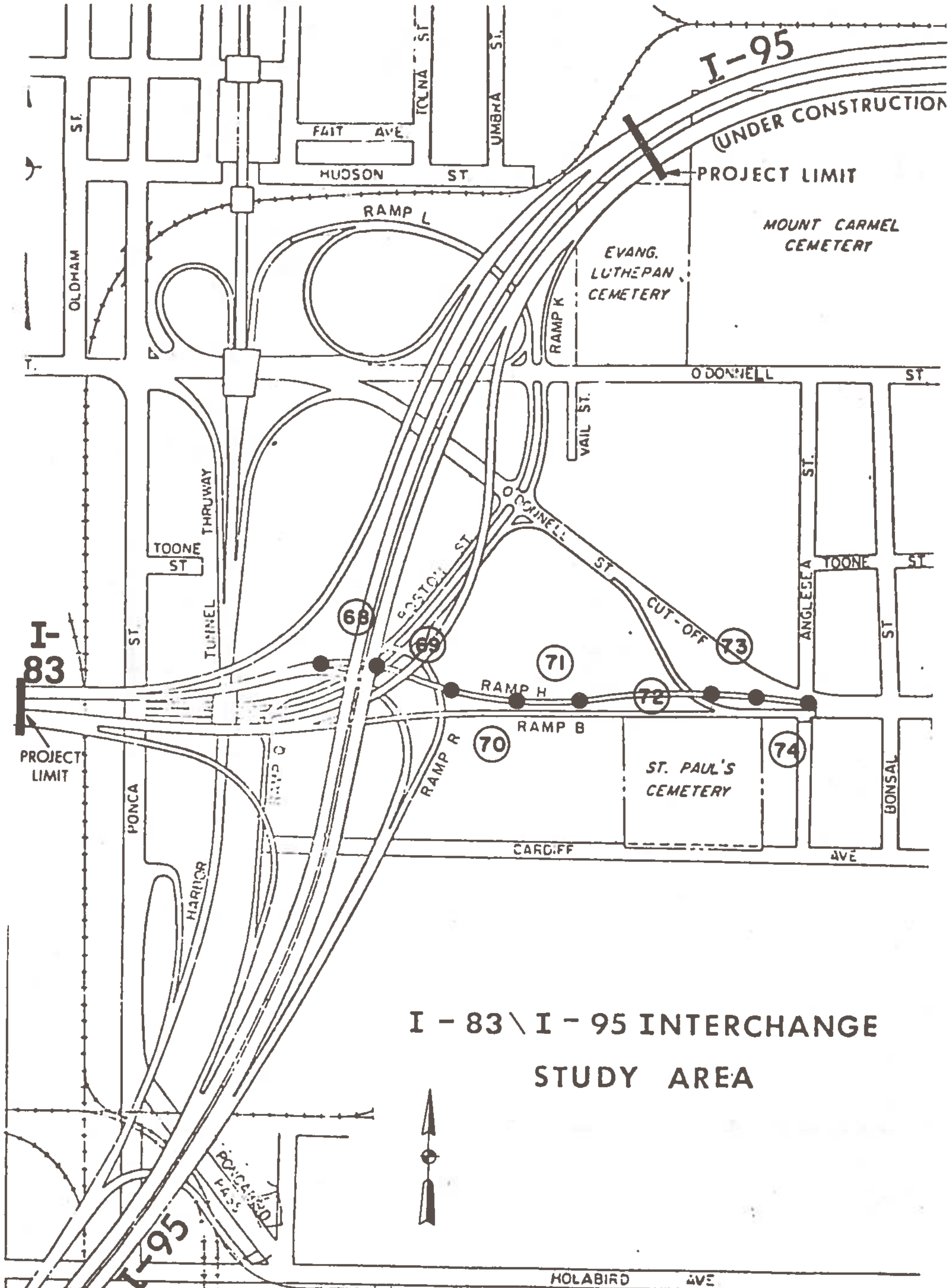

FIGURE B.8 RAMP H

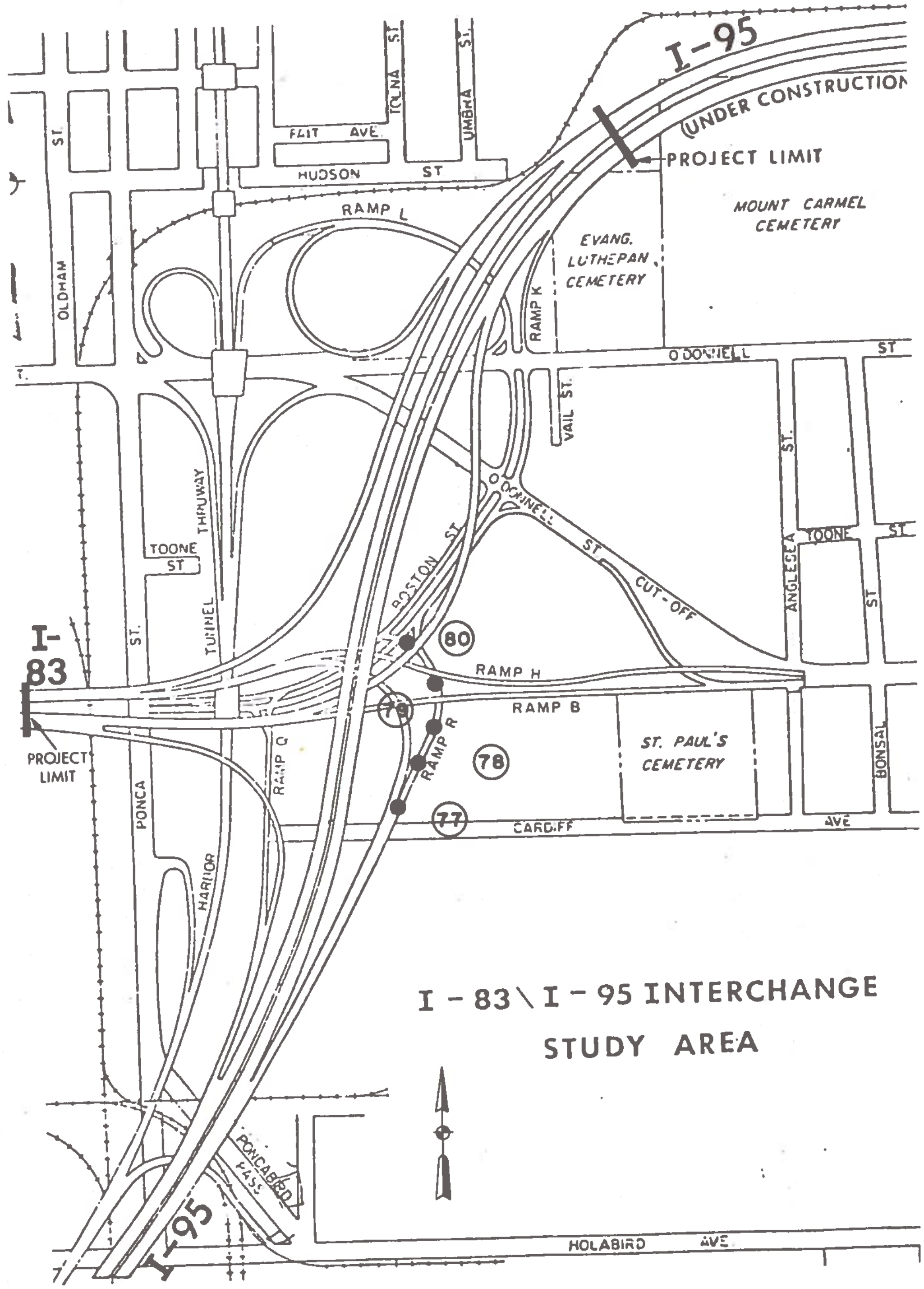

FIGURE B.9 RAMP R

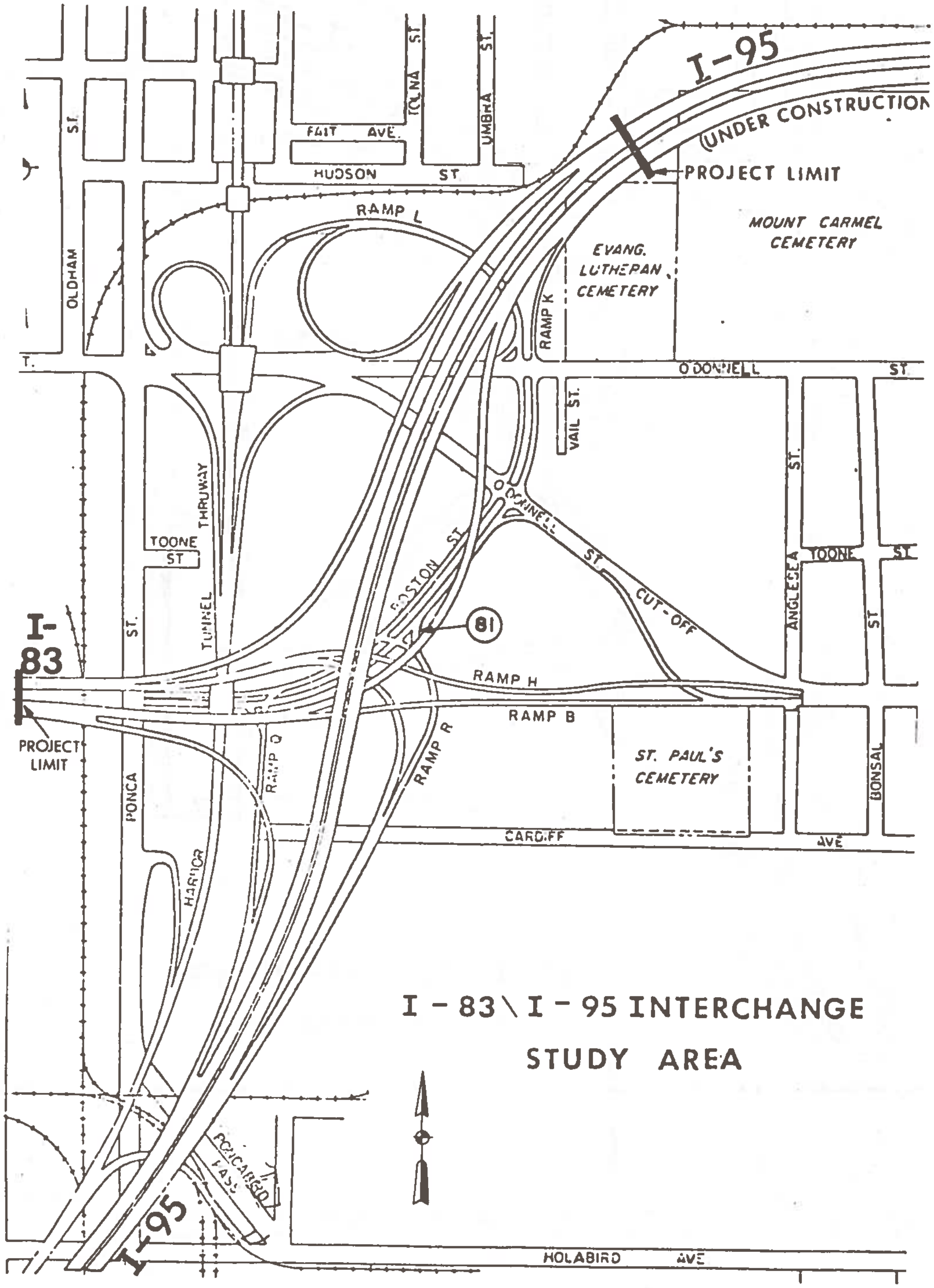

FIGURE B.10 RAMP R SPUR

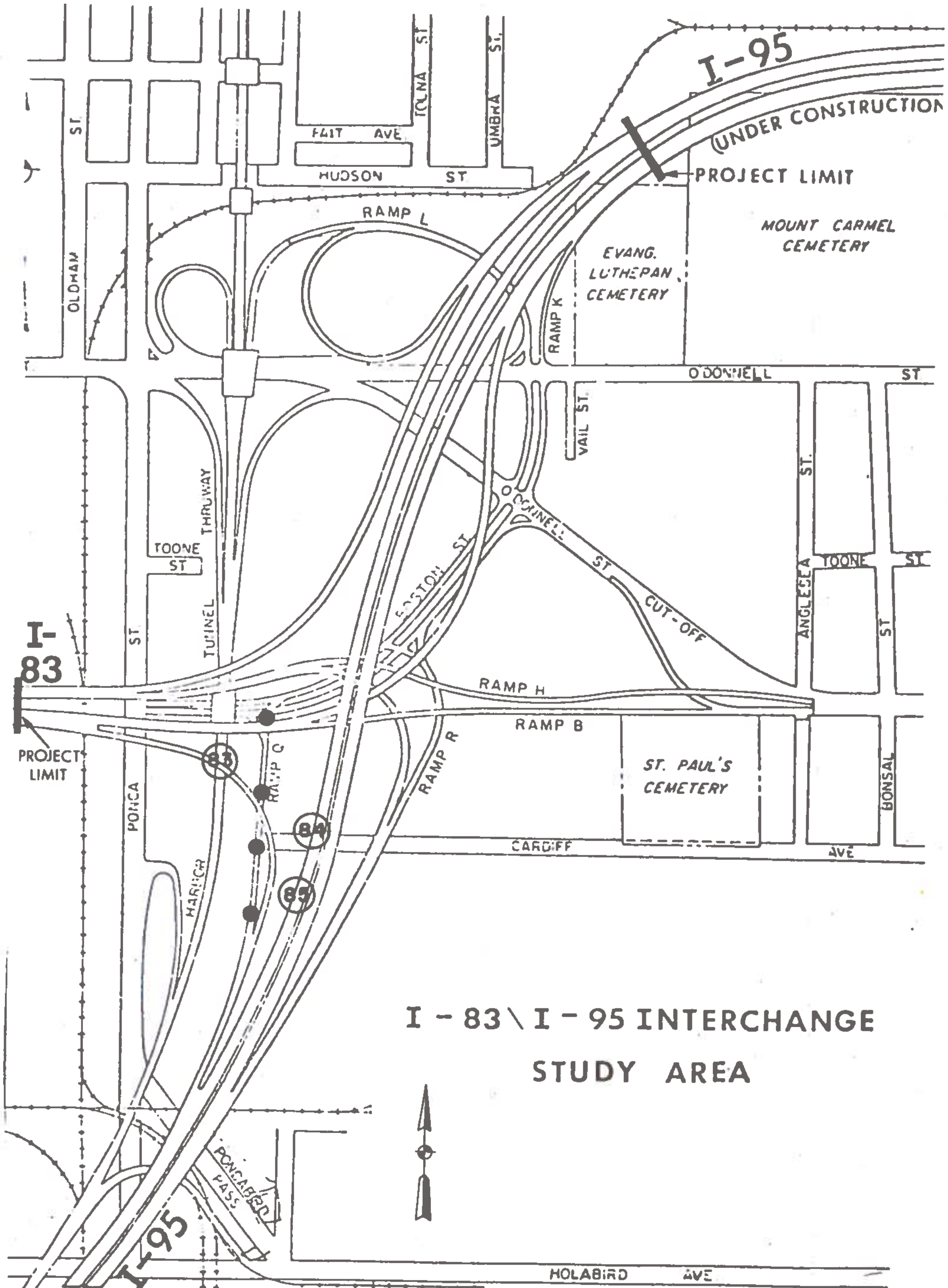

FIGURE B.11 RAMP Q

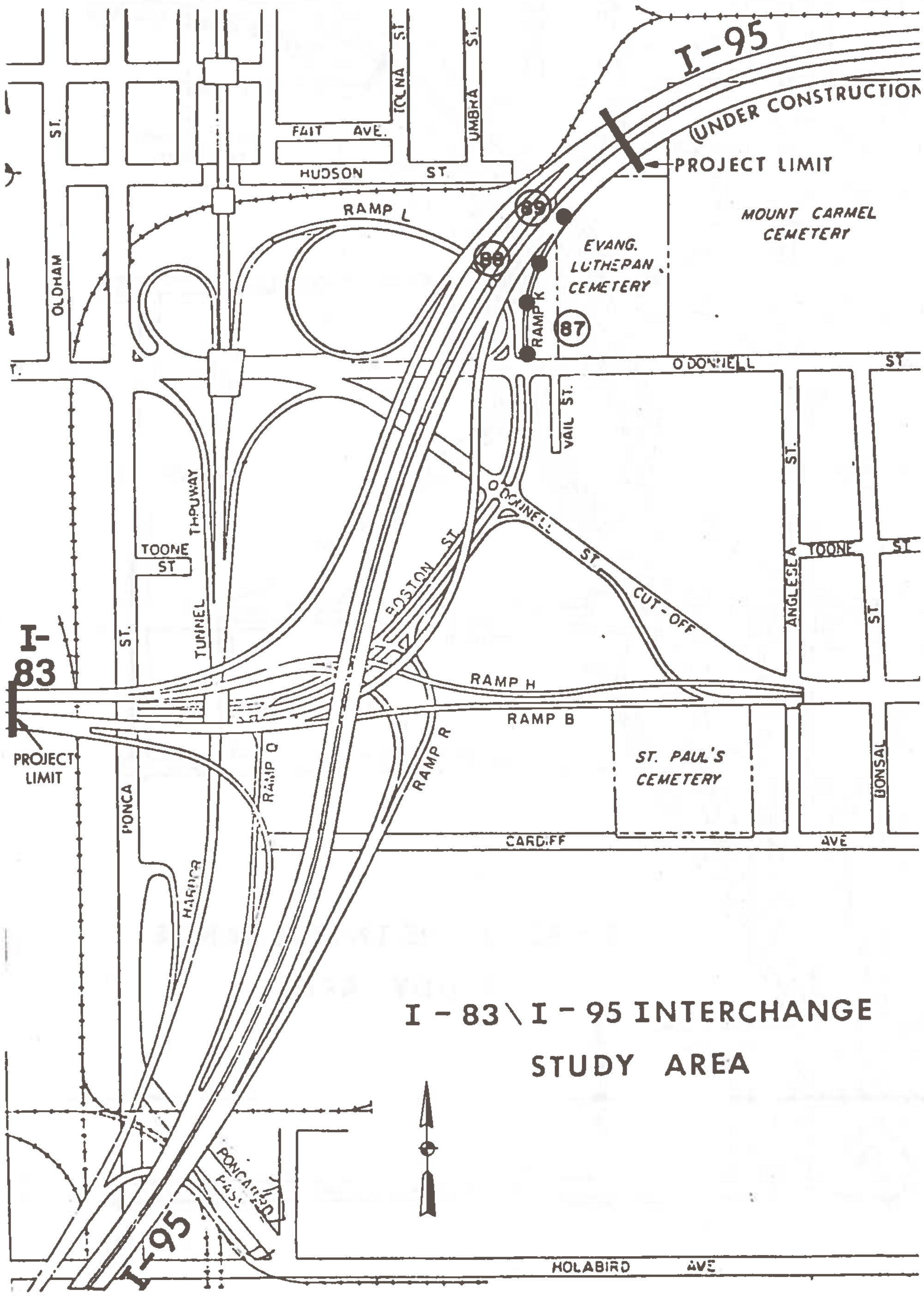

FIGURE B.12 RAMP K

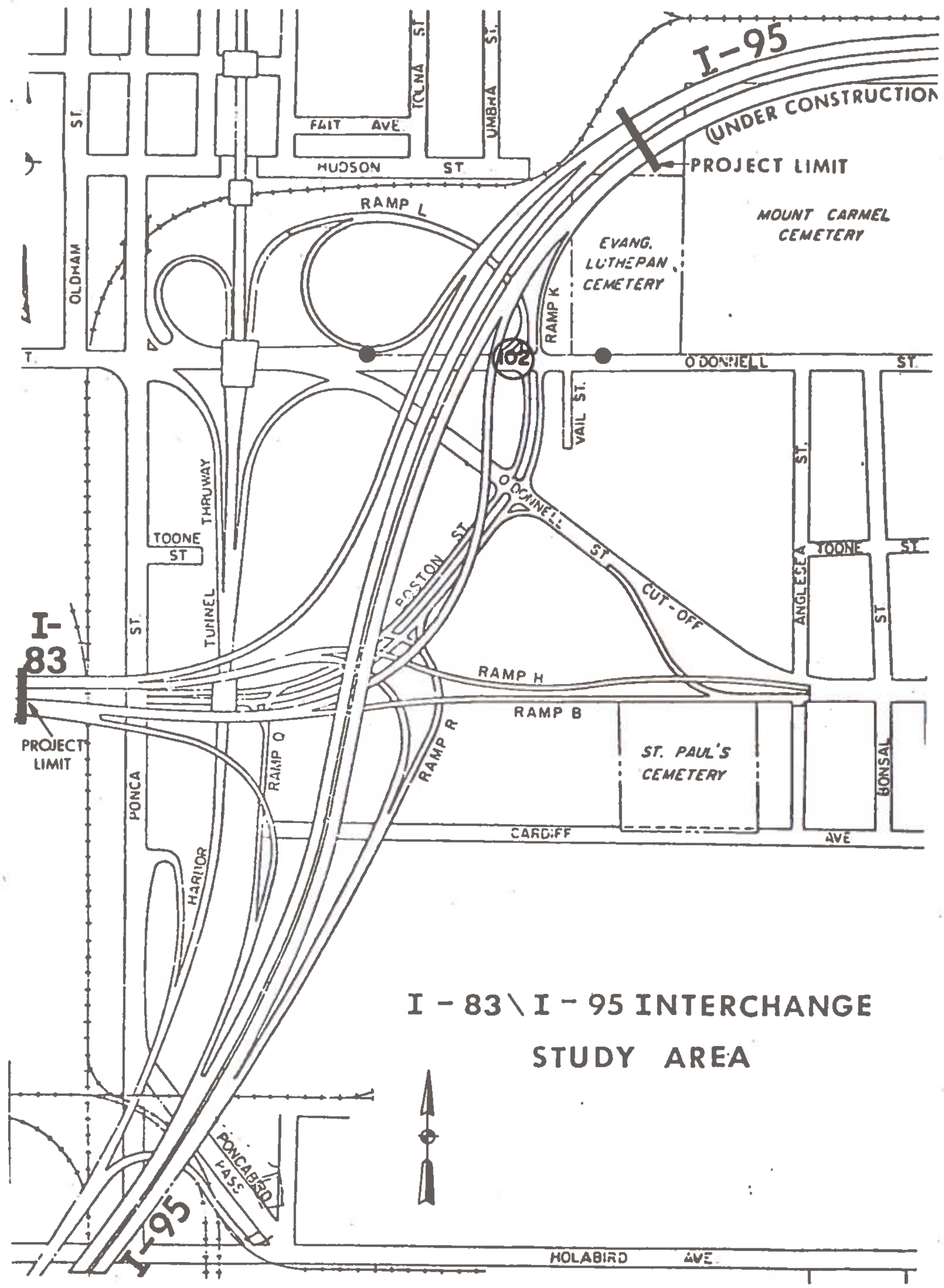

FIGURE B.13 RAMP L

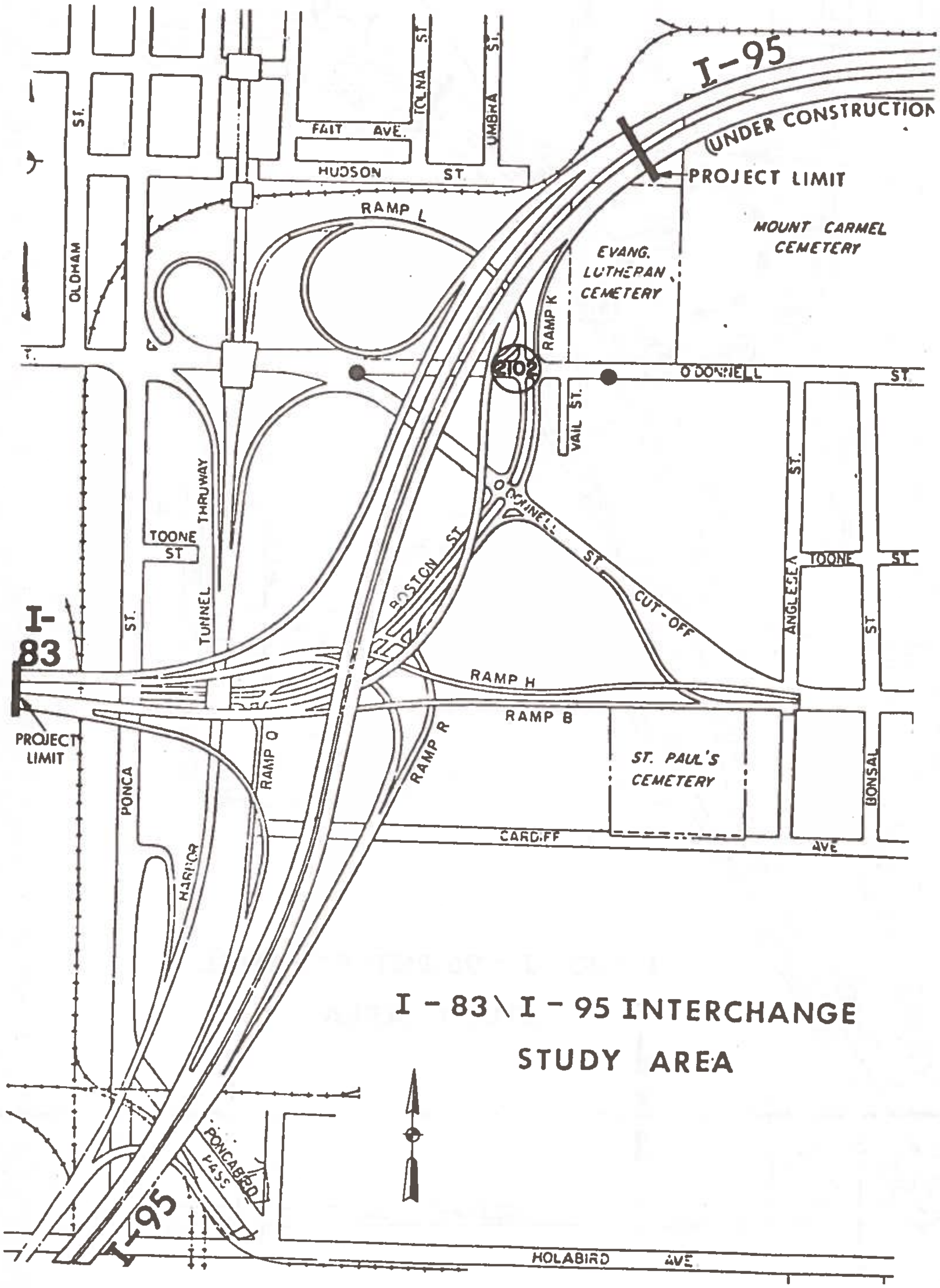

FIGURE B.14 O'DONNELL ST. EASTBOUND

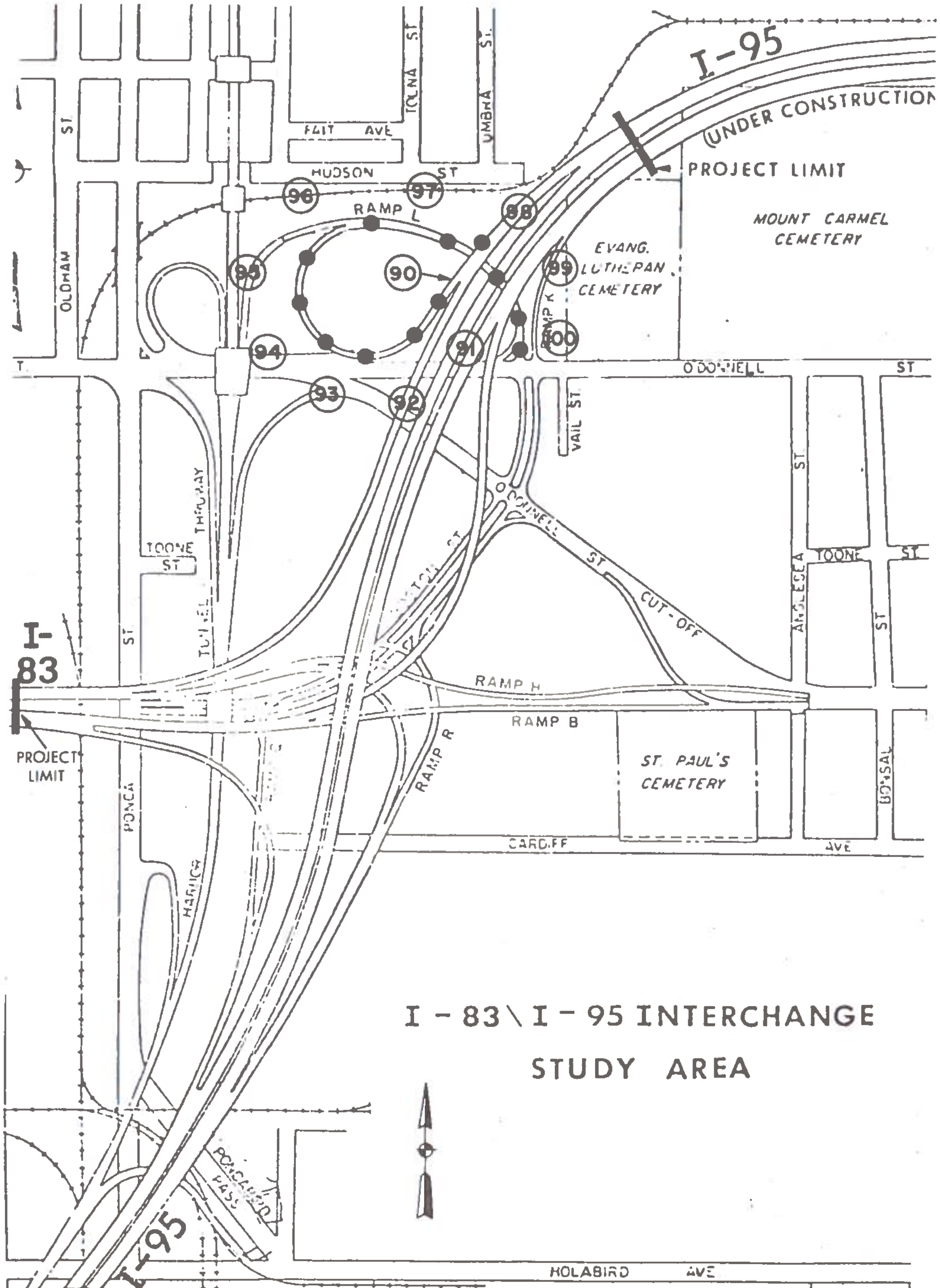

FIGURE B.15 O'DONNELL ST. WESTBOUND

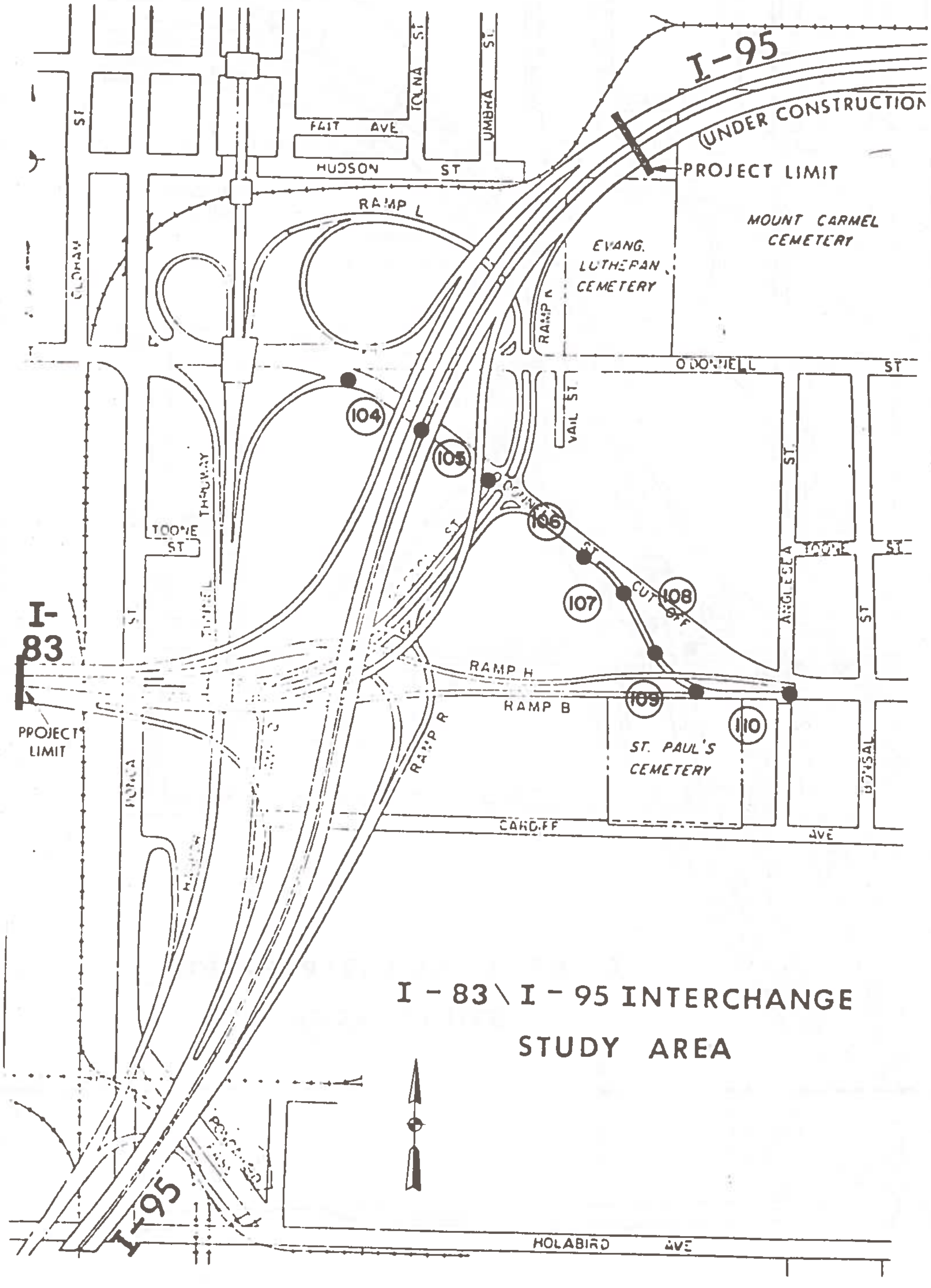

FIGURE B.16 O'DONNELL ST. CUTOFF EASTBOUND

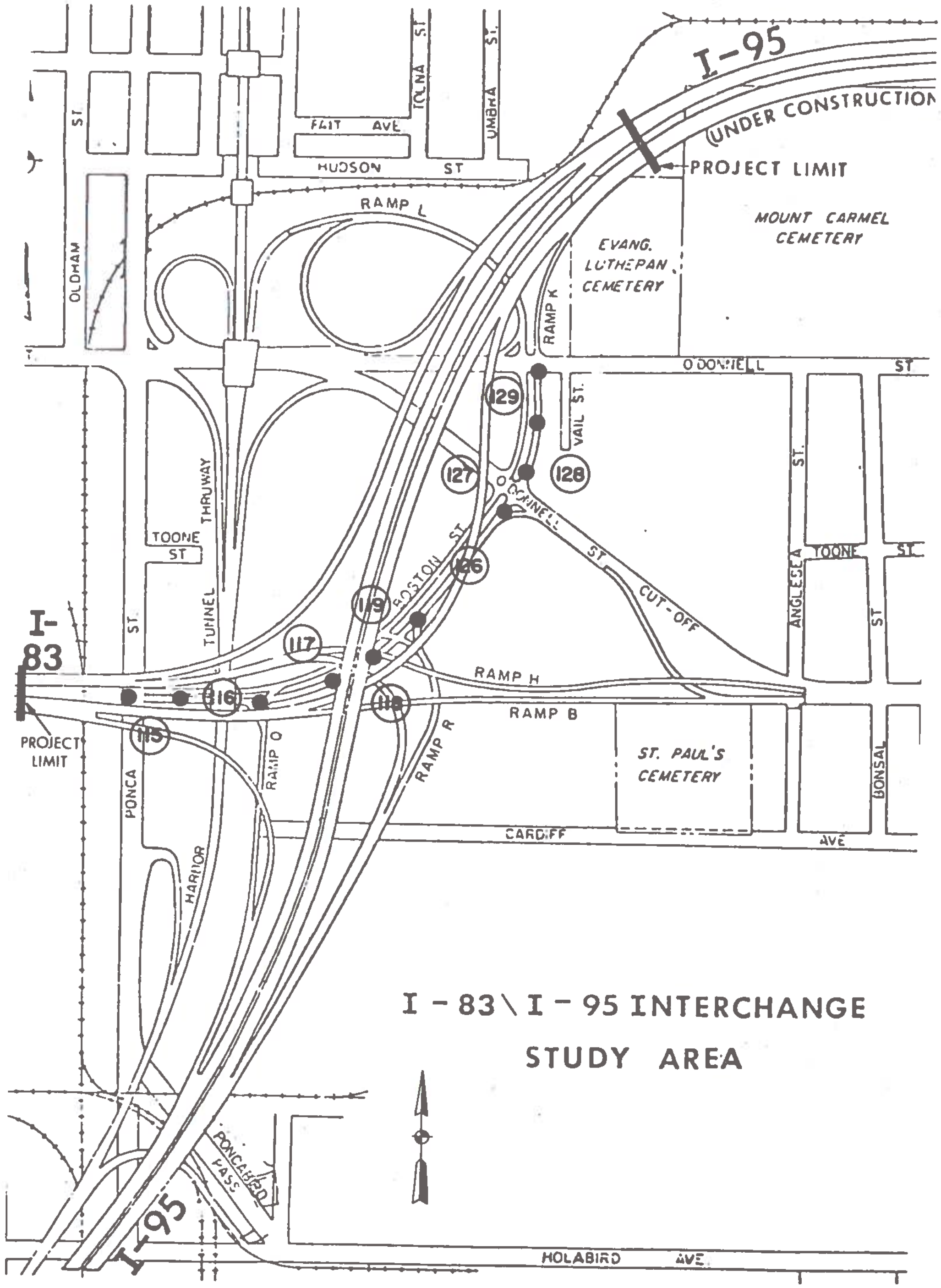

FIGURE B.17 O'DONNELL ST. CUTOFF WESTBOUND

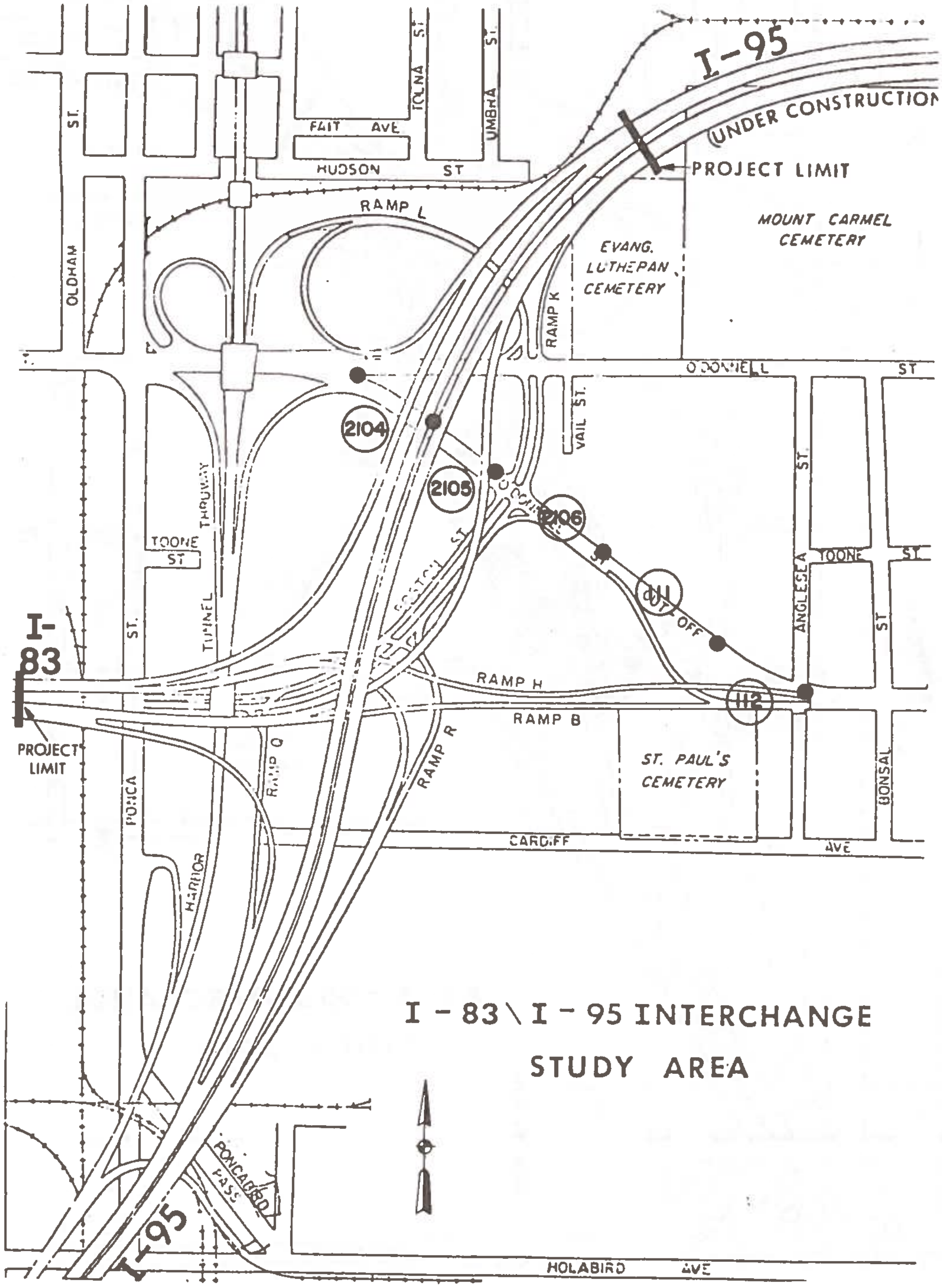

FIGURE B.18 BOSTON ST. EASTBOUND

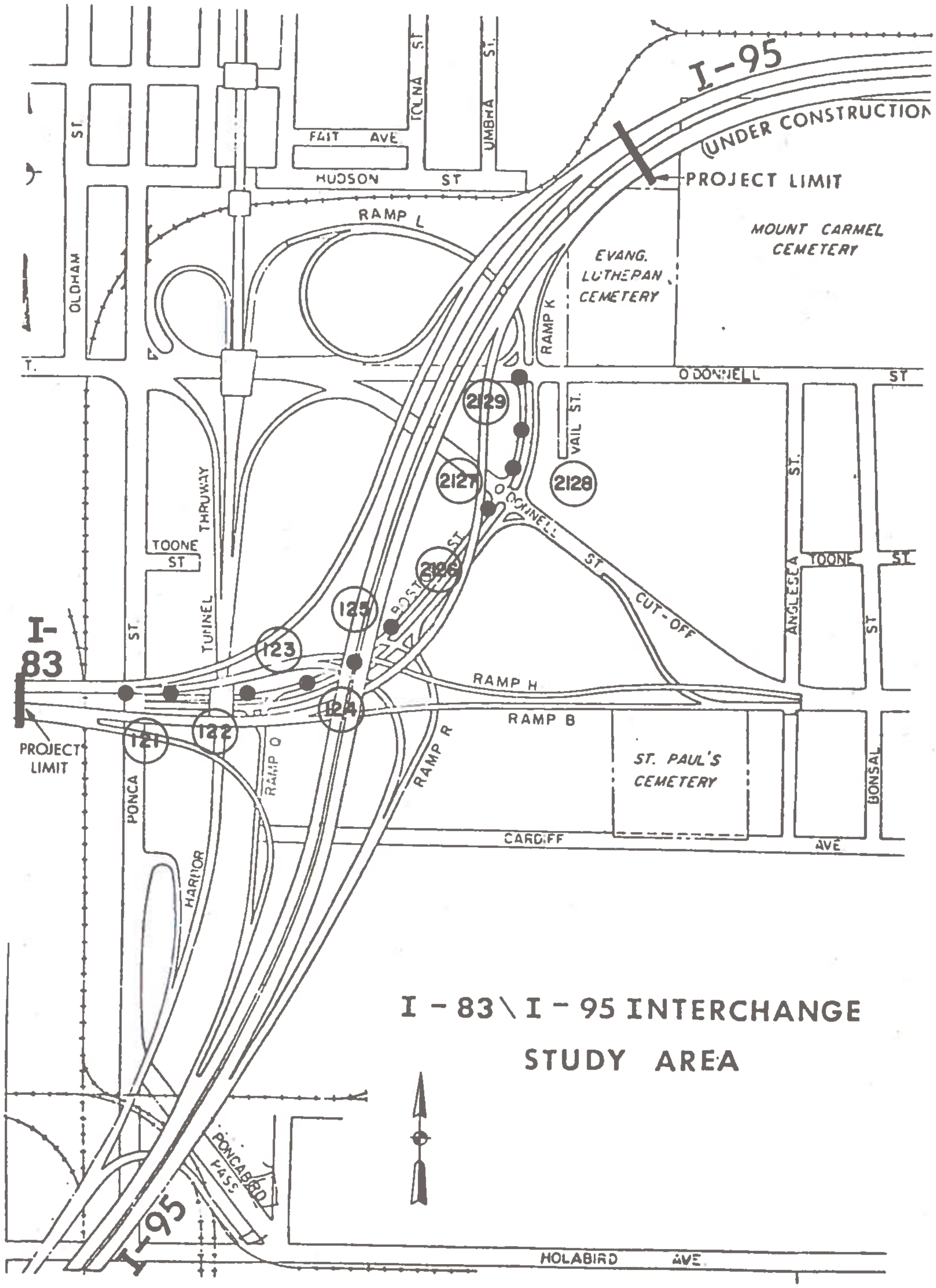

FIGURE B.19 BOSTON ST. WESTBOUND

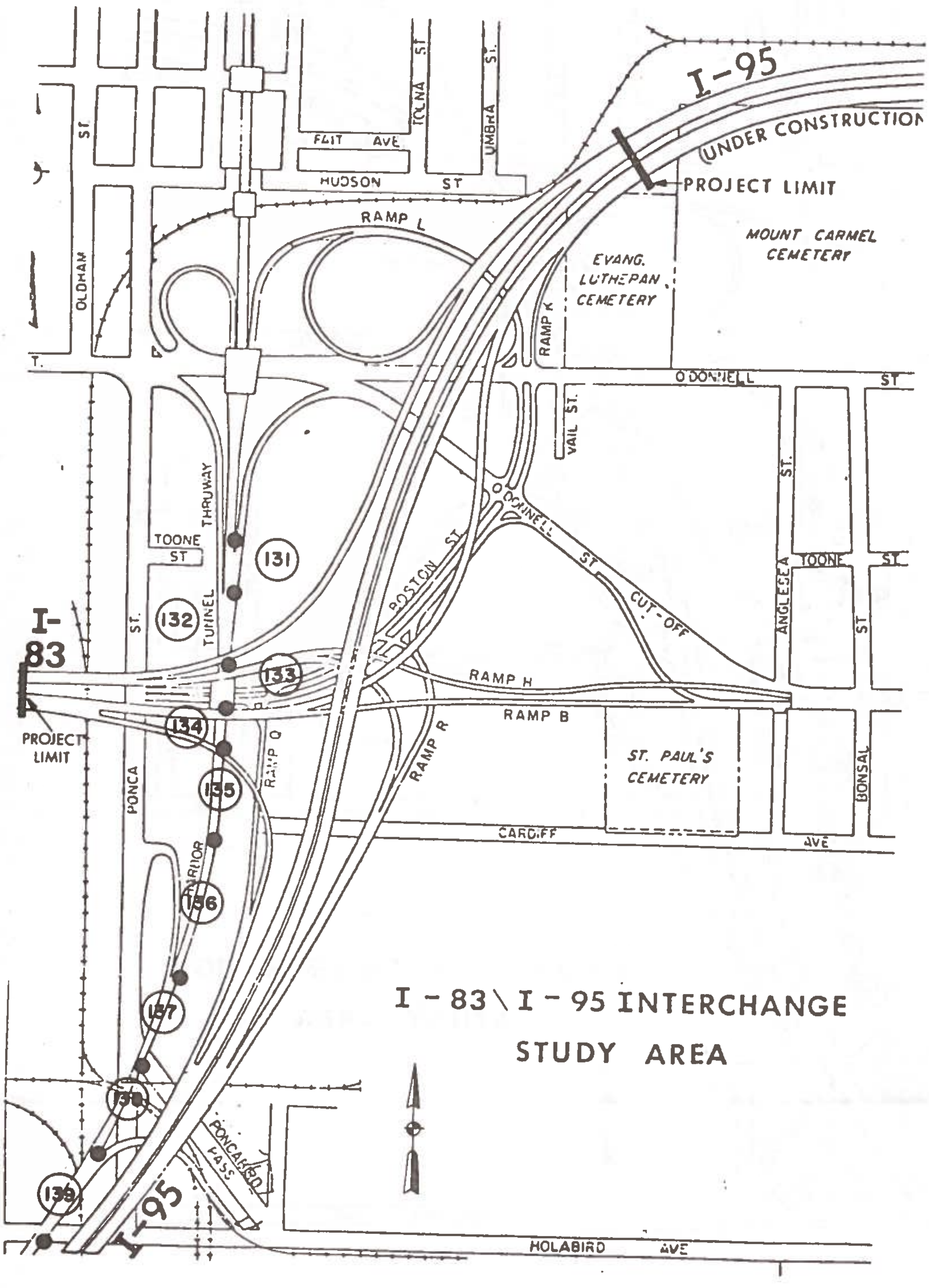

FIGURE B.20 HARBOR TUNNEL NORTHBOUND

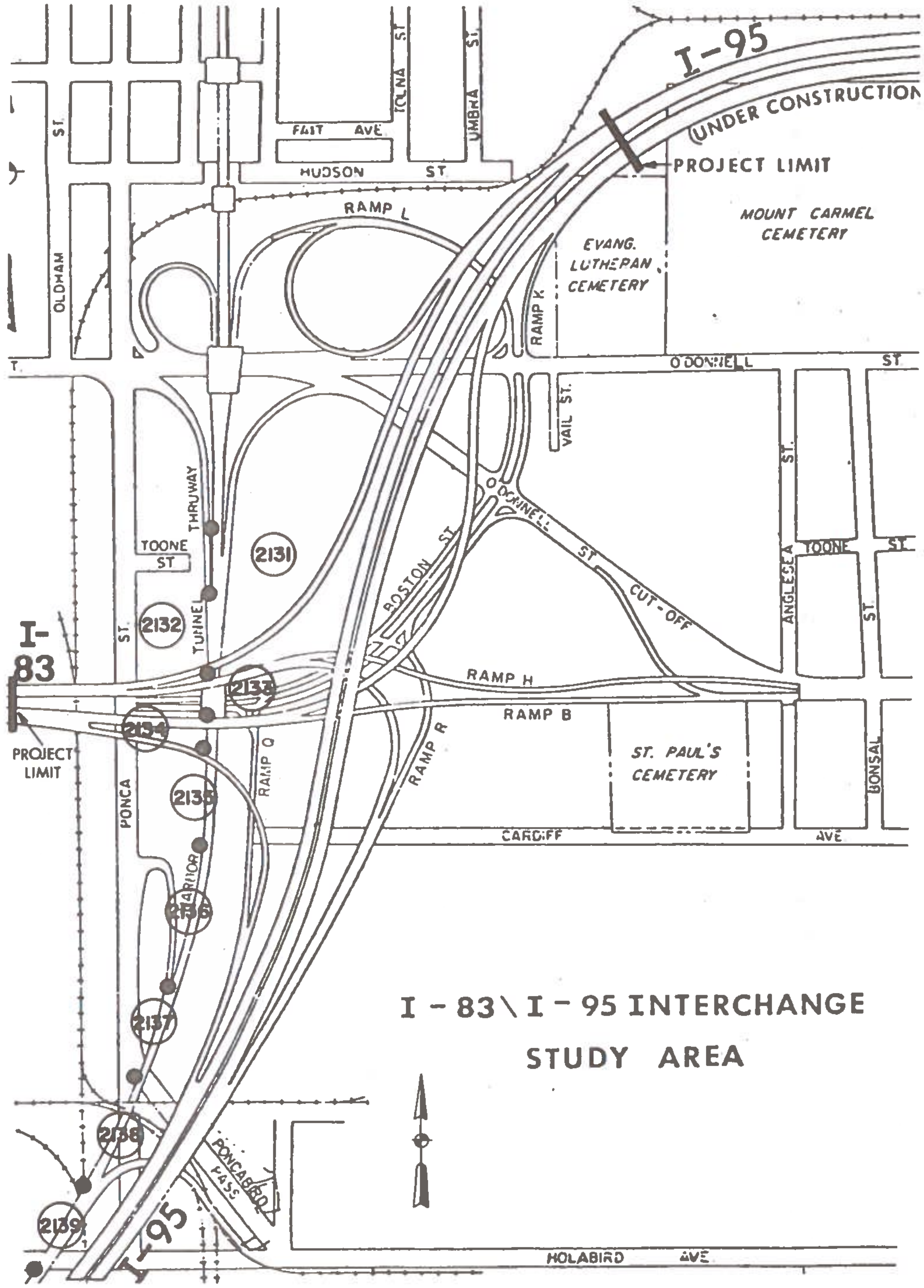

FIGURE B.21 HARBOR TUNNEL SOUTHBOUND

APPENDIX C: ROADWAY - SEGMENTATION DATA

TABLE C.1. ROAD SECTIONS

Z = Roadway Endpoint Ht. (above ground)
ZG = Ground Ht. (above sea level)
ZR = Roadway Endpoint Ht. (above sea level)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
1	469	7293	56	80	24	937	7614	53	77	24	48	4
2	937	7614	53	77	24	1511	7905	46	77	31	48	4
3	1511	7905	46	77	31	2155	8074	62	94	32	36	3
4	2155	8074	62	94	32	2990	8192	71	105	34	36	3
5	2990	8192	71	105	34	4087	8489	35	81	46	36	3
6	4087	8489	35	81	46	4479	8702	22	70	48	36	3
7	4479	8702	22	70	48	4696	8893	22	64	42	48	5
8	4696	8893	22	64	42	4888	9136	9	64	55	60	6
17	4959	9092	9	64	55	4752	8829	22	64	42	36	3
16	4752	8829	22	64	42	4516	8640	22	70	48	36	3
15	4516	8640	22	70	48	4115	8425	35	81	46	36	3
14	4115	8425	35	81	46	2998	8122	71	105	34	36	3
13	2998	8122	71	105	34	2166	8007	62	94	32	36	3
12	2166	8007	62	94	32	1536	7842	46	77	31	36	3
11	1536	7842	46	77	31	974	7545	53	77	24	36	3
10	974	7545	53	77	24	517	7231	56	80	24	48	4

TABLE C.1 ROAD SECTIONS (CONTINUED)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
20	2663	6968	32	70	38	2786	6678	38	76	38	36	3
21	2786	6678	38	76	38	2680	7078	42	79	37	36	3
22	2680	7078	42	79	37	2651	7475	41	82	41	36	3
23	2651	7475	41	82	41	2676	7886	39	80	41	36	3
24	2683	7888	39	80	41	2855	8241	46	80	34	24	2
25	2855	8241	46	80	34	3306	8482	49	83	34	24	2
26	3306	8482	49	83	34	3894	8522	40	80	40	24	2
27	3894	8522	40	80	40	4478	8705	23	68	45	24	2
30	2627	7085	42	78	36	2588	7395	41	80	39	12	1
31	2588	7395	41	80	39	2511	7656	23	80	57	12	1
32	2511	7656	23	80	57	2295	7857	32	68	36	12	1
33	2295	7857	32	68	36	2002	7891	26	58	32	12	1
34	2002	7891	26	58	32	1808	7851	31	61	30	12	1
35	1803	7852	31	61	30	1420	7733	43	69	26	24	2
36	1420	7733	43	69	26	982	7536	52	76	24	12	1

TABLE C.1 ROAD SECTIONS (CONTINUED)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
40	1505	7945	50	79	29	2259	8214	20	54	34	24	2
41	2254	8214	20	54	34	2537	8310	13	45	32	12	1
42	2537	8310	13	45	32	2637	8327	13	46	33	12	1
43	2637	8327	13	46	33	2818	8254	24	51	27	12	1
44	2818	8254	24	51	27	2921	8095	28	62	34	12	1
45	2921	8095	28	62	34	2915	7955	28	70	42	12	1
46	2925	7955	28	70	42	2829	7601	33	88	55	24	2
47	2829	7601	33	88	55	2781	7226	47	89	42	12	1
50	4969	9069	2	66	64	4674	8692	15	69	54	24	2
51	4674	8692	15	69	54	4518	8534	17	72	55	24	2
52	4518	8534	17	72	55	4065	8320	27	75	48	24	2
53	4065	8320	27	75	48	3481	8132	33	78	45	24	2
54	3481	8132	33	78	45	3229	8021	41	81	40	24	2
55	3229	8021	41	81	40	2998	7840	45	86	41	24	2
56	2998	7840	45	86	41	2863	7569	45	89	44	24	2
57	2863	7569	45	89	44	2805	7225	48	88	40	24	2
58	2811	7225	48	88	40	2781	6876	44	82	38	36	3
59	2781	6876	44	82	38	2740	6077	32	70	38	36	3

TABLE C.1 ROAD SECTIONS (CONTINUED)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
61	2661	7889	43	80	37	2706	8120	44	81	37	12	1
62	2706	8120	44	81	37	2762	8513	32	69	37	12	1
63	2762	8513	32	69	37	2779	8913	3	49	46	12	1
64	2779	8913	3	49	46	2788	9113	1	52	51	12	1
65	2788	9113	1	52	51	2801	9413	12	67	55	12	1
74	2868	9755	0	87	87	2906	9557	10	83	73	12	1
73	2906	9557	10	83	73	2895	9358	17	82	65	12	1
72	2895	9358	17	82	65	2825	9066	17	67	50	12	1
71	2825	9066	17	67	50	2810	8767	12	53	41	12	1
70	2810	8767	12	53	41	2836	8476	17	54	37	12	1
69	2836	8476	17	54	37	2926	8203	14	59	45	12	1
68	2926	8203	14	59	45	2909	7949	23	71	48	12	1

TABLE C.1 ROAD SECTIONS (CONTINUED)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
77	2233	8251	20	54	34	2417	8331	13	45	32	12	1
78	2417	8331	13	45	32	2606	8400	4	37	33	12	1
79	2606	8406	4	37	33	2805	8407	0	33	33	12	1
80	2805	8407	0	33	33	2973	8293	0	31	31	12	1
81	2905	8396	0	33	33	3028	8354	0	32	32	12	1
83	2711	7865	0	40	40	2420	7805	9	42	33	12	1
84	2420	7805	9	42	33	2021	7824	34	54	20	12	1
85	2021	7824	34	54	20	1823	7815	40	60	20	12	1
87	4122	8720	0	41	41	4318	8733	12	53	41	12	1
88	4318	8733	12	53	41	4503	8808	20	61	41	12	1
89	4503	8808	20	61	41	4665	8922	20	61	41	12	1

TABLE C.1   ROAD SECTIONS (CONTINUED)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
90	4526	8520	16	73	57	4217	8319	22	74	52	12	1
91	4217	8319	22	74	52	4090	8178	15	71	56	12	1
92	4090	8178	15	71	56	4093	7996	11	71	60	12	1
93	4093	7996	11	71	60	4227	7866	0	73	73	12	1
94	4227	7866	0	73	73	4410	7870	0	74	74	12	1
95	4410	7870	0	74	74	4540	8000	1	73	72	12	1
96	4540	8000	1	73	72	4558	8096	4	70	66	12	1
97	4574	8096	4	70	66	4510	8382	0	55	55	24	2
98	4510	8382	0	55	55	4334	8634	0	42	42	24	2
99	4334	8634	0	42	42	4157	8672	0	39	39	24	2
100	4157	8672	0	39	39	4055	8676	0	40	40	24	2

TABLE C.1 ROAD SECTIONS (CONTINUED)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
102	3994	7908	0	62	62	4030	8608	0	40	40	12	1
2102	4070	8608	0	40	40	4034	7908	0	62	62	12	1
104	3926	8091	0	58	58	3785	8353	0	48	48	24	2
105	3785	8353	0	48	48	3668	8518	0	44	44	24	2
106	3668	8518	0	44	44	3338	9014	0	56	56	24	2
107	3338	9025	0	56	56	3226	9126	0	60	60	24	2
108	3226	9126	0	60	60	2951	9247	0	57	57	24	2
109	2951	9247	0	57	57	2829	9409	0	66	66	24	2
110	2829	9409	0	66	66	2825	9903	0	96	96	36	3
112	2864	9856	0	93	93	3015	9461	0	73	73	24	2
111	3015	9461	0	73	73	3358	9032	0	56	56	24	2
2106	3368	9038	0	56	56	3701	8538	0	44	44	24	2
2105	3701	8538	0	44	44	3813	8371	0	48	48	24	2
2104	3813	8371	0	48	48	3954	8104	0	58	58	24	2

TABLE C.1 ROAD SECTIONS (CONTINUED)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
115	2732	6878	0	37	37	2706	7477	0	42	42	24	2
116	2706	7477	0	42	42	2733	7811	0	40	40	24	2
117	2733	7811	0	40	40	2798	8066	0	35	35	24	2
118	2798	8066	0	35	35	2917	8232	0	31	31	24	2
119	2917	8232	0	31	31	3068	8362	0	32	32	24	2
126	3083	8374	0	32	32	3489	8632	0	42	42	24	2
127	3489	8632	0	42	42	3673	8721	0	43	43	24	2
128	3673	8721	0	43	43	3882	8739	0	41	41	24	2
129	3882	8739	0	41	41	4055	8726	0	39	39	24	2
2129	4055	8676	0	39	39	3882	8689	0	41	41	24	2
2128	3882	8689	0	41	41	3695	8669	0	43	43	24	2
2127	3695	8669	0	43	43	3520	8589	0	42	42	24	2
2126	3520	8589	0	42	42	3118	8324	0	32	32	24	2
125	3049	8270	0	30	30	2908	8131	0	33	33	24	2
124	2908	8131	0	33	33	2810	7960	0	37	37	24	2
123	2810	7960	0	37	37	2756	7771	0	41	41	24	2
122	2756	7771	0	41	41	2748	7476	0	42	42	24	2
121	2748	7476	0	42	42	2740	6877	0	37	37	24	2

TABLE C.1 ROAD SECTIONS (CONCLUDED)

HIGHWAY SECTION	X1	Y1	Z1	ZR1	ZG1	X2	Y2	Z2	ZR2	ZG2	HWY WDH	NO. LNS
139	390	7030	28	54	26	790	7285	26	53	27	30	2
138	790	7285	26	53	27	1222	7526	22	50	28	30	2
137	1222	7526	22	50	28	1800	7678	15	44	29	30	2
136	1800	7678	15	44	29	2200	7695	20	50	30	30	2
135	2200	7695	20	50	30	2667	7695	18	60	42	30	2
134	2667	7695	18	60	42	2884	7695	20	64	44	30	2
133	2884	7695	20	64	44	3400	7695	30	74	44	30	2
132	3400	7695	30	74	44	4000	7695	9	75	66	30	2
131	4000	7695	9	75	66	4800	7695	0	75	75	30	2
2131	4800	7631	0	75	75	4000	7631	9	75	66	30	2
2132	4000	7631	9	75	66	3400	7631	30	74	44	30	2
2133	3400	7631	30	74	44	2884	7631	20	64	44	30	2
2134	2884	7631	20	64	44	2667	7631	18	60	42	30	2
2135	2667	7631	18	60	42	2200	7631	20	50	30	30	2
2136	2200	7631	20	50	30	1800	7611	15	44	29	30	2
2137	1800	7611	15	44	29	1236	7495	22	50	28	30	2
2138	1236	7495	22	50	28	810	7255	26	53	27	30	2
2139	810	7255	26	53	27	410	7000	28	54	26	30	2

APPENDIX D. EMISSIONS INPUT DATA
D.1 1980 PEAK HOUR
D.2 1980 OFF-PEAK HOUR
D.3 1995 PEAK HOUR
D.4 1995 OFF-PEAK HOUR

TABLE D.1 EMISSIONS INPUT DATA, 1980 PEAK HOUR

1980 Peak Hour = 50% of 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only
I-83 and Others - 5%

I-95 HIGHWAY SECTION	veh/hr	veh/hr/lane	SPEED MPH	19 EMISSION FACTOR for CO % HDV gm/mi/veh % HDV		
NB						
1	6,100	1,525	50	11		
2	6,100	1,525	50	11		
3	4,400	1,100	50	11		
4	4,400	1,100	50	11		
5	4,400	1,100	50	11		
6	4,400	1,100	50	11		
7	6,350	1,270	50	11		
8	6,950	1,160	50	11		
SB						
10	3,750	938	50	11		
11	1,950	650	50	11		
12	1,950	650	50	11		
13	1,950	650	50	11		
14	1,950	650	50	11		
15	1,950	650	50	11		
16	1,950	650	50	11		
17	1,950	650	50	11		

TABLE D.1 EMISSIONS INPUT DATA, 1980 PEAK HOUR (CONTINUED)

1980 Peak Hour = 50% of 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	1980 EMISSION FACTOR for CO % HDV gm/mi / veh		
I-83 SB to I-95 NB				% HDV		
20	4150	1380	50	5		
21	4150	1380	50	5		
22	3250	1080	50	5		
23	3250	1080	50	5		
24	1950	975	20	5		
25	1950	975	20	5		
26	1950	975	20	5		
27	1950	975	20	5		
I-83 SB to I-95 SB						
30	900	900	20	5		
31	900	900	20	5		
32	900	900	20	5		
33	900	900	20	5		
34	900	900	20	5		
35	1800	900	20	5		
36	1800	1800	20	5		

TABLE D.1 EMISSIONS INPUT DATA, 1980 PEAK HOUR (CONTINUED)

1980 Peak Hour = 50% of 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
I-95 NB to I-83 NB				% HDV		
40	1700	850	20	5		
41	800	800	20	5		
42	800	800	20	5		
43	800	800	20	5		
44	800	800	20	5		
45	800	800	20	5		
46	2050	1025	20	5		
47	2050	2050	20	5		
I-95 SB to I-83 NB						
50	1800	900	20	5		
51	1800	900	20	5		
52	1500	750	20	5		
53	1500	750	20	5		
54	1500	750	20	5		
55	1500	750	20	5		
56	1500	750	20	5		
57	1500	750	20	5		
58	3550	1184	20	5		
59	3550	1184	50	5		

TABLE D.1 EMISSIONS INPUT DATA, 1980 PEAK HOUR (CONTINUED)

1980 Peak Hour = 50% of 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only
I-83 and Others - 5%

	HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
RAMP G					% HDV		
	61	1300	1300	20	5		
	62	1300	1300	20	5		
	63	1300	1300	20	5		
	64	1300	1300	20	5		
	65	1300	1300	20	5		
RAMP H							
	68	1250	1250	20	5		
	69	1250	1250	20	5		
	70	1250	1250	20	5		
	71	1250	1250	20	5		
	72	1250	1250	20	5		
	73	1250	1250	20	5		
	74	1250	1250	20	5		

TABLE D.1 EMISSIONS INPUT DATA, 1980 PEAK HOUR (CONTINUED)

1980 Peak Hour = 50% of 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
RAMP R				% HDV		
77	900	900	10	5		
78	900	900	10	5		
79	900	900	10	5		
80	500	500	10	5		
RAMP "R" SPUR						
81	400	400	10	5		
RAMP "Q"						
83	900	900	20	5		
84	900	900	20	5		
85	900	900	20	5		
RAMP "K"						
87	600	600	20	5		
88	600	600	20	5		
89	600	600	20	5		

TABLE D.1 EMISSIONS INPUT DATA, 1980 PEAK HOUR (CONTINUED)

1980 Peak Hour = 50% of 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
RAMP L				% HDV		
90	300	300	10	5		
91	300	300	10	5		
92	300	300	10	5		
93	300	300	10	5		
94	300	300	10	5		
95	300	300	10	5		
96	300	300	10	5		
97	450	225	10	5		
98	450	225	10	5		
99	450	225	10	5		
100	450	225	10	5		
O'DONNELL ST						
102	250	250	20	5		
2102	600	600	20	5		
O'DONNELL ST CUTOFF EB						
104	350	175	20	5		
105	350	175	20	5		
106	1350	675	20	5		
107	1350	675	20	5		
108	1350	675	20	5		
109	1350	675	20	5		
110	2650	883	20	5		

TABLE D.1 EMISSIONS INPUT DATA, 1980 PEAK HOUR (CONTINUED)

1980 Peak Hour = 50% of 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
O'DONNELL ST CUTTOFF WB				% HDV		
112	1600	800	20	5		
111	1600	800	20	5		
2106	1600	800	20	5		
2105	400	200	20	5		
2104	400	200	20	5		
BOSTON ST EB						
115	1050	525	20	5		
116	1050	525	20	5		
117	700	350	20	5		
118	700	350	20	5		
119	700	350	20	5		
126	1100	550	20	5		
127	1100	550	20	5		
128	600	300	20	5		
129	600	300	20	5		
BOSTON ST WB						
2129	300	150	20	5		
2128	300	150	20	5		
2127	1000	500	20	5		
2126	1000	500	20	5		
125	1500	750	20	5		
124	1500	750	20	5		
123	950	475	20	5		
122	950	475	20	5		
121	950	475	20	5		

TABLE D.1 EMISSIONS INPUT DATA, 1980 PEAK HOUR (CONCLUDED)

1980 Peak Hour = 50% of 1980 Peak Period (2-Hr)

Trucks - I-95 - 11% Mainline Only
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV. gm/mi / veh		
HARBOR TUNNEL				% HDV		
NORTH						
139	2025	1012	50	11		
138	2025	1012	50	11		
137	2025	1012	50	11		
136	2025	1012	50	11		
135	2025	1012	50	11		
134	2025	1012	50	11		
133	2025	1012	50	11		
132	2025	1012	50	11		
131	2025	1012	50	11		
SOUTH						
2131	2025	1012	50	11		
2132	2025	1012	50	11		
2133	2025	1012	50	11		
2134	2025	1012	50	11		
2135	2025	1012	50	11		
2136	2025	1012	50	11		
2137	2025	1012	50	11		
2138	2025	1012	50	11		
2139	2025	1012	50	11		

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR

1980 Off-Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
I-95 NB				17% HDV		
1	2280	570	50			
2	2280	570	50			
3	1422	474	50			
4	1422	474	50			
5	1422	474	50			
6	1422	474	50			
7	2238	448	50			
8	2478	413	50			
I-95 SB						
10	2082	521	50			
11	1212	404	50			
12	1212	404	50			
13	1212	404	50			
14	1212	404	50			
15	1212	404	50			
16	1212	404	50			
17	1212	404	50			

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR (CONTINUED)

1980 Off Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speed NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
I-83SB to I-95NB				9% HDV		
20	2010	670	50			
21	2010	670	50			
22	1590	530	50			
23	1590	530	50			
24	816	408	20			
25	816	408	20			
26	816	408	20			
27	816	408	20			
I-83SB to I-95NB						
30	420	420	20			
31	420	420	20			
32	420	420	20			
33	420	420	20			
34	420	420	20			
35	870	435	20			
36	870	870	20			

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR (CONTINUED)

1980 Off Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speed NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	
I-95NB to I-83NB				9% HDV	
40	858	429	20		
41	408	408	20		
42	408	408	20		
43	408	408	20		
44	408	408	20		
45	408	408	20		
46	1086	543	20		
47	1086	1086	20		
I-95SB to I-83NB					
50	1050	525	20		
51	1050	525	20		
52	816	408	20		
53	816	408	20		
54	816	408	20		
55	816	408	20		
56	816	408	20		
57	816	408	20		
58	1902	634	20		
59	1902	634	50		

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR (CONTINUED)

1980 Off Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speed NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

	HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
RAMP G					9% HDV		
	61	774	774	20			
	62	774	774	20			
	63	774	774	20			
	64	774	774	20			
	65	774	774	20			
RAMP H							
	68	678	678	20			
	69	678	678	20			
	70	678	678	20			
	71	678	678	20			
	72	678	678	20			
	73	678	678	20			
	74	678	678	20			

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR (CONTINUED)

1980 Off Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speed NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
RAMP "R"				9% HDV		
77	450	450	10			
78	450	450	10			
79	450	450	10			
80	180	180	10			
RAMP "R" SPUR						
81	270	270	10			
RAMP "Q"						
83	450	450	20			
84	450	450	20			
85	450	450	20			
RAMP "K"						
87	240	240	20			
88	240	240	20			
89	240	240	20			

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR (CONTINUED)

1980 Off Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speed NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

HIGHWAY SECTION	veh/hr	veh/hr/lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi/veh		
				9% HDV		
RAMP "L"						
90	234	234	10	9		
91	234	234	10	9		
92	234	234	10	9		
93	234	234	10	9		
94	234	234	10	9		
95	234	234	10	9		
96	234	234	10	9		
97	342	171	10	9		
98	342	171	10	9		
99	342	171	10	9		
100	342	171	10	9		
O'DONNEL ST EB						
102	126	126	20	9		
2102	324	324	20	9		

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR (CONTINUED)

1980 Off Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speed NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
O'DONNELL ST CUTOFF EB				% HDV		
104	222	111	20	9		
105	222	111	20	9		
106	822	411	20	9		
107	822	411	20	9		
108	822	411	20	9		
109	822	411	20	9		
110	1596	532	20	9		
WB						
112	804	402	20	9		
111	804	402	20	9		
2106	804	402	20	9		
2105	210	105	20	9		
2104	210	105	20	9		

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR (CONTINUED)

1980 Off Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speed NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
BOSTON ST EB				% HDV		
115	510	255	20	9		
116	510	255	20	9		
117	330	115	20	9		
118	330	115	20	9		
119	330	115	20	9		
126	600	300	20	9		
127	600	300	20	9		
128	234	117	20	9		
129	234	117	20	9		
WB						
2129	240	120	20	9		
2128	240	120	20	9		
2127	600	300	20	9		
2126	600	300	20	9		
125	780	390	20	9		
124	780	390	20	9		
123	510	255	20	9		
122	510	255	20	9		
121	510	255	20	9		

TABLE D.2 EMISSIONS INPUT DATA, 1980 OFF-PEAK HOUR (CONCLUDED)

1980 Off Peak Hour = 6% of 1980 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speed NL = 50 MPH
On Ramps - 20
Off Ramps - 10
Streets - 20

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh		
HARBOR TUNNEL				% HDV		
NORTH						
139	1518	759	50	17		
138	1518	759	50	17		
137	1518	759	50	17		
136	1518	759	50	17		
135	1518	759	50	17		
134	1518	759	50	17		
133	1518	759	50	17		
132	1518	759	50	17		
131	1518	759	50	17		
SOUTH						
2131	1518	759	50	17		
2132	1518	759	50	17		
2133	1518	759	50	17		
2134	1518	759	50	17		
2135	1518	759	50	17		
2136	1518	759	50	17		
2137	1518	759	50	17		
2138	1518	759	50	17		
2139	1518	759	50	17		

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
I-95 NB				11% HDV		
1	6700	1675	50			
2	6700	1675	50			
3	4650	1550	50			
4	4650	1550	50			
5	4650	1550	50			
6	4650	1550	50			
7	7050	1410	50			
8	7800	1300	50			
I-95 SB						
10	4300	1075	50			
11	2100	700	50			
12	2100	700	50			
13	2100	700	50			
14	2100	700	50			
15	2100	700	50			
16	2100	700	50			
17	2100	700	50			

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR (CONTINUED)

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
I-83SB to I-95NB				5% HDV		
20	5200	1734	50			
21	5200	1734	50			
22	4100	1367	50			
23	4100	1367	50			
24	2400	1200	20			
25	2400	1200	20			
26	2400	1200	20			
27	2400	1200	20			
I-83SB to I-95SB						
30	1100	1100	20			
31	1100	1100	20			
32	1100	1100	20			
33	1100	1100	20			
34	1100	1100	20			
35	2200	1100	20			
36	2200	2200	20			

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR (CONTINUED)

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
I-95NB to I-83NB				5%		
40	2050	1025	20			
41	950	950	20			
42	950	950	20			
43	950	950	20			
44	950	950	20			
45	950	950	20			
46	2500	1250	20			
47	2500	1250	20			
I-95SB to I-83NB						
50	2000	1000	20			
51	2000	1000	20			
52	1650	825	20			
53	1650	825	20			
54	1650	825	20			
55	1650	825	20			
56	1650	825	20			
57	1650	825	20			
58	4150	1383	20			
59	4150	1383	50			

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR (CONTINUED)

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
RAMP "G"				5% HDV		
61	1700	1700	20			
62	1700	1700	20			
63	1700	1700	20			
64	1700	1700	20			
65	1700	1700	20			
RAMP "H"						
68	1550	1550	20			
69	1550	1550	20			
70	1550	1550	20			
71	1550	1550	20			
72	1550	1550	20			
73	1550	1550	20			
74	1550	1550	20			

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR (CONTINUED)

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh 5% HDV	gm/mi / hr / lane	gm/m / sec / lane
RAMP "R"						
77	1100	1100	10			
78	1100	1100	10			
79	1100	1100	10			
80	600	600	10			
RAMP "R" SPUR						
81	500	500	10			
RAMP "Q"						
83	1100	1100	10			
84	1100	1100	10			
85	1100	1100	10			
RAMP "K"						
87	750	750	20			
88	750	750	20			
89	750	750	20			

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR (CONTINUED)

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

	HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
RAMP "L"					5% HDV		
	90	350	350	10			
	91	350	350	10			
	92	350	350	10			
	93	350	350	10			
	94	350	350	10			
	95	350	350	10			
	96	350	350	10			
	97	550	275	10			
	98	550	275	10			
	99	550	275	10			
	100	550	275	10			
O'DONNELL ST							
EB	102	300	300	20	5		
WB	2102	800	800	20	5		

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR (CONTINUED)

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

	HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
O'DONNELL ST. CUTOFF					% HDV		
EB	104	400	200	20	5		
	105	400	200	20	5		
	106	1650	825	20	5		
	107	1650	825	20	5		
	108	1650	825	20	5		
	109	1650	825	20	5		
	110	3350	1117	20	5		
WB							
	112	2000	1000	20	5		
	111	2000	1000	20	5		
	2106	2000	1000	20	5		
	2105	550	275	20	5		
	2104	550	275	20	5		

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR (CONTINUED)

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
BOSTON ST EB				% HDV		
115	1300	650	20	5		
116	1300	650	20	5		
117	850	425	20	5		
118	850	425	20	5		
119	850	425	20	5		
126	1350	675	20	5		
127	1350	675	20	5		
128	700	350	20	5		
129	700	350	20	5		
WB						
2129	350	175	20	5		
2128	350	175	20	5		
2127	1200	600	20	5		
2126	1200	600	20	5		
125	1800	900	20	5		
124	1800	900	20	5		
123	1150	575	20	5		
122	1150	575	20	5		
121	1150	575	20	5		

TABLE D.3 EMISSIONS INPUT DATA, 1995 PEAK HOUR (CONCLUDED)

1995 Peak Hour = 50% of 1995 Pk. Period

Trucks - I-95 - 11% (Mainline Only)
I-83 and Others - 5%

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO @ HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
HARBOR TUNNEL				% HDV		
NORTH						
139	2450	1225	50	11		
138	2450	1225	50	11		
137	2450	1225	50	11		
136	2450	1225	50	11		
135	2450	1225	50	11		
134	2450	1225	50	11		
133	2450	1225	50	11		
132	2450	1225	50	11		
131	2450	1225	50	11		
SOUTH						
2131	2450	1225	50	11		
2132	2450	1225	50	11		
2133	2450	1225	50	11		
2134	2450	1225	50	11		
2135	2450	1225	50	11		
2136	2450	1225	50	11		
2137	2450	1225	50	11		
2138	2450	1225	50	11		
2139	2450	1225	50	11		

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
I-95 NB				17% HDV		
1	2406	602	50			
2	2406	602	50			
3	1518	506	50			
4	1518	506	50			
5	1518	506	50			
6	1518	506	50			
7	2580	516	50			
8	2898	483	50			
I-95 SB						
10	2436	609	50			
11	1446	482	50			
12	1446	482	50			
13	1446	482	50			
14	1446	482	50			
15	1446	482	50			
16	1446	482	50			
17	1446	482	50			

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
I-83SB to I-95NB				9% HDV		
20	2628	876	50			
21	2628	876	50			
22	2094	698	50			
23	2094	698	50			
24	1062	531	20			
25	1062	531	20			
26	1062	531	20			
27	1062	531	20			
I-83SB to I-95SB						
30	534	534	20			
31	534	534	20			
32	534	534	20			
33	534	534	20			
34	534	534	20			
35	990	495	20			
36	990	990	20			

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR (CONTINUED)

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
I-95NB to I-83NB				9% HDV		
40	888	444	20			
41	432	432	20			
42	432	432	20			
43	432	432	20			
44	432	432	20			
45	432	432	20			
46	1326	663	20			
47	1326	1326	20			
I-95SB to I-83NB						
50	1434	717	20			
51	1434	717	20			
52	1112	561	20			
53	1112	561	20			
54	1112	561	20			
55	1112	561	20			
56	1112	561	20			
57	1112	561	20			
58	2448	816	20			
59	2448	816	50			

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR (CONTINUED)

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
RAMP "G"				9% HDV		
61	1032	1032	20			
62	1032	1032	20			
63	1032	1032	20			
64	1032	1032	20			
65	1032	1032	20			
RAMP "H"						
68	894	894	20			
69	894	894	20			
70	894	894	20			
71	894	894	20			
72	894	894	20			
73	894	894	20			
74	894	894	20			

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR (CONTINUED)

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
RAMP "R"				9% HDV		
77	456	456	10			
78	456	456	10			
79	456	456	10			
80	186	186	10			
RAMP "R" SPUR						
81	270	270	10			
RAMP "Q"						
83	456	456	20			
84	456	456	20			
85	456	456	20			
RAMP "K"						
87	318	318	20			
88	318	318	20			
89	318	318	20			

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR (CONTINUED)

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

	HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
RAMP "L"					9% HDV		
	90	312	312	10			
	91	312	312	10			
	92	312	312	10			
	93	312	312	10			
	94	312	312	10			
	95	312	312	10			
	96	312	312	10			
	97	450	225	10			
	98	450	225	10			
	99	450	225	10			
	100	450	225	10			
O'DONNELL ST							
EB	102	168	168	20	9		
WB	2102	438	438	20	9		

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR (CONTINUED)

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

	HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
O'DONNELL ST CUTOFF					% HDV		
EB	104	294	147	20	9		
	105	294	147	20	9		
	106	1032	516	20	9		
	107	1044	522	20	9		
	108	1044	522	20	9		
	109	1044	522	20	9		
	110	2076	692	20	9		
WB	112	1032	516	20	9		
	111	1032	516	20	9		
	2106	1044	522	20	9		
	2105	288	144	20	9		
	2104	288	144	20	9		

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR (CONTINUED)

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

	HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
BOSTON ST					% HDV		
EB	115	672	336	20	9		
	116	672	336	20	9		
	117	486	243	20	9		
	118	486	243	20	9		
	119	486	243	20	9		
	126	756	378	20	9		
	127	756	378	20	9		
	128	312	156	20	9		
	129	312	156	20	9		
WB	2129	318	159	20	9		
	2128	318	159	20	9		
	2127	756	378	20	9		
	2126	756	378	20	9		
	125	942	471	20	9		
	124	942	471	20	9		
	123	672	336	20	9		
	122	672	336	20	9		
	121	672	336	20	9		

TABLE D.4 EMISSIONS INPUT DATA, 1995 OFF-PEAK HOUR (CONCLUDED)

1995 Off Peak Hour = 6% of 1995 ADT

Trucks - I-95 Mainline 17%
All Others 9%

Speeds - ML - 50 MPH
On Ramp - 20 MPH
Off Ramp - 10 MPH
Street - 20 MPH

HIGHWAY SECTION	veh/hr	veh/hr / lane	SPEED	19 EMISSION FACTOR for CO % HDV gm/mi / veh	gm/mi / hr / lane	gm/m / sec / lane
HARBOR TUNNEL				% HDV		
NORTH						
139	1830	915	50	17		
138	1830	915	50	17		
137	1830	915	50	17		
136	1830	915	50	17		
135	1830	915	50	17		
134	1830	915	50	17		
133	1830	915	50	17		
132	1830	915	50	17		
131	1830	915	50	17		
SOUTH						
2131	1830	915	50	17		
2132	1830	915	50	17		
2133	1830	915	50	17		
2134	1830	915	50	17		
2135	1830	915	50	17		
2136	1830	915	50	17		
2137	1830	915	50	17		
2138	1830	915	50	17		
2139	1830	915	50	17		

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