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CARBON MONOXIDE EMISSION INVENTORY AND ANALYSIS OF NONATTAINMENT IN ADA COUNTY, IDAHO

Final Report

by

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DISCLAIMER

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SECTION 1

INTRODUCTION

DEFINITION OF THE NONATTAINMENT AREA

The first task under this contract was a review of existing air quality data in order to determine the extent of the CO problem and to define the area for which air quality modeling will be performed.

In performing this analysis, three data sources were utilized: (1) several years of CO data recorded at the permanent monitor site on 9th Street; (2) a study of CBD CO concentrations conducted by EPA during the winter of 1977-1978; and (3) a study of the Boise urban area performed by the State of Idaho, also during last winter. Data collected at a new permanent monitoring site located on Orchard Street were not reviewed as the station was not operating during the peak CO season (winter) and the State's urban analysis has already established this as a nonattainment site.

A review of the 9th Street data indicated, for the most recent 1-yr period, July 1977 through June 1978, a maximum 8-hr CO level of 18.4 ppm and a second-high value of 15.9 ppm. During this 1-yr period, the 8-hr standard was exceeded on 48 days, the majority (71 percent) occurring in November, December, and January. Maximum 1-hr CO levels exceeded the 35 ppm standard twice during this period; the highest level was 40.9 ppm and the second-highest 39.5. Review of historical calendar year data for 1975 through 1978 indicate second-high 8-hr CO levels ranging from 17.5 ppm to 18.3 ppm.

The EPA study provided a high degree of resolution as to the variation in CO levels throughout the CBD. About 40 monitors were operated for 10 to 20 days, 10 a.m. to 6 p.m., during November and December 1977; all were located within about 10 blocks of the 9th Street monitor. The results of the study showed 70 percent of the monitors exceeding 9 ppm at least once and that on 19 of the 20 days, the standard was exceeded at at least one site. The study also documented that the 9th Street station may not represent the worst site in the city; a monitor located at Idaho and 8th Sts. recorded a second-high 8-hr average of 16.5 ppm, 0.6 ppm greater than the second-high value recorded at 9th Street. The short period-of-record for this monitoring study suggests that second-high values even greater than 16.5 ppm may occur at this site.

The CO study conducted by the State measured concentrations throughout the urbanized area. A total of 46 sites, bounded roughly by I-80 to the south, Cole Road to the west, and the foothills to the north and east were sampled for 1 week each. Exceedances of the standard were documented at all traffic corridor sites within the area bounded by I-80N, I-180, and Broadway Avenue. Eight-hour levels as high as 25 ppm were recorded. In addition, using ratios of site-to-concurrent 9th Street concentrations, it was hypothesized that virtually every traffic corridor and neighborhood site could potentially exceed standards during the year.

The conclusion of this review is that the CO problem is widespread and supports the expanded nonattainment area recommended by the Ada Planning Association and approved by EPA in 1978. The study area of this analysis should, hence, address this area to the greatest extent possible.

SUMMARY

Using assigned network traffic files supplied by the Idaho Transportation Department, a wintertime motor vehicle carbon monoxide emission inventory was prepared for Ada County and gridded on 625 1-km grid squares. The total emissions, presented below, indicate that only a slight emission reduction (4 percent)

Year	Regional CO motor vehicle emissions (10^9 g/day)	Percent reduction (1976 base)	Urban core grid emissions (10^6 g/day)	Percent reduction (1976 base)
1976	0.223	-	6.74	-
1982	0.215	3.6	7.06	(4.7)
1987	0.167	25.1	5.69	15.6
1982 with I/M	0.193	13.5	6.34	5.9
1987 with I/M	0.133	40.4	4.57	32.2

is likely to occur by 1982. A typical motor vehicle inspection/maintenance (I/M) program can be expected to lead to a total emission reduction of 25 percent by 1982. By 1987, total reductions from 1976 levels are likely to be 13 percent without I/M and 40 percent with an I/M program. Emission reductions will be considerably less for a Boise urban area grid, presented in this table for comparison.

An inventory of emissions from parking lots indicates that such emissions are, on a regional basis, negligible (2 percent) though significant emissions do occur in some CBD grids. Parking lot emissions are likely only to be significant as localized sources, or CO hotspots.

A worst case modeling analysis of the 9th Street monitor, using the Intersection/Midblock Model[1] (IMM) and APRAC-2 dispersion models, indicates that almost all of the ambient CO at the monitor location can be attributed to traffic on 9th Street and Main Street. Approximately three-quarters of this concentration is due to emissions from vehicles queuing at the traffic signals. An attempt to validate the IMM model from 1 month of concurrent ambient CO, meteorological and traffic data was unsuccessful. Notwithstanding the poor validation, it is still our opinion that the 9th Street monitor concentrations are predominately due to traffic on 9th Street. We also expect that other locations in the CBD will be similarly influenced by traffic on nearby streets.

A comparison of CO episodes with preceding nonviolating days suggests that no major meteorological anomaly is causing the excursions above the standard. Episodes are apparently caused by a combination of higher "per vehicle" emissions, possible resulting from such factors as low ambient temperature and poor traffic flow caused by fog, fewer hours of daylight, and reduction in road capacity by snow; and by routine wintertime dispersion characteristics, including low wind speed, low mixing height, and stable atmosphere (temperature inversion).

Using a statistical relationship which uses traffic, emissions, and location parameters to predict maximum CO levels, it is estimated that an additional 12 to 15 percent reduction in CO emissions, beyond that which will be achieved through implementation of I/M, is necessary to meet the 8-hr standard in 1987. This reduction represents a best estimate based upon the analysis presented in this study. Several factors would result in a different range of needed reduction. Among these are:

- Failure to implement the I/M program described, both with regard to timing and stringency,* will most likely require a greater reduction from other control measures.
- The degree of emissions reduction ascribed to I/M has not been fully proven, particularly at higher altitude.
- The use of a higher second-highest design 8-hr CO level than the value 16.9 ppm (see Section 6 for further discussion) would require greater emissions reductions.
- Implementation of the CBD Signal System, which was not evaluated as a part of this study, will most likely reduce the needed reductions to some extent.
- Variations in growth assumptions, project committments, and parking strategies from those implicit in the traffic data may change reduction estimates.

Evaluation of the possible variance in reduction estimates resulting from these factors was not performed as a part of this study.

* All automobiles regularly traveling in the study area were assumed to be subject to I/M.

SECTION 2

EMISSION INVENTORY DEVELOPMENT

A gridded emissions inventory of motor vehicle carbon monoxide emissions for the year 1976, and projections to 1982 and 1987 were prepared using a modified version of the APRAC-2 model.* Projected emissions inventories for 1982 and 1987 were also prepared which assumed the implementation of a motor vehicle inspection-maintenance program. In this section the standard methodology of emission calculation in the modified APRAC-2 model is first presented. Then the changes in that methodology to calculate emissions in Ada County are examined. Next the assumptions and input data are described and, finally, the emission inventory is presented.

APRAC-2 METHODOLOGY[2]

The principal input data is the assigned traffic network. This is a transportation planning forecasting model in which the metropolitan area highway system is described as a series of geographically coded links. Each link has assigned to it an estimate of average daily traffic (ADT) and average speed.

The emissions for a single 1-hr period are then calculated for each link in the network. The hourly traffic on the link is first calculated from the ADT and a diurnal traffic distribution. The diurnal distribution describes the proportion of the 24-hr traffic that occurs in each hour. Different diurnal distributions are input to the model for freeway and nonfreeway facilities in each of the following locales: CBD; suburban and core city commercial; residential; industrial; and rural or other. Thus, depending on the hour of the day, the type of link, and the location of the link, an hourly traffic volume is calculated from the assigned 24-hr traffic on the link.

The speed for that hour on the link can be either the average speed provided on the assigned network or a speed calculated via the capacity-restraint equation.

Two mode split distributions (i.e., proportion of VMT by light duty vehicles (LDV), two classes of light duty trucks defined by weight (LDT1 and LDT2), heavy-duty gasoline powered trucks (HDV-G), heavy-duty diesel powered trucks (HDV-D), and motorcycles (MC) are input, one for freeways and one for nonfreeways. Each modal split for each link is thus designated depending on the type of link.

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* The APRAC-2 model modified to incorporate the MOBILE1 emission factors.

Twelve cold-start hot-start mixes* are input to the model, describing the vehicle operating states for four time periods (viz., 1800 to 0700, 0700 to 0900, 1000 to 1600, and 1600 to 1800) and three locales (viz., downtown, suburban-commercial, and residential-other). Thus, depending on the time of day and location of the link, a cold-start hot-start mix is assigned to each link.

The remaining data necessary for the calculation of emissions do not vary among links or depend on the time of day. They are input separately to the model and are thus constant. These data include calendar year, ambient temperature, the vehicle age distribution, the vehicle mileage accumulation distribution, and the optional correction factors for air-conditioning, loading, trailer towing, humidity, heavy duty vehicle engine displacement and load, and the parameters of an inspection-maintenance program.

All the necessary data for the calculation of emissions using the MOBILE1 emission factors is consequently available for each link for the hour of interest. Once the emissions for each link are calculated, these emissions are assigned to a grid square on the basis of the coordinates of the end-points of each link. Links spanning grid square boundaries are apportioned among the relevant grid squares on the basis of length of link in each grid square.

APRAC-2 also provides for the calculation of emissions from vehicular traffic that is not on the coded highway network. This is principally traffic on minor streets that are too numerous to code individually. Two options are provided. The first inflates the traffic in each grid square by a specified percentage unique to each grid square. The second inflates the traffic in each grid square by an amount that is a function of the locale of the grid square (e.g., CBD, commercial, residential, industrial, and rural-other).

APRAC-2 METHODOLOGY AS IMPLEMENTED IN ADA COUNTY

Application of the Ada County traffic files required that several assumptions be made concerning street locations and usage based upon APA's facility/area type matrix as presented in Table 1. Area type 1 facility type 1 corresponds to ramps. Area type 1, facility types 2 through 5 are one-way streets. Area type 1, facility type 6 are interstates. Area type 2 are centroid connectors. Area types 3, 4, and 5 are two-way streets.

The lack of area-type index numbers impairs APRAC-2's treatment of diurnal distribution and the cold-start hot-start mix. This is especially critical for the cold-start hot-start mix, since these proportions show

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* Vehicles operating during the period from startup until the stabilized engine temperature is reached emit CO at a greater rate than when stabilized. Those vehicles starting with the engine temperature equal to the ambient are said to be cold-starting. Those vehicles which have been not operating for a short time and are, thus, still somewhat warm are said to be operating in a hot-start mode. The mix of vehicles in the three classes (cold start, hot start, and stabilized) is an important parameter in analyzing emissions.

TABLE 1. FACILITY-TYPE AREA-TYPE MATRIX OF SPEED AND CAPACITY

		Facility type					
		1	2	3	4	5	6
Area type	1	25.0* (550)†	20.0 (650)	25.0 (650)	30.0 (700)	35.0 (900)	53.0 (1,750)
	2	15.0 10,000					
	3	15.0 (525)	17.5 (525)	20.0 (525)	22.5 (600)	25.0 (675)	27.5 (750)
	4	30.0 (825)	32.5 (900)	35.0 (925)	37.5 (950)	40.0 (975)	42.5 (1,000)
	5	45.0 (1,025)	47.5 (1,050)	50.0 (1,100)	52.5 (1,150)	(55.0) (1,150)	57.5 (1,175)

*Average speed (mph)

†Lane capacity (vph)

considerable variation by location, especially between the CBD and residential areas. To preserve the discrimination between these areas in APRAC-2, it was assumed that all of the one-way streets are located in the CBD and the two-way streets are non-CBD. While this assumption is not totally accurate, it is our judgment that it is preferable to the alternative of using a single cold-start hot-start mix.

Consequently, area type 1, facility types 2 through 5 on Table 1 were assumed to be located in the CBD. The remaining nonfreeway links were assumed to be non-CBD. All freeway facilities were also assumed to be non-CBD.

The other significant change concerns the calculation of daily emissions. The most rigorous method of calculating emissions for a 24-hr period would be to calculate emissions for each hour and then sum over the entire 24-hr period. The resources to perform this calculation were not available. Consequently, APRAC-2 was executed once with the diurnal distribution factor effectively set equal to 1.0. In other words, the entire 24-hr traffic volume was treated as 1 hour's volume. (This was done only for the execution of APRAC-2 for the preparation of the emission inventory; when executed as a dispersion model to predict intraurban background or mesoscale concentrations, hourly traffic volumes were used.) The midday cold-start hot-start mix was specified for the emission calculation.

INPUT DATA

Traffic assignment data used in this study were those supplied by the Ada Planning Association (APA). These data represented the base planning network plus, for projection years, those projects committed by the APA Advisory Committee. No modal split was assumed in these data; all trips were completed by private vehicle with average occupancy of 1.2 persons. The impact of the CBD signalization improvement program was not reflected in this analysis.

The diurnal distributions shown on Table 2, based on data obtained from the Idaho Transportation Department (ITD) permanent ATR stations, were used.

The vehicle age distribution shown on Table 3, provided by ITD, was used. The national average mileage accumulations rates were used.

Based on the O and D classification data, obtained from ITD, the following vehicle mixes were derived:

	LDV (%)	LDT-1 (%)	LDT-2 (%)	HDV-G (%)	HDV-D (%)	MC (%)
Freeway	68.0	8.6	8.6		14.6	0.2
Nonfreeway	67.5	12.9	12.9		5.7	0.9

TABLE 2. DIURNAL DISTRIBUTION

Ending hour	Freeway		Nonfreeway
	Inbound (%)	Outbound (%)	
1	0.7	0.8	0.84
2	0.5	0.5	0.53
3	0.3	0.2	0.25
4	0.3	0.2	0.16
5	0.8	0.7	0.17
6	2.0	1.5	0.40
7	3.2	2.8	1.58
8	4.1	2.9	6.70
9	3.2	2.8	6.06
10	2.3	2.2	4.82
11	1.6	1.9	5.14
12	1.8	2.2	6.42
13	1.8	2.7	7.61
14	1.8	2.2	7.08
15	2.5	3.0	6.95
16	3.2	3.8	7.34
17	3.6	4.4	8.67
18	3.6	4.4	9.22
19	2.7	3.3	5.58
20	2.2	2.3	4.21
21	2.0	2.0	3.22
22	1.7	1.8	3.07
23	1.4	1.6	2.40
24	1.2	1.3	1.62

TABLE 3. VEHICLE AGE DISTRIBUTION

	Vehicle age (years)																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	≥ 19
LDV	0.045	0.086	0.087	0.066	0.083	0.090	0.086	0.069	0.065	0.062	0.054	0.047	0.040	0.039	0.028	0.020	0.014	0.008	0.006	0.004
LDT-1	0.036	0.081	0.080	0.065	0.077	0.094	0.083	0.057	0.060	0.059	0.051	0.042	0.042	0.038	0.033	0.026	0.021	0.015	0.016	0.025
LDT-2	0.036	0.081	0.080	0.065	0.077	0.094	0.083	0.057	0.060	0.059	0.051	0.042	0.042	0.038	0.033	0.026	0.021	0.015	0.016	0.025
HDV-G	0.096	0.069	0.067	0.107	0.130	0.102	0.062	0.057	0.063	0.042	0.037	0.037	0.028	0.018	0.016	0.014	0.009	0.008	0.006	0.024
HDV-D	0.095	0.093	0.057	0.102	0.119	0.096	0.061	0.054	0.063	0.044	0.037	0.038	0.033	0.023	0.016	0.014	0.008	0.008	0.007	0.039
MC	0.030	0.074	0.079	0.134	0.135	0.144	0.108	0.094	0.075	0.050	0.030	0.024	0.023							

As discussed previously, the average speeds on each link were obtained from Table 1, without further adjustment for capacity restraint.

Based on GCA's experience elsewhere, the following cold-start hot-start were assumed:

	CBD	Non-CBD
Night	15 % C	15 % C
	10 % H	7 % H
Morning peak	5 % C	42 % C
	5 % H	5 % H
Day	20 % C	35 % C
	20 % H	40 % H
Evening peak	60 % C	13 % C
	20 % H	7 % H

A linear interpolation between low and high altitude emission factors was made, based on a low altitude reference of 500 ft, a high altitude reference of 5,500 ft, and Boise's altitude of 2,700 ft.

Consistent with the average January minimum daily temperature, an ambient temperature of 22°F was used. However, the choice of a specific temperature should not significantly affect any conclusions as to the degree of control necessary for attainment of standards.

Where an inspection-maintenance program is assumed adopted, the following parameters, typical of I/M programs presently being planned in the U.S. were assumed: Implementation will begin in 1981, a mechanics training program will be required, a stringency of 20 percent will be adopted, and new vehicles and and vehicles over 12 years old will be exempted. The program will apply to LDV, LDT1, LDT2 and MC.

All secondary traffic was assumed to be accounted for through the centroid connectors.

EMISSION INVENTORY

The emission inventory of traffic on the assigned network, based on the assumptions detailed above, is presented below as regional totals and shown on a gridded basis on the following five figures. Emissions in these figures are in grams per day and are presented in scientific notation. Hence, an entry 0.170E+06 represents 0.17×10^6 g/day of CO from the grid. The gridded emission inventory is based on a 1 km by 1 km grid system whose origin is 319100, 660200 in the traffic network coordinate system. Maps of the grid square network are presented as Figures 6, 7 and 8.

NORTH GRIDS	GRIDS EAST-- 1	2	3	4	5	6	7	8	9	10	11	12	13
25	0.0	0.162E+06	0.229E+06	0.251E+06	0.245E+06	0.346E+06	0.481E+06	0.204E+06	0.0	0.198E+06	0.0	0.0	0.0
24	0.170E+06	0.137E+06	0.976E+05	0.0	0.0	0.0	0.167E+06	0.481E+06	0.222E+06	0.321E+06	0.114E+06	0.529E+05	0.314E+05
23	0.0	0.121E+06	0.651E+05	0.0	0.0	0.0	0.167E+06	0.284E+05	0.0	0.390E+06	0.792E+06	0.421E+06	0.127E+06
22	0.0	0.944E+05	0.0	0.231E+05	0.0	0.0	0.167E+06	0.148E+05	0.109E+04	0.0	0.747E+05	0.475E+06	0.924E+06
21	0.120E+06	0.208E+06	0.138E+06	0.173E+06	0.180E+06	0.165E+06	0.340E+06	0.163E+06	0.256E+06	0.252E+06	0.219E+06	0.143E+06	0.723E+06
20	0.235E+05	0.907E+05	0.169E+05	0.333E+05	0.574E+05	0.570E+05	0.180E+06	0.690E+05	0.233E+06	0.263E+06	0.406E+06	0.425E+06	0.888E+06
19	0.0	0.787E+05	0.0	0.369E+05	0.468E+05	0.163E+05	0.141E+06	0.886E+04	0.202E+06	0.208E+06	0.271E+06	0.723E+06	0.130E+07
18	0.674E+05	0.149E+06	0.641E+05	0.141E+06	0.214E+06	0.164E+06	0.317E+06	0.180E+06	0.400E+06	0.438E+06	0.386E+06	0.755E+06	0.143E+07
17	0.117E+05	0.139E+06	0.205E+06	0.122E+06	0.280E+06	0.544E+05	0.195E+06	0.693E+05	0.403E+06	0.426E+06	0.461E+06	0.832E+06	0.173E+07
16	0.157E+06	0.364E+06	0.646E+06	0.604E+06	0.814E+06	0.540E+06	0.642E+06	0.469E+06	0.925E+06	0.111E+07	0.133E+07	0.142E+07	0.279E+07
15	0.131E+06	0.319E+06	0.376E+06	0.388E+06	0.576E+06	0.356E+06	0.527E+06	0.332E+06	0.649E+06	0.667E+06	0.686E+06	0.801E+06	0.251E+07
14	0.189E+07	0.203E+07	0.155E+07	0.848E+06	0.969E+06	0.948E+06	0.102E+07	0.100E+07	0.149E+07	0.140E+07	0.128E+07	0.112E+07	0.183E+07
13	0.840E+05	0.146E+06	0.371E+06	0.880E+06	0.229E+06	0.132E+06	0.249E+06	0.255E+06	0.642E+06	0.641E+06	0.733E+06	0.828E+06	0.215E+07
12	0.707E+05	0.122E+06	0.655E+05	0.192E+06	0.852E+05	0.228E+05	0.815E+05	0.191E+05	0.312E+06	0.351E+06	0.676E+05	0.269E+06	0.308E+06
11	0.0	0.0	0.427E+04	0.209E+06	0.837E+05	0.806E+05	0.142E+06	0.102E+06	0.346E+06	0.271E+06	0.330E+06	0.480E+06	0.544E+06
10	0.481E+05	0.622E+05	0.522E+05	0.202E+06	0.779E+05	0.446E+05	0.948E+05	0.506E+05	0.228E+06	0.225E+06	0.960E+05	0.143E+06	0.746E+05
9	0.152E+04	0.195E+05	0.176E+04	0.148E+06	0.187E+05	0.870E+03	0.476E+05	0.469E+04	0.215E+06	0.171E+06	0.304E+05	0.101E+06	0.141E+06
8	0.322E+05	0.531E+05	0.393E+05	0.169E+06	0.519E+05	0.443E+05	0.926E+05	0.614E+05	0.276E+06	0.150E+06	0.414E+05	0.846E+05	0.702E+05
7	0.283E+05	0.419E+05	0.332E+05	0.188E+06	0.559E+05	0.532E+05	0.700E+05	0.286E+05	0.230E+06	0.121E+06	0.589E+05	0.176E+05	0.0
6	0.0	0.185E+05	0.0	0.147E+06	0.282E+05	0.786E+04	0.183E+05	0.683E+03	0.501E+05	0.0	0.0	0.0	0.0
5	0.115E+05	0.251E+05	0.174E+05	0.151E+06	0.268E+05	0.178E+05	0.0	0.114E+05	0.484E+05	0.0	0.0	0.0	0.0
4	0.271E+05	0.640E+05	0.161E+05	0.133E+06	0.356E+04	0.0	0.0	0.112E+04	0.386E+05	0.0	0.0	0.0	0.0
3	0.135E+06	0.135E+06	0.115E+06	0.897E+05	0.244E+04	0.163E+04	0.327E+04	0.343E+03	0.386E+05	0.0	0.0	0.0	0.0
2	0.522E+05	0.103E+06	0.638E+05	0.564E+05	0.269E+04	0.269E+04	0.357E+04	0.0	0.863E+05	0.513E+05	0.513E+05	0.588E+05	0.532E+05
1	0.536E+05	0.623E+05	0.224E+05	0.157E+05	0.0	0.0	0.364E+04	0.0	0.304E+05	0.0	0.0	0.211E+05	0.0

NORTH GRIDS	GRIDS EAST-- 14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.166E+05	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.102E+05	0.649E+04	0.0	0.0	0.0	0.0
23	0.811E+05	0.0	0.0	0.0	0.0	0.0	0.166E+05	0.0	0.0	0.0	0.0	0.0
22	0.273E+06	0.265E+06	0.0	0.0	0.0	0.0	0.166E+05	0.0	0.0	0.0	0.0	0.0
21	0.115E+07	0.628E+05	0.149E+06	0.920E+04	0.0	0.0	0.166E+05	0.0	0.0	0.0	0.0	0.0
20	0.0	0.111E+07	0.790E+06	0.630E+06	0.464E+05	0.342E+05	0.991E+04	0.0	0.0	0.0	0.0	0.0
19	0.626E+06	0.887E+05	0.162E+07	0.124E+07	0.108E+07	0.121E+07	0.401E+05	0.0	0.0	0.0	0.0	0.0
18	0.121E+07	0.194E+07	0.171E+06	0.252E+07	0.223E+07	0.123E+07	0.650E+06	0.253E+05	0.0	0.0	0.0	0.0
17	0.113E+07	0.131E+07	0.214E+07	0.228E+07	0.335E+07	0.371E+07	0.442E+06	0.0	0.0	0.0	0.0	0.0
16	0.309E+07	0.461E+07	0.457E+07	0.361E+07	0.603E+07	0.674E+07	0.214E+07	0.121E+06	0.166E+06	0.0	0.0	0.0
15	0.170E+07	0.181E+07	0.178E+07	0.186E+07	0.203E+07	0.411E+07	0.318E+07	0.143E+07	0.212E+06	0.0	0.0	0.0
14	0.101E+07	0.161E+07	0.163E+07	0.156E+07	0.248E+07	0.240E+07	0.301E+07	0.174E+06	0.908E+06	0.0	0.0	0.0
13	0.203E+07	0.166E+07	0.203E+07	0.247E+07	0.233E+07	0.134E+07	0.180E+07	0.192E+06	0.231E+06	0.172E+06	0.0	0.0
12	0.271E+06	0.959E+06	0.757E+06	0.673E+06	0.127E+07	0.499E+06	0.109E+07	0.511E+06	0.295E+06	0.188E+06	0.301E+05	0.0
11	0.458E+06	0.400E+06	0.152E+07	0.111E+07	0.230E+07	0.146E+07	0.112E+07	0.483E+06	0.280E+06	0.171E+06	0.618E+05	0.258E+06
10	0.0	0.955E+05	0.231E+06	0.951E+06	0.558E+06	0.113E+06	0.187E+07	0.675E+06	0.253E+06	0.136E+06	0.114E+06	0.170E+06
9	0.388E+05	0.0	0.169E+06	0.314E+06	0.220E+05	0.140E+05	0.264E+06	0.535E+06	0.341E+06	0.443E+05	0.0	0.0
8	0.0	0.0	0.0	0.576E+05	0.0	0.802E+04	0.408E+05	0.197E+05	0.579E+06	0.614E+06	0.0	0.0
7	0.0	0.0	0.0	0.576E+05	0.0	0.0	0.0	0.0	0.519E+05	0.466E+06	0.807E+05	0.0
6	0.0	0.0	0.0	0.576E+05	0.0	0.0	0.0	0.0	0.0	0.172E+06	0.260E+06	0.309E+05
5	0.0	0.0	0.0	0.744E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.407E+06	0.973E+04
4	0.0	0.0	0.0	0.974E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.141E+05	0.403E+06
3	0.0	0.0	0.0	0.973E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.254E+06
2	0.532E+05	0.532E+05	0.532E+05	0.290E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.651E+05	0.503E+05	0.503E+05	0.503E+05	0.556E+05	0.0	0.0	0.0	0.0

Figure 1. 1976 gridded emissions.

NORTH GRIDS	GRIDS EAST-- 1	2	3	4	5	6	7	8	9	10	11	12	13
25	0.0	0.176E+06	0.246E+06	0.251E+06	0.254E+06	0.361E+06	0.504E+06	0.218E+06	0.0	0.194E+06	0.0	0.0	0.0
24	0.155E+06	0.135E+06	0.107E+06	0.0	0.0	0.0	0.189E+06	0.474E+06	0.223E+06	0.325E+06	0.153E+06	0.921E+05	0.540E+05
23	0.0	0.131E+06	0.769E+05	0.0	0.0	0.0	0.189E+06	0.254E+05	0.0	0.389E+06	0.816E+06	0.511E+06	0.197E+06
22	0.0	0.984E+05	0.0	0.202E+05	0.0	0.0	0.189E+06	0.152E+05	0.111E+04	0.0	0.867E+05	0.508E+06	0.947E+06
21	0.121E+06	0.217E+06	0.141E+06	0.174E+06	0.183E+06	0.171E+06	0.366E+06	0.174E+06	0.290E+06	0.282E+06	0.239E+06	0.166E+06	0.649E+06
20	0.429E+05	0.111E+06	0.141E+05	0.306E+05	0.572E+05	0.530E+05	0.184E+06	0.660E+05	0.341E+06	0.302E+06	0.427E+06	0.475E+06	0.829E+06
19	0.0	0.885E+05	0.0	0.345E+05	0.460E+05	0.146E+05	0.145E+06	0.706E+04	0.240E+06	0.232E+06	0.298E+06	0.648E+06	0.120E+07
18	0.833E+05	0.174E+06	0.954E+05	0.153E+06	0.230E+06	0.170E+06	0.327E+06	0.178E+06	0.430E+06	0.456E+06	0.395E+06	0.700E+06	0.130E+07
17	0.252E+05	0.167E+06	0.218E+06	0.131E+06	0.298E+06	0.634E+05	0.213E+06	0.709E+05	0.456E+06	0.454E+06	0.432E+06	0.781E+06	0.152E+07
16	0.208E+06	0.416E+06	0.630E+06	0.610E+06	0.782E+06	0.528E+06	0.650E+06	0.461E+06	0.939E+06	0.108E+07	0.124E+07	0.138E+07	0.248E+07
15	0.140E+06	0.335E+06	0.370E+06	0.402E+06	0.637E+06	0.376E+06	0.555E+06	0.342E+06	0.658E+06	0.648E+06	0.627E+06	0.710E+06	0.226E+07
14	0.172E+07	0.185E+07	0.141E+07	0.823E+06	0.100E+07	0.909E+06	0.972E+06	0.921E+06	0.145E+07	0.134E+07	0.117E+07	0.104E+07	0.168E+07
13	0.812E+05	0.150E+06	0.345E+06	0.840E+06	0.234E+06	0.134E+06	0.255E+06	0.255E+06	0.708E+06	0.681E+06	0.782E+06	0.843E+06	0.210E+07
12	0.704E+05	0.128E+06	0.870E+05	0.196E+06	0.951E+05	0.272E+05	0.845E+05	0.163E+05	0.354E+06	0.374E+06	0.101E+06	0.273E+06	0.306E+06
11	0.0	0.0	0.404E+04	0.207E+06	0.811E+05	0.781E+05	0.139E+06	0.980E+05	0.362E+06	0.276E+06	0.327E+06	0.493E+06	0.585E+06
10	0.438E+05	0.576E+05	0.483E+05	0.201E+06	0.747E+05	0.429E+05	0.924E+05	0.511E+05	0.236E+06	0.226E+06	0.979E+05	0.144E+06	0.814E+05
9	0.133E+04	0.189E+05	0.163E+04	0.150E+06	0.171E+05	0.828E+03	0.456E+05	0.444E+04	0.235E+06	0.175E+06	0.364E+05	0.106E+06	0.150E+06
8	0.297E+05	0.491E+05	0.365E+05	0.171E+06	0.503E+05	0.432E+05	0.891E+05	0.591E+05	0.255E+06	0.142E+06	0.422E+05	0.878E+05	0.739E+05
7	0.265E+05	0.397E+05	0.306E+05	0.193E+06	0.559E+05	0.526E+05	0.678E+05	0.277E+05	0.207E+06	0.116E+06	0.694E+05	0.190E+05	0.0
6	0.0	0.160E+05	0.0	0.156E+06	0.252E+05	0.673E+04	0.157E+05	0.574E+03	0.466E+05	0.0	0.0	0.0	0.0
5	0.108E+05	0.230E+05	0.150E+05	0.159E+06	0.238E+05	0.152E+05	0.0	0.108E+05	0.451E+05	0.0	0.0	0.0	0.0
4	0.307E+05	0.701E+05	0.174E+05	0.143E+06	0.335E+04	0.0	0.0	0.108E+04	0.360E+05	0.0	0.0	0.0	0.0
3	0.151E+06	0.155E+06	0.139E+06	0.959E+05	0.277E+04	0.175E+04	0.291E+04	0.333E+03	0.360E+05	0.0	0.0	0.0	0.0
2	0.580E+05	0.113E+06	0.668E+05	0.543E+05	0.219E+04	0.219E+04	0.291E+04	0.0	0.811E+05	0.486E+05	0.486E+05	0.530E+05	0.479E+05
1	0.672E+05	0.692E+05	0.221E+05	0.152E+05	0.0	0.0	0.306E+04	0.0	0.281E+05	0.0	0.0	0.179E+05	0.0

NORTH GRIDS	GRIDS EAST-- 14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.162E+05	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.986E+04	0.631E+04	0.0	0.0	0.0	0.0
23	0.114E+06	0.0	0.0	0.0	0.0	0.0	0.162E+05	0.0	0.0	0.0	0.0	0.0
22	0.372E+06	0.312E+06	0.0	0.0	0.0	0.0	0.162E+05	0.0	0.0	0.0	0.0	0.0
21	0.127E+07	0.733E+05	0.173E+06	0.103E+05	0.0	0.0	0.162E+05	0.0	0.0	0.0	0.0	0.0
20	0.0	0.125E+07	0.819E+06	0.560E+06	0.436E+05	0.501E+05	0.963E+04	0.0	0.0	0.0	0.0	0.0
19	0.646E+06	0.684E+05	0.180E+07	0.123E+07	0.994E+06	0.112E+07	0.357E+05	0.0	0.0	0.0	0.0	0.0
18	0.119E+07	0.202E+07	0.132E+06	0.246E+07	0.191E+07	0.113E+07	0.630E+06	0.246E+05	0.0	0.0	0.0	0.0
17	0.948E+06	0.122E+07	0.178E+07	0.179E+07	0.324E+07	0.340E+07	0.433E+06	0.0	0.0	0.0	0.0	0.0
16	0.271E+07	0.407E+07	0.397E+07	0.302E+07	0.545E+07	0.706E+07	0.215E+07	0.121E+06	0.162E+06	0.0	0.0	0.0
15	0.156E+07	0.158E+07	0.157E+07	0.161E+07	0.161E+07	0.318E+07	0.343E+07	0.157E+07	0.192E+06	0.0	0.0	0.0
14	0.844E+06	0.153E+07	0.142E+07	0.134E+07	0.200E+07	0.207E+07	0.304E+07	0.200E+06	0.113E+07	0.0	0.0	0.0
13	0.184E+07	0.139E+07	0.178E+07	0.204E+07	0.190E+07	0.120E+07	0.172E+07	0.208E+06	0.322E+06	0.240E+06	0.0	0.0
12	0.280E+06	0.958E+06	0.716E+06	0.553E+06	0.107E+07	0.434E+06	0.107E+07	0.619E+06	0.506E+06	0.308E+06	0.434E+05	0.0
11	0.478E+06	0.415E+06	0.155E+07	0.107E+07	0.222E+07	0.140E+07	0.122E+07	0.707E+06	0.466E+06	0.259E+06	0.117E+06	0.390E+06
10	0.0	0.104E+06	0.241E+06	0.101E+07	0.562E+06	0.115E+06	0.181E+07	0.782E+06	0.416E+06	0.207E+06	0.196E+06	0.282E+06
9	0.489E+05	0.0	0.177E+06	0.339E+06	0.290E+05	0.185E+05	0.280E+06	0.567E+06	0.524E+06	0.801E+05	0.0	0.0
8	0.0	0.0	0.0	0.539E+05	0.0	0.106E+05	0.588E+05	0.333E+05	0.677E+06	0.107E+07	0.0	0.0
7	0.0	0.0	0.0	0.540E+05	0.0	0.0	0.0	0.0	0.115E+06	0.515E+06	0.249E+06	0.0
6	0.0	0.0	0.0	0.539E+05	0.0	0.0	0.0	0.0	0.0	0.147E+06	0.224E+06	0.286E+05
5	0.0	0.0	0.0	0.697E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.349E+06	0.835E+04
4	0.0	0.0	0.0	0.912E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.121E+05	0.345E+06
3	0.0	0.0	0.0	0.912E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.217E+06
2	0.479E+05	0.479E+05	0.479E+05	0.274E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.620E+05	0.479E+05	0.479E+05	0.479E+05	0.529E+05	0.0	0.0	0.0	0.0

Figure 2. 1982 gridded emissions.

NORTH GRIDS	GRIDS EAST-- 1	2	3	4	5	6	7	8	9	10	11	12	13
25	0.0	0.137E+06	0.298E+06	0.203E+06	0.210E+06	0.299E+06	0.416E+06	0.186E+06	0.0	0.153E+06	0.0	0.0	0.0
24	0.117E+06	0.106E+06	0.911E+05	0.0	0.0	0.0	0.157E+06	0.380E+06	0.183E+06	0.272E+06	0.174E+06	0.992E+05	0.566E+05
23	0.0	0.108E+06	0.667E+05	0.0	0.0	0.0	0.157E+06	0.185E+05	0.0	0.319E+06	0.705E+06	0.497E+06	0.237E+06
22	0.0	0.799E+05	0.0	0.142E+05	0.0	0.0	0.157E+06	0.121E+05	0.926E+03	0.0	0.773E+05	0.451E+06	0.853E+06
21	0.921E+05	0.173E+06	0.109E+06	0.134E+06	0.142E+06	0.133E+06	0.298E+06	0.139E+06	0.242E+06	0.232E+06	0.197E+06	0.159E+06	0.572E+06
20	0.468E+05	0.101E+06	0.109E+05	0.234E+05	0.444E+05	0.401E+05	0.151E+06	0.515E+05	0.326E+06	0.256E+06	0.347E+06	0.379E+06	0.673E+06
19	0.0	0.773E+05	0.0	0.254E+05	0.364E+05	0.105E+05	0.120E+06	0.617E+04	0.207E+06	0.195E+06	0.248E+06	0.468E+06	0.914E+06
18	0.774E+05	0.156E+06	0.841E+05	0.131E+06	0.196E+06	0.142E+06	0.270E+06	0.144E+06	0.354E+06	0.367E+06	0.311E+06	0.518E+06	0.935E+06
17	0.273E+05	0.151E+06	0.190E+06	0.114E+06	0.248E+06	0.532E+05	0.176E+06	0.510E+05	0.372E+06	0.360E+06	0.314E+06	0.575E+06	0.108E+07
16	0.196E+06	0.363E+06	0.494E+06	0.492E+06	0.610E+06	0.421E+06	0.532E+06	0.371E+06	0.753E+06	0.860E+06	0.908E+06	0.102E+07	0.178E+07
15	0.120E+06	0.282E+06	0.295E+06	0.332E+06	0.536E+06	0.312E+06	0.459E+06	0.279E+06	0.519E+06	0.503E+06	0.425E+06	0.523E+06	0.167E+07
14	0.126E+07	0.137E+07	0.104E+07	0.637E+06	0.800E+06	0.687E+06	0.731E+06	0.674E+06	0.109E+07	0.992E+06	0.851E+06	0.774E+06	0.124E+07
13	0.634E+05	0.122E+06	0.260E+06	0.646E+06	0.189E+06	0.109E+06	0.206E+06	0.201E+06	0.565E+06	0.537E+06	0.610E+06	0.645E+06	0.160E+07
12	0.569E+05	0.104E+06	0.678E+05	0.163E+06	0.832E+05	0.242E+05	0.684E+05	0.121E+05	0.282E+06	0.292E+06	0.800E+05	0.210E+06	0.245E+06
11	0.0	0.0	0.306E+04	0.170E+06	0.640E+05	0.612E+05	0.109E+06	0.752E+05	0.274E+06	0.211E+06	0.249E+06	0.395E+06	0.489E+06
10	0.325E+05	0.426E+05	0.356E+05	0.165E+06	0.577E+05	0.333E+05	0.743E+05	0.416E+05	0.185E+06	0.178E+06	0.810E+05	0.119E+06	0.737E+05
9	0.222E+04	0.151E+05	0.296E+04	0.129E+06	0.128E+05	0.156E+04	0.364E+05	0.369E+04	0.182E+06	0.137E+06	0.355E+05	0.914E+05	0.132E+06
8	0.226E+05	0.364E+05	0.271E+05	0.145E+06	0.399E+05	0.347E+05	0.715E+05	0.468E+05	0.193E+06	0.112E+06	0.354E+05	0.763E+05	0.647E+05
7	0.204E+05	0.[illegible]93E+05	0.232E+05	0.167E+06	0.462E+05	0.438E+05	0.561E+05	0.232E+05	0.154E+06	0.926E+05	0.651E+05	0.172E+05	0.0
6	0.0	0.112E+05	0.0	0.139E+06	0.191E+05	0.534E+04	0.124E+05	0.359E+03	0.341E+05	0.0	0.0	0.0	0.0
5	0.797E+04	0.166E+05	0.105E+05	0.140E+06	0.182E+05	0.121E+05	0.0	0.735E+04	0.331E+05	0.0	0.0	0.0	0.0
4	0.278E+05	0.624E+05	0.157E+05	0.129E+06	0.279E+04	0.0	0.0	0.728E+03	0.265E+05	0.0	0.0	0.0	0.0
3	0.138E+06	0.143E+06	0.136E+06	0.861E+05	0.213E+04	0.133E+04	0.215E+04	0.224E+03	0.265E+05	0.0	0.0	0.0	0.0
2	0.508E+05	0.986E+05	0.590E+05	0.449E+05	0.177E+04	0.177E+04	0.230E+04	0.0	0.595E+05	0.356E+05	0.356E+05	0.389E+05	0.350E+05
1	0.629E+05	0.617E+05	0.190E+05	0.129E+05	0.0	0.0	0.245E+04	0.0	0.207E+05	0.0	0.0	0.136E+05	0.0

NORTH GRIDS	GRIDS EAST-- 14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.124E+05	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.756E+04	0.484E+04	0.0	0.0	0.0	0.0
23	0.127E+06	0.0	0.0	0.0	0.0	0.0	0.124E+05	0.0	0.0	0.0	0.0	0.0
22	0.427E+06	0.270E+06	0.0	0.0	0.0	0.0	0.124E+05	0.0	0.0	0.0	0.0	0.0
21	0.114E+07	0.705E+05	0.147E+06	0.882E+04	0.0	0.0	0.124E+05	0.0	0.0	0.0	0.0	0.0
20	0.0	0.115E+07	0.642E+06	0.412E+06	0.324E+05	0.473E+05	0.739E+04	0.0	0.0	0.0	0.0	0.0
19	0.500E+06	0.528E+05	0.148E+07	0.904E+06	0.718E+06	0.815E+06	0.252E+05	0.0	0.0	0.0	0.0	0.0
18	0.826E+06	0.146E+07	0.894E+05	0.195E+07	0.137E+07	0.829E+06	0.475E+06	0.186E+05	0.0	0.0	0.0	0.0
17	0.646E+06	0.851E+06	0.126E+07	0.128E+07	0.250E+07	0.249E+07	0.329E+06	0.0	0.0	0.0	0.0	0.0
16	0.194E+07	0.294E+07	0.287E+07	0.215E+07	0.403E+07	0.569E+07	0.167E+07	0.954E+05	0.127E+06	0.0	0.0	0.0
15	0.115E+07	0.109E+07	0.113E+07	0.100E+07	0.114E+07	0.240E+07	0.277E+07	0.133E+07	0.151E+06	0.0	0.0	0.0
14	0.570E+06	0.103E+07	0.860E+06	0.782E+06	0.139E+07	0.151E+07	0.237E+07	0.147E+06	0.104E+07	0.0	0.0	0.0
13	0.134E+07	0.952E+06	0.126E+07	0.138E+07	0.133E+07	0.904E+06	0.139E+07	0.196E+06	0.309E+06	0.231E+06	0.0	0.0
12	0.224E+06	0.741E+06	0.535E+06	0.366E+06	0.746E+06	0.313E+06	0.839E+06	0.599E+06	0.510E+06	0.310E+06	0.428E+05	0.0
11	0.389E+06	0.336E+06	0.123E+07	0.815E+06	0.172E+07	0.107E+07	0.103E+07	0.696E+06	0.461E+06	0.279E+06	0.126E+06	0.400E+06
10	0.129E+04	0.853E+05	0.194E+06	0.819E+06	0.454E+06	0.921E+05	0.139E+07	0.692E+06	0.437E+06	0.209E+06	0.211E+06	0.297E+06
9	0.472E+05	0.0	0.142E+06	0.280E+06	0.286E+05	0.182E+05	0.232E+06	0.464E+06	0.536E+06	0.877E+05	0.0	0.0
8	0.0	0.0	0.0	0.401E+05	0.0	0.104E+05	0.588E+05	0.354E+05	0.591E+06	0.116E+07	0.0	0.0
7	0.0	0.0	0.0	0.401E+05	0.0	0.0	0.0	0.0	0.126E+06	0.444E+06	0.306E+06	0.0
6	0.0	0.0	0.0	0.401E+05	0.0	0.0	0.0	0.0	0.0	0.103E+06	0.156E+06	0.210E+05
5	0.0	0.0	0.0	0.518E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.243E+06	0.576E+04
4	0.0	0.0	0.0	0.678E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.852E+04	0.241E+06
3	0.0	0.0	0.0	0.678E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.152E+06
2	0.350E+05	0.350E+05	0.350E+05	0.204E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.466E+05	0.361E+05	0.361E+05	0.361E+05	0.403E+05	0.0	0.0	0.0	0.0

Figure 3. 1987 gridded emissions.

NORTH GRIDS	GRIDS EAST-- 1	2	3	4	5	6	7	8	9	10	11	12	13
25	0.0	0.157E+06	0.220E+06	0.225E+06	0.227E+06	0.323E+06	0.451E+06	0.195E+06	0.0	0.173E+06	0.0	0.0	0.0
24	0.139E+06	0.121E+06	0.959E+05	0.0	0.0	0.0	0.169E+06	0.424E+06	0.200E+06	0.291E+06	0.137E+06	0.824E+05	0.483E+05
23	0.0	0.117E+06	0.688E+05	0.0	0.0	0.0	0.169E+06	0.227E+05	0.0	0.348E+06	0.730E+06	0.457E+06	0.177E+06
22	0.0	0.881E+05	0.0	0.180E+05	0.0	0.0	0.169E+06	0.136E+05	0.994E+03	0.0	0.775E+05	0.455E+06	0.848E+06
21	0.108E+06	0.194E+06	0.126E+06	0.156E+06	0.164E+06	0.153E+06	0.328E+06	0.156E+06	0.259E+06	0.252E+06	0.214E+06	0.148E+06	0.581E+06
20	0.384E+05	0.989E+05	0.126E+05	0.274E+05	0.511E+05	0.474E+05	0.164E+06	0.590E+05	0.305E+06	0.270E+06	0.381E+06	0.425E+06	0.742E+06
19	0.0	0.792E+05	0.0	0.309E+05	0.412E+05	0.131E+05	0.130E+06	0.631E+04	0.215E+06	0.207E+06	0.266E+06	0.579E+06	0.107E+07
18	0.746E+05	0.155E+06	0.854E+05	0.137E+06	0.206E+06	0.153E+06	0.292E+06	0.159E+06	0.385E+06	0.408E+06	0.353E+06	0.625E+06	0.115E+07
17	0.225E+05	0.149E+06	0.195E+06	0.117E+06	0.266E+06	0.518E+05	0.183E+06	0.554E+05	0.400E+06	0.398E+06	0.378E+06	0.691E+06	0.136E+07
16	0.178E+06	0.364E+06	0.556E+06	0.538E+06	0.692E+06	0.470E+06	0.582E+06	0.413E+06	0.841E+06	0.967E+06	0.111E+07	0.123E+07	0.222E+07
15	0.125E+06	0.300E+06	0.331E+06	0.360E+06	0.570E+06	0.337E+06	0.497E+06	0.306E+06	0.589E+06	0.580E+06	0.561E+06	0.635E+06	0.202E+07
14	0.154E+07	0.166E+07	0.126E+07	0.738E+06	0.900E+06	0.817E+06	0.873E+06	0.827E+06	0.130E+07	0.120E+07	0.105E+07	0.934E+06	0.150E+07
13	0.727E+05	0.134E+06	0.309E+06	0.753E+06	0.209E+06	0.120E+06	0.228E+06	0.225E+06	0.630E+06	0.607E+06	0.697E+06	0.751E+06	0.188E+07
12	0.599E+05	0.111E+06	0.747E+05	0.173E+06	0.819E+05	0.212E+05	0.730E+05	0.186E+05	0.317E+06	0.335E+06	0.904E+05	0.244E+06	0.274E+06
11	0.0	0.0	0.362E+04	0.186E+06	0.726E+05	0.699E+05	0.124E+06	0.877E+05	0.323E+06	0.246E+06	0.291E+06	0.440E+06	0.522E+06
10	0.382E+05	0.505E+05	0.422E+05	0.179E+06	0.658E+05	0.374E+05	0.817E+05	0.447E+05	0.211E+06	0.203E+06	0.876E+05	0.129E+06	0.728E+05
9	0.118E+04	0.169E+05	0.146E+04	0.134E+06	0.153E+05	0.740E+03	0.409E+05	0.396E+04	0.210E+06	0.156E+06	0.326E+05	0.946E+05	0.134E+06
8	0.266E+05	0.439E+05	0.327E+05	0.153E+06	0.450E+05	0.386E+05	0.798E+05	0.529E+05	0.228E+06	0.127E+06	0.378E+05	0.785E+05	0.661E+05
7	0.237E+05	0.356E+05	0.274E+05	0.173E+06	0.501E+05	0.471E+05	0.607E+05	0.248E+05	0.185E+06	0.104E+06	0.620E+05	0.170E+05	0.0
6	0.0	0.143E+05	0.0	0.139E+06	0.225E+05	0.601E+04	0.181E+05	0.513E+03	0.417E+05	0.0	0.0	0.0	0.0
5	0.963E+04	0.205E+05	0.134E+05	0.142E+06	0.213E+05	0.136E+05	0.0	0.964E+04	0.404E+05	0.0	0.0	0.0	0.0
4	0.274E+05	0.627E+05	0.156E+05	0.128E+06	0.300E+04	0.0	0.0	0.970E+03	0.322E+05	0.0	0.0	0.0	0.0
3	0.135E+06	0.139E+06	0.124E+06	0.858E+05	0.248E+04	0.157E+04	0.261E+04	0.298E+03	0.322E+05	0.0	0.0	0.0	0.0
2	0.519E+05	0.101E+06	0.598E+05	0.486E+05	0.196E+04	0.196E+04	0.261E+04	0.0	0.725E+05	0.434E+05	0.434E+05	0.474E+05	0.428E+05
1	0.601E+05	0.619E+05	0.198E+05	0.136E+05	0.0	0.0	0.274E+04	0.0	0.252E+05	0.0	0.0	0.160E+05	0.0

NORTH GRIDS	GRIDS EAST-- 14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.145E+05	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.882E+04	0.564E+04	0.0	0.0	0.0	0.0
23	0.102E+06	0.0	0.0	0.0	0.0	0.0	0.145E+05	0.0	0.0	0.0	0.0	0.0
22	0.332E+06	0.279E+06	0.0	0.0	0.0	0.0	0.145E+05	0.0	0.0	0.0	0.0	0.0
21	0.114E+07	0.655E+05	0.155E+06	0.925E+04	0.0	0.0	0.145E+05	0.0	0.0	0.0	0.0	0.0
20	0.0	0.112E+07	0.732E+06	0.501E+06	0.390E+05	0.448E+05	0.861E+04	0.0	0.0	0.0	0.0	0.0
19	0.578E+06	0.612E+05	0.161E+07	0.110E+07	0.889E+06	0.100E+07	0.320E+05	0.0	0.0	0.0	0.0	0.0
18	0.105E+07	0.180E+07	0.118E+06	0.220E+07	0.171E+07	0.101E+07	0.563E+06	0.220E+05	0.0	0.0	0.0	0.0
17	0.847E+06	0.109E+07	0.159E+07	0.160E+07	0.291E+07	0.305E+07	0.387E+06	0.0	0.0	0.0	0.0	0.0
16	0.242E+07	0.364E+07	0.356E+07	0.271E+07	0.488E+07	0.634E+07	0.192E+07	0.108E+06	0.145E+06	0.0	0.0	0.0
15	0.140E+07	0.141E+07	0.141E+07	0.144E+07	0.144E+07	0.285E+07	0.307E+07	0.140E+07	0.172E+06	0.0	0.0	0.0
14	0.755E+06	0.137E+07	0.127E+07	0.119E+07	0.178E+07	0.185E+07	0.272E+07	0.179E+06	0.101E+07	0.0	0.0	0.0
13	0.164E+07	0.124E+07	0.159E+07	0.182E+07	0.170E+07	0.108E+07	0.154E+07	0.186E+06	0.289E+06	0.215E+06	0.0	0.0
12	0.251E+06	0.858E+06	0.641E+06	0.494E+06	0.955E+06	0.388E+06	0.954E+06	0.552E+06	0.452E+06	0.275E+06	0.388E+05	0.0
11	0.426E+06	0.371E+06	0.139E+07	0.960E+06	0.199E+07	0.125E+07	0.109E+07	0.633E+06	0.417E+06	0.231E+06	0.104E+06	0.349E+06
10	0.0	0.927E+05	0.216E+06	0.900E+06	0.502E+06	0.104E+06	0.162E+07	0.700E+06	0.373E+06	0.185E+06	0.175E+06	0.252E+06
9	0.437E+05	0.0	0.159E+06	0.303E+06	0.260E+05	0.165E+05	0.250E+06	0.510E+06	0.469E+06	0.717E+05	0.0	0.0
8	0.0	0.0	0.0	0.483E+05	0.0	0.945E+04	0.526E+05	0.298E+05	0.607E+06	0.955E+06	0.0	0.0
7	0.0	0.0	0.0	0.483E+05	0.0	0.0	0.0	0.0	0.103E+06	0.462E+06	0.222E+06	0.0
6	0.0	0.0	0.0	0.483E+05	0.0	0.0	0.0	0.0	0.0	0.132E+06	0.201E+06	0.255E+05
5	0.0	0.0	0.0	0.624E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.313E+06	0.751E+04
4	0.0	0.0	0.0	0.817E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.109E+05	0.310E+06
3	0.0	0.0	0.0	0.817E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.195E+06
2	0.428E+05	0.428E+05	0.428E+05	0.245E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.554E+05	0.428E+05	0.428E+05	0.428E+05	0.473E+05	0.0	0.0	0.0	0.0

Figure 4. 1982 gridded emissions (with I/M).

NORTH GRIDS / GRIDS EAST--

NORTH GRIDS	1	2	3	4	5	6	7	8	9	10	11	12	13
25	0.0	0.109E+06	0.165E+06	0.162E+06	0.167E+06	0.237E+06	0.331E+06	0.147E+06	0.0	0.122E+06	0.0	0.0	0.0
24	0.930E+05	0.847E+05	0.722E+05	0.0	0.0	0.0	0.125E+06	0.302E+06	0.146E+06	0.217E+06	0.138E+06	0.788E+05	0.449E+05
23	0.0	0.860E+05	0.529E+05	0.0	0.0	0.0	0.125E+06	0.146E+05	0.0	0.254E+06	0.561E+06	0.395E+06	0.188E+06
22	0.0	0.636E+05	0.0	0.113E+05	0.0	0.0	0.125E+06	0.957E+04	0.734E+03	0.0	0.612E+05	0.359E+06	0.679E+06
21	0.734E+05	0.138E+06	0.867E+05	0.106E+06	0.113E+06	0.106E+06	0.237E+06	0.110E+06	0.193E+06	0.185E+06	0.156E+06	0.126E+06	0.455E+06
20	0.371E+05	0.801E+05	0.861E+04	0.185E+05	0.353E+05	0.318E+05	0.120E+06	0.408E+05	0.258E+06	0.203E+06	0.275E+06	0.301E+06	0.536E+06
19	0.0	0.615E+05	0.0	0.202E+05	0.290E+05	0.830E+04	0.952E+05	0.489E+04	0.165E+06	0.155E+06	0.197E+06	0.371E+06	0.725E+06
18	0.617E+05	0.124E+06	0.670E+05	0.105E+06	0.155E+06	0.113E+06	0.215E+06	0.115E+06	0.281E+06	0.292E+06	0.247E+06	0.411E+06	0.737E+06
17	0.216E+05	0.120E+06	0.151E+06	0.904E+05	0.197E+06	0.391E+05	0.135E+06	0.354E+05	0.291E+06	0.281E+06	0.244E+06	0.452E+06	0.854E+06
16	0.151E+06	0.284E+06	0.387E+06	0.386E+06	0.480E+06	0.333E+06	0.424E+06	0.296E+06	0.599E+06	0.685E+06	0.722E+06	0.810E+06	0.142E+07
15	0.952E+05	0.224E+06	0.234E+06	0.264E+06	0.426E+06	0.248E+06	0.365E+06	0.222E+06	0.413E+06	0.400E+06	0.338E+06	0.416E+06	0.133E+07
14	0.100E+07	0.109E+07	0.822E+06	0.509E+06	0.638E+06	0.548E+06	0.584E+06	0.538E+06	0.872E+06	0.791E+06	0.678E+06	0.617E+06	0.981E+06
13	0.505E+05	0.972E+05	0.206E+06	0.515E+06	0.150E+06	0.855E+05	0.162E+06	0.156E+06	0.445E+06	0.423E+06	0.482E+06	0.510E+06	0.127E+07
12	0.409E+05	0.781E+05	0.504E+05	0.126E+06	0.625E+05	0.157E+05	0.515E+05	0.957E+04	0.225E+06	0.233E+06	0.634E+05	0.167E+06	0.195E+06
11	0.0	0.0	0.243E+04	0.135E+06	0.509E+05	0.488E+05	0.864E+05	0.598E+05	0.217E+06	0.167E+06	0.197E+06	0.313E+06	0.388E+06
10	0.250E+05	0.330E+05	0.275E+05	0.131E+06	0.450E+05	0.255E+05	0.572E+05	0.312E+05	0.146E+06	0.141E+06	0.634E+05	0.937E+05	0.576E+05
9	0.738E+03	0.109E+05	0.132E+04	0.102E+06	0.914E+04	0.328E+03	0.290E+05	0.292E+04	0.145E+06	0.109E+06	0.282E+05	0.726E+05	0.105E+06
8	0.180E+05	0.240E+05	0.216E+05	0.116E+06	0.318E+05	0.276E+05	0.569E+05	0.372E+05	0.153E+06	0.894E+05	0.282E+05	0.606E+05	0.513E+05
7	0.163E+05	0.233E+05	0.185E+05	0.133E+06	0.368E+05	0.349E+05	0.447E+05	0.185E+05	0.122E+06	0.735E+05	0.516E+05	0.136E+05	0.0
6	0.0	0.887E+04	0.0	0.111E+06	0.151E+05	0.423E+04	0.980E+04	0.286E+03	0.272E+05	0.0	0.0	0.0	0.0
5	0.632E+04	0.132E+05	0.631E+04	0.112E+06	0.144E+05	0.956E+04	0.0	0.583E+04	0.264E+05	0.0	0.0	0.0	0.0
4	0.221E+05	0.497E+05	0.125E+05	0.102E+06	0.221E+04	0.0	0.0	0.579E+03	0.211E+05	0.0	0.0	0.0	0.0
3	0.109E+06	0.113E+06	0.108E+06	0.686E+05	0.170E+04	0.106E+04	0.171E+04	0.178E+03	0.211E+05	0.0	0.0	0.0	0.0
2	0.403E+05	0.784E+05	0.468E+05	0.358E+05	0.141E+04	0.141E+04	0.183E+04	0.0	0.473E+05	0.282E+05	0.282E+05	0.308E+05	0.277E+05
1	0.498E+05	0.490E+05	0.150E+05	0.103E+05	0.0	0.0	0.195E+04	0.0	0.165E+05	0.0	0.0	0.108E+05	0.0

NORTH GRIDS / GRIDS EAST--

NORTH GRIDS	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.984E+04	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.600E+04	0.384E+04	0.0	0.0	0.0	0.0
23	0.101E+06	0.0	0.0	0.0	0.0	0.0	0.984E+04	0.0	0.0	0.0	0.0	0.0
22	0.339E+06	0.215E+06	0.0	0.0	0.0	0.0	0.984E+04	0.0	0.0	0.0	0.0	0.0
21	0.909E+06	0.560E+05	0.117E+06	0.701E+04	0.0	0.0	0.984E+04	0.0	0.0	0.0	0.0	0.0
20	0.0	0.919E+06	0.510E+06	0.327E+06	0.257E+05	0.375E+05	0.586E+04	0.0	0.0	0.0	0.0	0.0
19	0.397E+06	0.418E+05	0.118E+07	0.718E+06	0.569E+06	0.647E+06	0.200E+05	0.0	0.0	0.0	0.0	0.0
18	0.650E+06	0.115E+07	0.709E+05	0.155E+07	0.109E+07	0.658E+06	0.376E+06	0.147E+05	0.0	0.0	0.0	0.0
17	0.512E+06	0.675E+06	0.100E+07	0.102E+07	0.199E+07	0.198E+07	0.261E+06	0.0	0.0	0.0	0.0	0.0
16	0.154E+07	0.234E+07	0.229E+07	0.173E+07	0.322E+07	0.457E+07	0.133E+07	0.756E+05	0.100E+06	0.0	0.0	0.0
15	0.915E+06	0.868E+06	0.895E+06	0.794E+06	0.907E+06	0.190E+07	0.220E+07	0.105E+07	0.120E+06	0.0	0.0	0.0
14	0.451E+06	0.816E+06	0.680E+06	0.616E+06	0.110E+07	0.119E+07	0.188E+07	0.116E+06	0.824E+06	0.0	0.0	0.0
13	0.106E+07	0.752E+06	0.996E+06	0.110E+07	0.105E+07	0.717E+06	0.111E+07	0.156E+06	0.246E+06	0.183E+06	0.0	0.0
12	0.178E+06	0.589E+06	0.425E+06	0.291E+06	0.592E+06	0.248E+06	0.667E+06	0.475E+06	0.405E+06	0.246E+06	0.341E+05	0.0
11	0.308E+06	0.266E+06	0.978E+06	0.648E+06	0.136E+07	0.846E+06	0.821E+06	0.552E+06	0.365E+06	0.221E+06	0.100E+06	0.318E+06
10	0.0	0.668E+05	0.154E+06	0.648E+06	0.359E+06	0.738E+05	0.111E+07	0.551E+06	0.348E+06	0.166E+06	0.168E+06	0.236E+06
9	0.374E+05	0.0	0.113E+06	0.222E+06	0.228E+05	0.145E+05	0.184E+06	0.371E+06	0.427E+06	0.698E+05	0.0	0.0
8	0.0	0.0	0.0	0.319E+05	0.0	0.829E+04	0.467E+05	0.282E+05	0.472E+06	0.923E+06	0.0	0.0
7	0.0	0.0	0.0	0.319E+05	0.0	0.0	0.0	0.0	0.100E+06	0.354E+06	0.243E+06	0.0
6	0.0	0.0	0.0	0.319E+05	0.0	0.0	0.0	0.0	0.0	0.822E+05	0.125E+06	0.166E+05
5	0.0	0.0	0.0	0.413E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.194E+06	0.460E+04
4	0.0	0.0	0.0	0.540E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.681E+04	0.192E+06
3	0.0	0.0	0.0	0.540E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.121E+06
2	0.277E+05	0.277E+05	0.277E+05	0.162E+05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.370E+05	0.286E+05	0.286E+05	0.286E+05	0.319E+05	0.0	0.0	0.0	0.0

Figure 5. 1987 gridded emissions (with I/M).

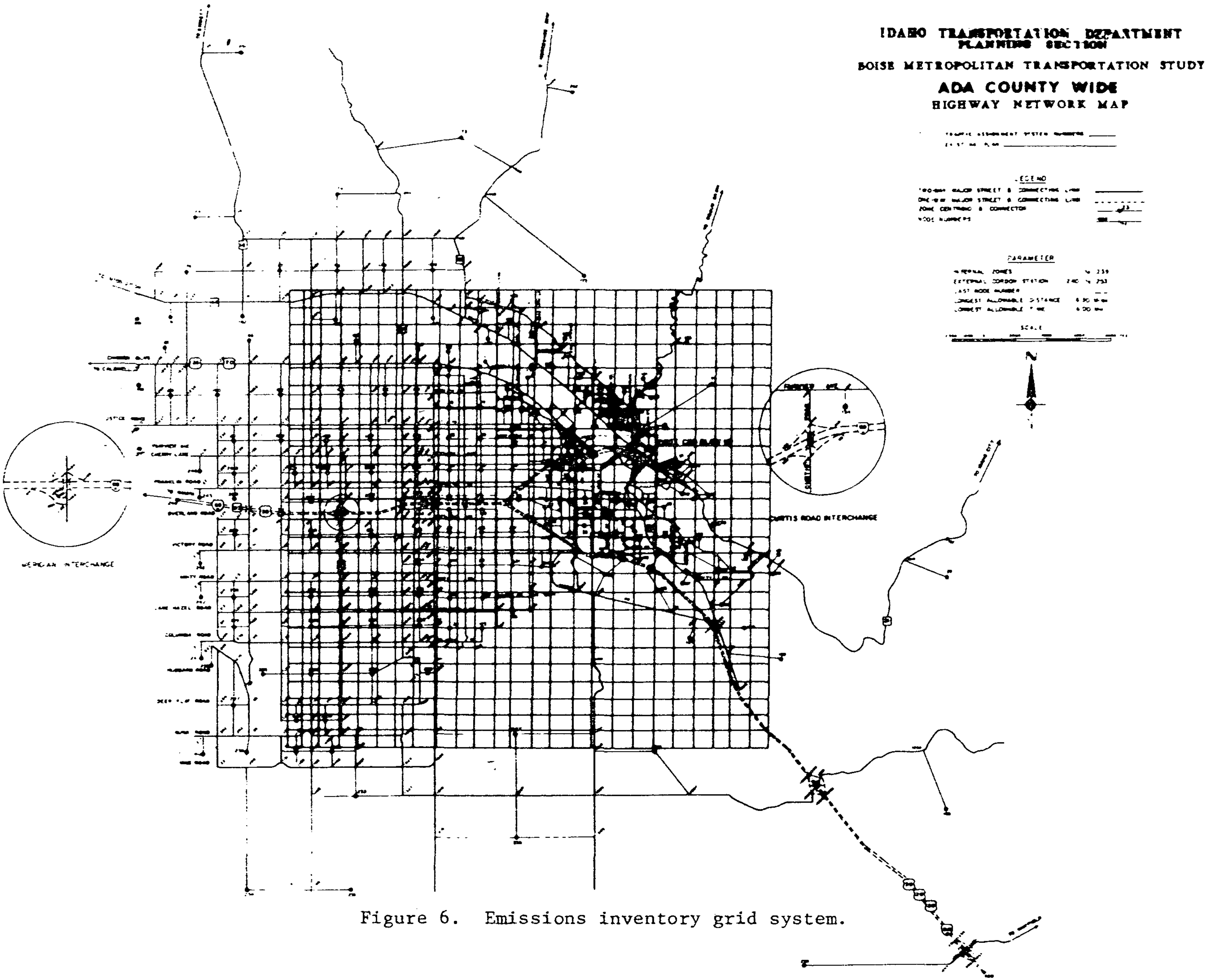

Figure 6. Emissions inventory grid system.

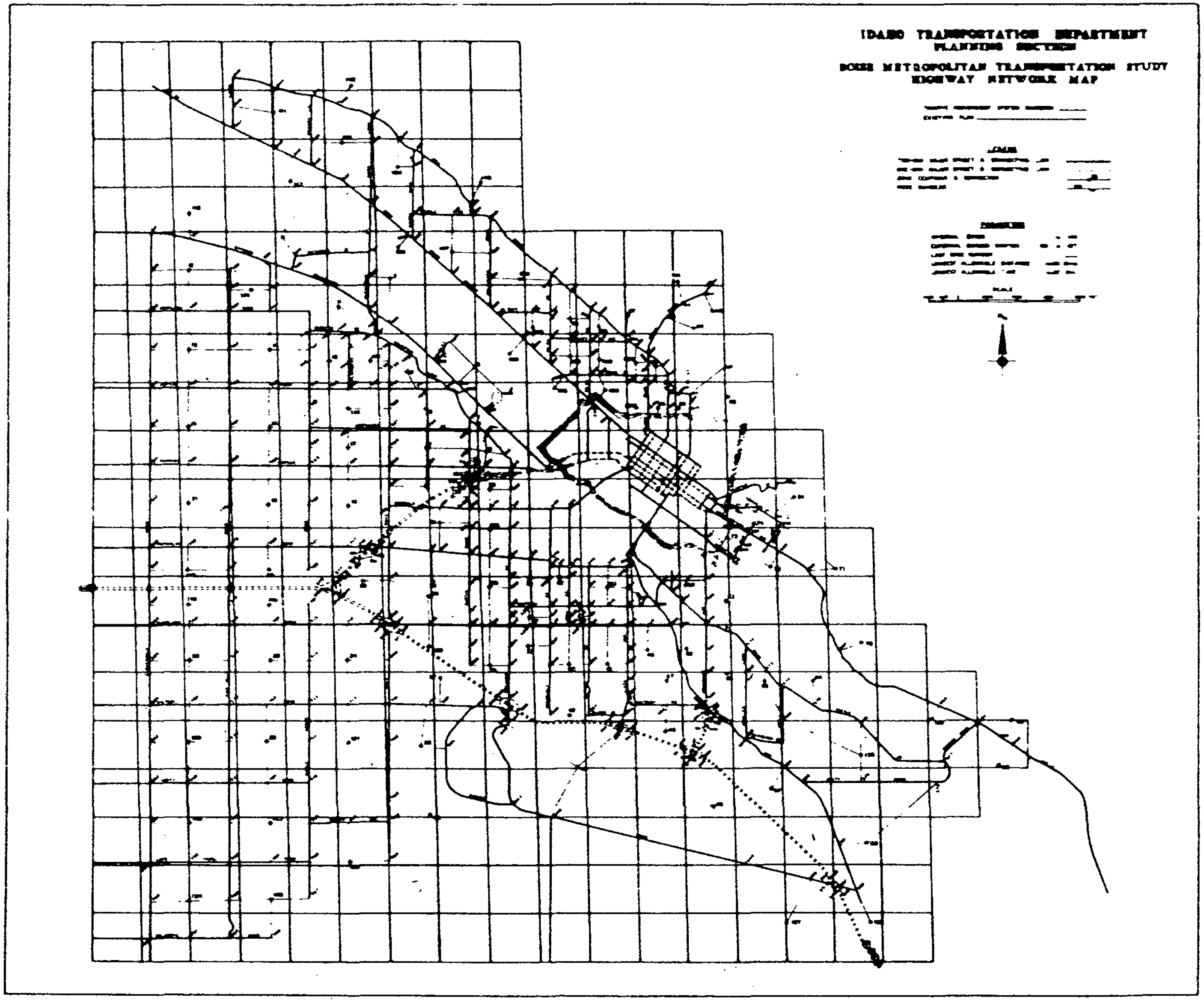

Figure 7. Emissions inventory grid system - Metropolitan Boise.

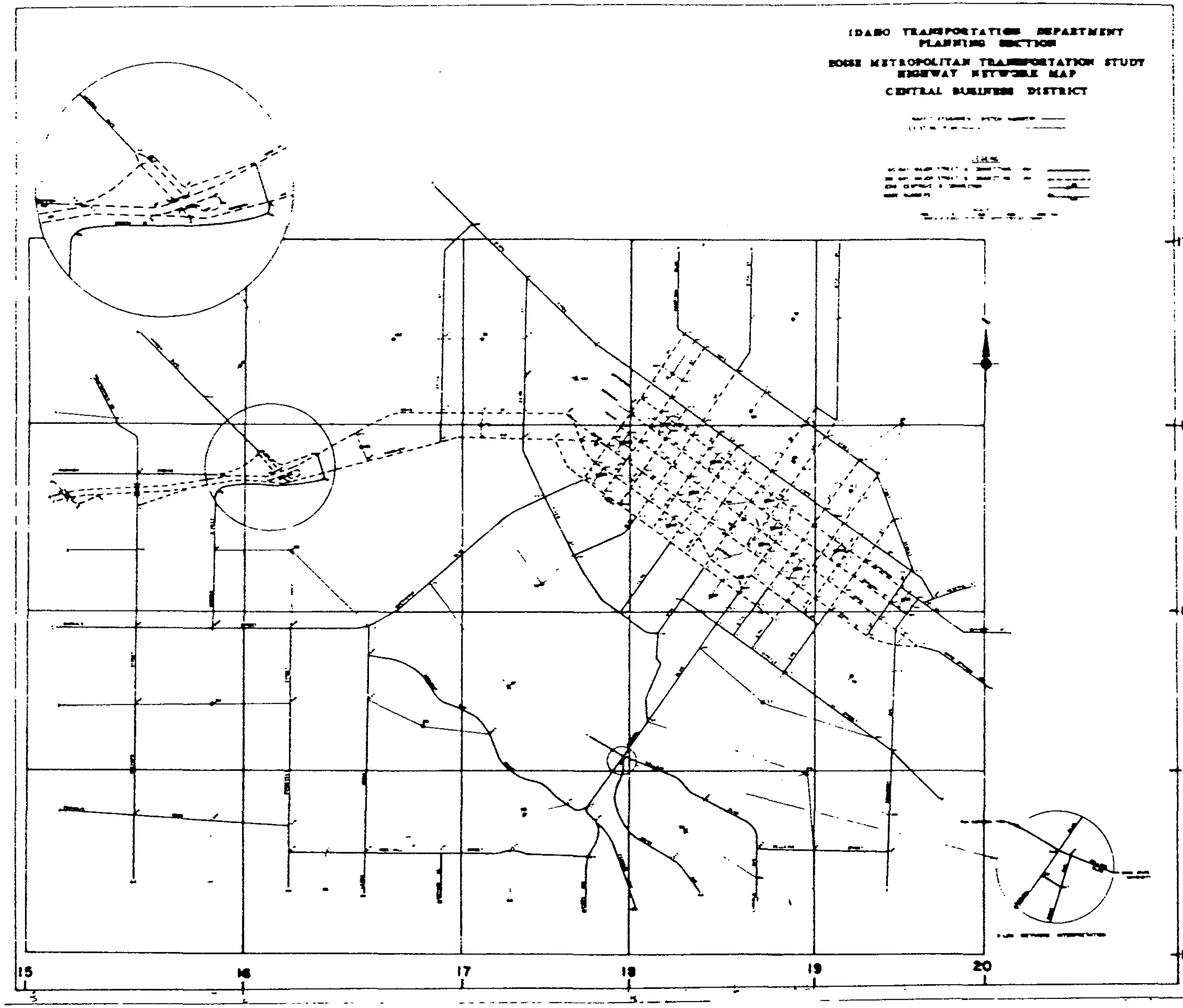

Figure 8. Emissions inventory grid system - Boise urban area.

Year	Regional CO motor vehicle emissions (10^9 g/day)	Percent reduction (1976 base)	Urban core grid emissions (10^6 g/day)	Percent reduction (1976 base)
1976	0.223	-	6.74	-
1982	0.215	3.6	7.06	(4.7)
1987	0.167	25.1	5.69	15.6
1982 with I/M	0.193	13.5	6.34	5.9
1987 with I/M	0.133	40.4	4.57	32.2

SECTION 3

PARKING LOT EMISSION INVENTORY

The VMT on the assigned network consists of trips between specific origins and destinations. It does not consider the terminal times, that is the time spent parking or unparking a car and walking to one's destination. Consequently, it is of interest to estimate the quantity of CO emissions occurring in parking lots, since these emissions are not adequately reflected in the network based emission inventory.

Due to the interest in this subject, it is appropriate to identify the appropriate use and limitations of this section. The emission inventory presented here was compiled to complement the regional emission inventory described in the previous section. It may be used to estimate the total emissions from parking lots in the region and, with less confidence, to identify those grid squares in which parking lot emissions are a relatively larger proportion of total emissions than other grid squares. Because of the data and methodological limitations described in the following paragraph, these data cannot be confidently used to estimate the magnitude of parking lot emissions in a single grid and it would be entirely inappropriate to use the following data to estimate the emissions from a single parking lot. The emissions from a single lot or small number of lots can be estimated very adequately by using the Indirect Source Guidelines (ISG), which is based on a more detailed methodology, or the ISMAP model; a computer model based on the Indirect Source Guidelines. These techniques also allow one to consider the impairment of traffic flow on adjacent streets by vehicles entering or exiting from a parking facility, a consideration which is not addressed in this section. One may view the distinction between the parking lot inventory presented in this section and the more detailed techniques such as the ISG as similar to the distinction between mesoscale CO models (e.g., APRAC-2) and microscale CO models (e.g., IMM).

Emissions from parking lots are principally a function of the time required to enter the lot, search for an available stall, and park the vehicle plus the time spent idling after starting, and then exiting from the lot. These times are greatly influenced by the lot and entrance/exit capacity and demand. Other important parameters affecting emissions include the speed of vehicles in the lot and the proportion of vehicles in cold, hot, or stabilized running modes. All of these parameters can be expected to display considerable variation among different parking lots as well as with time of day. Almost all of these parameters were unavailable for this study; the only available information was the total capacity and a single estimate of occupancy of the principal parking facilities in the Boise metropolitan area.* Consequently, a method was devised, described below, to estimate the average vehicle's running time from lot capacity and demand. Certain cold and hot start proportions are also assumed. The resulting estimates should, as previously discussed, be viewed as an approximation.

The methodology that was employed can briefly be summarized as follows. Based on the number of parking spaces in a lot, the area of the lot was estimated. The average travel distance from a parking stall to an exit or entrance was then taken to be a function of area. With an assumed speed, this distance can be converted to the amount of time a car is running in the lot. After adjustments for near capacity situations, the time estimate can be converted to an estimate of vehicle emissions. Total emissions are then estimated from the average lot occupancy and the turnover of parking spaces.

Specifically, the area for the parking lot in square miles was estimated by

$$\frac{C * 350}{(5280)^2}$$

where C is the lot capacity in vehicles and an assumed 350 square feet of stall and aisle area per vehicle.

The distance a vehicle travels from a stall to an exit or entrance is then estimated as

$$2 * \sqrt{\frac{C * 350}{(5280)^2}}$$

where the radical is the length of a side of a square whose area is equal to the lot area. A vehicle is conservatively assumed to travel a distance equal to two sides.

Assuming a vehicle speed of 15 miles per hour, the time between unparking the car and exiting, in seconds is then

$$\frac{2 * 3600}{15} * \sqrt{\frac{C * 350}{(5280)^2}}$$

To account for congestion and delay because of near capacity, this expression is adjusted by a factor which effectively doubles the time estimate at near capacity situations,

$$\frac{2 * 3600}{15} \sqrt{\frac{C * 350}{(5280)^2}} \left[1 + \left(\frac{V}{C}\right)^2\right]$$

where V is the actual occupancy of the lot in vehicles.

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* As supplied from the EPA project officer and derived from several CBD parking studies and a survey of non-CBD facilities.

Finally, 20 seconds is added as a estimate of idling time while parked in the stall,

$$T = 20 + \frac{2 * 3600}{15} \sqrt{\frac{C * 350}{(5280)^2}} \left[1 + \left(\frac{V}{C}\right)^2\right]$$

Total parking lot emissions are then estimated by

$$E = T F_I V X + T F_O V X$$

where T and V are defined as before, X is the turnover of parking spaces per day and F_I and F_O are the idle emission factors for entering and exiting vehicles, respectfully. Turnover is assumed to be related to lot use, viz.,

Lot Use	X
Employment	1
Shopping Centers	5
Fast Foods, Drug Stores, etc.	10
Miscellaneous	3

The emission factors vary between entering and exiting vehicles because of varying hot/cold start assumptions, viz.,

Entering Vehicles	100% stabilized
Exiting Vehicles, Employment Lots	100% cold starts
Exiting Vehicles, Shopping Centers & Miscellaneous	50% cold/50% hot
Exiting Vehicles, Fast Foods, Drug Stores, etc.	100% hot starts

Following the above methodology, total CO emissions from the major off-street lots is 5488 kg/day, as shown in Table 4. This a negligible amount on a regional basis, since the parking lot emissions are 2.4 percent of the network emissions, 0.223×10^9 g/day.* One may conclude that control measures principally targeted at reducing emissions in parking lots do not have the potential, on a regional basis, of significantly improving the ambient CO concentrations in Ada County.

However, this statement must be qualified by several significant considerations. First, major parking facilities and associated congestion on

* After the completion of this study, the EPA project officer determined that a considerable number of CBD parking lots were not included in the original data supplied to GCA. The emissions from these lots indicate that parking lots may account for up to 20 percent of the emissions in the CBD.

TABLE 4. CO EMISSIONS (kg/day) FROM IDLING VEHICLES IN PARKING LOTS IN BOISE, IDAHO - 1977

No.	Location	Capacity (vehicles)	Volume (vehicles)	Turnovers/ day	Running Time (secs)	Entering CO emission factor (g/sec)	Exiting CO emission factor (g/sec)	Entering CO emissions (kg/day)	Exiting CO emissions (kg/day)	Total CO emissions (kg/day)
1a	K-Mart	699	280	5	72.18	0.43	1.22	43.45	123.28	166.73
b	Boise Pantry Restaurant	47	24	5	34.70	0.43	1.22	1.79	5.08	6.87
c	Shoreline Center	172	172	1	64.61	0.43	2.01	4.78	22.34	27.12
d	Post Office	247	247	3	73.46	0.43	1.22	23.41	66.41	89.82
e	Graybar Electrical Supply	20	15	3	31.88	0.43	1.22	0.62	1.75	2.37
f	State Liquor Store	15	5	10	27.32	0.43	0.43	0.59	0.59	1.18
g	Offstreet diagonal parking	60	30	1	36.47	0.43	2.01	0.47	2.20	2.67
h	Rocky Mountain Bank Note	45	45	1	42.82	0.43	2.01	0.83	0.47	1.30
i	Shoreline Plaza	34	34	1	39.83	0.43	2.01	0.58	2.72	3.30
j	European Health Spa	63	47	3	41.01	0.43	1.22	2.49	7.05	9.54
2	Franklin Shopping Center	462	155	5	62.42	0.43	1.22	24.83	70.44	95.27
3	Patti Plaza	252	252	5	74.00	0.43	1.22	40.09	113.75	153.84
4	Hillcrest Shopping Center	1194	478	5	88.17	0.43	1.22	90.61	257.09	347.70
5	Waremart	306	61	5	50.94	0.43	1.22	6.68	18.96	25.64
6	Overland Park	718	539	5	91.21	0.43	1.22	105.70	299.88	405.58
7	Westgate Mall	941	847	5	114.43	0.43	1.22	208.38	591.23	799.61
8	Two Westgate Plaza	218	218	1	70.22	0.43	2.01	6.58	30.77	37.35
9	Collister Shopping Center	389	350	5	80.71	0.43	1.22	60.74	172.33	233.07
10a	Albertson's customer	259	233	5	69.52	0.43	1.22	34.83	98.81	133.64
10b	Albertson's employee	136	122	1	55.90	0.43	2.01	2.93	13.71	16.64
11	Hewlett-Packard	1100	1100	1	132.82	0.43	2.01	62.82	293.67	356.49
12a	Village Shopping (North)	185	139	5	56.14	0.43	1.22	16.78	47.61	64.38
b	Village Shopping (South)	657	263	5	70.57	0.43	1.22	39.90	113.21	153.12
13	Five mile plaza	411	206	5	63.10	0.43	1.22	27.95	79.29	107.24
14	Country Square	438	110	5	57.82	0.43	1.22	13.67	38.80	52.47
15	Bishop Kelly H.S.	312	78	1	51.92	0.43	1.22	1.74	4.94	6.68

(continued)

TABLE 4 (continued).

No.	Location	Capacity (vehicles)	Volume (vehicles)	Turnovers/ day	Running Time (secs)	Entering CO emission factor (g/sec)	Exiting CO emission factor (g/sec)	Entering CO emissions (kg/day)	Exiting CO emissions (kg/day)	Total CO emissions (kg/day)
16	Borah H.S.	850	850	1	119.17	0.43	2.01	43.56	203.60	247.16
17	Capital H.S.	757	757	1	113.59	0.43	2.01	36.97	172.83	209.81
18	Buttrey-Osco	171	154	5	60.25	0.43	1.22	19.95	56.60	76.55
19	Grand Central	583	292	5	71.33	0.43	1.22	44.78	127.06	171.84
20	Capitol Mall Complex	825	660	1	100.11	0.43	2.01	28.41	132.81	161.22
21	Federal Building	430	344	1	77.84	0.43	2.01	11.51	53.82	65.33
22	Boise City Hall	192	154	1	58.65	0.43	2.01	3.88	18.15	22.04
23	State Employment	237	190	1	62.94	0.43	2.01	5.13	23.99	29.12
24a	Boise State U. reserved	650	520	1	91.11	0.43	2.01	20.37	95.23	115.60
24b	Boise Permit	1000	800	1	108.20	0.43	2.01	37.22	173.99	211.21
24c	Boise Stadium	2000	500	1	100.81	0.43	2.01	21.67	101.52	122.19
25	Boise Cascade	410	328	1	76.46	0.43	2.01	10.79	50.42	61.21
26	Morris-Knudson	800	640	1	98.89	0.43	2.01	27.21	127.21	154.43
27	Park Center Development	830	664	1	100.36	0.43	2.01	28.65	133.94	162.59
28	St Luke's Hospital	573	458	1	86.77	0.43	2.01	17.09	79.88	96.96
29	Idaho 1st NTC Bldg.	338	270	1	71.28	0.43	2.01	8.28	38.68	46.96
30	Mountain Bell	81	65	1	45.10	0.43	2.01	1.26	5.89	7.15
31	Idaho Power	137	110	1	52.65	0.43	2.01	2.49	11.64	14.13
32	Sears	428	342	5	77.70	0.43	1.22	57.15	162.12	219.27
								1248.32	4239.47	5487.79

adjacent streets can be and, in Ada County, likely are important localized sources of CO emissions. As discussed in Section IV, a monitor located immediately adjacent to a highway facility such as 9th Street can be heavily influenced by emissions from vehicles on that street. Similarly, the concentration at a monitor placed near a major parking facility such as a shopping center will often be mostly due to emissions from vehicles in and entering or leaving the lot. Existing and planned facilities suspected to be significant localized sources should be analyzed with the ISG.*

A second and very important consideration is that the provision of parking, especially for employment purposes in the CBD, can significantly influence the number of trips made into the CBD and the use of the public transit system. CBD parking lots are of interest less because of the emissions occurring within them but because of their ability to influence the travel patterns in and out of the CBD and the resulting emissions. Public policy on the availability and price of CBD parking can be an important air quality planning tool. Parking restrictions and pricing are significant transportation control measures in major metropolitan areas, especially when combined with improved public transit systems or carpooling programs. The potential effectiveness of such measures can be analyzed by the combined use of the Ada County transportation model chain and the APRAC-2 model, specifically in the mode choice and auto occupancy models. Over the longer term, parking policy can influence the relative attractiveness of the CBD versus outlying locations for development and employment growth. This too influences a region's travel patterns.

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* It is noted that, although EPA cannot require an indirect source regulation as part of a SIP, states are free to adopt one. See section 110(a)(5) of the Clean Air Act as amended August 1977.

SECTION 4

WORST CASE 9th St. MODELING ANALYSIS

The purpose of this task is to determine the geographical extent and relative impact of emissions on CO concentrations measured at the 9th St. monitor. The effort was carried out using design traffic, signalization, and meteorological parameters and appropriate atmospheric dispersion models.

The combination of the Intersection/Midblock Model (IMM) and the APRAC-2 models were selected to best represent mobile source-entitled CO in the 9th St. vicinity. These models are well described in EPA literature.[1,2] IMM includes a traffic submodel to estimate concentrations resulting from queue and delay at intersections; the dispersion kernel of this model is EPA's HIWAM model. APRAC-2 is a mesoscale model which was used to predict the impact of non-adjacent roadways on 9th St. air quality.

INPUT DATA

Inputs to the model include traffic, signalization, and meteoroligical conditions. Two intersections were chosen for representation by IMM: 9th and Main and 9th and Idaho. Both intersections are controlled by fixed time signals with 90 sec cycle times, 33 sec of which is green time to 9th St. and 49 sec of green time to the crossing road during the morning cycle. All streets in this area are 3-lane and one-way.

Meteorological and traffic data were chosen as "worst-case," i.e., those conditions which will result in highest predicted concentrations. The meteorological conditions chosen are:

wind speed	1.0 m/s
stability	D*
mixing height	100 m
temperature	22°F

The wind direction was varied in order to determine maximum concentration.

Design traffic data were developed from a monitoring program conducted during November of 1978. The maximum hourly traffic volume recorded on 9th street and the concurrent counts on all other roads were used to represent worst case.

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* "D" stability is defined as a neutral atmosphere, the most stable conditions typically observed in an urban area.

MODELING RESULTS

The results of this analysis indicate a maximum impact at the 9th St. monitor of 73 ppm. This value can be considered the design 1-hour CO concentration subject to the limitations discussed below. The disaggregation of the impacts at the site indicated that almost all (72.5 ppm)* of the CO results from traffic on 9th St. (51 ppm) and Main St. (21 ppm) with 79 percent of the emissions resulting from queuing at signals. Comparison of the magnitude of these results with measured 1-hour CO concentrations is consistent with past modeling efforts (i.e., a factor of 2 too great). This occurs due to the extreme unlikelihood that the worst case meteorological conditions, and, in particular, the wind direction, will remain constant for an entire hour under low wind speed conditions. Coupled with this degree of conservation is the requirement that these meteorological conditions occur during the time of peak traffic.

For control purposes, however, this analysis provides an indication of the relative impacts of adjacent streets on CO levels and provides a basis for designing control strategies. The conclusion of this analysis is that significant improvements in CO levels can be achieved if efforts are focused on reduction in excess CO emissions caused by traffic delays.

VALIDATION

An attempt to validate the IMM model was made using meteorological and traffic data collected at 9th St. during November 1978. A total of 48 hours were chosen at random from the 10 days for which complete hourly data were available for simulation by the IMM model.

The results of this analysis were very poor. Figure 9 presents a scatter diagram of the modeling results. The correlation between predicted and observed data was approximately zero, indicating that one or a combination of several of the following conditions is occurring:

- The traffic data are incorrect.
- The monitoring data are incorrect.
- The meteorological data are incorrect, incomplete, or not representative of the 9th St. canyon.
- The model is unrepresentative of the 9th Street area.

The amount of validation and theory which stand behind the IMM model suggest that it is most likely properly representing the impacts of traffic on air quality. The most likely source of this error is in the meteorological data; the attempt to use winds recorded on top of a building to represent conditions within a nearby street canyon can lead to errors in prediction.

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*This concentration occurred with winds from the south-southwest.

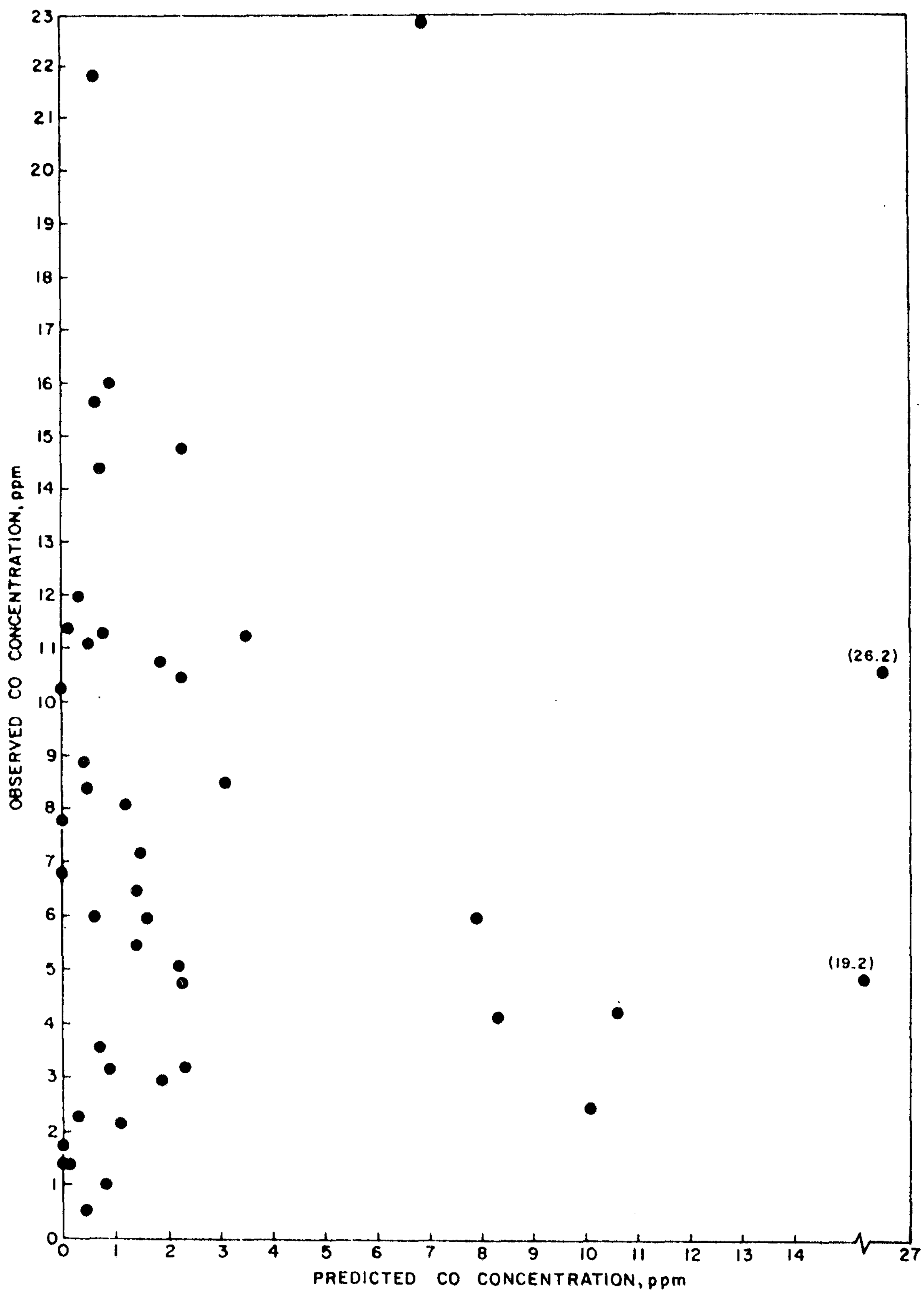

Figure 9. IMM validation results.

SECTION 5

ANALYSIS OF CRITICAL METEOROLOGICAL CONDITIONS

An analysis was performed to isolate the role of meteorology in excursions of CO levels above ambient standards in Boise. This task was performed first by analyzing a series of CO episodes in order to discern apparent effects and then by using statistical techniques to develop relationships between CO emissions and concentrations.

EPISODE ANALYSIS

Eight-hour CO concentrations recorded during 1976 were reviewed and all excursions above the 9 ppm standard were tabulated. It was noted in this summary that no violations of the standard occurred between late spring and early fall. A total of 77 violations occurred between January through April, and September through December of 1976. This cold weather-violation pattern corresponds with higher vehicle emission rates and poorer traffic flow during winter time temperatures.

Those violations were first categorized by day-of-week with the following results:

	Weekdays	Weekends
No. of Violations	73	4
Percent of Total	95	5
Mean 9th St. Traffic	406	208

This analysis indicates that 95 percent of all violations occur during the weekdays. This table also presents mean hourly traffic counts on 9th St. for a limited sampling period performed during November 1978. These data tend to confirm a pattern which suggests that meteorology may aggregate high CO levels but that high concentrations are caused by increases in source activity.

To further explore this point, wind speed and direction and surface pressure data were collected for violation days, for each day preceding a violation, and for the months of September through April as an average.

It was found that the average sea level pressure on violating days was 1023 mb, as compared to an average of 1021 mb. The majority (58 percent) of observations were between 1020 mb and 1030 mb with none less than 1000 mb. Wind speeds on violating days averaged 7.4 mph at 5 AM; this wind speed exactly equals the annual 5 AM wind speed in Boise. All observations on violating days were less than 17 mph and 97 percent were less than 11 mph; 6 percent were calm. A review of the wind rose for violating days was also extremely similar to that which is normally observed.

Comparison of each violation day with the preceding day's meteorology again suggested that no major meteorological anomaly had occurred and led to the violation. Mean 5 AM wind speed on preceding days was 7.5 mph and the distribution of wind speed by class and wind direction were almost identical.

Finally, comparison was made between mean and maximum CO levels on Mondays (the day with most violations) and Sunday (no violations). These are as follows:

	Sunday	Monday
Mean 8-hr CO (ppm)	2.8	7.5
Std. Dev. of Mean CO	0.8	1.5
Max 8-hr CO (ppm)	7.3	21.5
Std. Dev. of Max CO	2.9	5.2
Ratio of Mean over Max	0.38	0.35
Ratio of Std. Dev. (Mean over Max)	0.28	0.29

The extreme similarity of these ratios suggests that the sources of CO affecting the 9th St. monitor are located in the same geographic areas and are being dispersed identically; only the magnitude of the emissions varies.

The conclusion of this analysis, coupled with the conclusion of the IMM worst case analysis presented in Section IV, is as follows: high CO levels result from a combination of typical wintertime meteorology — low wind speed and mixing height — and high vehicle emissions caused by low ambient temperatures and, most likely, poor traffic flow.

RELATIONSHIP OF CO EMISSIONS AND CONCENTRATIONS

With the knowledge that CO violations are related primarily to source factors, the various combinations of these factors which may result in violations of the ambient standard can be identified. The goal of this effort would be a relationship which can be used to predict maximum CO levels at a site without resorting to monitoring.

This task was undertaken using source and concentration factors derived from the IDHW monitoring program conducted in the winter of 1977 and the emissions inventory developed as a part of this contract. Approximately one week of monitor data was available at each site. Factors, which were collected for 28 sites included:

- Maximum 8-hr CO concentration.
- Ratio of 8-hr CO to 9th St. CO during peak period.
- Traffic on adjacent roadway.
- Emissions in grid containing site.
- Emissions in 4 grids to the east and south of the monitor.
- Emissions in 4 grids to the west and north of the monitor.

and 2 dummy variables indicating:

- Location (valley or bench).
- Site type (traffic corridor or neighborhood).

Other variables which could have been considered in this analysis but which were not available include queue and delay at each intersection, type of signalization and traffic flow on cross streets. The relatively short period of record also limits this effort as higher maximum CO levels could occur at other times. These data were subjected to step-wise multiple regression analysis with the following results:

- The best single predictor of maximum CO level is the average traffic on the adjacent roadway.
- Other significant predictors include the emissions in the grid, the location variable and the site type variable.

These variables provide the best model for prediction of maximum CO levels. This is:

$$C = G_i + A_i \ (0.0015\ V - 4.9\ S - 2.8\ L + 8.5)$$

where C = 8-hr maximum CO level (ppm)

V = Hourly traffic volume on nearby roadway (vph)

G_i = Emissions from grid containing site for scenario i (10^6 gr/day)

S = Site type (0 = traffic corridor, 1 = neighborhood)

L = Location code (1 = bench, 0 = valley)

A_i = Projection factor to scenario/year i

The conversion factors required to make predictions in "parts per million" are implicit in each regression coefficient.

The projection factors, A_i, are as follows:

Scenario/year	Factor
1978	0.99
1982	0.96
1982/IM	0.87
1987	0.75
1987/IM	0.60

These factors were developed from the regional emissions burden data presented in Section 2. The fit of the data was significant at the 99 percent level (r = 0.66).

These results confirm the analysis presented in Section I that most sites in the valley will exceed the 8-hr standard.

These results also conform with the analysis presented in Section IV, as well as experience and theory elsewhere, in that ambient concentrations of carbon monoxide are strongly influenced by the presence of nearby streets due to carbon monoxide's inert nature and low elevation release.

This analysis implicitly includes all existing emissions associated with parking, both on and off-street, inasmuch as these emissions had impact at the IDHW and 9th Street monitoring sites. Growth in vehicle travel has been accounted for as described in Section II. The emissions generated by new parking facilities such as those associated with the proposed downtown mall were not included in this analysis.

SECTION 6

PROJECTION OF CO CONCENTRATIONS

In order to determine the degree of control which will be needed to attain the 8-hour standard by 1982 and 1987, the model described in Section 5 was applied. Changes in grid emissions and regional emissions were used in combination to "roll-back" 1977 emissions taking into account growth in VMT and implementation of Federal emissions controls.

The methodology applied was to make predictions of second-highest 8-hour CO concentration at the 24 traffic corridor sites used to develop the regression model for each of five scenarios/years. These are:

- 1977
- 1982
- 1987
- 1982 with Inspection/Maintenance
- 1987 with Inspection/Maintenance

Figures 10 through 14 present an estimate of the extent of the CO nonattainment problem for each of these scenarios. The area defined in each of these figures provides a rough estimate of the area within which traffic corridor sites will exceed the 8-hr standard. Care should be taken in interpreting these diagrams with respect to two points:

- Isolated hotspots most likely exist outside of the bounded region, and
- Locations within the region but not adjacent to intersections or roadways are not likely to exceed the standard.

Review of these figures indicates that the nonattainment area is widespread in 1977 and that only minor improvements will occur by 1982. Projection to 1987 indicates substantial reductions in the extent of nonattainment; only the CBD and major access road corridors are expected to exceed 9 ppm.

Implementation of an Inspection/Maintenance program in 1981 will reduce the nonattainment region slightly in 1982 and, in 1987, leave only the CBD projected to be above standards. Based both on rollback and the model presented in Section 5, the second-highest 8-hr CO concentration at 9th Street in 1987 with I/M in effect will be about 10.3 to 10.6 ppm. This indicates

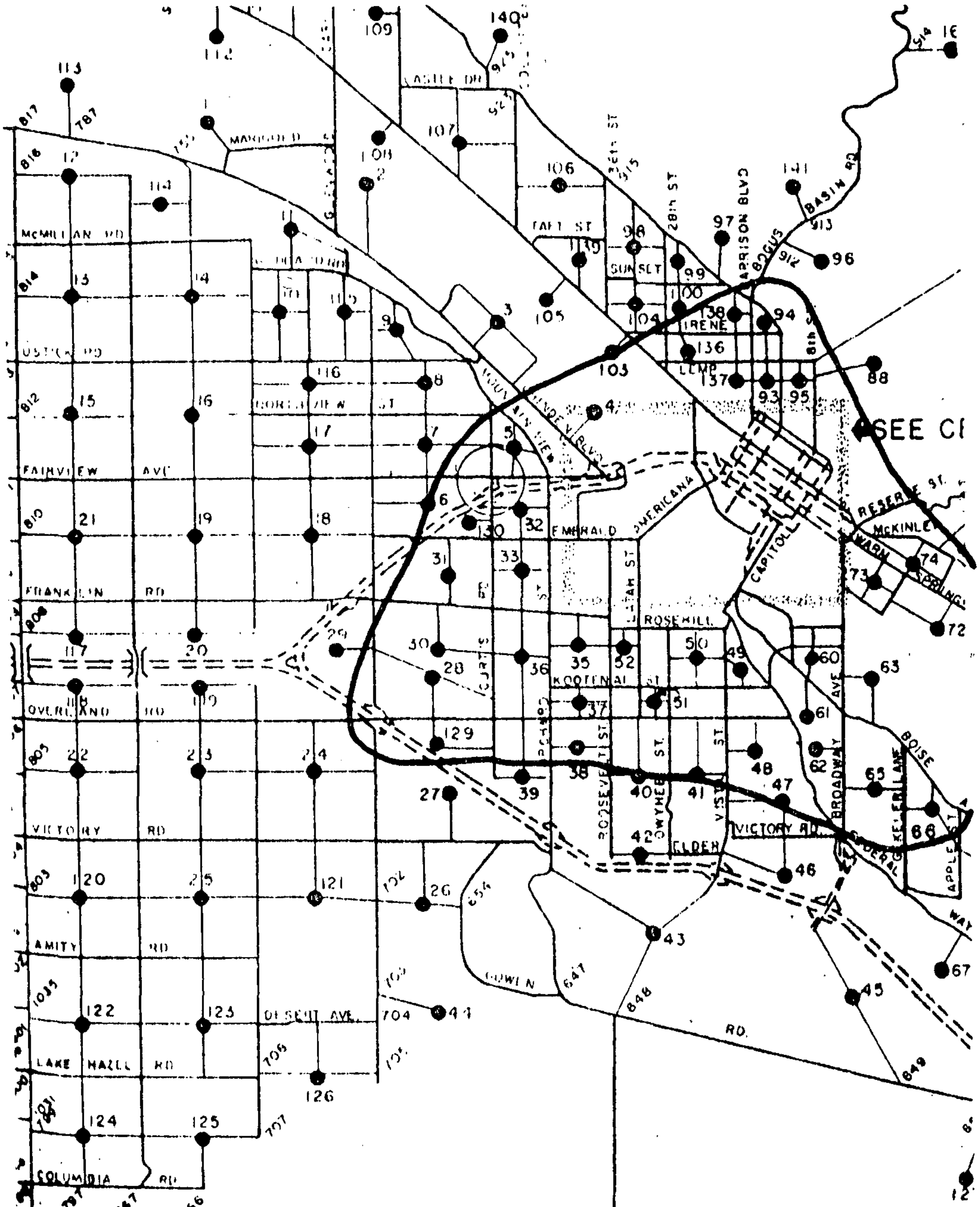

Figure 10. 1977 nonattainment area.

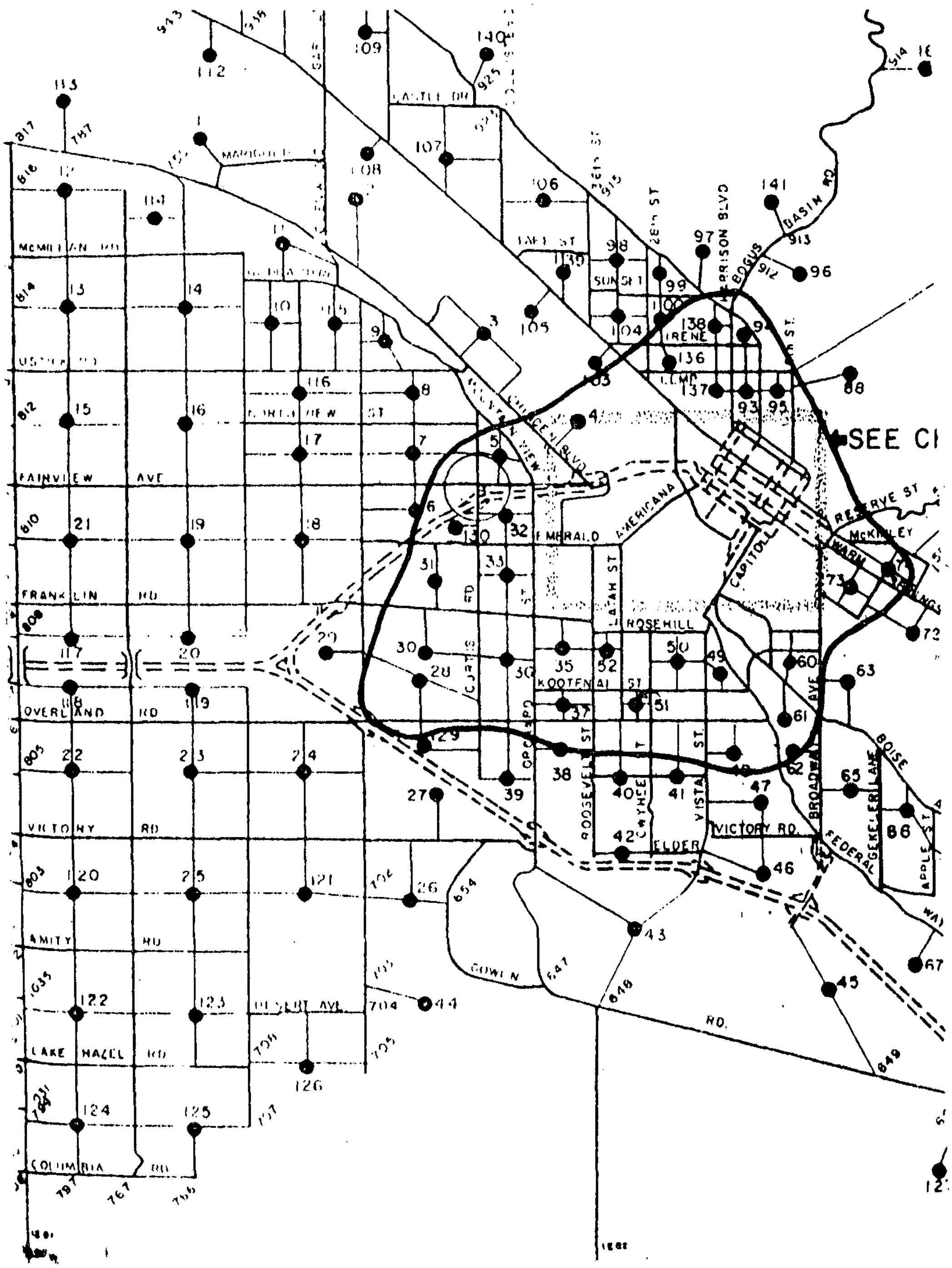

Figure 11. 1982 nonattainment area.

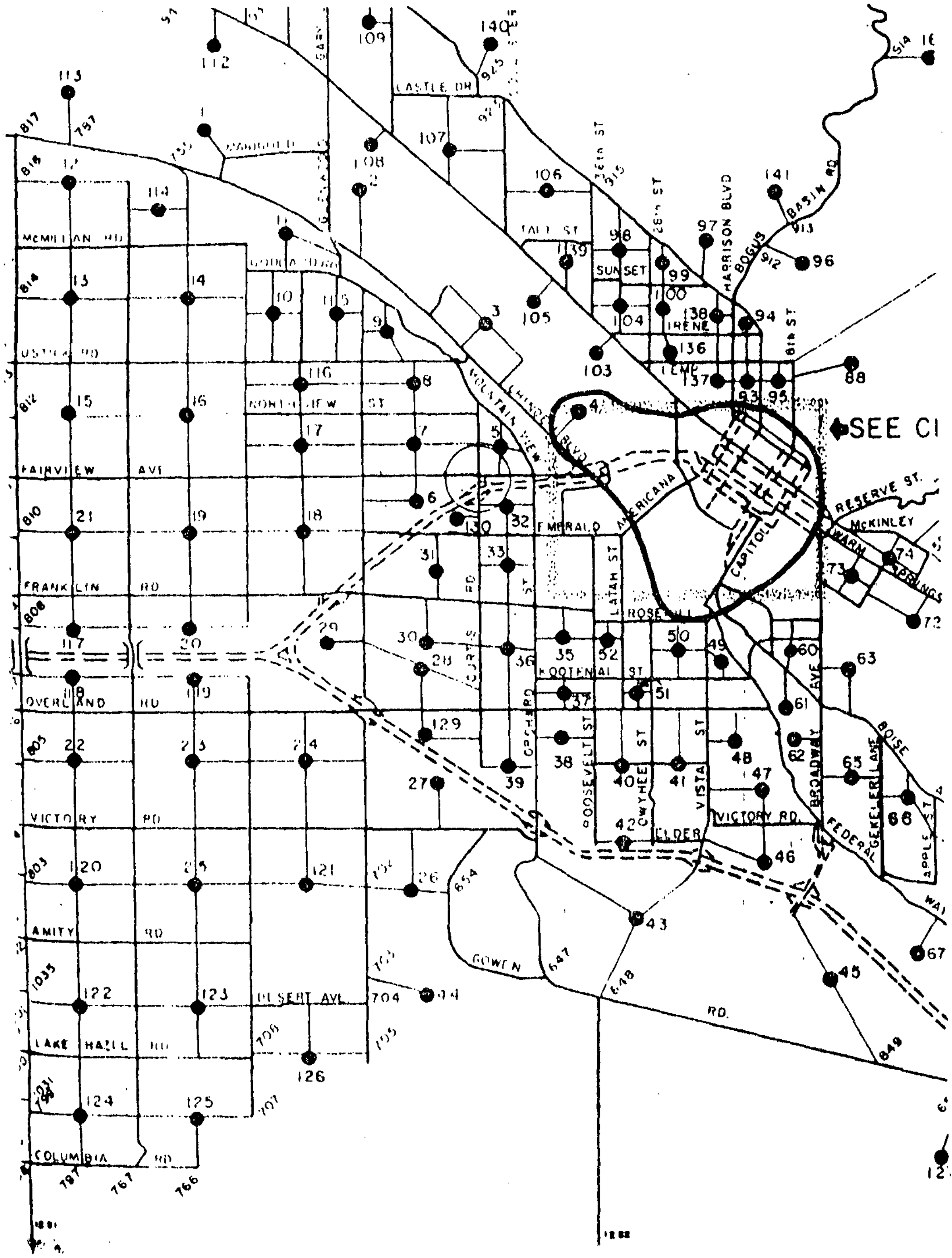

Figure 12. 1987 nonattainment area.

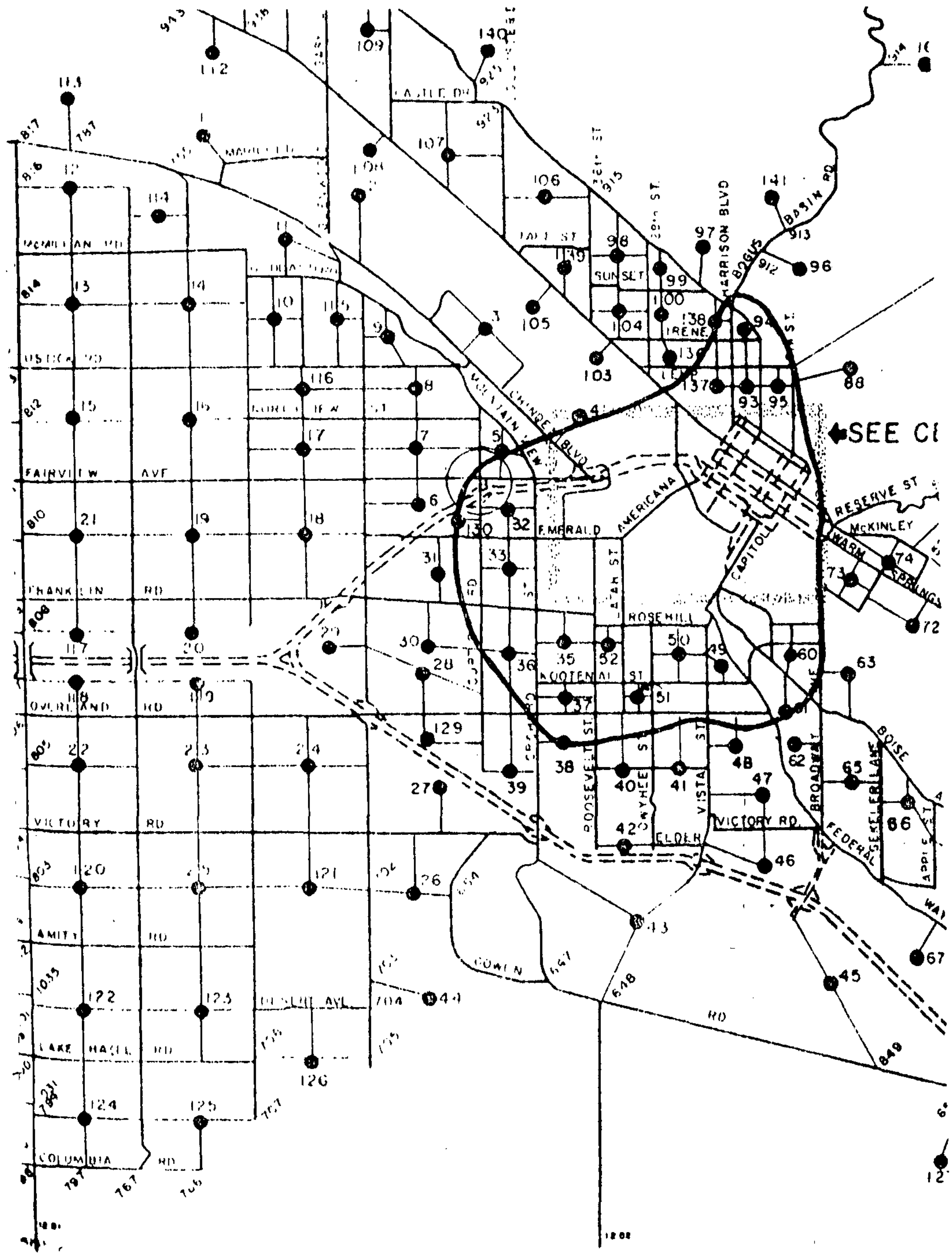

Figure 13. 1982 nonattainment area with Inspection/Maintenance.

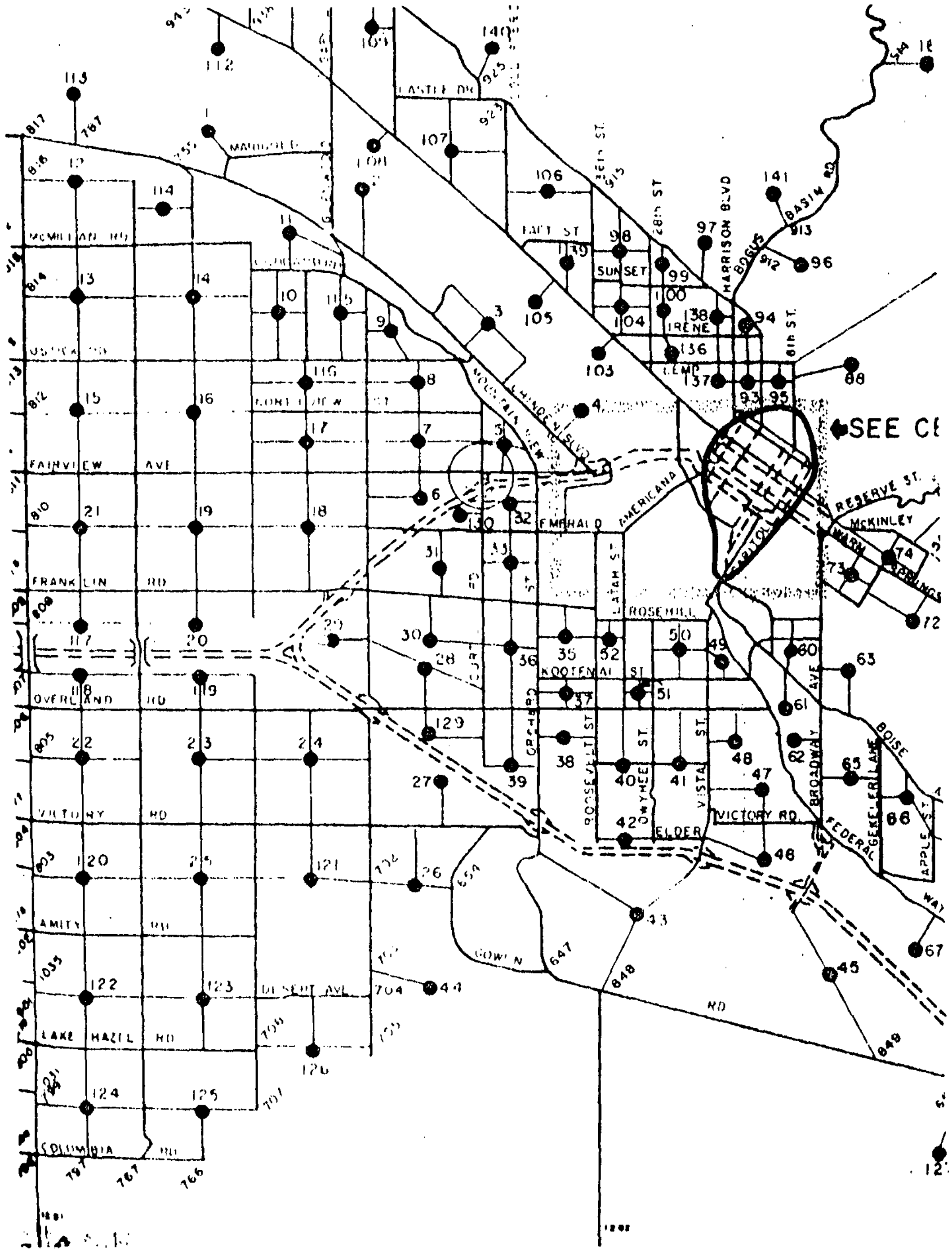

Figure 14. 1987 nonattainment area with Inspection/Maintenance.

that an additional 12 to 15 percent reduction in emissions above that resulting from implementation of full Federal emission controls and I/M will be necessary to attain standards by 1987. This reduction is based primarily upon the monitor data recorded at 9th Street. As was noted earlier, the model presented in Section 5 was based upon a second-highest value of 15.9 ppm for this site. The model residual for this variable was +1.0 ppm, hence, resulting in these strategies being based upon a design value of 16.9 ppm. The variance of this value in relation to predicting needed reductions and in relation to other sources of variance has been described in Section 1.

SECTION 7

REFERENCES

1. Benesh, F. Carbon Monoxide Hot Spot Guidelines: Volume V: User's Manual for Intersection Midblock Model. EPA-450/3-78-037. August 1978.

2. Ludwig, F. L., et al. User's Manual for the APRAC-2 Emissions and Diffusion Model. PB-275-479. June 1977.

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

Using assigned network traffic files, a comprehensive wintertime motor vehicle carbon monoxide emission inventory was prepared for Ada County, Idaho. The Intersection Midblock Model (IMM) and APRAC-2 dispersion models modified to include MOBILE1 emission factors was used in performing the analysis. As a part of this study, CO episodes were compared with preceeding nonviolating days to determine if meteorological anomalies may cause excursions above the standard, but it was found that episodes are apparently caused by a combination of higher "per vehicle" emissions and routine wintertime dispersion characteristics. Additional reductions in CO emissions beyond implementation of an inspection/maintenance program were found to be necessary to meet the 8-hour standard in 1987.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Air Pollution Carbon Monoxide APRAC Intersection/Midblock Model		

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