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1992 Missoula carbon monoxide saturation study

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1992 MISSOULA CARBON MONOXIDE SATURATION STUDY

by

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Bag samplers were placed at 15 locations where carbon monoxide (CO) concentrations were expected to be highest in the Missoula area. From December 5 through December 20, the bag samplers collected 8-hour composite samples between the hours of 4pm and midnight. Eight hour samples were collected because Missoula has violated the 8-hour National Ambient Air Quality Standards of 9.0 parts per million for CO. The main objectives of the study were to confirm that the CO monitoring site at the intersection of Brooks, Russell, and South Avenue represents the highest CO levels in Missoula, to monitor other areas with potentially high levels of CO, and to determine the impact of wood burning on ambient CO levels.

Six bag samplers and a continuous monitor were located at the intersection of Brooks, Russell, and South Avenue (MFJ). On twelve days of the study, one of the MFJ bag samplers had the highest CO reading. All six of the bag samplers and the continuous monitor at MFJ had higher CO study averages than the other sampling sites. On the poorest dispersion day, the MFJ site clearly had the highest concentrations of CO. This verifies that MFJ generally has the highest levels of CO in the Missoula area.

The two intersections Russell and Third Street, and Reserve and South Avenue also tend to have relatively high levels of CO. While the CO levels were not as high as those found at MFJ, they were at concentrations where these intersections may become CO problems in the future if traffic increases.

Two sampling sites were in residential areas. One of these sites, Boyd Park, had violated the CO standard as recently as 1985. In this study, none of the residential samples came close to violating the CO standard. This shows that changed residential wood burning practices have reduced total CO production from wood stoves over the last several years.

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INTRODUCTION

The Missoula urban area has a history of exceeding the Montana and National Ambient Air Quality Standards for 8-hour carbon monoxide (CO) levels and 24-hour PM-10 levels. The first recorded exceedances were 1977 for CO and 1969 for particulates. Missoula, which has the largest urban population surrounded by the Rocky Mountains in the U.S., often has temperature inversions in the winter months because of its mountain valley topography. It is during these periods of stagnant air, caused by the inversions, that Missoula exceeds the 8-hour CO National Ambient Air Quality Standard of 9.0 parts per million (ppm).

Carbon monoxide, along with PM-10, Ozone, Nitrogen Dioxide, and Sulfur Dioxide, is considered a criterion pollutant by the United States Environmental Protection Agency because of its adverse affects on human health. Researchers monitor locations that are likely to exceed the standard for a criterion pollutant, and if levels violate the standards, the state with a violation must write and implement a state implementation plan to reduce said pollutant below the standard.

The main way in which CO harms people is by combining with hemoglobin in the red blood cells to form carboxyhemoglobin. CO's affinity for hemoglobin is more than 200 times stonger than oxygen's affinity for hemoglobin (U.S. Environmental Protection Agency, 1991). When CO displaces

oxygen on hemoglobin, less oxygen is available for the body to use; this can reduce the efficiency of body tissues and organs in carrying out their functions. People most at risk from even low levels of CO are infants, older people, fetuses, and those with cardiovascular disease. At higher CO levels, "impairment of visual perception, work capacity, manual dexterity, learning ability, and performance of complex tasks" can occur (U.S. Environmental Protection Agency, 1992, p 1-5).

In 1974, Jackson B. Sosebee, Jr., did the first CO study in the Missoula Valley and probably the first in Montana (Sosebee, 1974). The objective of Sosebee's study was to "determine the concentration of CO in the Missoula Valley and its variability with respect to geography, time of day, sources, and meteorology and to relate those concentrations to air quality standards" (Sosebee, 1974, 1). Sosebee found micrometeorological variables were often a greater influence on CO concentrations than vehicle traffic. He did find a significant correlation between high traffic levels and high CO concentrations at the intersection of Brooks, Russell, and South Avenue, known as Malfunction Junction; and at the Orange Street Tunnel in the downtown area. Based on one-hour samples, the highest concentrations found were 19.4 ppm at Malfunction Junction and 45.5 ppm in the Orange Street Tunnel.

Soon after Sosebee's study, and probably because of the study, the state of Montana began continuous CO monitoring at several sites in Missoula. During the late 1970's and early

1980's, several locations in Missoula violated the 8-hour CO standard. Some of these locations, such as Boyd Park, were in residential areas (Carlson, 1992). Since 1985, no site in Missoula has violated the 8-hour standard of 9.0 ppm CO except for the Malfunction Junction site. This overall reduction in CO levels for Missoula was caused by a change in residential wood burning methods, a more efficient automobile fleet, and reduced CO output from industry (1990 Missoula CO Emission Inventory, 1990). Because the relative amounts of CO produced from each source have changed since Sosebee's study, the relative distributions of CO throughout Missoula have also changed.

During the 1960's, most CO in the Missoula valley probably came from industrial sources and vehicles (Sosebee, 1974). CO is produced when carbon-based fuels are burned incompletely. In the 1960's, both industry and vehicles were burning fuels with relatively inefficient methods. There were several teepee burners in the valley and Stone Container had less efficient CO control methods than it does today. By the late 1970's and early 1980's, the inefficient teepee burners had been closed down, emissions from Stone Container were probably lower, and use of residential wood stoves had increased because of the Middle East Oil embargo (Carlson, 1992). The net effect of all this was to make automobiles and residential wood burning the primary sources of CO in the Missoula Valley. Currently, automobiles are the primary

source of CO, followed by residential wood burning and then industry (1990 Missoula CO Emission Inventory, 1990).

At the national level, transportation has been the major source of CO ever since researchers began tracking CO emissions (EPA, 1992). In 1991, for example, transportation accounted for approximately 70% of CO emissions. Although vehicle miles traveled has steadily increased, today's automobiles pollute far less than they did a few decades ago. This is the main reason why CO emissions have decreased by 50% in the United States since 1970. Other sources of CO, such as industry and fuel combustion, have varied only slightly when compared to the amount of CO generated by transportation.

At the request of EPA Region VIII and with the support of the Montana Air Quality Bureau (AQB), a Carbon Monoxide Saturation Study was done in Missoula from December 5 through December 20, 1992. The following were the goals and objectives of the Missoula CO saturation study:

1) Confirm that the current Malfunction Junction (MFJ) microscale monitoring site represents the highest CO concentrations for Missoula, Montana. If higher CO levels were found in other areas, the study would aid in locating another continuous microscale carbon monoxide analyzer.

2) Monitor potential CO hotspots not previously monitored by a continuous CO analyzer.

3) Monitor the distribution of high CO concentrations around several high traffic intersections.

4) Determine the impact of wood burning on the ambient CO levels.

5) Gain experience with the Region X bag sampler saturation study technique.

6) Validate the bag sampling monitoring technique by co-locating two samplers at the continuous monitoring site.

PROJECT SUMMARY

Twenty-four bag samplers were loaned to the Missoula City-County Health Department (MCCHD) by the Air Quality Bureau. For the 16 day study a total of 319 non-compromised samples out of a possible 384 were collected and analyzed. This is a collection rate of 83.1%. When looking at data collection over the final 15 days of the study, there were a total of 307 out of a possible 360 samples collected, for a collection rate of 85.3%. Since the minimum number of days for this type of study is 15, according to EPA guidelines, the goal of an 85% retrieval rate was met (O'Neal, 1982). This study was done on consecutive days because of time constraints on equipment availability and because the AQB wanted the study to include weekends during the Christmas shopping rush. One of the reasons for the poor data collection at the start of the study was the cold ambient temperatures which caused the sample bags to become brittle and develop leaks. The low temperature for December 5 was -8° Fahrenheit. Climatological data for December from the National Weather Service office at the Missoula Airport is in Appendix A.

Because air dispersion was "good" on most days, CO concentrations were low at every sampling site through most of the study. On December 11, one of the few days when

dispersion was poor, MFJ had the highest CO readings, supporting the hypothesis that MFJ has the highest concentrations of CO in Missoula. MFJ sampler 2d had a reading of 9.4 ppm CO on December 11, the only exceedance of the 8-hour average 9.0 ppm standard. For a complete summary of the study results and a detailed description of sampler locations, consult Appendix B. Appendix C contains photographs of all the sites.

All field precision and accuracy results were within the quality assurance study objectives of ± 1 ppm. All laboratory precision and accuracy results were also within the desired range of ± 1 ppm. Therefore, valid comparisons between the network sites is possible.

For a detailed description of the quality control and assurance methods used, equipment description, and laboratory analysis method, consult Appendix D.

NETWORK DESIGN AND DESCRIPTION

The siting criteria for the bag sampling network were based on the EPA's Carbon Monoxide Hot Spot Guideline (EPA 450/3-78-035). When choosing the sampling sites, five factors were considered; the individual and composite average daily traffic burden on intersecting street legs, traffic dynamics, street canyon effects, inherent physical topography such as open spaces or hills and proximity to non-vehicular sources of CO such as wood burning. Since vehicular traffic accounts for

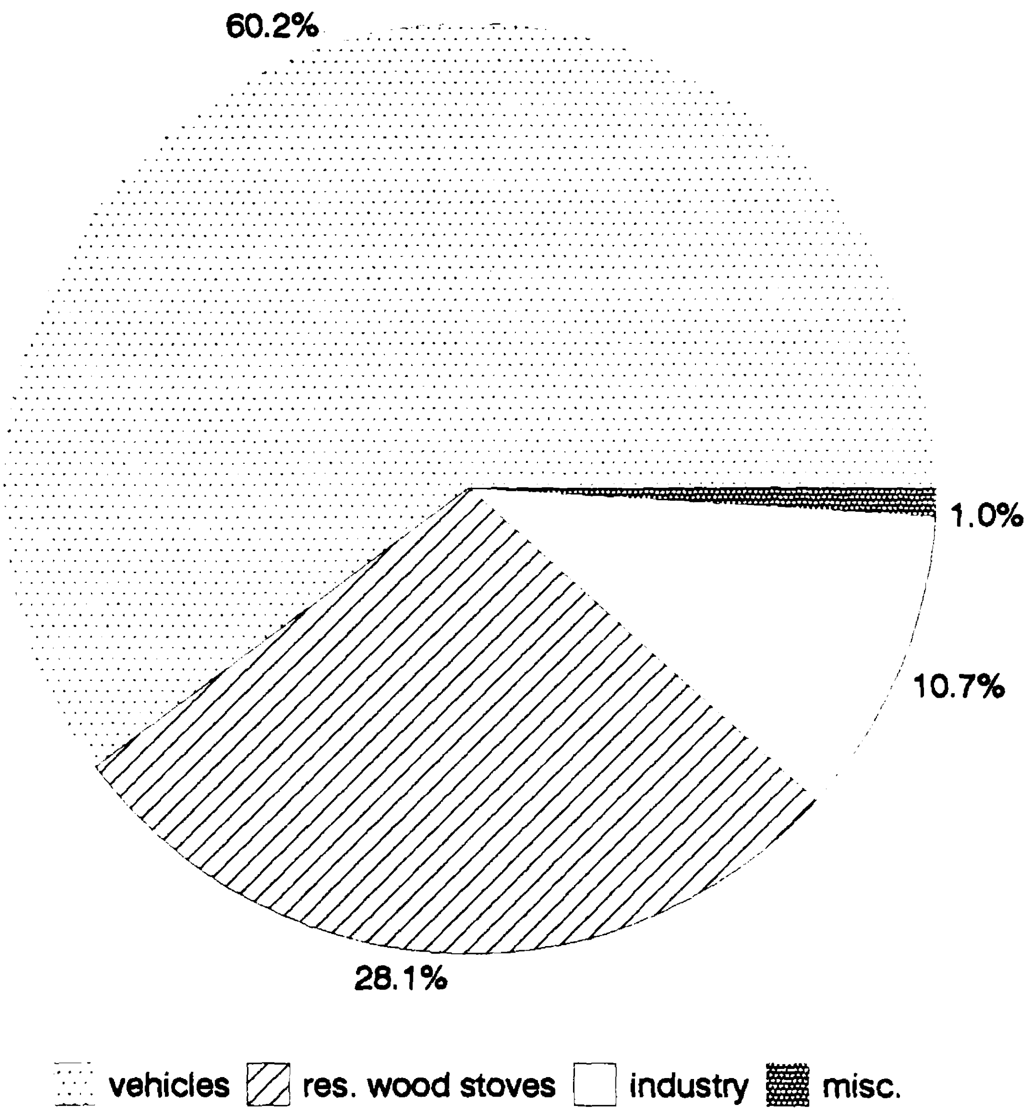
approximately 60% of the CO emissions in Missoula, (1990 Missoula Carbon Monoxide Emissions Inventory, Figure 1, pg 8), the primary siting criterion used was high Average Daily Traffic Entering (ADTE) the intersections. It should also be noted that neighborhood air movement or dispersion can have a large effect on local CO concentrations. For instance, some Broadway intersections have high traffic counts, but breezes flowing from Hellgate Canyon, which can occur during inversions, may disperse CO and make for lower relative CO concentrations. The following are the sampling sites:

Site #	Sampling Location	# of Samplers
1a	Brooks & Reserve	1
2a,b,c,d,e,f	MFJ	6
3a	Brooks & Stephens	1
4a	Brooks & Higgins	1
5a,b	Higgins, south of Broadway	2
6a	Broadway & Madison	1
7a	Broadway & Van Buren	1
8a	Broadway & Orange	1
9a,b	Russell & Broadway	2
10a,b	Russell & 3rd St.	2
11a	Reserve & 3rd St.	1
12a	Reserve & South Ave.	1
13a	Grant & S. 11th W.	1
14a,b	Park & Fairview	2
15a	Boyd Park	1

Even though Sosebee's study found very high levels of CO in the Orange Street tunnel, no monitor was located there for this study because the site does not fit the EPA definition of ambient air (Carbon Monoxide Hot Spot Guideline, EPA 450/3-78-035). It was also felt that people do not work or loiter in this area and so even if the 8-hour standard is violated,

FIGURE 1

Sources of Missoula's Carbon Monoxide Emissions
Winter 1990



1990 Base Year Carbon Monoxide
Emission Inventory
Missoula, Montana

human health would not be endangered. However, when financially possible, an alternate route for pedestrians should be built.

Three sites, 13, 14 and 15, were chosen to sample the effects of residential wood burning and were located in residential neighborhoods. These residential sites helped determine the CO levels in the Missoula Air Stagnation Zone away from high traffic areas. Figure 2 on page 10 is a map of the CO sampling locations in Missoula. Table 1 on page 11 lists the high traffic intersections monitored in the study along with their corresponding ADTE's.

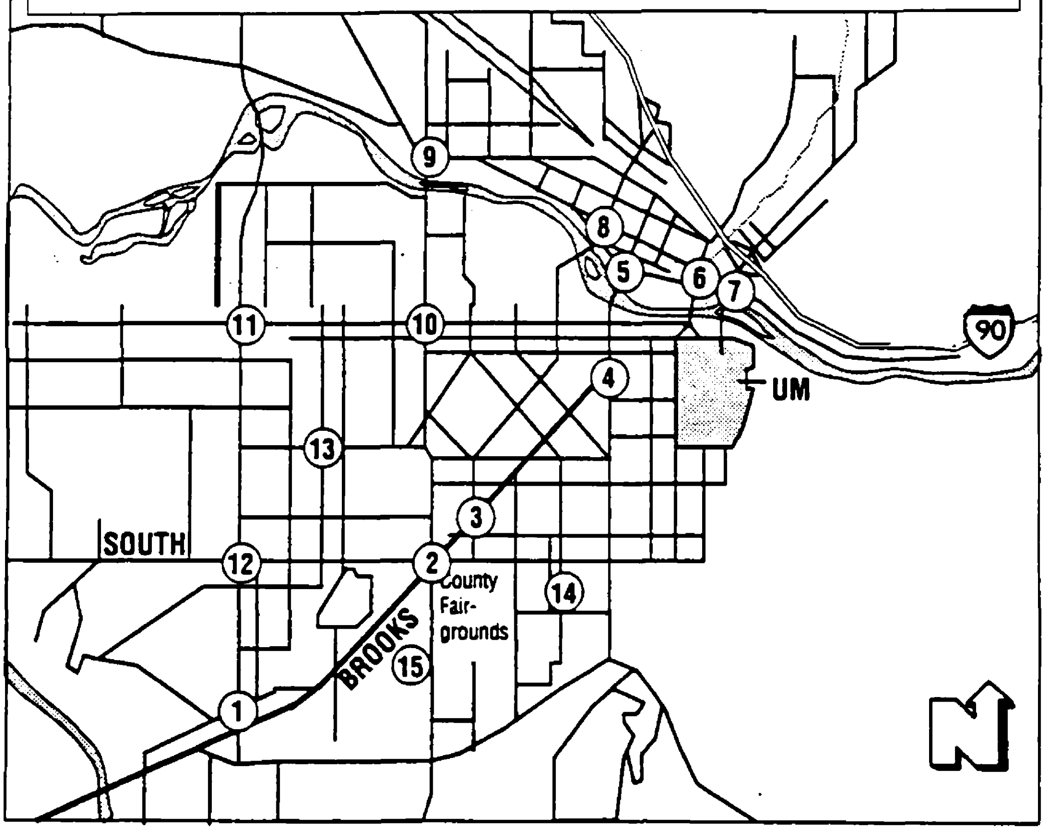
Sites 1 through 12 were chosen because of their high average daily traffic. Site 5, in the downtown, was also chosen because it is one of the few street canyons in Missoula. Carbon monoxide measurements have exceeded the 9.0 ppm standard in the past at site 5, possibly because this is the major "cruising" street on Friday and Saturday nights. Other sites that were picked because of past CO exceedances were 2 and 15.

In the 1990 CO emissions inventory, the city of Missoula and the surrounding area were divided into 64 sections of one square mile each (Figure 3, pg 12). Then the amount of CO produced in each section was computed. Section 37 had the highest CO production at 17,229 pounds per day (#/day) and section 44 had the second highest CO production at 15,765 #/day. Section 37 ranks number one in automotive CO

FIGURE 2

STUDY SITE LOCATIONS

Sampling location	Number of samplers	Sampling location	Number of samplers
(1) Brooks and Reserve	1	(9) Russell and Broadway	2
(2) Malfunction Junction	6	(10) Russell and Third Street	2
(3) Brooks and Stephens	1	(11) Reserve and Third Street	1
(4) Brooks and Higgins	1	(12) Reserve and South Avenue	1
(5) Higgins, south of Broadway	2	(13) Grant and S. 11th W.	1
(6) Broadway and Madison	1	(14) Park and Fairview	2
(7) Broadway and Van Buren	1	(15) Boyd Park	1
(8) Broadway and Orange	1		



Missoulian

Composite

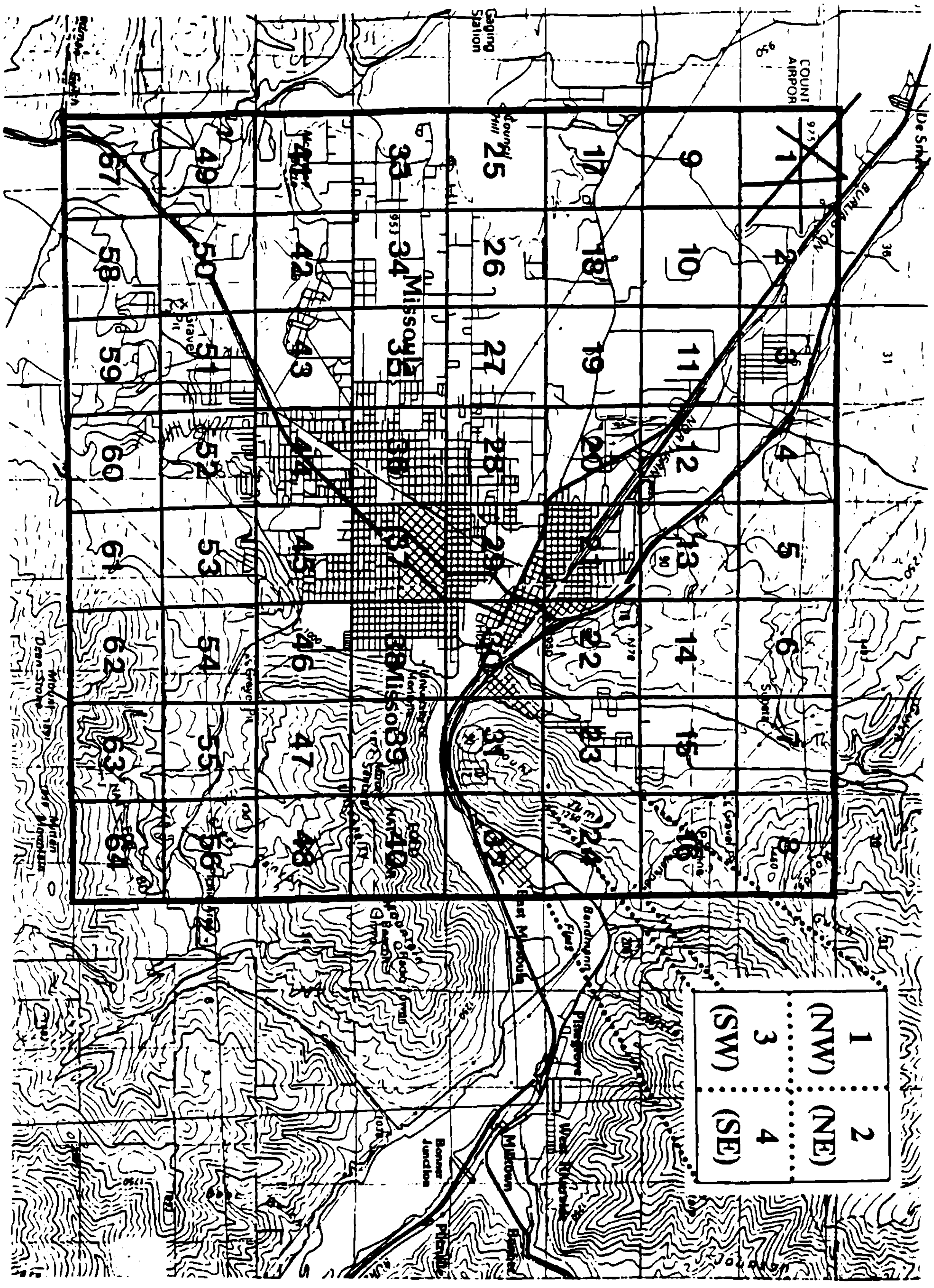
TABLE 1

MISSOULA CO SATURATION STUDY SAMPLING SITES' AVERAGE DAILY TRAFFIC ENTERING THE INTERSECTION

Site	Intersection	ADTE[1]
1	Brooks and Reserve	30630
2	Malfunction Junction	48195
3	Brooks and Stephens	28220
4	Brooks and Higgins	23785
5	Higgins, South of Broadway	22360
6	Broadway and Madison	30385
7	Broadway and Van Buren	21425
8	Broadway and Orange	27045
9	Russell and Broadway	33630
10	Russell and 3rd Street	28630
11	Reserve and 3rd Street	23050
12	Reserve and South Avenue	28025

[1]ADTE = Average Daily Traffic Entering the intersection. Based on the November, 1991, Missoula Transportation Study Area Traffic Counting Program.

FIGURE 3
1990 CO EMISSION INVENTORY GRID



production while section 44 ranks number one in residential wood burning CO production.

Three sampling sites are located in section 37. MFJ (site 2) had six samplers and is located at the Southwest corner of section 37, Brooks & Stephens (site 3) is approximately in the middle of section 37 and Brooks & Higgins (site 4) is near the Northeast corner of section 37. MFJ is a good place for samplers to be located because it is the highest daily traffic intersection in Missoula and traffic is often backed up at this location.

MFJ is also in the Northeast corner of section 44. The other sampling sites in section 44 are Brooks & Reserve (site 1), Reserve & South Avenue (site 12) located at the Northwest corner of section 44, and Boyd Park (site 15). Sites 1 and 12 were chosen because of their high average daily traffic, potential for traffic backing up, and because the county is growing rapidly in those directions. Boyd Park (site 5) was chosen because of past CO violations at that monitoring site and because we wish to monitor the background level of CO from residential wood burning in this section.

Samples were collected between 4 pm and 12 midnight because many of the past violations have occurred near this time (Table 2, pg 14). Other reasons for collecting samples in the evening hours are because the inversions are starting to strengthen, many people light up their wood stoves in the evenings after work, and because the afternoon rush hour could

Table 2

CARBON MONOXIDE VIOLATIONS
1985-1992
MISSOULA, MT

SITE	DATE	HOURS	PPM	
Boyd Park	12-4/5-85	1700-2400	10.6	
Boyd Park	12-23/24-85	1900-0200	9.9	*
MFJ	2-10/11-87	1800-0100	10.4	
MFJ	2-11/12-87	1800-0100	10.6	*
MFJ	2-12/13-87	1900-0200	9.6	*
MFJ	2-13/14-87	1800-0100	9.2	*
MFJ	1-12/13-88	1700-2400	9.8	
MFJ	12-6/7-88	1800-0100	9.6	*
MFJ	1-9-89	1200-1900	12.3	
MFJ	12-4-89	1500-2200	9.7	*
MFJ	12-31-90	1400-2100	9.7	
MFJ	1-8-91	0800-1500	9.7	
MFJ	1-14-91	0800-1500	9.8	*
MFJ	2-1-91	1600-2300	9.8	*
MFJ	11-3-91	1500-2200	10.2	*
MFJ	11-4-91	1000-1700	9.9	*

STANDARD = 9.0 PPM AVERAGED OVER 8 HOURS
NOT TO BE EXCEEDED MORE THAN ONCE PER YEAR
*Counts as violation of the Federal Standard

then be included in the sampling period. Since most cruising and some of the Christmas shopping occurs on weekends, monitoring was done seven days a week during the study.

EQUIPMENT DESCRIPTION AND CALIBRATION

Two sets of samplers were provided for this study. The first dozen samplers were shipped to the AQB on May 14, 1991 and the second dozen were shipped to the AQB on May 15, 1992. The earlier set of pumps had identification numbers in the two hundreds and the 1992 set of pumps had identification numbers in the three hundreds. According to the Lane Regional Air Pollution Authority, there is no difference between the sets of samplers (Lane Regional Air Pollution Authority, 1993).

Each bag sampling site included the following:

1. The sample pump module.
2. The lead acid battery which attached to the base of the pump module.
3. The sample bag module and a central bar from which the pump and bag modules were suspended.
4. The bracket, attached to the mounting unit, which held the pump and bag modules horizontally from the mounting unit.
5. The mounting unit which attached to either a pole or tree and elevated the pump and bag assembly three meters above ground level.

Every effort was made to deploy the air samplers in a manner consistent with EPA'S probe siting criteria for monitoring carbon monoxide in a microscale situation (40 CFR 58, Appendix E). Due to the proliferation of signs and a shortage of strategically located poles, EPA's probe siting criterion were not always attained. The tolerance limits

proposed for the study were:

1) Probe inlet elevation will be 3 meters, ± .5 meters above the ground (height is to reduce vandalism).
2) Horizontal distance separating the probe inlet and the edge of the nearest traffic lane will be 3 meters, ± 1 meter (or above the side walk).
3) Probe inlet will be free of any significant obstructions within an imaginary sphere having a radius of 1 meter.
4) Probe inlet will be located at least 10 meters from the nearest intersection.

All 24 Lane portable air samplers were used in the sampling network. The pump module consisted of a low volume pump, on/off digital timers that could be preset, and a calculator that counted the number of pulses from the pump. The pumps could also be switched on/off manually. The bag module consisted of a polyvinyl chloride pipe surrounding a tedlar bag of approximately 4.1 liters. The pump and bag modules are connected together by plastic tubing with quick disconnect fittings. Samplers were designed to be suspended from brackets that could be attached to light poles, telephone poles, sign post, or trees.

Pump calibration was based on the pulse rate. Calibration of the pulse rate was accomplished using a stopwatch and timing the pump pulse rate. The appropriate potentiometer was then adjusted until the desired pulse rate was achieved. For more details on calibration, consult Appendix D.

At each sampling site, a mounting unit was strapped to a pole or tree with nylon straps so that the sampler inlet was

approximately 3 meters above ground level. The brackets holding the pump and bag assemblies were preattached to the mounting units.

FIELD PROCEDURES

Ambient air sampling for carbon monoxide was done from December 5 through December 20, 1992. Eight hour composite samples were collected from 4:00 pm till midnight every day of the week. This time period was chosen because of past exceedance patterns. An 8-hour sampling period was chosen so that the results could be compared to the 8-hour National Ambient Air Quality Standard of 9.0 ppm. Monitoring was done every day of the week to monitor the effects of weekend cruising and normal weekday driving.

Sample bags were collected and replaced each day with empty bags. When a bag was collected, the sampler's calculator was reset to record the next sample's pump count, the pump calibration was checked, and, if needed, the sampler's battery was replaced. Field documentation included recording the pulse rate count, bag volume, timer and pump checks, and general comments. The samples were analyzed at MFJ the day they were collected so that the bags could be used the following day.

RESULTS RELATIVE TO GOALS AND OBJECTIVES

Confirmation of MFJ as Representing the Highest CO Concentrations in Missoula

The first objective was to confirm that the current MFJ microscale monitoring site does generally represent the highest CO concentrations in Missoula. If higher concentrations were found at other locations, the study would help locate a new monitoring site. On 12 days of the study, one of the six MFJ samplers recorded the highest CO reading (Table 3, pg 19). For the other 4 days, a MFJ monitor recorded the second highest CO concentration.

For the four days that MFJ did not have the highest CO readings, the high values were 5.5 ppm on the 19th (site 9a), 4.2 ppm on the 17th (site 3a), 3.8 ppm on the 13th (site 10b), and 3.7 ppm on the 18th (site 5a). On three of these four days, a MFJ sampler was within 0.3 ppm of the non-MFJ high value. On the fourth day, the 19th of December, the MFJ samplers 2d and 2f had readings of 5.0 ppm, 0.5 ppm less than the high concentration measured at Broadway and Russell (site 9a). When MFJ did not record the highest CO concentrations, the CO concentrations around Missoula were relatively low and MFJ was still close to the other high CO concentrations. Since the accuracy and precision of this sampling technique is $\pm$ 1 ppm, differences less than 0.5 ppm are not significant. On five of the days that MFJ had the highest CO concentration, the difference between MFJ and the next highest site was

TABLE 3

DAILY HIGH CARBON MONOXIDE CONCENTRATIONS AND LOCATIONS
MISSOULA, MONTANA
DECEMBER, 1992

Date	Maximum 8 hr conc. by date	Site #	Second highest conc. by date *	Site *	Wind Speed (mps) 8 hr Avg	Wind Direction (degrees) 8 hr Avg
12/5/92	4.9	2f	3.8	5a	0.4	222
12/6/92	4.8	2f	4.5	3a	0.25	172
12/7/92	5.8	2f	5.3	5a	0.31	251
12/8/92	5.7	2f	3.8	4a	0.96	207
12/9/92	6.1	2d	5.3	10a	0.86	169
12/10/92	4.6	2f	4.4	5b	1.21	188
12/11/92	9.4	2d	7.7	3a	0.29	198
12/12/92	6.3	2f	3.4	5b,6a, 11a	0.61	155
12/13/92	3.8	10b	3.7	2a	0.36	251
12/14/92	5.1	2c	4.5	5a	0.87	192
12/15/92	5.0	2c	4.9	12a	0.86	172
12/16/92	3.6	2d	3.3	3a	1.71	123
12/17/92	4.2	3a	3.9	2c	0.53	179
12/18/92	3.7	5a	3.6	2a, 2c	2.33	257
12/19/92	5.5	9a	5.0	2d, 2f	0.35	171
12/20/92	3.4	2b	1.3	5a	2.18	265
Mean	---	---	---	---	0.88	198

* Only the highest CO reading were considered from each intersection. The purpose is to compare CO levels from different locations.
\# Lower case letters in the site columns denote specific locations at intersections. See page 45 in Appendix B.

2 = Malfunction Junction
3 = Brooks and Stephens
4 = Brooks and Higgins
5 = Higgins, South of Broadway
6 = Broadway and Madison
9 = Broadway and Russell
10 = Russell and Third Street
11 = Reserve and Third Street
12 = Reserve and South Avenue

Wind speed and wind direction data collected by Climatronics unit at Malfunction Junction.

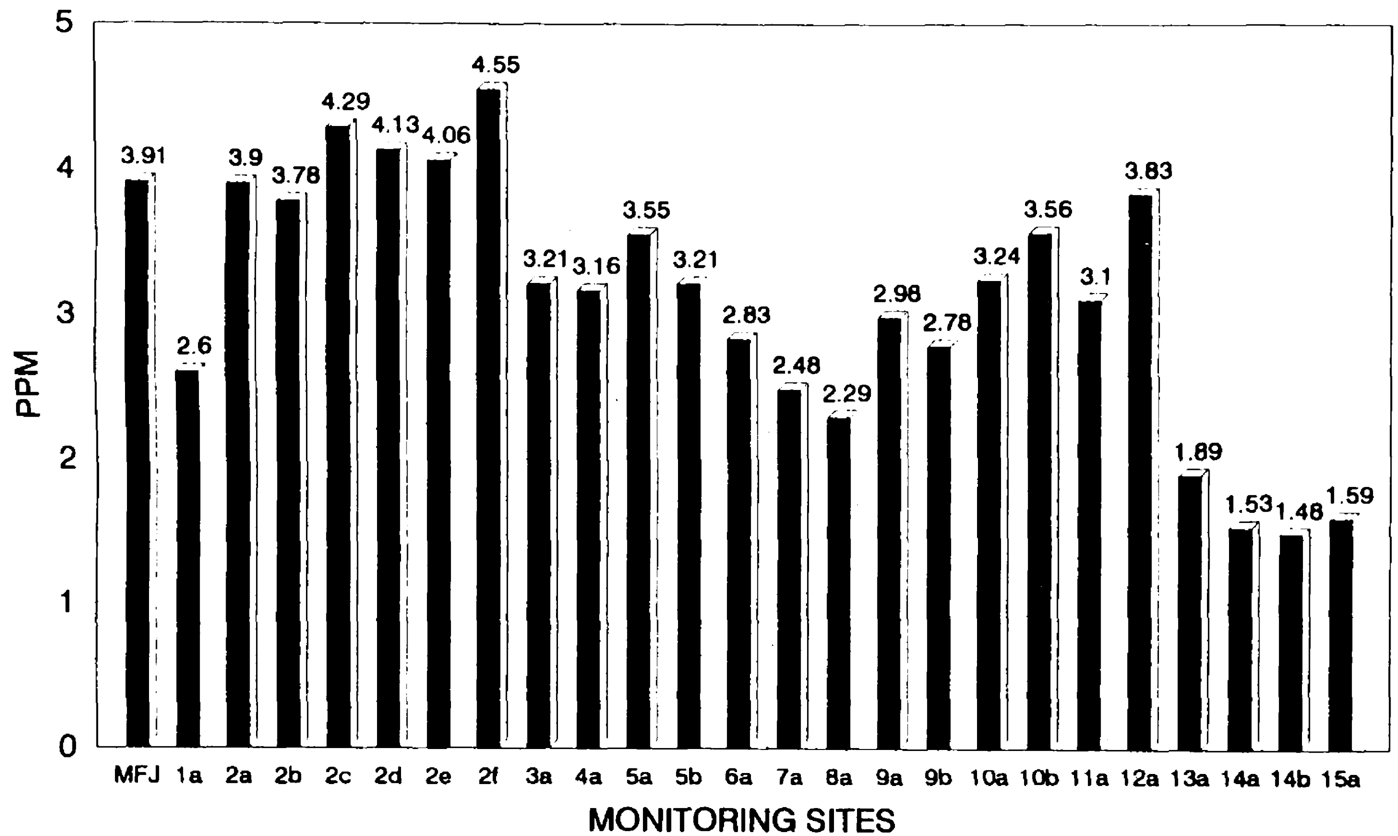
greater than 1 ppm (Table 3). On December 11, for instance, sampler 2d at MFJ had a reading of 9.4 while the next highest non-MFJ concentration was 7.7 at Higgins and Stephens (site 3a). Differences greater than 1 ppm are significant.

Another way to verify that MFJ has the highest CO concentrations was to look at the site averages (Figure 4, pg 21). The five highest study averages were recorded by MFJ monitors. The only site that had a higher study average than MFJ 2b was the Reserve and South Avenue sampler, site 12a. Since MFJ 2b and the Reserve and South Avenue site had valid data for the same day only six times, partly because of the cold weather making the tedlar bags brittle, it made more sense to compare the average for these six days rather than the study period averages. When compared in this way, MFJ 2b had an average of 3.9 and the Reserve and South Avenue site (12a) had an average of 3.4 ppm. When averages were compared in this manner, (i.e. based only on days when valid data was collected at both sites), all the MFJ sites had a higher average than the other sites in the study. This showed that MFJ generally has the highest CO levels in Missoula, especially during poor dispersion periods.

Potential CO Hotspots and CO Distribution

The next two objectives of the study were to monitor potential CO hotspots not previously studied and to monitor the distribution of CO concentrations around high traffic

FIGURE 4
1992 MISSOULA CARBON MONOXIDE SATURATION STUDY
MONITORING SITE AVERAGES FOR A 16 DAY STUDY



intersections. As mentioned previously, the other potential CO hotspots did not exceed the overall CO concentrations found at MFJ.

From the data collected at the downtown monitoring sites, (5a and 5b), a characterization of the worst street site could not be made. Because dispersion was good during most of the study, it was difficult to characterize which part of the intersection had the highest CO levels at those intersections with multiple monitors. The location with the highest CO concentration varied.

Impact of Wood Burning on Ambient CO Levels

Past monitoring at residential areas like Boyd Park (site 15) and Lions Park (Carlson, 1992), regularly recorded exceedances of the 8-hour CO standard of 9 ppm. During the study, the residential sites (13, 14a, 14b, and 15) recorded CO concentrations as high as 3.6 ppm with study averages of 1.89, 1.53, 1.48 and 1.59 ppm respectively. The residential CO concentrations were always less than the intersection concentrations through out the study. In 1985, Boyd Park recorded violations of the CO standard while the MFJ intersection monitor did not violate the standard (Table 2). This shows that changed wood burning practices have reduced total CO production from residential wood burning and that wood burning makes up a smaller percent of the total CO emissions for Missoula.

Overall CO production from wood stoves has been reduced because of ordinances governing what types of stoves can be installed in Missoula County (Missoula City-County Air Pollution Control Program, Rule 1428 (4ci)), restrictions on types of wood stoves that can be used during stage I air alerts, (Ibid., Rule 1428 (5)), and use of cleaner fuels for heating (1990 Base Year Carbon Monoxide Emission Inventory, 1990). All wood stoves altered or installed in Missoula County must meet the class II criteria (Missoula City-County Air Pollution Program, Rule 1428 (5)). Emissions from a class II stove do not exceed 8.5 grams per hour of PM-10 after a 20 minute warm up period by the EPA method (40 CFR Part 60, Subpart AAA, Sections 60.531, 60.534, and 60.535). Wood stoves that emit less particulates are more efficient and also emit less CO. So these wood stove regulations are helping to reduce CO levels in Missoula.

Another City-County ordinance that reduces the impact of wood stoves on CO levels during periods of poor dispersion is that only registered class I stoves, stoves whose emissions do not exceed 4.1 grams per hour by the EPA Method, may burn during stage I air alerts. Stage one alerts are called when PM-10 levels exceed 100 ug/m^3.

A third factor that may be reducing CO levels is education. Programs in the schools and coverage in the local media help convince people to reduce the amount of wood they burn and to use cleaner fuels such as natural gas for heating.

EPA Region X Bag Sampler Saturation Study Technique

The fifth objective of the study was to gain experience with the EPA Region X bag sampler saturation study technique. Even though we were initially inexperienced in the use of these samplers, we were able to use and calibrate the samplers with only minimal assistance. However, problems did develop with some of the samplers that caused us to lose data. These problems and some possible solutions are discussed in the recommendations section.

Validation of the Bag Sampling Monitoring Technique

This objective is discussed in the following field accuracy section:

FIELD PRECISION AND ACCURACY

Field Precision

Field precision was assessed by co-locating 2a with 2b and 14a with 14b. Co-located samplers should be within 2 meters of each other; in this study they were within 1 meter. Samplers 2a and 2b were located next to the permanent continuous monitor at MFJ and samplers 14a and 14b were located at the intersection of Park and Fairview. The MFJ site was chosen because high CO concentrations were expected and the residential site was chosen to measure the precision at low CO concentrations.

Samplers 2a and 2b had a correlation coefficient of 0.908

and a slope of 0.819 (Table 4, pg 26). The mean of the absolute values of the differences in CO concentrations measured by samplers 2a and 2b was 0.23 ppm with a maximum absolute difference of 0.6 ppm.

Samplers 14a and 14b had a correlation coefficient of 0.995 and a slope of 0.952. The mean of the absolute values of the differences in CO concentrations measured by samplers 14a and 14b was 0.05 with a maximum absolute difference of 0.1 ppm.

One of the quality assurance objectives was to yield an absolute difference less than 1.0 ppm between the co-located samplers as established through the EPA Region X sampling program (O'Neal, 1982). Since the maximum absolute difference was 0.6 ppm, this objective was met.

Field Accuracy

Samplers 2a and 2b were co-located with the MFJ continuous monitor to assess the accuracy of the bag samplers. In the traditional sense this was not a true measure of sampler accuracy since an absolute standard was not employed. However, it was assumed that the data collected by the continuous monitor, which was subjected to absolute standards, was of sufficient quality to be considered a "quasi" audit source. This also provided a measure of method comparability between the continuous monitor and the bag samplers. The objective was an absolute difference of less than $\pm$ 1.0 ppm

TABLE 4

FIELD PRECISION SUMMARY

Date	Site 2a	Site 2b	PPM Diff.	Site 14a	Site 14b	PPM Diff.
12/5	3.2	3.2	0.0	ND	1.6	--
12/6	3.6	3.3	0.3	ND	2.0	--
12/7	4.8	4.7	0.1	ND	2.2	--
12/8	4.8	4.6	0.2	2.4	2.3	0.1
12/9	4.2	3.6	0.6	ND	1.0	--
12/10	3.7	3.9	-0.2	1.6	1.6	0.0
12/11	6.2 c	ND	--	2.8	ND	--
12/12	3.0 c	ND	--	1.8	1.8	0.0
12/13	3.7	5.3 c	--	1.7	1.6	0.1
12/14	4.3 c	9.3 c	--	1.6	1.7	-0.1
12/15	ND	ND	--	1.3	1.2	0.1
12/16	1.2 c	ND	--	0.6	0.6	0.0
12/17	3.0 c	ND	--	1.3	1.3	0.0
12/18	3.6	3.4	0.2	0.7	0.7	0.0
12/19	4.2	3.9	0.3	2.2	2.2	0.0
12/20	3.2	3.4	-0.2	0.3	0.4	-0.1
mean	3.90	3.78	0.23	1.53	1.48	0.05
corr.	--	--	0.908	--	--	0.995
slope	--	--	0.819	--	--	0.952

C = compromised data. Such data is not used for computations or comparisons.
ND = No Data
PPM Difference = [sampler a] - [sampler b]
mean = average of the absolute values of the differences.
corr. = correlation coefficient

between the continuous analyzer and the bag samplers 2a and 2b. For more details on precision and accuracy, see Precision and Accuracy in Appendix D.

The MFJ continuous CO analyzer and sampler 2a had a correlation coefficient of 0.943 and 2a ran 1.7% higher on average than the continuous analyzer. The maximum absolute difference between 2a and the continuous analyzer was 0.39 ppm with an average absolute difference of 0.19 (Table 5, pg 28).

Sampler 2b and the MFJ continuous CO analyzer had a correlation coefficient of 0.840 with 2b averaging 2.7% lower readings than the continuous analyzer. The maximum absolute difference between 2b and the continuous analyzer was 0.80 ppm with an average absolute difference of 0.27.

LABORATORY PRECISION AND ACCURACY

Laboratory Precision

To assess laboratory precision, gas mixtures with known quantities of Carbon monoxide were analyzed by the Dasibi 3003 according to EPA Reference Method Number RFCA-0381-051 before sample analysis began each day. According to the EPA reference method, three different concentrations of CO gas, called the zero, span, and precision points, are analyzed to gauge how precise the Dasibi is in measuring throughout its range of 0-50 ppm CO. Zero refers to gas that contains no measurable amounts of CO, the span point has a CO concentration near 80% of the analyzers range, and the

TABLE 5

FIELD ACCURACY SUMMARY

DATE	MFJ CONTINUOUS ANALYZER (ppm)	MFJ Site 2a	Absolute Difference (ppm)	MFJ Site 2b	Absolute Diff. (ppm)
12/5/92	3.26	3.2	0.06	3.2	0.06
12/6/92	3.21	3.6	0.39	3.3	0.09
12/7/92	4.71	4.8	0.09	4.7	0.01
12/8/92	4.95	4.8	0.15	4.6	0.35
12/9/92	4.40	4.2	0.2	3.6	0.8
12/10/92	3.76	3.7	0.06	3.9	0.14
12/11/92	5.72	6.2 C	C	ND	ND
12/12/92	3.76	3.0 C	C	ND	ND
12/13/92	3.64	3.7	0.06	5.3 C	C
12/14/92	4.80	4.3 C	C	9.3 C	C
12/15/92	5.67	ND	ND	ND	ND
12/16/92	1.25	1.2 C	C	ND	ND
12/17/92	2.83	3.0 C	C	ND	ND
12/18/92	3.86	3.6	0.26	3.4	0.46
12/19/92	3.92	4.2	0.28	3.9	0.02
12/20/92	2.88	3.2	0.32	3.4	0.52
Mean	3.91	3.90	0.19	3.77	0.27
Corr.	--	--	0.943	--	0.840
Standard Deviation	--	--	0.227	--	0.383

C = compromised data. Such data are not used for computations nor comparisons.
ND = No Data.
Mean = the average of the absolute values.
Corr.= Correlation Coefficient between the continuous analyzer and the samplers.

precision point has a CO concentration near 18% of the analyzers range.

After the zero, span, and precision points were run, the zero and span potentiometers were adjusted on the Dasibi 3003 to agree with the initial zero/span responses. This adjustment increased the precision of sample analysis. A precision check was also done after analysis was completed for the day to ensure that the Dasibi 3003 had not drifted. Absolute differences between the Dasibi and the check points never exceeded 1.0 ppm. The results of these checks are summarized below.

The absolute maximum difference between the initial span response and the actual concentration was 0.77 ppm CO. The span gas concentration was performed at 43.28 ppm. The span % change column on Table 6, page 30, shows the % difference between the initial span response and the span gas concentration. The zero % difference column in Table 6 does the same for the daily zero checks. The initial zero responses had a range of -0.3 to 0.1 ppm.

Table 7 on page 31 summarizes the precision checks. The reference concentration was 9.23 ppm and the initial precision results ranged from 8.95 to 9.2 ppm. The final precision results ranged from 8.8 to 9.2 ppm with an average drift from the initial precision response of -0.6%.

These responses show that the Saturation Study CO Analyzer exceeded the precision quality assurance guidelines.

TABLE 6

DAILY ZERO-SPAN CHECKS ON THE SATURATION STUDY CO ANALYZER

DATE	SPAN CONC. ppm	INITIAL SPAN ppm	FINAL SPAN ppm	INITIAL ZERO ppm	FINAL ZERO ppm	INITIAL ZERO % DIFF. FULL SCALE	INIT. SPAN % DIFF.
12/5	43.28	43.7	43.3	-.3	0	-.6	0.97
12/6	43.28	43.2	43.2	0	0	0	-0.18
12/7	43.28	43.0	43.2	-.1	0	-.2	-0.65
12/8	43.28	44.0	43.3	.1	0	.2	1.66
12/9	43.28	42.6	43.2	-.1	0	-.2	-1.57
12/10	43.28	43.7	43.3	-.1	0	-.2	0.97
12/11	43.28	43.7	43.3	0	0	0	0.97
12/12	43.28	43.7	43.2	-.2	.1	-.6	0.97
12/13	43.28	42.9	43.3	0	0	0	-0.88
12/14	43.28	43.7	43.3	-.1	0	-.2	0.97
12/15	43.28	43.7	43.3	-.4	0	-.8	0.97
12/16	43.28	42.55	43.25	0	0	0	-1.69
12/17	43.28	43.55	43.25	-.05	0	-.1	0.62
12/18	43.28	43.4	43.4	-.05	0	-.1	0.28
12/19	43.28	43.3	43.3	.1	0	.2	0.05
12/20	43.28	44.05	43.25	-.1	0	-.2	1.78

$$\text{Zero \% difference F.S.} = \frac{\text{[Initial Zero Response (ppm) - 0 ppm]}}{\text{Analyzer Full Scale (50 ppm)}} \times 100$$

$$\text{Span \% difference} = \frac{\text{(Initial Span - Span Concentration)}}{\text{Span Concentration (43.28 ppm)}} \times 100$$

Reference: Montana Air Quality Bureau Quality Assurance Manual

TABLE 7

DAILY PRECISION CHECKS ON THE SATURATION STUDY CO ANALYZER

DATE	REFERENCE CONC. PPM	INITIAL RESPONSE PPM	FINAL RESPONSE PPM	INITIAL PERCENT DIFFERENCE
12/5	9.23	9.2	9.0	-0.3
12/6	9.23	9.2	9.1	-0.3
12/7	9.23	9.2	9.1	-0.3
12/8	9.23	9.0	9.2	-2.5
12/9	9.23	9.2	8.9	-0.3
12/10	9.23	9.1	9.1	-1.4
12/11	9.23	9.1	9.1	-1.4
12/12	9.23	9.1	9.1	-1.4
12/13	9.23	9.2	9.1	-0.3
12/14	9.23	9.1	8.9	-1.4
12/15	9.23	8.95	8.95	-3.0
12/16	9.23	9.05	8.95	-2.0
12/17	9.23	8.9	9.15	-3.6
12/18	9.23	9.2	9.15	-0.3
12/19	9.23	9.2	9.2	-0.3
12/20	9.23	8.95	8.8	-3.0

$$\text{Percent Difference} = \frac{\text{Initial Response - Reference Conc.}}{\text{Reference Concentration}} \times 100$$

Reference: Montana Air Quality Bureau Quality Assurance Manual

Laboratory Duplicates

Two or three laboratory duplicates were analyzed during each analysis session. During a session, all samples from the previous day were analyzed so that the sample bags could be ready for the next day. Bags selected for reanalysis were at least 90% full. After half the bag had been analyzed, the bag was set aside and reanalyzed later in the analysis session. Of the 46 duplicates run, only three of the bags varied by more than 0.1 ppm from their initial analysis. These three bags varied by .15, .2 and .3 ppm, a variance that is not significant. The Dasibi 3003 carbon monoxide analyzer was stable through the analysis session.

Laboratory Accuracy

On December 16, 1992, the Montana Air Quality Bureau conducted performance audits on the Dasibi 3003 used to analyze the bag samples and on the MFJ continuous analyzer. The percent difference full scale was -0.2% for the saturation study analyzer and +3.8% for the compliance continuous CO analyzer. A copy of the audit reports can be found in Appendix E. The laboratory precision and accuracy limits were more stringent than the precision and accuracy limits allowed for compliance continuous CO analyzers.

STUDY PROBLEMS AND RECOMMENDATIONS

Several problems were noted during this study which resulted in data loss. The major causes of lost data were faulty pump modules, cold weather, and leaking bags.

For instance, pump number 234 started blowing fuses on the first night of the study. By the time this pump was completely repaired, four days of data had been lost at a downtown site. Pump number 231 refused to pump in cold weather, so five of the first six days at the residential co-located site were lost before a replacement pump reached Missoula. Three samples were lost because pump 365 at site 2d drained the battery over night. Several of the newer pumps had problems with their clocks and pulse settings. Both pump 361 and pump 363 switched themselves to continuous pump mode occasionally. Availability of spare pumps could have dramatically improved data collection.

One of the reasons that data collection was low on the first two days of the study was low temperatures. Climatological data can be found in Appendix A. When temperatures dropped below zero degrees Fahrenheit, many of the pumps lost efficiency or did not work at all. One possible explanation is that in lower temperatures there is more friction present and this stops or reduces the pump efficiency. The pumps varied widely in their reaction to being calibrated in a +70 degree Fahrenheit room and then operated in a below zero degree Fahrenheit environment.

Another problem that occurred, possibly intensified by the cold weather, was that many of the bags developed leaks in their top corners. It appeared these leaks resulted from crinkling or pinching of the bags when the plastic bar was pushed through the bag module. These leaks could be prevented by pushing the bag to the side with a finger when the plastic bar came through the second hole of the bag module.

CONCLUSIONS

The intersection of Brooks, Russell, and South Avenue, known as Malfunction Junction (MFJ), does have the highest concentrations of carbon monoxide in Missoula. MFJ had the highest CO concentrations 12 out of 16 days of the study and all six samplers at MFJ had higher averages than the other sampling sites. Continued development in the MFJ area and Missoula's street layout encourages people to use this intersection. As a result, MFJ still has the highest CO concentrations in the air stagnation zone. But this may change when MFJ is redesigned in a couple of years.

It is not clear which street leg of MFJ has the highest CO concentrations. Sampler 2f has the highest average at 4.55 ppm while 2d has the highest reading at 9.4 ppm for the entire study. Another possible location for the highest CO concentrations would be MFJ 2c with a study average of 4.29 ppm and a high reading of 8.9 ppm.

The microscale air quality at sites 11 and 12 on Reserve

Street may improve in the near future because road work being done on Reserve Street will be completed. While the study was taking place, road construction often caused long lines of traffic to form at the study intersections. When construction is finished, traffic flow will improve and there should be fewer idling cars on Reserve Street. But, if more cars use Reserve Street after the repairs are finished, the improved effects on CO concentrations may be offset by more traffic. Also, instead of making vehicles wait in block long single file lines like they did during the study, they will wait at the stop light two or three abreast once the road work is done. This may increase the microscale CO concentrations at the intersection. Hence, when another CO study is done in Missoula, this intersection should be included.

Carbon monoxide concentrations were always higher at the intersection locations than at the residential sites. This verifies that most CO in Missoula comes from automobiles and that the high CO concentrations tend to be localized near high ADTE intersections. With increased wood stove regulations, residential wood burning is not the major contributor to CO concentrations that it once was.

From a strictly technical view point, the "fixing" of MFJ so that Missoula no longer violates the CO standard is very doable. It is just a matter of redesigning the intersection so that traffic can move through at a quicker pace or using cleaner burning fuels. But solutions like this, which can

have great impact on specific pollutants or locations, do little or nothing to reduce the rapid use of non-renewable resources. There is also the danger that a specific solution, like redesigning MFJ, may create other problems by promoting more traffic and development in a dispersed pattern.

One project currently being considered to alleviate CO concentrations at MFJ is a redesigning of MFJ. Some proposed solutions are an overpass or underpass for Brooks, a roundabout for MFJ, a restructuring of the street network for Missoula south of the Clark Fork River, and reducing traffic by using alternate modes of transportation such as mass transit.

Another way to potentially reduce CO levels at MFJ is to prohibit people from idling their cars at the intersection while they wait for the lights to change. Before this type of solution is implemented though, the actual amount of CO reduced from this should be estimated in some logical manner. For instance, if most CO is emitted when cars are accelerating or decelerating, having people idle may have minimal impact.

Looking at a larger area than MFJ, there is a possibility that as the Missoula Valley experiences more growth, other intersections such as South and Reserve or Third and Russell may begin to exceeed the CO standard. To prevent this, Missoula will need to control future growth so that other intersections do not become oversaturated. Some ways to control growth so that more compact development is encouraged

are through zoning and/or economic incentives. By promoting more compact development, fewer vehicle miles need to be traveled, bikes become a more viable form of transportation, and less total pollution would be generated.

Two other ways to reduce pollution over the long term are through education and through development of a master road system plan for the Missoula Valley. Education is important because if people don't understand the reasons for and methods behind pollution reduction, they are less likely to support and take actions that reduce pollution. A master road plan should be developed so that traffic flows smoothly on the arterial streets and so that another MFJ is not created. When creating a road plan, minimizing air pollution and promotion of compact growth should always be primary goals.

APPENDIX A

CLIMATOLOGICAL DATA FROM THE NATIONAL WEATHER SERVICE

Station WSO, Missoula, Montana

December, 1992

Preliminary Local Climatological Data (WS Form: F-6)

Station: WSO, Missoula, MT
Month: December, 1992

Temperature is given in degrees Fahrenheit.
Precipitation is given in inches of water.
Wind Speed is given in miles per hour.
WIND Max is the peak gust of wind recorded for that day.

	TEMPERATURE			WIND			
DATE	Max	Min	Avg	Max	Avg	Dir	PRECIP.
5	11	-8	2	14	3.6	SE	0.00
6	14	-5	5	7	1.3	E	0.00
7	20	-3	9	10	3.5	NW	0.02
8	34	17	26	16	4.8	SE	0.03
9	38	15	27	29	7.8	W	TRACE
10	36	16	26	31	10.1	SE	0.08
11	34	7	21	17	3.8	W	TRACE
12	24	8	16	9	2.6	SE	TRACE
13	26	13	20	9	2.8	W	0.00
14	33	23	28	25	5.0	NW	TRACE
15	32	17	25	18	7.2	NW	TRACE
16	27	13	20	32	7.5	E	TRACE
17	28	15	22	24	9.7	E	TRACE
18	26	4	15	26	7.1	W	0.03
19	21	9	15	09	3.2	NW	TRACE
20	37	17	27	31	5.8	W	0.02

Average temperature for the month was 19.5 degrees Fahrenheit. Departure from norm was -5.4 degrees. Highest temperature was 43 degrees on December 23 and December 24. Lowest temperature was -8 degrees on December 5.

Total precipitation for the month was 0.78 inches. Departure from normal precipitation for the month was -0.43 inches.

GTFCLMMSO
TTAA00 KMSO 011546
WEATHER SUMMARY FOR MISSOULA MT FOR DECEMBER, 1992.
NATIONAL WEATHER SERVICE FOR MISSOULA MT.
10 AM MST FRIDAY JANUARY 1 1993.

3	CLEAR DAYS
6	PARTLY CLOUDY DAYS
22	CLOUDY DAYS

WEATHER-NUMBER OF DAYS WITH:

0.01 INCHES OR MORE PRECIPITATION	11
0.10 INCHES OR MORE PRECIPITATION	3
0.50 INCHES OR MORE PRECIPITATION	0
1.00 INCHES OR MORE PRECIPITATION	0

December weather was colder then average and drier then average.

The month of December started off much colder than normal with the first below zero temperatures in two years. Temperatures warmed to above normal over the Christmas week and then arctic air moved back in for the end of the year.

As the year ended Missoula had another below normal year for precipitation. The total precipitation for the year was 11.60 inches which was 1.69 inches below normal.

APPENDIX B

1992 CARBON MONOXIDE STUDY DATA AND SAMPLER LOCATIONS

TABLE 8

1992 CARBON MONOXIDE SATURATION STUDY SUMMARY
DECEMBER 5 THROUGH DECEMBER 20
MISSOULA, MONTANA

SITE	12/5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	# of 8 hr Samples	Site 8 hr Maximum	Site Average
1a	2.0	3.0	3.5	2.9	3.0	2.6	4.7	3.7	2.3	2.2	2.9	1.3	2.6	1.6	3.1 C	0.7	15	4.7	2.60
2a	3.2	3.6	4.8	4.8	4.2	3.7	6.2 C	3.0 C	3.7	4.3 C	ND	1.2 C	3.0 C	3.6	4.2	3.2	10	4.8	3.90
2b	3.2	3.3	4.7	4.6	3.6	3.9	ND	ND	5.3 C	9.3 C	ND	ND	ND	3.4	3.9	3.4	9	4.7	3.78
2c	ND	4.3	3.6	3.9	3.4	4.2	8.9	4.1	3.5	5.1	5.6	3.0	3.9	3.6	4.7	2.6	15	8.9	4.29
2d	ND	ND	4.9	4.0	6.1	ND	9.4	3.2	2.9	4.0	3.6	3.6	3.6 C	1.8	5.0	1.1	12	9.4	4.13
2e	4.5	4.6	4.7	4.7	4.0	4.4	7.1	5.4	3.0	4.1	4.2	2.9	4.1	1.6	4.8	0.9	16	7.1	4.06
2f	4.9	4.8	5.8	5.7	4.6	4.6	7.2	6.3	ND	4.8	4.5	1.6	3.8	3.1	5.1	1.5	15	7.2	4.55
3a	ND	4.5	1.7	3.1	ND	3.9	7.7	3.2	2.0	2.8	2.6	3.3	4.2	1.3	4.0	0.6	14	7.7	3.21
4a	ND	3.9	3.1	3.8	ND	3.9	6.7	2.6	2.8	2.9	4.3	.8	2.2	1.8	4.3	1.1	14	6.7	3.16
5a	3.8	3.5	5.3	3.7	4.2	4.0	5.7	2.9	3.0	4.5	4.5	1.7	1.6	3.7	3.4	1.3	16	5.7	3.55
5b	ND	ND	ND	ND	3.6	4.4	5.8	3.4	2.5	3.7	2.4	3.1	3.3	1.8	3.8	0.7	12	5.8	3.21
6a	3.2	3.9	2.3 C	3.0	2.7	4.0	4.7	3.4	2.9	3.0	3.0	1.7	2.0	1.3	2.9	0.7	15	4.7	2.83

C = compromised data. Such data are not used for computations nor comparisons.
ND = No Data

1 = Brooks and Reserve
2 = Malfunction Junction (Brooks, South Avenue, and Russell)
3 = Brooks and Stephens
4 = Brooks and Higgins
5 = Higgins, South of Broadway (Mid block - street canyon affect monitoring)
6 = Broadway and Madison

TABLE 8 CONTINUED

1992 CARBON MONOXIDE SATURATION STUDY SUMMARY
DECEMBER 5 THROUGH DECEMBER 20
MISSOULA, MONTANA

SITE	12/5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	# of 8 hr Samples	Site 8 hr Maximum	Site Average
7a	ND	ND	2.8	2.4	1.9	3.8	4.1	2.7	2.9	2.7	2.7	1.9	1.6	1.6	2.7	0.9	14	4.1	2.48
8a	ND	2.7	2.3	2.9	3.2	3.1	3.9	2.2	1.8	2.0	1.8	3.4 C	ND	1.1	2.2	0.6	13	3.9	2.29
9a	1.6 C	2.9	2.9	2.8	3.2	ND	5.5	3.2	1.9	2.4	2.7	3.3	3.5	1.4	5.5	0.5	14	5.5	2.98
9b	1.9	2.9	2.8	3.0	4.7	4.1	4.3	2.5 C	1.9	3.2	3.2	1.8	2.6	1.5	2.7	1.1	15	4.7	2.78
10a	ND	ND	3.0	2.8	5.3	3.7	6.3	3.0	2.2	2.2	3.5	2.0	ND	1.4	3.5	ND	12	6.3	3.24
10b	ND	ND	3.2	3.7	5.2	4.0	7.4	3.1	3.8	3.3	4.4	0.5	2.7	3.2	ND	1.8	13	7.4	3.56
11a	ND	ND	ND	2.4	4.3	2.6	5.4	3.4	ND	ND	3.5	1.9	3.7	ND	2.7	1.1	10	5.4	3.10
12a	3.7	ND	2.9	2.6	4.4	ND	6.8	2.8	2.8 C	2.8 C	4.9	3.3	4.2 C	2.5	4.4	ND	10	6.8	3.83
13a	1.8	3.4	1.8	1.5	2.2	1.7	3.5	ND	1.4	1.0	2.3	0.9	1.9	0.8 C	2.5	0.6	14	3.5	1.89
14a	ND	ND	ND	2.4	ND	1.6	2.8	1.8	1.7	1.6	1.3	0.6	1.3	0.7	2.2	0.3	12	2.8	1.53
14b	1.6	2.0	2.2	2.3	1.0	1.6	ND	1.8	1.6	1.7	1.2	0.6	1.3	0.7	2.2	0.4	15	2.3	1.48
15a	2.1	3.6	2.0	1.6	1.7	1.4	4.4 C	2.0	1.6	1.0 C	1.7	0.3	1.6	0.6	1.8	0.3	14	3.6	1.59

C = compromised data. Such data are not used for computations nor comparisons.
ND = No Data

7 = Broadway and Van Buren
8 = Broadway and Orange
9 = Broadway and Russell
10 = Russell and Third Street
11 = Reserve and Third Street
12 = Reserve and South Avenue
13 = Grant and South 11th West
14 = Park and Fairview
15 = Boyd Park

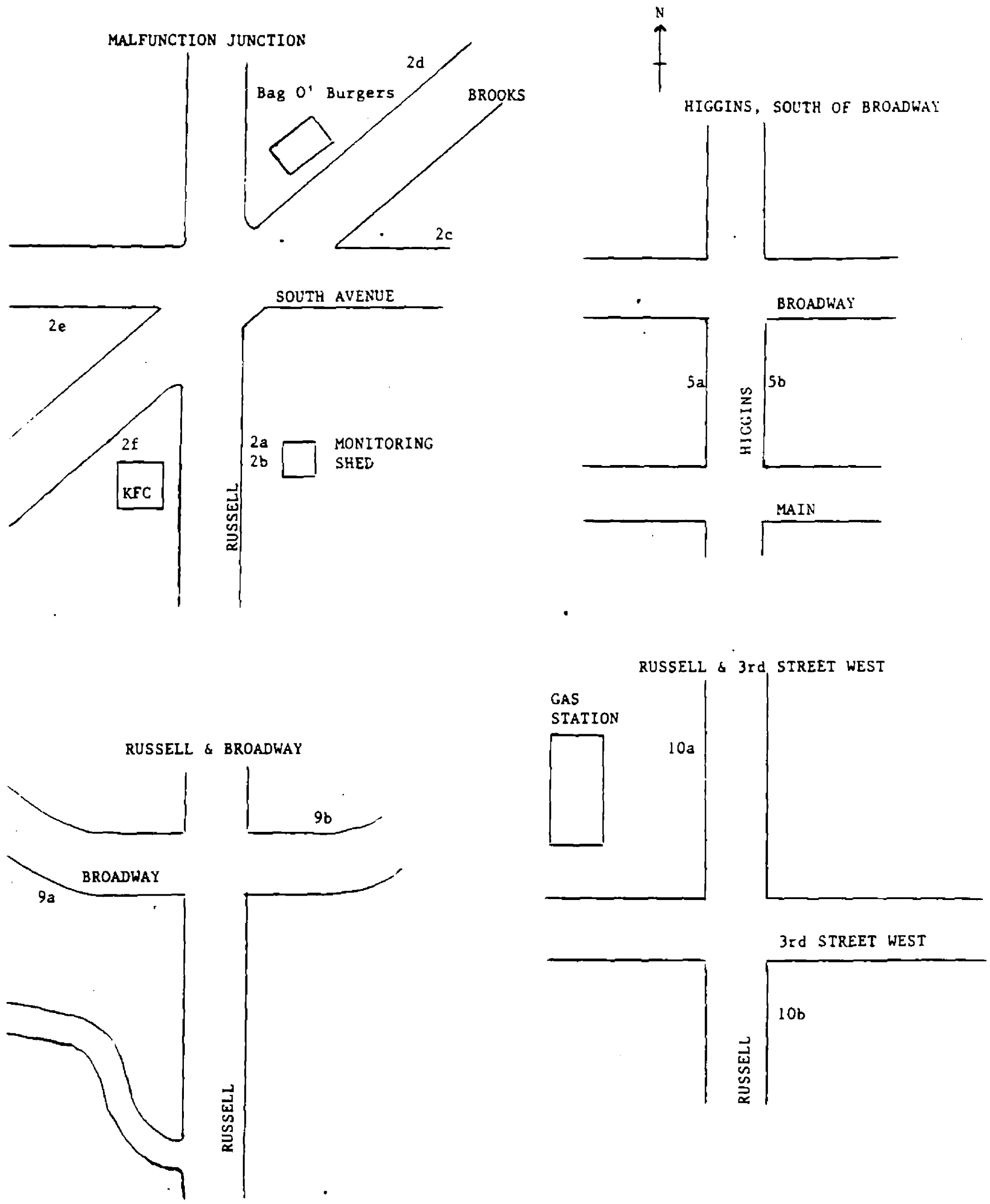
TABLE 9

CARBON MONOXIDE MONITOR LOCATIONS

SAMPLE LOCATION	SITE #	DISTANCE FROM TRAFFIC LANE (FEET)	DISTANCE FROM INTERSECTION (FEET)	CORNER
BROOKS and RESERVE	1	9	41	SW
MALFUNCTION JUNCTION	2a	18	63	S
MALFUNCTION JUNCTION	2b	18	63	S
MALFUNCTION JUNCTION	2c	9	83	SE
MALFUNCTION JUNCTION	2d	8	125	E
MALFUNCTION JUNCTION	2e	7	159	W
MALFUNCTION JUNCTION	2f	7	69	SW
BROOKS and STEPHENS	3	8	120	NW
BROOKS and HIGGINS	4	8	89	NE
HIGGINS, south of BROADWAY	5a	10	105	S
HIGGINS, south of BROADWAY	5b	10	105	S
BROADWAY and MADISON	6	14	63	SW
BROADWAY and VAN BUREN	7	14	134	SW
BROADWAY and ORANGE	8	17	115	SW
RUSSELL and BROADWAY	9a	10	195	SW
RUSSELL and BROADWAY	9b	12	150	NE
RUSSELL and THIRD STREET	10a	43	110	NW
RUSSELL and THIRD STREET	10b	14	59	SE
RESERVE and THIRD STREET	11	8	88	NW
RESERVE and SOUTH AVENUE	12	28	56	NE
GRANT and SOUTH 11th WEST	13	15	15	SE
PARK and FAIRVIEW	14a	7	20	NW
PARK and FAIRVIEW	14b	7	20	NW
BOYD PARK	15	CENTER OF	BLOCK	N.A.

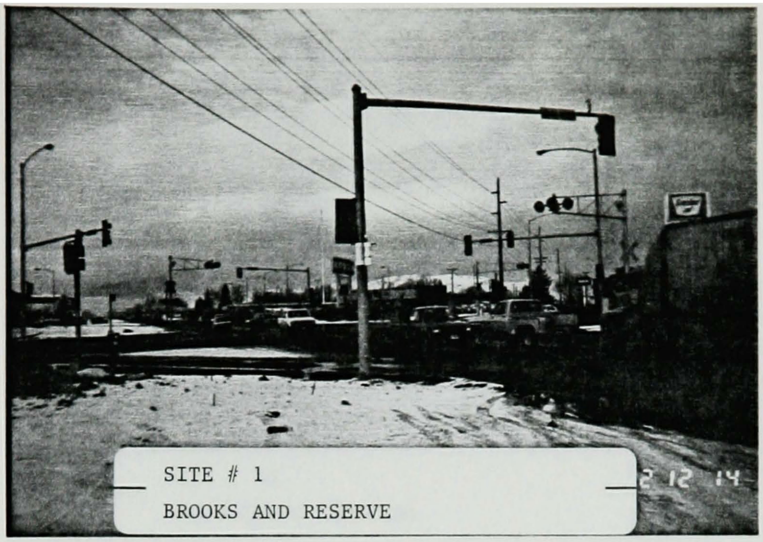
FIGURE 5

INTERSECTIONS WITH MULTIPLE MONITORS

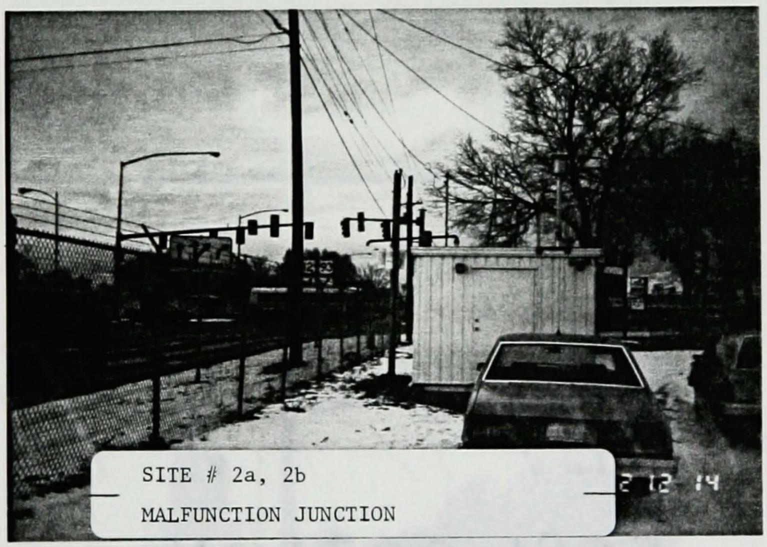


APPENDIX C

SITE PHOTOGRAPHS

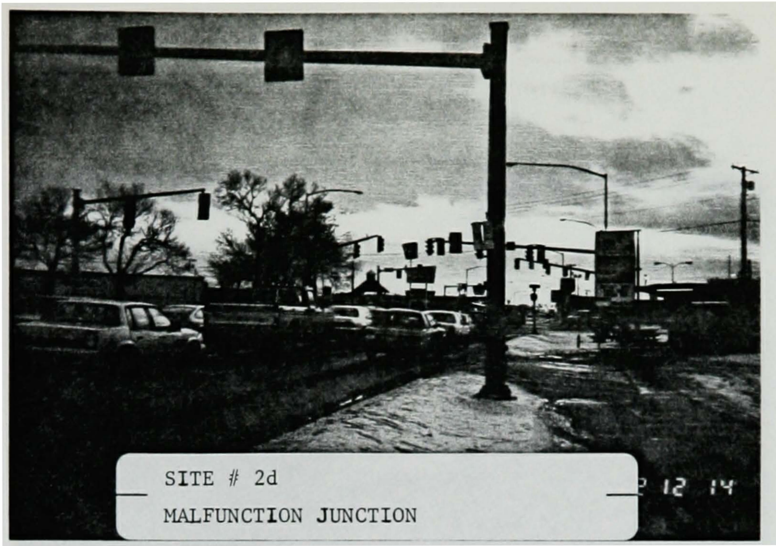


SITE # 1
BROOKS AND RESERVE

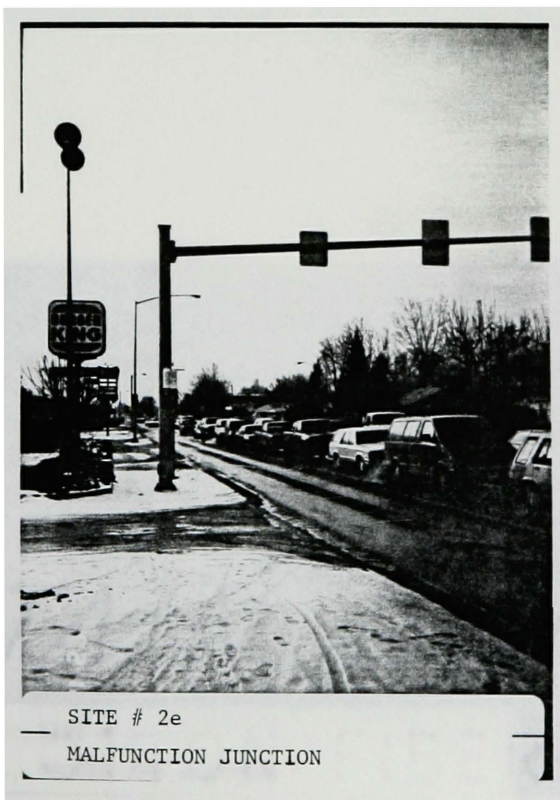


SITE # 2a, 2b
MALFUNCTION JUNCTION


SITE # 2c
MALFUNCTION JUNCTION



SITE # 2d
MALFUNCTION JUNCTION



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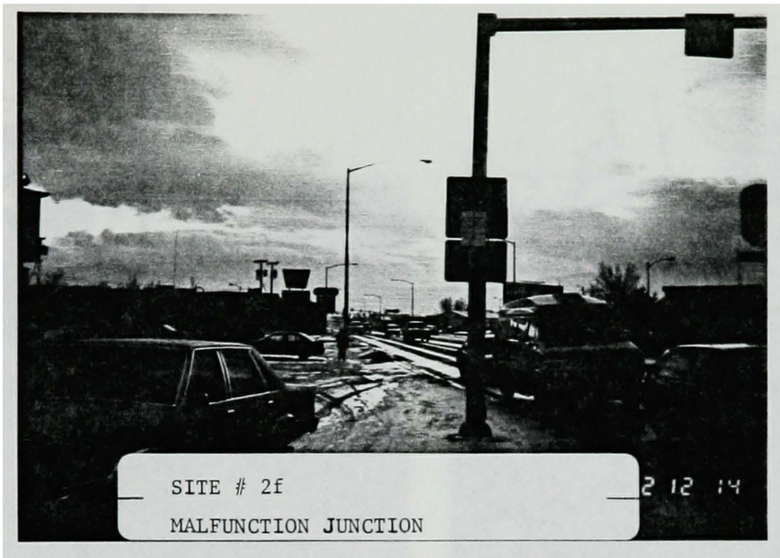
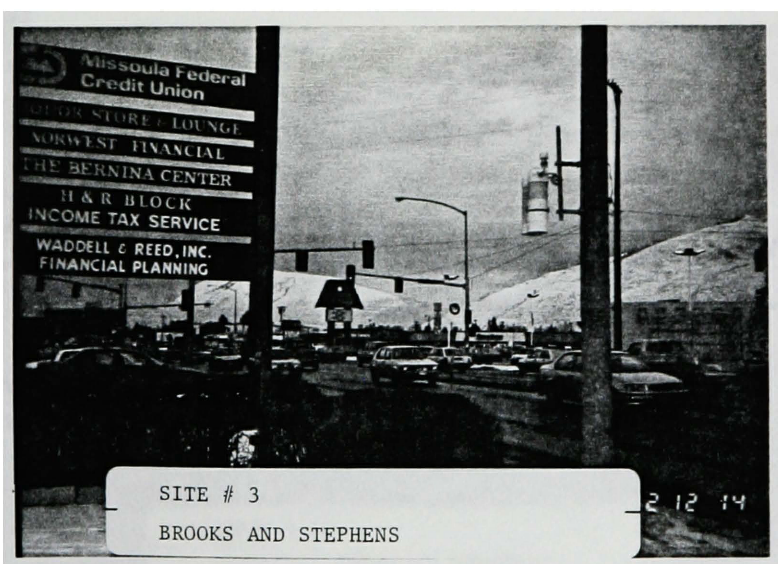
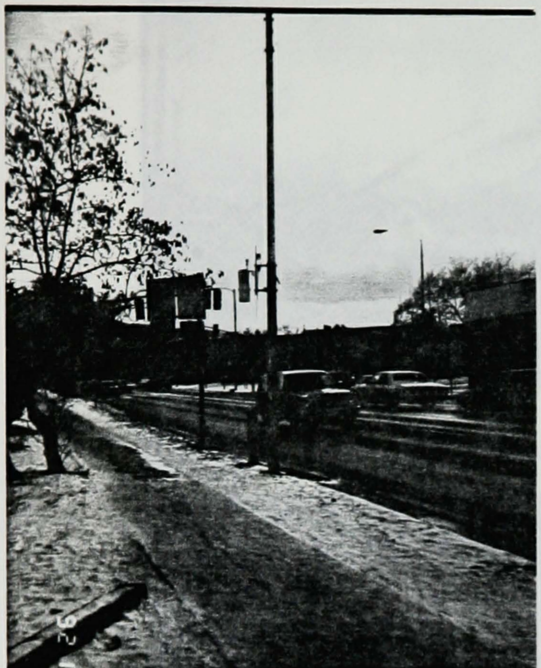
MALFUNCTION JUNCTION



SITE # 2f
MALFUNCTION JUNCTION

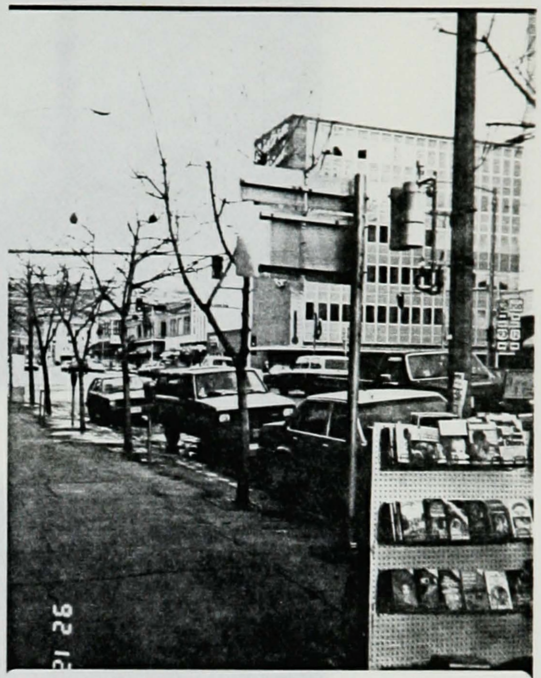


SITE # 3
BROOKS AND STEPHENS



SITE # 4

BROOKS AND HIGGINS

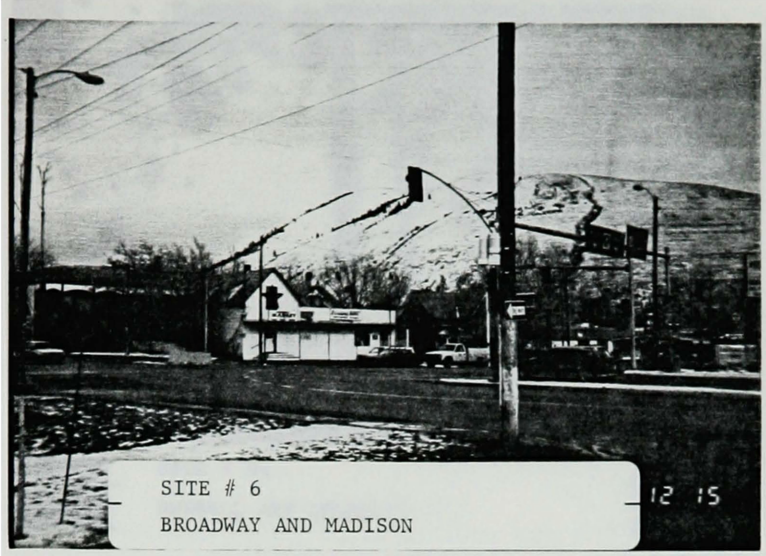


SITE # 5a

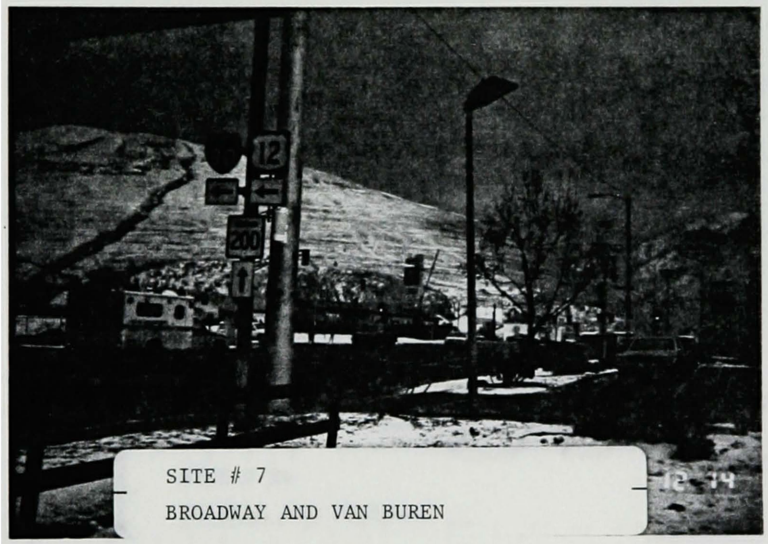
HIGGINS, SOUTH OF BROADWAY

SITE # 5b

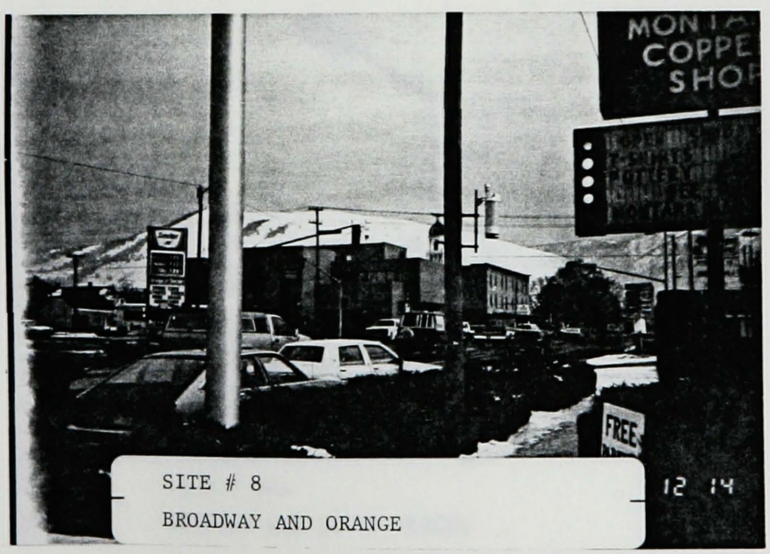
HIGGINS, SOUTH OF BROADWAY



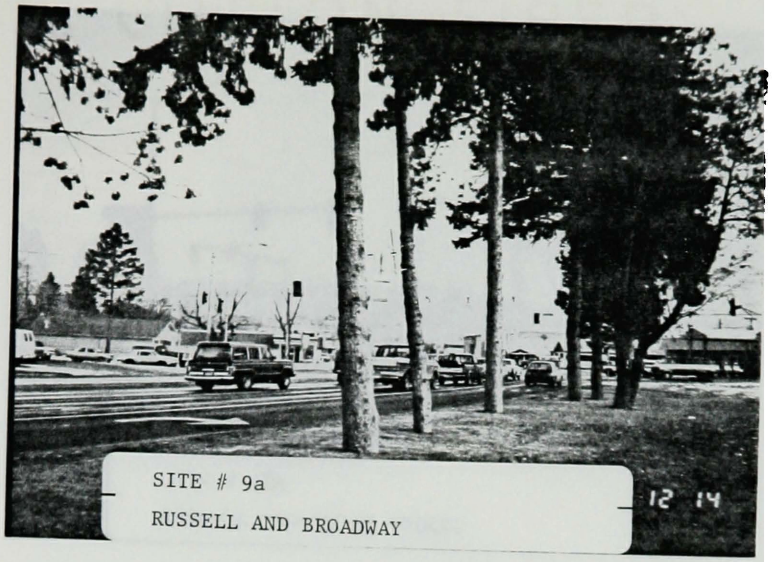
SITE # 6
BROADWAY AND MADISON



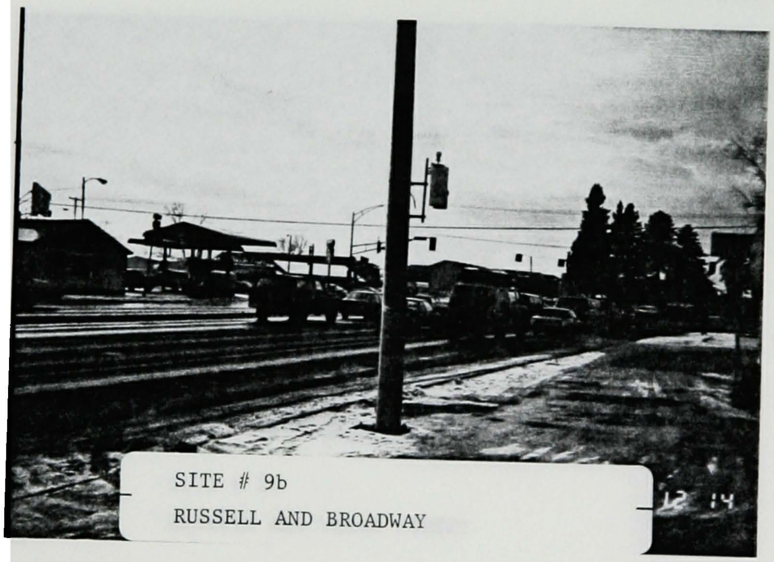
SITE # 7
BROADWAY AND VAN BUREN



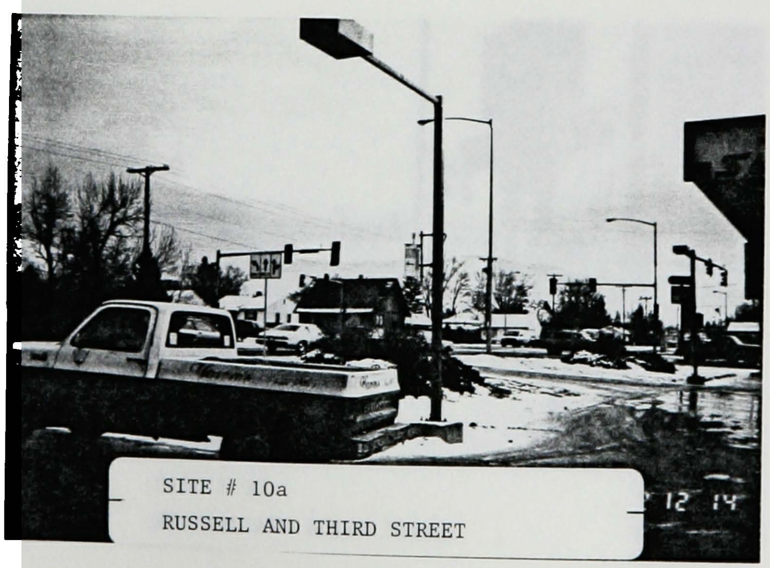
SITE # 8
BROADWAY AND ORANGE



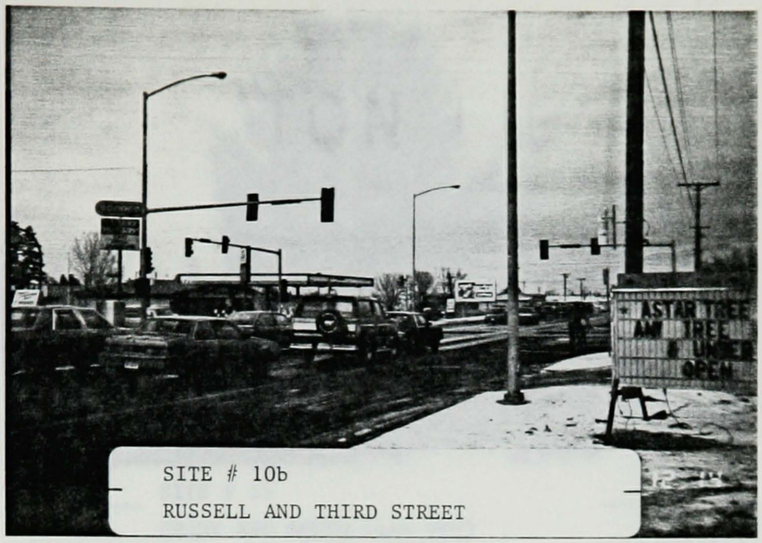
SITE # 9a
RUSSELL AND BROADWAY



SITE # 9b
RUSSELL AND BROADWAY

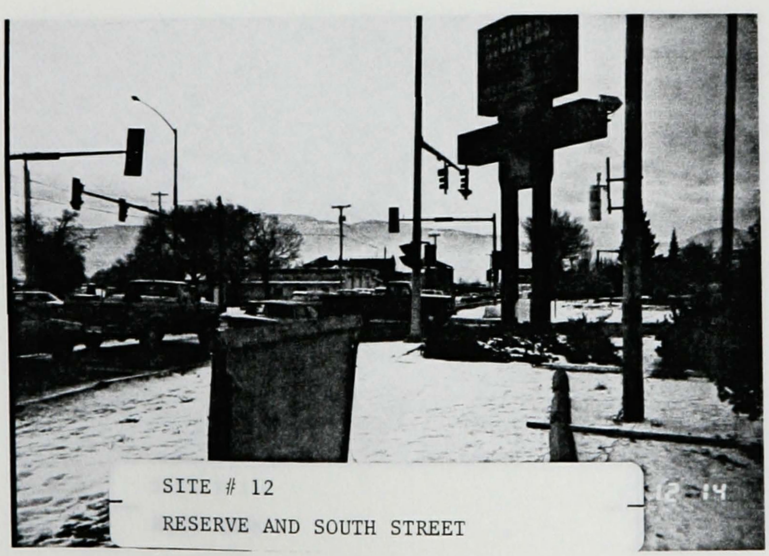


SITE # 10a
RUSSELL AND THIRD STREET

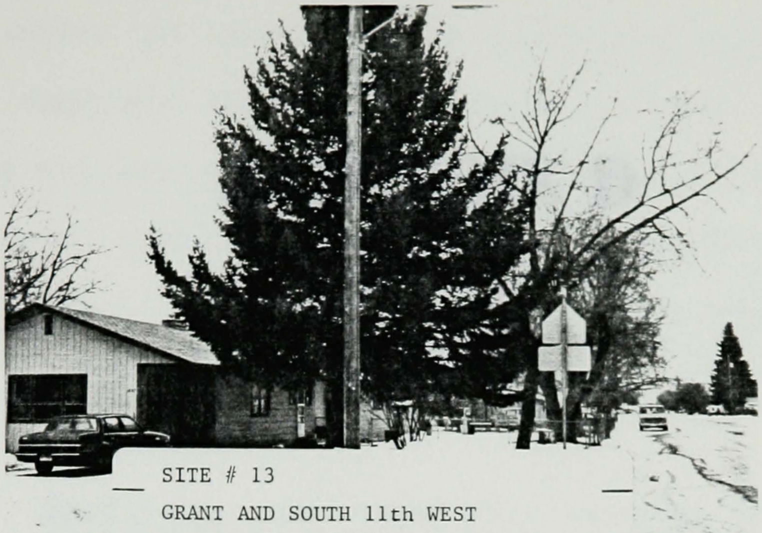


SITE # 10b
RUSSELL AND THIRD STREET

SITE # 11
RESERVE AND THIRD STREET

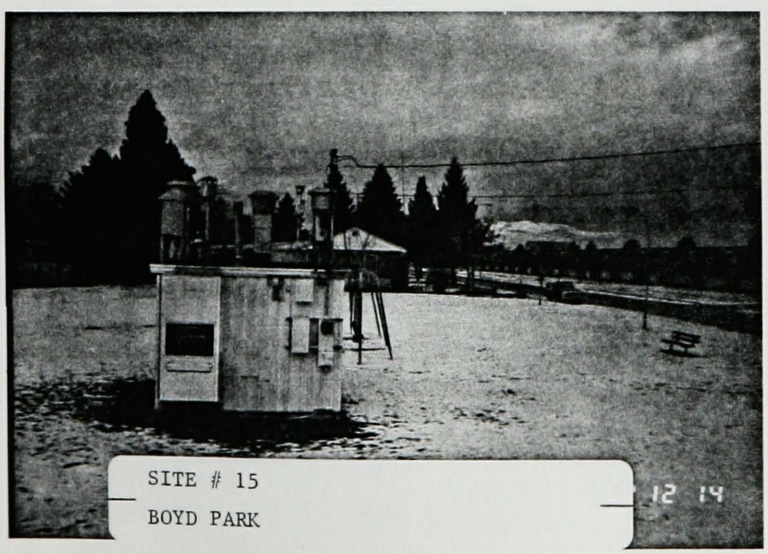


SITE # 12
RESERVE AND SOUTH STREET



SITE # 13
GRANT AND SOUTH 11th WEST

SITE # 14a, 14b
PARK AND FAIRVIEW



SITE # 15
BOYD PARK

APPENDIX D

QUALITY CONTROL, EQUIPMENT DESCRIPTIONS

AND

LABORATORY ANALYSIS METHODS USED

QUALITY ASSURANCE

In order to determine an effective Quality Assurance program, explicit objectives must be defined, documented and issued to all activities that affect the precision, accuracy, completeness, representativeness and comparability of the data (O'Neal, 1982). The objectives specific to this study are as follows:

1) Precision - Measures will be made of both sampling and analytical precision. Detailed protocols for these measures can be found in subsequent sections of this appendix. The objective for sampling and analytical precision is to apply controls sufficient to yield absolute differences less than or equal to 1.0 ppm.

2) Accuracy - Measures will be made of analytical and data processing accuracy. Detailed protocols relative to these measures are prescribed in subsequent sections of the appendix. Another quasi-measure of sampling accuracy will be performed and is discussed under the section on comparability. Two separate measures of analytical accuracy will be conducted: re-analysis audits of the samples and audits of the analyzer performance itself. The objective for the re-analysis audit is not to exceed a difference in concentration of more than 1.0 ppm. The objectives for analytic accuracy is identical to that for analytical precision described previously.

3) Completeness - The objective for data completeness is to retrieve valid data for 85 percent of the attempts.

4) Representativeness - A prime objective of the study is to investigate the representativeness of the existing permanent monitoring site. The quality assurance objective for representativeness is to ensure that data are generated from sites which are configured uniformly with respect to the physical placement of probe inlets.

5) Comparability - The objective for comparability is to standardize both the method of sample analysis and the form and units in which data are presented to facilitate their accurate and appropriate comparison.

LABORATORY INSTRUMENTATION

A Dasibi 3003 Carbon Monoxide analyzer will be used in the laboratory to analyze the bag samples. The Dasibi is a gas filter correlation (GFC) infrared analyzer, designed by USEPA as a reference method for measurement of ambient air concentrations of CO specified as RFCA-0381-051.

For additional information regarding the principle of operation of the Dasibi 3003, installation instructions, gas sampling requirements, electrical connections, recorder connection, operation of the front panel controls and indicators, as well as diagrams of the optical and electrical systems, consult the operation manual which is supplied with the instrument.

EQUIPMENT INVENTORY/ACCEPTANCE TESTING AND INSTALLATION

Bag Samplers

Upon receipt, the bag samplers and the corresponding equipment will be inspected, logged onto an inventory form and if appropriate, tested for acceptable integrity and/or gross performance. Upon receipt of these samplers, the following procedure should be initiated:

1. Unpack and verify that all component parts were received.
2. Log items onto inventory form.

3. Physically inspect items for any damage incurred during shipment.

4. Physically test the integrity of all fastened components, and correct if necessary.

5. Test pump operation including the pulse rate potentiometer.

6. Fill sample bags to 90% of capacity and subject to below water immersion or overnight leak-down test to check bag integrity.

The support brackets from which the bag samplers will be suspended will be installed using the necessary tools and following the appropriate mechanical protocol. The type of bracket (chimney TV antenna clamps or gutter mounts) used at each site shall be predicated by the diameter of the pole which fulfills the siting criteria.

Dasibi 3003 CO Analyzer

The Montana State Air Quality Bureau will supply and install a Dasibi 3003 Carbon Monoxide monitor at MFJ. When the instrument reaches Missoula it will be visually inspected for damage and loose parts. If no damage is evident, the instrument will be ready to operate.

CALIBRATION

Calibration of the bag samplers

The pumps will be calibrated by two criteria. The first is sample volume. The sampler contains a rotameter which indicates the flow while the pump is operating. A

potentiometer can be adjusted until the desired volume is achieved on the rotameter. The second item is calibration of the sample frequency (pulse rate). This will be accomplished by using a stop watch and timing the difference between initial and final pulses. A potentiometer will be adjusted until the correct pulse rate is achieved. All samplers will be tested in the laboratory to assure correct operation and the results will be recorded in the gross operation column of the inventory form.

Frequency - The pulse pumps will be calibrated prior to the commencement of the sampling study as well as following any major repair.

Procedure - The theory of bag sampling requires the pumping of a sample of air into a bag at a constant rate without filling the bag to capacity. Based on this theory, flow meters are not required. The following protocol should be followed to calibrate the pump rate of each pump:

1. Note number of pump on pump inventory form.
2. Install fresh batteries to the pump.
3. Turn pump on and allow it to operate for five minutes to warm up and stabilize. Then adjust pulse rate potentiometer to pulse once per 25 seconds.
4. Time five consecutive intervals between pulses, calculate and note the average.
5. Connect pump to sample bag.

6. Inspect bag every 2 hours for the next 6 hours and estimate percent of bag filled. If bag is obviously overfilling, return to step three and adjust flow potentiometer.

7. At the conclusion of 8 hours, note percent of bag filled in the gross operation column of the inventory form. Ideally, bags should be filled to approximately 75% to allow for possible bag expansion. Adjustments to the flow potentiometer may be necessary to bring the sample volume into the appropriate 60-80% range.

8. Label each pump with calibration date and pulse rate.

Calibration of the Dasibi 3003 CO Analyzer

The Dasibi 3003 CO Analyzer will be calibrated no earlier than two weeks prior to the commencement of the saturation study and after any major repairs. Initial calibration will be done by the Missoula City-County Health Department Staff.

Calibrating the instrument involves a complete multipoint definition of the analyzer's response to accurate, reliable standards over the entire analyzer range. Such calibrations must be performed dynamically, allowing the analyzer to measure in its normal mode of operation, air containing known concentrations of CO. We will use a single cylinder of CO, certified according to EPA protocol 2, diluted as necessary with zero air, aero air has no measurable concentration of CO, to obtain the various calibration concentrations needed.

The Dasibi 3003 CO Analyzer referenced in the section above will be calibrated in concert with the protocol described in the EPA approved Montana Air Quality Bureau Quality Assurance plan.

CONTROL CHECKS

Bag Samplers

1. Upon completion of the eight hour sample the bag collector inspects the bag in the field for sample volume, noting percent of bag filled on the route worksheet. If the bag is filled to less than 50% capacity the collector should ensure that the pump is still delivering sample. If the pump is still delivering sample, then the bag should be tested for leaks.

2. Before the sample in the bag is analyzed, the sample analyst should check the bag's volume against the volume noted in the field.

3. The quick disconnect fitting shall be inspected daily for signs of brittleness and fatigue in which event it should be replaced. Sample and pump tubing should be inspected for cleanliness and fastener integrity and remedied when necessary.

4. The pump rate should be noted each time a sample is deployed and retrieved on the route worksheet. If, at the daily changeout, the pump is either found to be malfunctioning or has otherwise dropped more than 15% in pulse rate, it should either be replaced with a calibrated pump or readjusted.

Dasibi 3003 CO Analyzer

To ensure that the Dasibi is operating within parameters, a zero check, a precision check, and a span check will be done each day of the study before samples are read. A precision check will also be done after all samples have been read for the day.

The checks will be carried out by the Missoula City-County Health Department (MCCHD) staff, who will receive training from the Montana Air Quality Bureau.

QUALITY CONTROL/ASSURANCE

Precision and Accuracy

Zero, span, and precision checks (zsp) will be run every day before bag analysis begins. Recalibration of the CO analyzer is needed before the bags are analyzed when the unadjusted results of the zsp check exceed the control limits of $\pm$ 2% full scale, $\pm$ 10% and $\pm$ 12%, respectively. The zero is checked and the analyzer adjusted to read zero, if needed. Then a span point is run and if needed, the analyzer is adjusted to read the actual span concentration. Finally the precision check is run, the result recorded, and the bags are analyzed. After all the bags have been run, the operator performs a final precision check.

The source of CO for the checks will come from a single cylinder of CO that has been certified according to EPA protocol 2, diluted as necessary with zero air to provide the desired CO concentrations.

Field duplicates will be collected using co-located bag samplers. There are no limits on the number of field duplicates and they will be used to comment on the precision of the study.

Field accuracy will be assessed by comparing the values of two bag samplers collocated with the continuous monitor run by the MCCHD.

One of every nine samples collected will be re-analyzed. The objective is to not exceed a difference in concentration

of 1 ppm.

Audits

At least once during the duration of the CO saturation study, the Montana Air Quality Bureau will perform an audit of the Dasibi CO analyzer using test atmospheres traceable to the National Institute of Standards and Technology.

LABORATORY ANALYSIS METHOD

This method covers the determination of carbon monoxide in ambient air samples collected using a bag sampler method. The approximate working range for the analysis is 0 ppm to 50 ppm CO in air.

Samples are collected in tedlar bags and remain stable for at least 2 days after collection. We plan daily analysis so that bags can be reused in the field the following day.

Apparatus - Dasibi model 3003 CO analyzer
Soltech 1241 strip chart recorder
EESI model 3000 Gas Calibrator
Digital Volt Meter
Teflon tubing

Reagents - A cylinders of carbon monoxide certified according to EPA Protocol 2 to be used for calibration, span, and precision checks. Self generated zero air and dilution air from an EESI 3000.

Procedure

1. Leave the Dasibi analyzer with power on for the duration of the saturation study. The analyzer will be multipoint calibrated not more than two weeks before the start of the study. Zero, span, and precision checks will be done each day before analysis to assure proper performance.

2. On the analysis worksheet, record the rotameter setting along with zero and span potentiometer settings. Start the chart recorder.

3. Using the EESI 3000 Gas Calibrator, introduce zero gas into the analyzer and wait for a stable reading. Repeat for span and precision gases using the EESI 3000 and the certified cylinder of CO gas. On the recorder strip chart, record the date and time, label the zero, span, and precision peaks as well as each sample peak. Also, note the Digital Volt Meter reading for each peak on the chart.

4. Record the approximate bag volume on the analysis worksheet, and then compare with the recorded field volume. If volumes differ by more than 10%, analyze the sample and then check bag for leaks using the previously mentioned procedure.

5. Connect the sample bag to the analyzer inlet and allow the instrument to pull sample from the bag until a stable reading is obtained or the bag is empty. Record the digital volt meter readings and the % chart on the strip chart. Disconnect the bag from the inlet and allow the reading to return to base line before connecting the next sample bag.

6. Analyze nine samples following procedures 4 and 5. Choose one of the nine bags for a duplicate analysis and analyze this as the tenth sample. Analyze one duplicate for every ten samples analyzed. Perform a precision check at the end of analysis.

APPENDIX E

MONTANA AIR QUALITY BUREAU AUDIT REPORTS

Continuous Audit Report
12-16-92

Site: Missoula Saturation

Operator: Ben Schmidt

Audit Calibrator: EESI 3000-116022
Audit Cylinder: #JJ18983
Audit Concentration: .1930 ppm

Parameter: co
Instrument: Dasibi 3003-028
Range : 0 - 50 ppm

Range	% Chart	Volts	Audit Conc.	Station Conc.	% Diff
0	3.7	-0.013	0.000	-0.600	-1.2% FS
3.0-8.0	17.4	0.124	6.810	6.400	-6.0%
15.0-20.0	36.1	0.308	15.900	15.700	-1.3%
21.0-34.0	63.4	0.580	29.460	29.300	-0.5%
40.0-45.0	86.2	0.808	40.920	40.700	-0.5%

Regression Analysis:

Slope : 1.004965

Intercept : -.3630352

Correlation Coef: .9999852

Slope % Difference: .496459

Intercept % Difference: -0.73

% Difference Full Scale: -0.2

Auditor: Robert K. Jeffrey - AQB Ambient Monitoring & QA Coordinator

Montana AQB Criteria for Acceptable Audit Results:

% Difference Full Scale and % Difference Each Point	Linear Regression Slope (% Difference From Unity)
Excellent < ± 10%	Excellent ≤ ± 5%
Satisfactory < ± 15%	Satisfactory ≤ ± 15%
Unsatisfactory ≥ ± 15%	Unsatisfactory > ± 15%

Linear Regression Correlation Coefficient (r)	Linear Regression Y-Intercept (% of Analyzer Range)
Satisfactory ≥ 0.995	Satisfactory ≤ ± 3%
Unsatisfactory < 0.995	Unsatisfactory > ± 3%

Continuous Audit Report
12-16-92

Site: Missoula - MFJSE

Operator: Ben Schmidt

Audit Calibrator: EESI 3000-116022
Audit Cylinder: #JJ18983
Audit Concentration: 1930 ppm

Parameter: CO - 42101
Instrument: Dasibi 3003-615
Range : 0 - 50 ppm

Range	% Chart	Volts	Audit Conc.	Station Conc.	% Diff
0	5.1	+0.002	0.000	+0.500	+1.0% FS
3.0-8.0	18.7	0.135	6.810	7.150	+5.0%
15.0-20.0	37.3	0.325	15.900	16.400	+3.1%
21.0-34.0	65.5	0.605	29.460	30.500	+3.5%
40.0-45.0	90.0	0.852	40.920	42.550	+4.0%

Regression Analysis:

Slope : 1.038391
Intercept : -1.594544E-02
Correlation Coef: .9999801

Slope % Difference: 3.839064
Intercept % Difference: -0.03
% Difference Full Scale: +3.8

Auditor: Robert K. Jeffrey - AQB Ambient Monitoring & QA Coordinator

Montana AQB Criteria for Acceptable Audit Results:

% Difference Full Scale and % Difference Each Point

Excellent < ± 10%
Satisfactory < ± 15%
Unsatisfactory ≥ ± 15%

Linear Regression Slope (% Difference From Unity)

Excellent ≤ ± 5%
Satisfactory ≤ ± 15%
Unsatisfactory > ± 15%

Linear Regression Correlation Coefficient (r)

Satisfactory ≥ 0.995
Unsatisfactory < 0.995

Linear Regression Y-Intercept (% of Analyzer Range)

Satisfactory ≤ ± 3%
Unsatisfactory > ± 3%

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