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CARBON MONOXIDE (CO) SATURATION STUDY

Final Report (P.O #172634)

Prepared for:

Clark County
Department of Air Quality Management
Las Vegas, NV 89106

Prepared by:

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Pasadena, CA

April 1, 2002

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EXECUTIVE SUMMARY

CARBON MONOXIDE (CO) SATURATION STUDY

Study Purpose

The Clark County, Nevada, Department of Air Quality Management (DAQM) contracted a "saturation" study to measure carbon monoxide (CO) throughout the Las Vegas Valley. The Study was performed during the seasonal period historically experiencing CO levels that exceeded the 8-hour National Ambient Air Quality Standard (NAAQS). The purposes of the Las Vegas CO Saturation Study were to:

- Identify geographic patterns of CO concentrations, including potential areas with higher concentrations not previously known
- See if the DAQM routine CO monitoring station locations are representative of areas with higher CO occurrences in the Valley, and
- Improve the conceptual understanding of the relationship between land use, meteorology, and ambient CO concentrations.

Summary of Carbon Monoxide Saturation Study Sampling

The Study began with a network of 32 continuous CO samplers operating throughout the Las Vegas Valley. Stations were added during the program to refine the spatial distribution of higher concentrations, ending with 63 stations. A mobile van equipped with an EPA equivalent CO analyzer and a sophisticated position recording system operated during two Intensive Operating Periods when higher CO concentrations were likely to occur. An extensive quality assurance program adds credibility to the results. This extensive sampling and quality assurance program provided an effective "saturation" of the Valley producing the data needed to fulfill the purposes of the Study.

Summary of Results

The primary result of the Study is that the DAQM CO monitoring station locations are representative of the higher CO concentrations in the Valley. In summary:

- The highest 8-hour average CO concentration observed in the Saturation Study network of sites occurred in a residential area near Eastern Avenue and Charleston Boulevard, a few blocks south of the DAQM Sunrise Acres monitoring station. The CO concentrations were comparable at both sites and well below the corresponding NAAQS of 9 ppm. Except for one downtown Study site purposely located with a definite micro-scale exposure, the higher 8-hour average concentrations all occurred in the area east of downtown Las Vegas near the DAQM Sunrise Acres monitoring station. **Figure 1** is a smoothed contour map plot of peak 8-hour average CO concentrations measured at the sites in the Saturation Study area. The DAQM CO monitoring station locations are also shown in Figure 1 depicting how the distribution of higher CO concentrations identified by the Saturation Study sampling was well-defined by six surrounding DAQM stations.

- Many of the Study sites with relatively high 8-hour CO averages were near the Eastern-Charleston-Fremont area in residential neighborhoods, away from the busier streets in the area. These occurrences were on cold nights with low wind speeds, which indicates low rates of atmospheric dispersion and probable accumulation of CO in the first 100 feet above ground level. Other parts of the Valley with apparently similar emission sources do not experience as high CO concentrations, suggesting the possibility of local meteorological features that tend to trap CO in this area. Traffic flow and a different mix of CO sources in this area, such as automobiles and home appliances, are other possible factors that can contribute to this observation.

- A micro-scale Saturation Study site along Casino Center Drive near Fremont at a taxi stand and a parking garage showed the highest one-hour CO average, 18.3 ppm. This is about half the 1-hour NAAQS (35 ppm). The highest associated 8-hour average CO concentration was 7.0 ppm. None of the other micro-scale stations located in the immediate downtown area, nor anywhere else in the tourist-oriented areas approached these values that were probably influenced by a few vehicles with relatively high CO emissions.

Recommendations

The closely spaced group of DAQM CO stations near the Sunrise Acres station was correctly located to identify the higher 8-hour average CO concentrations occurring in the Las Vegas valley. Diminishing or greatly changing site locations in this area is not advised. Further definition of the spatial extent of lesser, but still relatively high for the Valley, CO concentrations could be achieved with more monitoring toward the southeast along Boulder Highway, south of Sahara, and northwest of downtown Las Vegas near Rancho Drive and the U.S. 95 interchange with I-15.

Further investigation may be warranted of the relative influence of CO emissions from small, non-mobile sources such as home heating appliances.

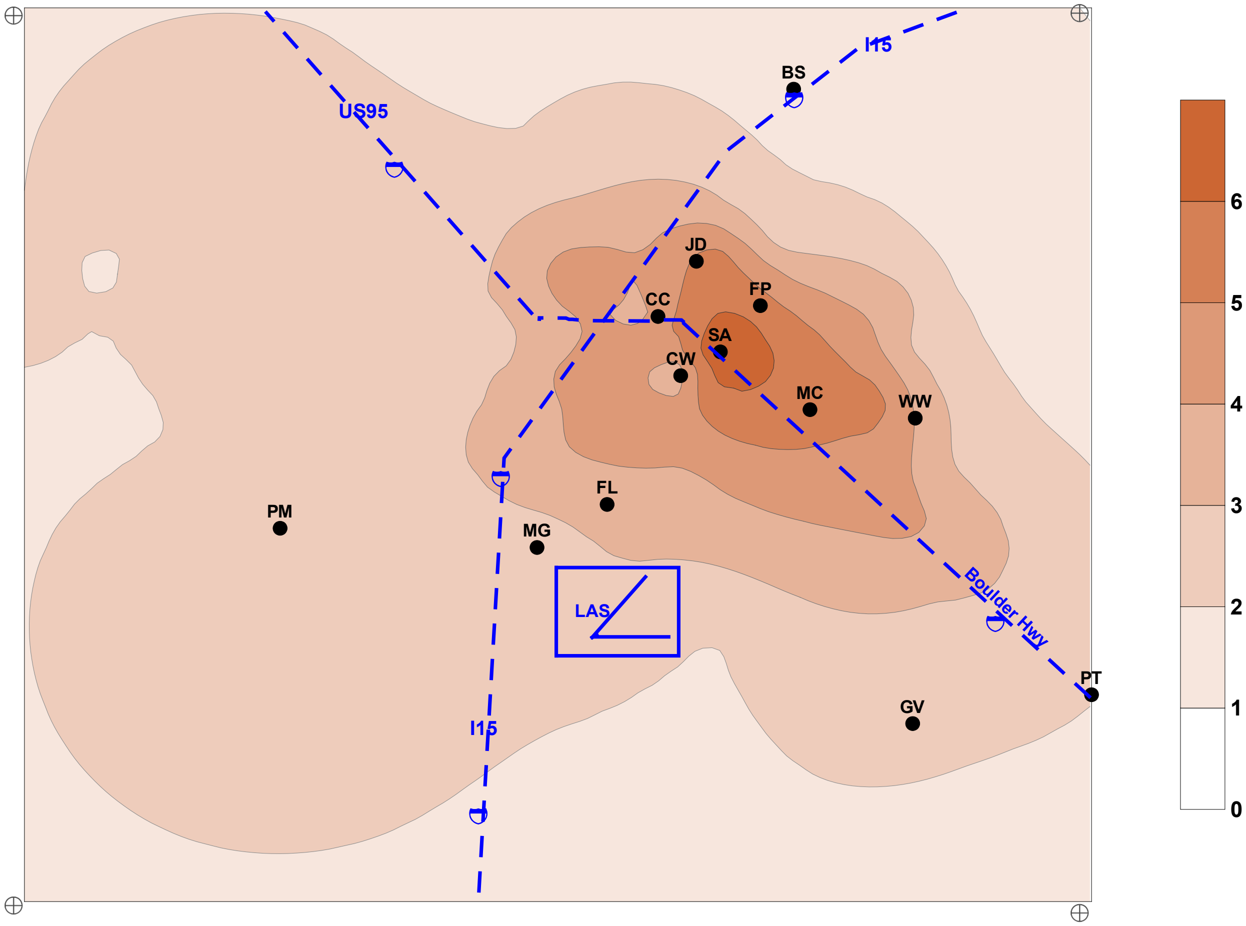


Figure 1. Peak 8-Hour Average CO (ppm) for Period November 20, 2001 to January 5, 2002. Showing DAQM Network Sites.

1. INTRODUCTION

The Clark County, Nevada, Department of Air Quality Management (DAQM) contracted a “saturation” study of carbon monoxide (CO) concentrations occurring during the seasonal period from before Thanksgiving to after New Year’s Day, specifically, November 20, 2001 through January 5, 2002. Historically, this is the most likely period to have the highest CO concentrations measured by the County’s air monitoring network. The study objectives are:

- Obtain additional CO concentration information in areas where the National Ambient Air Quality Standard (NAAQS) for CO has been exceeded (exceedances)
- Improve the conceptual understanding of the relationship between land use, meteorology, and ambient CO concentrations
- Identify geographic areas with high CO concentrations to support risk assessment and potential population exposure to CO exceedances, and
- Evaluate the current Clark County DAQM monitoring network CO sampling locations in accordance with U.S. Environmental Protection Agency (EPA) siting criteria.

In short, the study was planned to answer two primary questions: are the DAQM monitoring sites adequately identifying the highest 8-hour average concentrations occurring in the metropolitan Las Vegas Valley area, and what geographic areas are affected by high CO concentrations? Prior to 1999, at least one 8-hour average per year exceeded the primary National Ambient Air Quality Standard (NAAQS) for CO, 9 parts-per-million (ppm). Aggressive efforts to reduce CO emissions have contributed to the significant decline in exceedance occurrences; none have been recorded since 1998. The saturation study was planned to provide the information to assess the adequacy of the spatial distribution of County DAQM monitoring sites.

1.1 Overview of the Field Program

The technical approach to meeting the study objectives was to operate a network of CO monitoring sites throughout the Valley, with emphasis on the locales historically most likely to experience the highest CO concentrations and where rapid recent development has occurred. Increasing the number of sampling locations well above the number of sites in the DAQM monitoring network effectively “saturates” the community with sampling locations to provide the data needed to achieve the study objectives. The Saturation Network was to be achieved by a combination of fixed (called “Static”) sites and moveable (called “Dynamic”) sites operated during the anticipated worst-case meteorological conditions. The samplers ran nearly continuously at the monitoring sites, producing a very complete record of CO concentrations at the selected locations. Another element in saturating the Valley with measurements was conducting mobile sampling using an instrument van during intensive operating periods (IOP). The van was driven around the Valley to observe CO loading in a real-time mode during nighttime and early-morning hours when meteorological conditions conducive to peak CO concentrations occur.

The network monitoring sites were located throughout the Las Vegas Valley, with a higher density east of the downtown area. Previous monitoring and modeling results indicated this to be the most likely area to encounter higher CO concentrations during periods of typical worst-case meteorological conditions and higher CO emission rates. The dynamic sites were located both to increase the density of sampling locations in the static network and to test other areas that might produce higher CO concentrations due to expected airflow pathways. As dynamic sites were installed and the preliminary data appeared useful in delineating spatial CO patterns, many were left operating continuously to maximize the amount of information collected.

The samplers used at the Saturation Network sites were small self-contained units manufactured by the Onset Computer Corporation. The sampler consists of an electrochemical sensor and on-board datalogger housed in a rectangular plastic container about four inches long by three inches wide and 1.5 inches high. The sampler was housed in a polyvinyl chloride (PVC) circular pipe section closed on the top with a grate on the bottom and holes in the side for air circulation. EPA recognizes the virtual impossibility of operating a network of reference analyzers in the density needed for a saturation study. Hence, various saturation studies have utilized non-reference sampling methods with appropriate comparisons to ensure adequacy of the information for the intended purposes. Preliminary tests in sampling chambers and the ambient environment coupled with comparative results from samplers collocated with DAQM designated equivalent analyzers at monitoring sites and in the mobile sampling van all showed excellent justification for recognizing results from the samplers as adequate for the purposes of this study.

1.2 Overview of the Data Processing and Analysis

All the individual Onset samplers were calibrated in a chamber using “zero” (pure) and NIST traceable concentrations of CO gas. The sampler responses were checked throughout the program to ensure continued performance within the quality control guidelines. Sampler responses to ambient conditions were recorded on a one-minute interval as the raw data. The raw data were transferred to a standard computer data base at frequent intervals and immediately reviewed by the field personnel to ensure proper operation. In this manner, problems were identified and corrected in a timely manner.

The Saturation Network data base consists of approximately <u>three-million validated</u> one-minute instantaneous CO measurements from the continuous monitoring network and mobile sampling. The one-minute continuous data have been transformed to hourly and eight-hourly averages and included in the electronic data base.

Comparisons between the Onset samples and collocated CO measurements made by DAQM reference analyzers at two select sites indicated a small diurnal cycle bias of the

Onset readings, generally less than 0.5 ppm. This bias apparently depends on ambient air temperature. Thus, in addition to factoring the individual sampler multipoint calibration responses a correction was also made for the apparent temperature bias. The corrected data files were then used in the statistical analysis to determine the comparability of the Saturation Network results and the DAQM routine network results.

The analysis task consisted of two major elements: the Saturation Network of fixed sites and the mobile sampling with the monitoring van. The geographic distribution of CO concentrations throughout the Valley as defined by the Saturation Network of fixed sites was determined for those periods of observed high levels and for the overall maximum levels experienced during the field study. The maximum impacted areas were then compared with the locations of the DAQM sites. The mobile sampling measurements mapped the CO distribution to verify that the Saturation network was correctly configured to identify peak CO concentrations, and provided justification for Dynamic sites that were installed during the course of the field study.

2. INSTRUMENTATION

Two types of CO sampling instrumentation were used to collect the carbon monoxide (CO) data. The CO samplers used in the network study sites were manufactured by Onset Computer Corporation (Onset). The samplers are small, self-contained units that include the CO sampler and a datalogger. The primary CO sampling in the mobile van used during the Intensive Operating Periods (IOP) was a Dasibi 3003 CO analyzer, which is an EPA Equivalent Method per 40 CFR 53.

2.1 Network Sampling Instrumentation

Extensive testing of the samplers was performed prior to proposing them in this study because the CO samplers had not yet been used for an ambient measurement application. During testing, individual sampler calibration responses were measured using a Dasibi 3003 CO analyzer. These responses were used in data processing. During operations, aggressive quality control checks and operating samplers at two sites collocated with DAQM sites typically receiving higher CO concentrations helped to provide good comparability of results from the Study samplers and the DAQM CO monitors. **Figure 2-1** shows the CO analyzer, as received from Onset. The preliminary manufacturers specifications are shown in Appendix G.

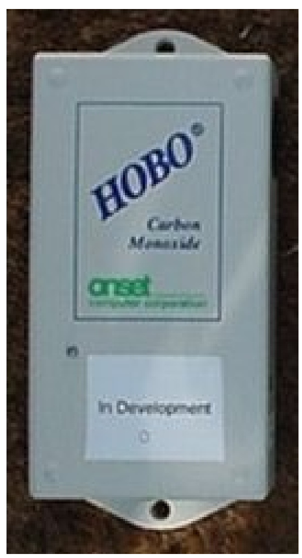


Figure 2-1. Onset CO Analyzer

Tests were performed to ensure that natural ventilation through the polyvinyl chloride cylindrical tube housings would provide an adequate time response to changing CO concentrations. The initial response to increasing CO concentrations was at least as quick as that of the Dasibi analyzer, but a small lag time in the Onset sampler response was noted during decreasing concentrations. This lag was shown to be inherent in the detector technology and not in the natural ventilation of the sampler housing.

Other tests also indicated a small temperature dependence in the Onset sampler response. This temperature relationship was further defined by both laboratory controlled conditions and by comparing the collocated measurements made in the field (between the DAQM Dasibi analyzer and the Onset sampler) during field conditions occurring in the Study. The relationship was applied during data processing. A summary of each of the evaluations is described in Appendix G.

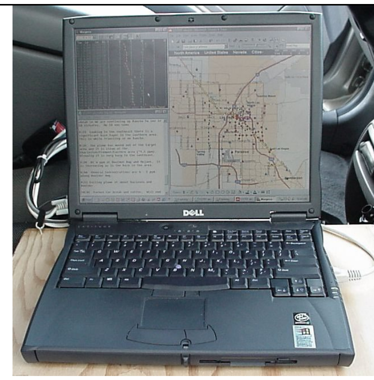
2.2 Mobile Sampling Instrumentation

To aid in the spatial mapping of CO concentrations and assess the adequacy of the placement of the fixed site sampling network, a van was outfitted for mobile CO monitoring. The real time observations mapped the horizontal extent of the CO plume and aided in understanding the areas of highest concentration for placement of fixed site samplers during the IOPs. The mobile van was a late model sport-utility vehicle known to have low CO emissions, minimizing the potential impact of the van on the measurements.

Figure 2-2 shows several views of the vehicle with the sampling probe mounted on the roof. This inlet height allowed sampling above the level of the tailpipe emissions and in the region of generally well-mixed air. The sample was drawn through the inlet by a pump system supplying air both to a Dasibi 3003 CO analyzer and to two Onset CO analyzers configured in a series flow arrangement. The first Onset CO sampler was programmed to collect data at 5-second intervals to help identify possible “spikes” (rapid rise and fall in concentration) possibly due to nearby vehicles. A laptop computer polled the second Onset CO sampler at one-second intervals to compute one-minute averages. CO readings from the Dasibi 3003 were also collected at one-second intervals and stored as one-minute averages on a Campbell CR10 datalogger and subsequently by the laptop computer. The CR10 datalogger also recorded the outside air temperature from a platinum RTD probe mounted on the support rod for the sample inlet. The temperature data were recorded at the end of each minute.

The mobile van position was monitored by a Garmin Etrex Global Positioning System (GPS) and recorded by a laptop computer. One-second position readings were calculated to one-minute averages of latitude, longitude and altitude. Once each minute the Dasibi, Onset analyzer and GPS data files were merged and a graphical “strip chart” type display of the data was updated on two laptop computers. This real-time display allowed “scrolling” capabilities to look back in time at past data. A second GPS receiver provided the real time position to a street map display on the same two laptop computers as the strip chart display. One of the computers was in the front seat where a scientist evaluated the data in real time and kept a log of events. The three computers were networked through a LAN hub and the computer times synchronized prior to the start to assure proper updating of the real-time files. Finally, on selected routes, 30-second pictures from a digital camera mounted and with a forward view were recorded on the laptop computer located in the front seat. **Figure 2-3** shows a block diagram of the van analyzer and computer layout.

Sampling Van (sample inlet & temperature probe were on roof-mounted antenna)



Display on front seat computer for CO concentration, vehicle position and observation log entry.

Rear view of rack with deep cycle battery & pump system feeding the analyzers.

View looking from front seat to the back instrument rack, inverter & computers.

Figure 2-2. Views of Sampling Van and Instrumentation

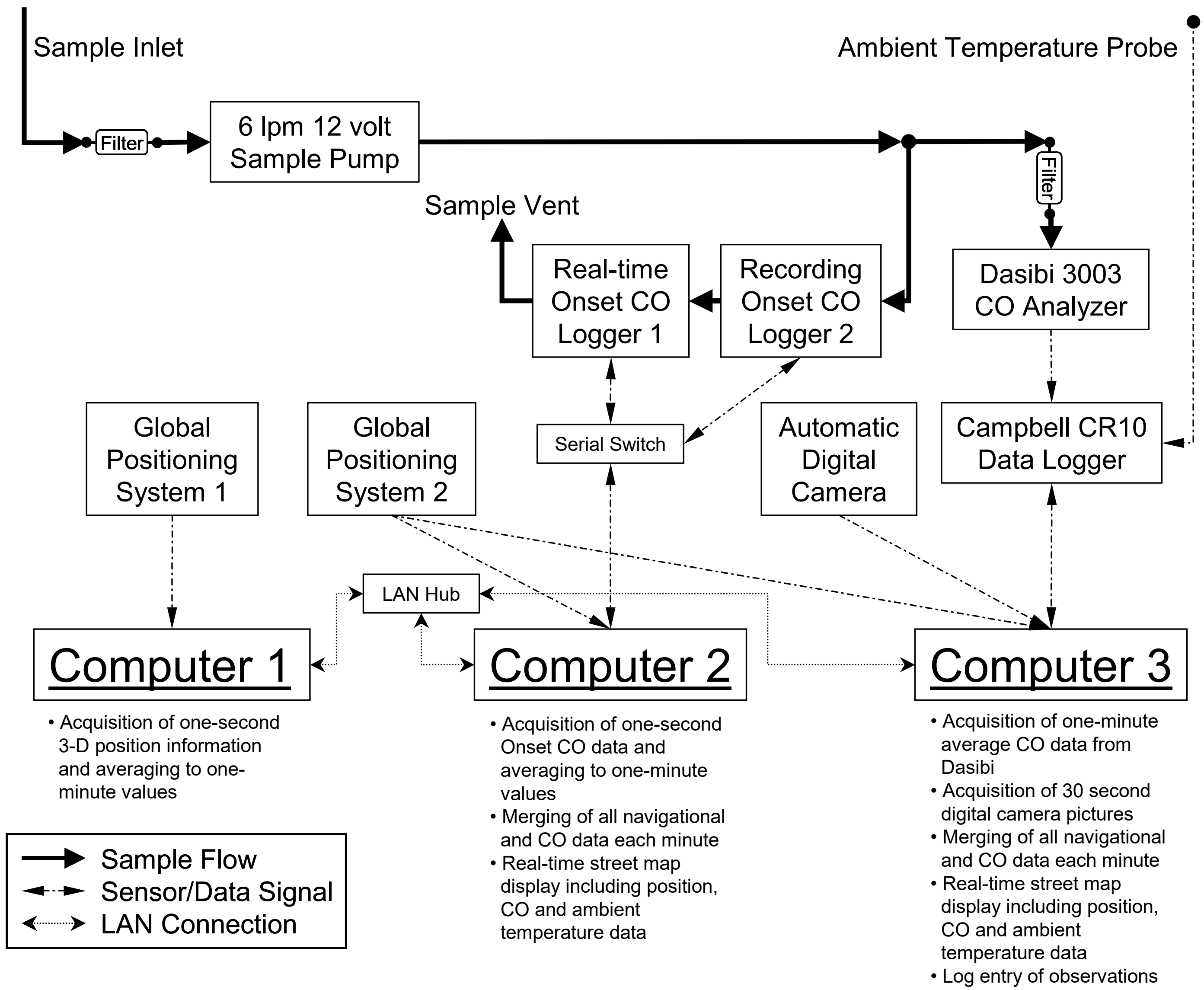


Figure 2-3. Block Diagram of Mobile Sampling Van Instrumentation

3. NETWORK OF SITES

The siting rationale and descriptions of the Static and Dynamic sites which comprise the Saturation Network operated in this study are presented in this section. Siting the network stations was accomplished complying with Title 40 of the Code of Federal Regulations, Part 58, including 58.14, "Special Purpose Monitors". A few of the sites fit a micro-scale site criterion of proximity to roads, but most of the sites have either middle- or neighborhood-scale exposures. These exposures were chosen to match the neighborhood scale exposure of most of the DAQM sites.

3.1 Rationale for Station Siting

Historically, the meteorological conditions producing the highest CO concentrations were a near-stagnation condition, consisting of low wind speeds in a shallow stable layer caused by a nighttime temperature inversion. These conditions, combined with high CO emission rates related to higher vehicle traffic occurring during nighttime and early morning hours, have produced the periods with concentrations exceeding the NAAQS (exceedance).

Past monitoring experience by Clark County (DAQM and its predecessor organization performing regulatory compliance monitoring, the Clark County Health District) has shown that the inner urban area east-southeast of downtown Las Vegas is the most likely area to experience higher 8-hour average CO concentrations. The single site in the DAQM Network continually responsible for recent exceedance cases is the Sunrise Acres site. This site is in an elementary school on the east side of Eastern Avenue, about 150 m north of Charleston Boulevard. The site location is about 400 m northwest of a previous monitoring site on East Charleston that also measured exceedance levels of CO. In addition to the routine monitoring results, DAQM air quality modeling and special CO and meteorological studies reported in Appendix E of the CO State Implementation Plan also predict the same geographic area as the location of the highest estimated CO concentrations.

The previous monitoring results, the modeling studies, and an understanding of the local meteorological conditions conducive to producing higher CO concentrations were used in designing a two-tier continuous monitoring Saturation Network of Static (fixed) and Dynamic (movable) sites. A higher density of both Static and Dynamic sites were located in the inner city area to optimize finding possible areas experiencing higher CO concentrations than those occurring at existing DAQM sites. Another purpose intended in the higher density of sites was to identify the extent of the geographical area affected by the higher CO concentrations. This area of historically higher incidence of CO is referred to as the inner core zone in this project.

Portions of the Saturation Network were also established in other areas of the Las Vegas Valley where routine DAQM CO monitoring was not taking place. Some of these sites were located in the outer perimeter of the valley air basin, in areas where very low levels of CO are predicted, but recent new development indicates that an increase in ambient CO levels may be possible. Other network sites were placed in areas that are more established, but where high CO levels were not encountered previously. Such areas were considered to be possible transition zones where CO levels may be increasing as higher concentrations from the inner core may occasionally impinge, or where increased emissions from the cleaner areas may transport. The objective of these transition zone sites was to document the gradient of CO concentrations from the inner core area to the cleaner outer fringe areas. Another objective for site placement was to measure fluctuating CO exposure in areas where local topography may affect transport of emissions due to the occurrence of "drainage" flow from surrounding elevated terrain. Those areas are referred to as transport zones.

Although the vast majority of the Saturation Network sites were intended to be sited at locations that are considered neighborhood scale by EPA guidelines, three Network sites were designed to be micro-scale sites. These sites were established to measure CO levels very close to emission sources in the downtown area, and in the resort corridor along Las Vegas Blvd., where pedestrians may be exposed to locally high levels of CO. A third micro-scale site was placed at the DAQM "Micro Site" (MS) on East Charleston where particulate measurements are taking place, but no CO monitoring is ongoing. Also, a number of middle scale monitoring sites were designed into the Network with the objective of measuring the CO exposure resident in possible higher risk locations. Middle sites were established in the near downtown area, at the Fashion Show Mall just off Las Vegas Blvd., originally near the M.A.S.H. homeless area, and in a high density housing project near East Las Vegas.

Two Saturation Network CO monitors were placed at existing DAQM sites with the specific objective of comparing results with the DAQM's CO monitoring effort in order to determine data comparability. The Onset monitors were mounted within 2 meters of the DAQM air-sampling inlet in order that both methods would sample "the same air". The sites designated as co-located were Crestwood School (DAQM CW) and Freedom Park (DAQM FP). The Sunrise Acres site was not used because of its accessibility issues.

Figures 3-1 and 3-2 provide maps depicting the names and geographical locations of the sites that comprise the Saturation network. The first map encompasses the entire project area. The naming convention used to identify the sites was developed at the outset of the study using a grid superimposed over a map of the entire area (not shown) and the alphanumeric site identifications derived from the letter/number coordinates in the grid. Figure 3-1 also includes the locations of the DAQM sites where CO is monitored. Figure 3-2 provides a closer view of the denser inner core monitoring area.

Detailed descriptions, including site coordinates, elevations, locations, characteristics and pictures are presented in Appendix A of this report. Each continuous monitoring Saturation Network site is depicted with a full description in the appendix.

fig. 3-1

Fig. 3-2

Table 3-1 presents a summary listing of the Saturation sites that were designated as Static sites at the beginning of the project. All of these sites ran continuously at the location indicated, except where vandalism or maintenance considerations temporarily interrupted monitoring. Also included in the summary are the initial siting objectives according to EPA scale guidelines, and the project zone criteria discussed above.

Table 3-2 presents a summary listing of the Dynamic sites. The Dynamic sites were established later in the monitoring program after initial monitoring results enabled the identification of areas where additional monitoring could prove useful. The results produced by these sites showed the locations to be worthwhile to measuring CO for the purposes intended. Hence, the analyzers were left in place for the remainder of the project.

3.2 Intensive Operating Period Measurement Areas

The sampling van traversed the valley in two general modes. One pattern was cross-section passes to identify possible new areas of higher concentrations not covered by the Saturation network. The other pattern was a close inspection of the immediate area in the vicinity of DAQM and Saturation Network sites to identify possible higher CO concentrations.

Table 3-1. Saturation Monitoring Network – Static Sites

Site ID	Start Date	Latitude (dd.ddddd)	Longitude (ddd.ddddd)	Elevation (m) (msl)	Site Objective (Scale)	Site Objective (Zone)
A17	20-Nov	36.17333	-115.33267	925	Neighborhood	Outer
AA8	07-Dec	36.09360	-115.04668	514	Middle	Transport
BB5	20-Nov	36.06533	-115.04017	531	Neighborhood	Outer
BB9	20-Nov	36.09832	-115.04283	507	Neighborhood	Transport
D19	21-Nov	36.19250	-115.30117	823	Neighborhood	Outer
E13	20-Nov	36.13950	-115.29233	832	Neighborhood	Outer
H17	20-Nov	36.16967	-115.26283	770	Neighborhood	Gradient
G22	27-Nov	36.21467	-115.27432	740	Neighborhood	Outer
J11	20-Nov	36.12233	-115.23700	709	Neighborhood	Gradient
J29	30-Nov	36.27050	-115.23800	703	Neighborhood	Outer
L16	20-Nov	36.16300	-115.21800	688	Neighborhood	Gradient
L20	20-Nov	36.19967	-115.21723	681	Neighborhood	Gradient
N14	20-Nov	36.14933	-115.19567	659	Neighborhood	Gradient
M17	20-Nov	36.17833	-115.19983	671	Neighborhood	Gradient
P12	27-Nov	36.12767	-115.16850	-	Middle	Gradient
P23	20-Nov	36.22753	-115.17767	658	Neighborhood	Outer
P8	20-Nov	36.09000	-115.17050	653	Neighborhood	Gradient
Q13	20-Nov	36.14090	-115.15897	621	Micro	Inner core
R3	22-Nov	36.04610	-115.15329	662	Neighborhood	Outer
R15	08-Dec	36.15748	-115.15184	614	Neighborhood	Inner core
Q20	20-Nov	36.19980	-115.15583	607	Neighborhood	Gradient
R8	20-Nov	36.09350	-115.14717	629	Neighborhood	Gradient
T11	20-Nov	36.12283	-115.12733	579	Neighborhood	Inner core
S13	20-Nov	36.13955	-115.13508	608	Neighborhood	Inner core
S16	20-Nov	36.17034	-115.14462	628	Micro	Inner core
S17	07-Dec	36.16963	-115.14023	617	Middle	Inner core
S18	30-Nov	36.18783	-115.13823	-	Middle	Inner core
SoH	30-Nov	35.99350	-115.20830	736	Neighborhood	Outer
T14	20-Nov	36.15004	-115.12131	566	Neighborhood	Inner core
T15	20-Nov	36.15522	-115.12792	589	Co-located	DAQM CW
T16	20-Nov	36.16238	-115.12269	572	Neighborhood	Inner core
U19	20-Nov	36.19175	-115.11730	554	Neighborhood	Inner core
U6	20-Nov	36.07300	-115.11783	618	Neighborhood	Gradient
U-3	22-Nov	35.99039	-115.11028	-	Neighborhood	Outer
V13	20-Nov	36.14262	-115.10532	560	Neighborhood	Inner core
V15	20-Nov	36.15902	-115.11089	562	Micro	Inner core
V17	20-Nov	36.17717	-115.10301	552	Co-located	DAQM FP
X16	20-Nov	36.16650	-115.08555	533	Neighborhood	Gradient
X15 (1st)	20-Nov	36.15350	-115.07333	530	Neighborhood	Gradient
X15 (2nd)	15-Dec	36.15561	-115.07902	530	Neighborhood	Gradient
X10	20-Nov	36.11050	-115.08800	562	Neighborhood	Gradient
X23	30-Nov	36.22600	-115.08467	568	Neighborhood	Outer
Y14	20-Nov	36.14671	-115.06779	531	Neighborhood	Transport
Z17	20-Nov	36.17765	-115.06097	541	Neighborhood	Gradient
Z19 (1st)	20-Nov	36.15350	-115.05733	541	Neighborhood	Gradient
Z19 (2nd)	23-Nov	36.19273	-115.05871	541	Neighborhood	Gradient

Table 3-2. Saturation Monitoring Network – Dynamic Sites

Site ID	Start Date	Latitude (dd.ddddd)	Longitude (ddd.ddddd)	Elevation (m) (msl)	Site Objective (Scale)	Site Objective (Zone)
xBB12	07-Dec	36.12972	-115.03817	TBA	Neighborhood	Transport
xBB15	07-Dec	36.15624	-115.04272	520	Neighborhood	Transport
xBB18	07-Dec	36.18500	-115.04267	546	Neighborhood	Outer
xM19	17-Dec	36.19217	-115.19878	660	Neighborhood	Gradient
xO16	08-Dec	36.16537	-115.18342	-	Neighborhood	Gradient
xP15	19-Dec	36.15517	-115.17195	-	Neighborhood	Inner core
xP17	19-Dec	36.17325	-115.16545	-	Neighborhood	Inner core
xP19	19-Dec	36.19047	-115.17383	635	Neighborhood	Gradient
xQ18	17-Dec	36.18443	-115.15647	621	Neighborhood	Inner core
xV21	07-Dec	36.21400	-115.10967	567	Neighborhood	Gradient
xW20	07-Dec	36.19983	-115.09600	550	Neighborhood	Gradient
xX18	07-Dec	36.18317	-115.08933	551	Neighborhood	Transport
xY12	17-Dec	36.13107	-115.07407	525	Neighborhood	Gradient
xZ16	07-Dec	36.16490	-115.05643	-	Neighborhood	Transport
xZ10	27-Dec	36.11031	-115.05715	507	Neighborhood	Gradient
xU16	26-Dec	36.16070	-115.11400	566	Neighborhood	Inner core
xP11	27-Dec	36.11680	-115.16538	631	Neighborhood	Inner core
xP13	27-Dec	36.14193	-115.16940	640	Neighborhood	Inner core
xR17	27-Dec	36.17397	-115.14247	617	Neighborhood	Inner core

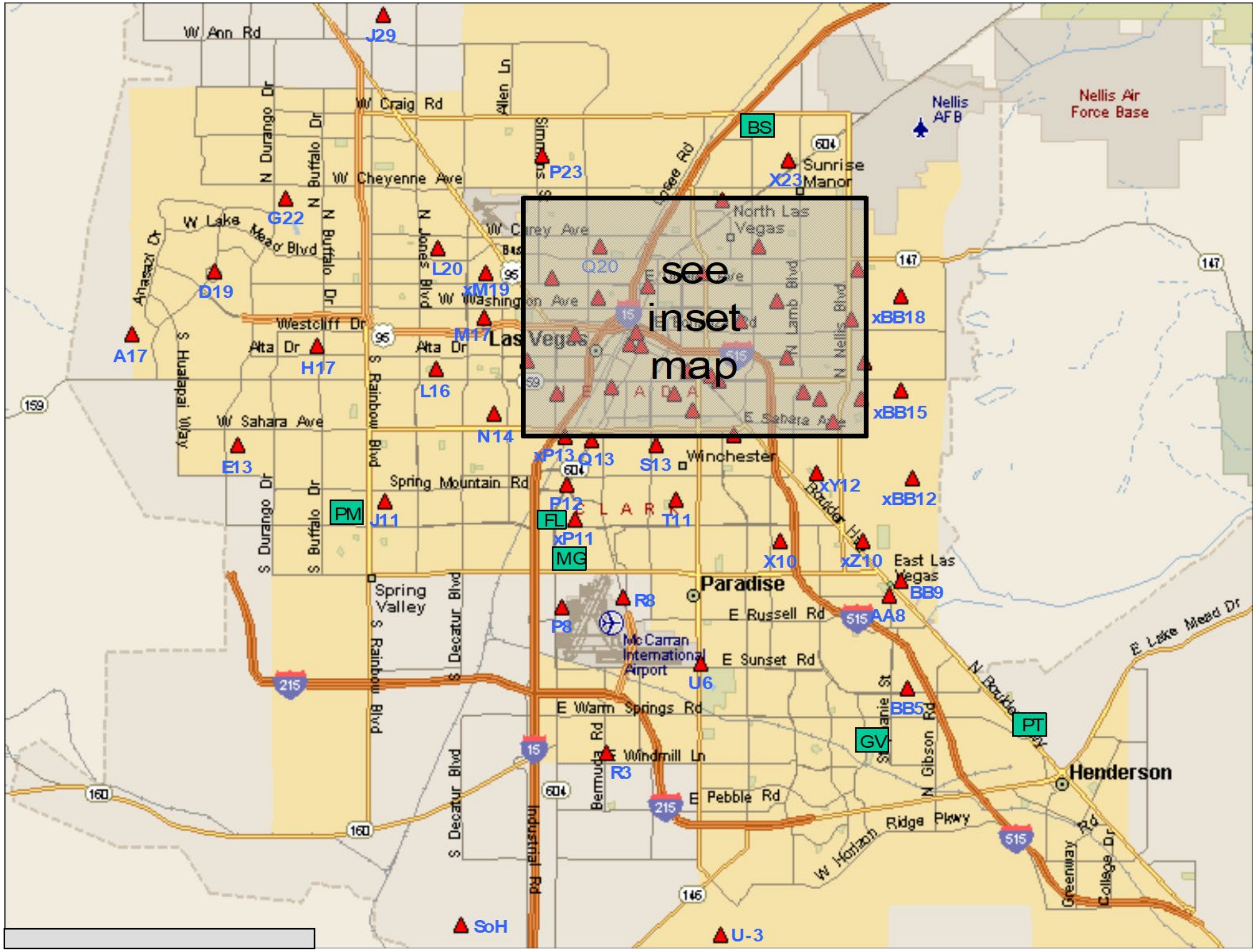


Figure 3-1. Map Showing Site Locations Used in the Study (DAQM sites indicated with a green square/Saturation sites with a red triangle)

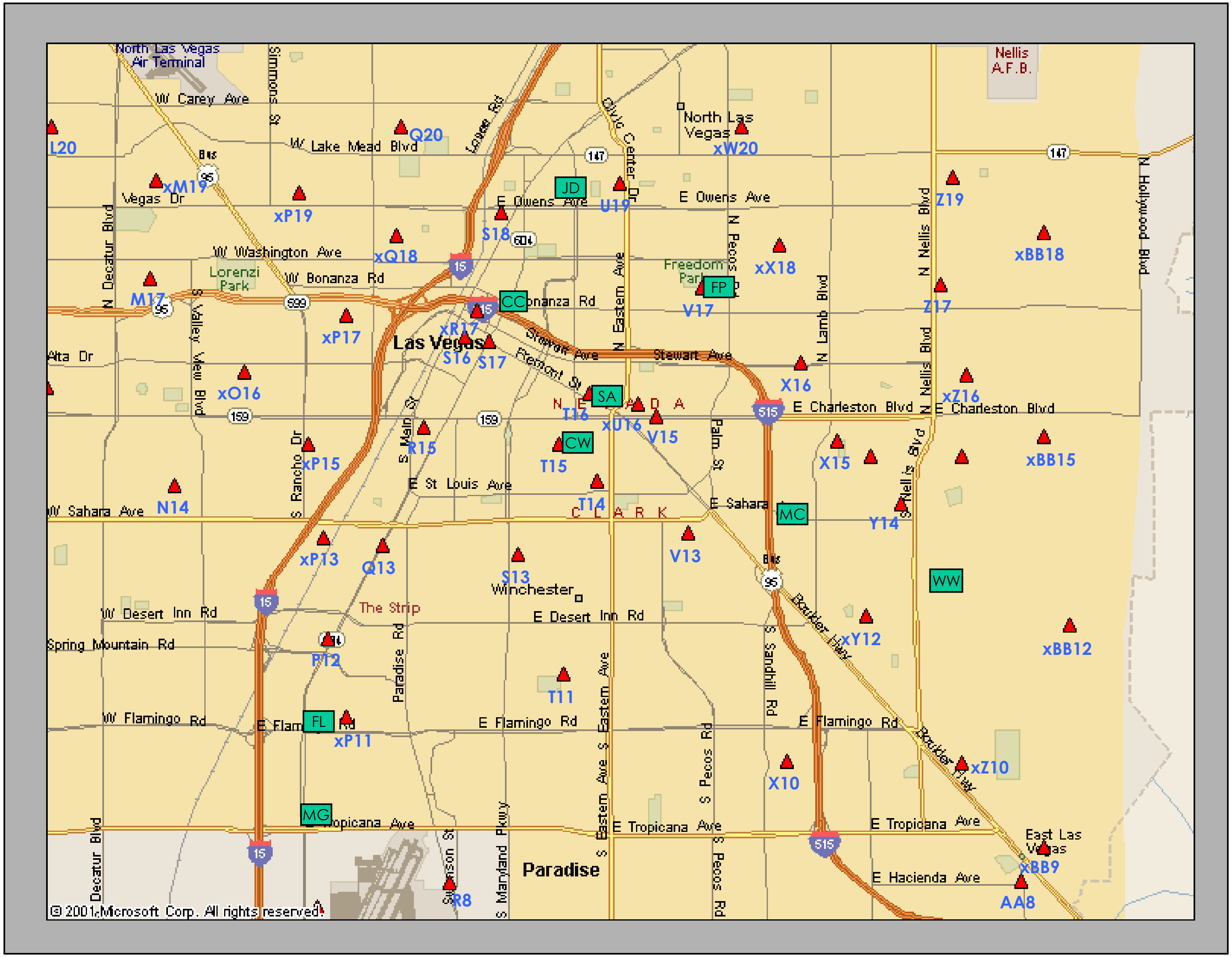


Figure 3-2. Inset Map Showing Site Locations Used in the Study (DAQM sites indicated with a green square/Saturation sites with a red triangle)

4. QUALITY ASSURANCE

Quality assurance activities were a fundamental portion of all phases of the Study. The activities included equipment tests and data validation following U.S. EPA monitoring guidance, network siting following a standard operating procedure written for the study, and independent audits of network siting, CO sampler calibrations, and data validation.

4.1 Acceptance Tests

The equipment and gas standards used in the Study underwent acceptance tests prior to use in data collection.

<u>Calibration Gases</u>

Zero air certified as containing less than 0.1 ppm CO, and two cylinders of CO in nitrogen at concentrations of 43.3 and 43.5 ppm for span gas were purchased from Scott-Marin, a reputable supplier of gases used in air quality studies. The concentrations in the span cylinders were verified using an EPA multiblend protocol gas within the supplier's analysis tolerance of ±5% using the Dasibi 3003 analyzer.

<u>Dasibi 3003 CO Analyzer</u>

The Dasibi 3003 analyzer used in testing and in the mobile van was calibrated using multiple concentrations diluted from an EPA protocol multiblend cylinder. The analyzer was calibrated to a slope of 1.00 and intercept of ±0.2 ppm at the laboratory temperature of 25°C. Subsequent zero and span checks were performed in the field to verify the instrument responded with a zero within 1 ppm and a span tolerance of ±10%, using the project cylinders described above. The operational environment for the analyzer was maintained at 25 ±4°C. In most instances the tolerance was maintained within ±2°C of 25°C. All calibrations during the acceptance test were performed while operating on the 12-volt powered sine wave inverter system to duplicate the power environment in the mobile van during the field program.

<u>Onset CO Analyzers</u>

The Onset CO analyzers selected for the field sampling were still in a prototype status at the time of the field program. In order to purchase the units we signed a release recognizing this status and accepted the role of evaluating and establishing our own calibration for each of the individual units. Prior to delivery, Onset performed their own manufacturing acceptance testing, which assured the units functioned properly and met their own internal acceptance criteria for performance. Upon delivery at the Parsons field office in Valencia, each of the units underwent a detailed performance evaluation to establish the logger response to known concentrations of CO.

The specific goals of the acceptance testing were as follows:

- Establish that the units could be programmed, operated and data offloaded in accordance with the manufacturers operating instructions
- Verify the appropriate time keeping of the internal clocks in each of the units
- Verify the physical serial number on the outside of the logger matched the serial number embedded in the data stream
- Establish the performance characteristics of each unit in terms of a calibration slope, zero intercept and correlation coefficient

Each of these goals was evaluated simultaneously through chamber testing of the CO instruments. The chamber consisted of a modified “lung” type sampler with three access ports for calibration gas input, sampling of the concentrations within the chamber, and an excess calibration gas exhaust. The concentration of the calibration gas within the chamber was kept uniform by using four mixing fans located at each corner of the chamber. **Figure 4-1** shows the chamber with the cover opened and approximately 30 units being prepared for testing. The line to the middle of the chamber provided the calibration gas input. The terminal block on the lower right connected power to the fans as well as a data line for one of the Onset analyzers to monitor the real-time CO concentration, as seen by their data loggers. The real-time unit is seen in the lower right. With the top closed the entire chamber was sealed and the only vent was from the exhaust port on the right side of the chamber.

Figure 4-1. Chamber for Calibrating the Onset CO Analyzers

Each of the instruments within the chamber was exposed to zero and three upscale concentrations of CO. The upscale CO concentrations were 11.2, 20.0 and 40.1 ppm. These concentrations were selected to represent anticipated concentrations within the normal operating range of a CO analyzer that is operated in accordance with EPA guidelines. Each unit then had a calibration sticker applied that provided the slope and intercept as well as a calculated tolerance for any subsequent zero or span test performed to determine if the calibration had changed. The criteria for acceptable response in these subsequent tests was ±1.5 ppm on the zero and ±10% on the span. This sticker can be seen on the sampler shown in Figure 4-1. A calibration database was maintained for all of the Onset samplers with the link to the sampler based on the unit specific serial number. The database of calibration factors for all samplers showed slopes ranging from 0.86 to 1.06, and zero intercepts ranging from –3.2 to +0.3 ppm. The average slope of all CO loggers was 0.94. The response of the samplers to the varying CO concentrations was very linear with the worst of the correlation coefficients being 0.9996.

4.2 Audit Results

Independent audits were conducted of all major components of the study. Internal reports including audit methods and results are included as **Appendix D** of this report. Findings are summarized below.

4.2.1 Clark County CO Network Performance Audits

On November 14 and 16, performance audits were conducted at four County air monitoring sites (City Center, Sunrise Acres, JD Smith, and Freedom Park). Complete audit results, including a summary of the audit standards, are included on forms found in Appendix D. A summary of the results is presented in **Table 4-1**. No problems were noted, with all analyzers reading within approximately 4 percent of true

Table 4-1. Clark County Audit Results

Site	Slope	Intercept	Correlation
City Center	0.987	-0.1	1.0000
Sunrise Acres	0.959	-0.1	1.0000
JD Smith	1.011	-0.7	1.0000
Freedom Park	0.977	0.1	1.0000

4.2.2 Static Network Siting Audits

On November 16 and 17, 25 of the Static sites were visited and reviewed against EPA criteria for siting micro-, middle-, and neighborhood-scale CO monitoring scales. Possible deviations from these criteria were noted and forwarded to the field personnel for consideration. Based on the audit observations, one of the static locations (Z19) was moved to better meet neighborhood-scale siting criteria.

4.2.3 Onset CO Analyzer Performance Audits

On November 14, performance audits were conducted at the Las Vegas field office of all 60 of the Onset CO analyzers available at the time. The audits consisted of exposing the monitors to three CO concentrations (0, 10.35 and 25.2 ppm). The audits were conducted using the same standards used during the audit the County's CO monitoring effort (above). Audit responses were compared against the calibration equations previously obtained for each Onset analyzer.

In general, the results of the audit were very good. Some variability was noted between the audit response and the original calibration response; however, this variability was centered around a slope of one, showing essentially no bias. Only two Onset analyzers had response differences that statistically fell outside of the audit results as a whole (based on two standard deviations from the mean). One of the units was removed from the study after further review of calibration data confirmed its poor performance.

As part of the performance audit, two additional calibration-related issues were investigated. First, several variations on the chamber calibration methodology were explored to see if they had a bearing on the calibrated response of the analyzers. While some differences in response were noted, they were minor and not considered significant. The second issue concerned the possibility of the Onset analyzer's response being affected by ambient temperature. Several units were put in a small calibration chamber and placed in a freezer. A span concentration was pumped into the chamber and the response noted. The chamber was then removed from the freezer and allowed to slowly warm up. Results of this test pointed to a significant change in the Hobo's response as a function of temperature, which resulted in further investigations that are discussed elsewhere in this report.

4.2.4 Sampling Van Performance Audit

The Dasibi model 3003 CO analyzer and the two Onset analyzers used in the sampling van were audited using procedures and standards identical to those of the performance audits described above. No problems were noted.

4.2.5 Data Processing Audit

On February 1, 2002, a systems audit was conducted of the study's data processing effort at the T&B Systems facility in Santa Rosa, CA. The audit consisted of interviews with key data processing personnel, and included tracking raw data points through the data processing effort to verify that procedures were being followed. The only data processing issue of note concerned the application of the zero factors to the Hobo data. A review of the data using the originally established slope and intercept calibration equations revealed a large number of CO concentrations that were negative, indicating that there might be problems with the zero (intercept) calibration factors, which were typically in the –0.5 to –2.0 ppm range. Further investigation showed that the zeros for the Hobos depend significantly on temperature, and that zero offsets essentially disappeared during cold nighttime hours. This issue is discussed elsewhere in this report.

4.3 Field Zero/span Checks

During the course of the field program there were routine zero and span quality control checks performed on the CO measurement equipment. These checks are described below for the mobile monitoring van and the Onset CO analyzers.

Mobile Van

For the mobile monitoring van, quality control checks that included zero and span gas checks were performed several times during each of the two intensive operational periods. The zero and span checks were performed by introducing the cylinder air through a "tee" arrangement placed on the inlet line on top of the van. All zero and span checks were therefore performed through the entire sample system, including filters and the relatively long inlet line. The zero check was performed prior to the span check, and both traces were allowed to stabilize at least 3 minutes before the readings were taken.

The results of the zero and span checks were noted in the field log book and compared to a criteria of ±1 ppm for zero and ±10% for the span concentration. All checks with the Dasibi were within criteria, while the calibration did shift on the real-time Onset analyzer after a sensor replacement on 12/18. The results of that zero/span immediately after replacement prompted a change in the calibration equation used for that unit.

Onset CO Analyzer

The same calibration chamber used to perform the acceptance testing and development of the initial response factors was used in the field to conduct routine zero and span checks on the Onset analyzers. Standardized project zero and span cylinders provided the calibration gas to conduct the checks. Any specific analyzer was checked at the field office at time intervals ranging from 2 to 3 weeks, depending on the schedule for deployment and retrieval of the units from the network. During each of the zero/span check runs, anywhere from 10 to 35 units were placed in the chamber and 30 minutes allowed for concentration stabilization. The calibration database was keyed to the Onset CO analyzer serial number and contained the results of the initial multipoint calibration as well as each zero and span. Any Onset analyzer failing to maintain either the zero or span tolerance was pulled from service and evaluated further to determine the reasons for the failure and the potential for re-calibration and return to service. With the exception of only two units, all Onset CO analyzers maintained their respective responses within the acceptance criteria of ±1.5 ppm on zero, and ±10% on span. Data from these two samplers were flagged for further investigation during data validation.

4.4 Data Processing and Data Base Structure

Processing the three million one-minute average data records taken during the Saturation Study was accomplished applying individual sampler calibration factors, a correction factor for apparent temperature bias, and deployment records tracking the samplers as they were used at various locations. The individual sampler calibration factors were computed from sampler tests in a controlled chamber environment applying EPA Protocol calibration CO gas flowing through the chamber. The relatively small (small fraction of a ppm) temperature bias was computed from comparisons of the collocated samplers at two DAQM CO stations. Preliminary data processing performed in the field maintained good continuity of the information on any Study site which characteristically included several different analyzers during the field study. The one-minute instantaneous measurements were compiled into a relational-structured data base. Both one-hour and running 8-hour averages were computed to conform with the time periods needed to show compliance with NAAQS. The subsequent data summaries were utilized in identifying the time periods when the highest CO concentrations were experienced.

4.4.1 Static and Dynamic Network Measurements

Raw (Data Validation Level 00) CO measurements underwent processing both in the field (Data Validation Level 0.5) and in Santa Rosa after the completion of the field study (to Data Validation Level 1.5). Standard Operating Procedures for both in-field and post-field data handling and processing are given in Appendix B. Those procedures are summarized below.

In-Field Processing

Data records in Onset's native format were exported to ASCII format after checking to ensure date and times were consistent with technician notes. The ASCII file was read into an Excel format, and each record transformed to include the Site ID, unit serial number, and a data validation flagging field. The first hour of data after installation was automatically flagged as "suspect" based on our experience with regard to the time required for the instrument to stabilize.

Post-Field Processing

A computer-based processing and objective screening program was developed. All of the Level 0.5 files that were created in the field were processed through the program. The one-minute CO readings were first screened to flag as invalid single-record spikes greater than 10 ppm. The one-minute CO readings were next span-adjusted using factors developed from multi-point calibrations (refer to Appendix E). The calibration corrections were applied on the basis of serial number rather than site as instruments moved between sites.

A data base of hourly-averaged one-minute records was compiled. At least 30 records (30 minutes) were required for a valid hourly-average. An hourly-average not meeting this requirement was flagged as invalid or missing. The hourly-averaged data were next adjusted for ambient temperature based on an algorithm developed from cold-chamber test results (refer to Appendix G). Time-series plots of the one-hour averaged data were produced and examined by experienced personnel for outliers.

A data base of eight-hour averaged CO levels was compiled from the validated hourly-averaged data set. A minimum of six valid hourly-averages were required to produce a valid eight-hour average.

Further validation (Level 1.5) of the data base was based on analyses of the data. As outliers were identified, records were flagged either as "suspect" or "invalid". Data was declared "invalid" only if there was compelling supporting evidence. Otherwise the data are flagged as "suspect".

Database Structure

The CO measurements acquired during the field study were compiled into an electronic data base for transfer to the Clark County DAQM. Both hourly-averaged and eight-hour running averages are available in Microsoft Excel compatible file formats. The file and record structure is shown in **Table 4-2**.

4.4.2 Sampling Van Measurements

The sampling van acquired measurements consisted of a number of components that were merged to form the final database of one-minute averages. The van and data recording system was described in Section 2.

The navigation, Dasibi and Onset data streams were merged in real-time at the end of each minute. The merging was performed based on the time of the Dasibi data stream as it was recorded on the CR10 data logger. All clocks in the data logger and computers were synchronized to the nearest second at the start of each sampling run based on the GPS reported time as the project standard. The merged data file then provided one-minute records containing date, time, latitude, longitude, altitude, ambient temperature, Dasibi CO and Onset CO. As the CO values had any needed correction factors applied in the initial data stream, the data in the merged file only needed validation to flag, as appropriate, any invalid or suspect data points based on observations noted in the observation log from each of the data collection periods.

Table 4-2. File and Record Format

File Format:
MicroSoft Windows Excel (XLS) -Version 2000 Naming convention: NNNNmmddyy, where NNNN refers to T&B Systems site names (See Appendix A) and mmddyy refers to version release data.

Record Format	
Column	Field Description
A	Site Name (Appendix A)
B	Onset Instrument Serial Number
C	Site Latitude
D	Site Longitude
E	Date
F	Start Time (PST) of averaging interval
G	CO average (hourly or running 8-hour average)
H	Data Validation Flag
	V= Valid
	S= Suspect
	I = Invalid

The observation logs were manually reviewed and validation flags applied to the merged data file to flag any values not considered valid. The validation codes used were as follows:

- -90 Interference from local sources such as high emitting vehicles
- -95 Data suspect due to calibration or temperature drift
- -99 Data invalid due to instrument malfunction

For all practical purposes no data were used in the analysis that had any of the above codes. In the analysis and data displays, the Dasibi data took precedence when that data were available; otherwise the data from the real-time Onset analyzer were used.

4.5 Comparison Tests

At two DAQM sites, Freedom Park and Crestwood, Onset CO analyzers were collocated with standard (Dasibi) CO monitors at the inlet to the DAQM system. The two sites were recommended by DAQM personnel based on potential CO exposure and site access considerations. Measurements were made continuously for the extent of the field study. Data was lost for approximately one-week (December 23-28) due to a data logger failure.

Both 1-hour and 8-hour averaged Onset data were compared with the DAQM monitor data set. The initial comparison was using Onset measurements corrected only for calibration span (slope). Results of the comparisons are summarized in **Table 4-3**. As can be seen, given the fact that hourly averages <0.50 ppm occurred with more than a 40 percent frequency during the field study and that the DAQM Standard Procedure is to report CO levels less than 0.50 ppm as zero (0.00 ppm), the data compare reasonably well. Eighty-five percent of the differences between the two instruments at Freedom Park, and 74 percent of the differences observed at Crestwood were less than 1 ppm.

It was noted that differences between the collocated instruments showed a distinct diurnal pattern, i.e. the Onset analyzers read lower than the Dasibi units during the nighttime and greater during the daytime. This was consistent with results of our cold-chamber tests of the Onset CO analyzer in which the calibrations appeared to be sensitive to ambient temperature. The relationship between monitor differences at the two sites and ambient temperature can be observed in **Figure 4-2,** which shows the differences observed at Freedom Park as a function of ambient temperature. The best fit linear regression to the data yielded a slope of 0.163 and intercept of -1.78 (shown on figure).

The results of applying this adjustment to the Onset measurements are shown in Table 4-3 as well and can be compared to the non-adjusted data. It should be noted that the adjustment factor was derived from the Freedom Park collocated instruments, and applied to Crestwood as validation that this adjustment can be likewise applied to the other sites in the network. All the comparative parameters were improved. The Crestwood data set correlation improved from 0.69 to 0.76 and the standard deviation of the differences decreased from 0.86 to 0.82. Perhaps even more significant is that after adjustment for ambient temperature 92 percent of the differences were less than 1 ppm and all (100 percent) were less than 2 ppm at Crestwood. The calculations included DAQM readings <0.5 ppm that had been truncated to 0.0 ppm.

The two data sets were subjected to Wilcoxon Matched Pairs tests. Results showed that the actual probability of the differences occurring by chance is less than .01 percent.

Table 4-3. Intercomparison Descriptive Statistics

Standard Deviation	0.81	0.62	0.86	0.64
Correlation Coefficient	0.79	0.86	0.69	0.85
< 1 ppm*	85%	97%	74%	92%
<2 ppm*	97%	99%	94%	100%

*percent of CO measurement differences less than indicated amount.

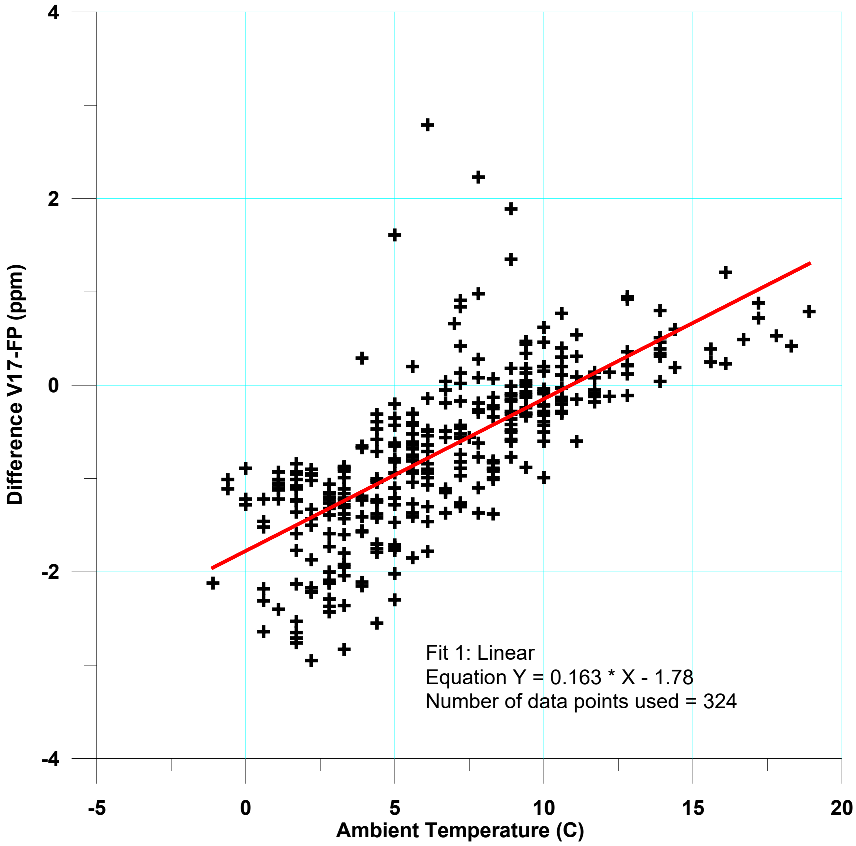


Figure 4-2. Differences Between Onset and Dasibi CO Analyzers vs Ambient Temperature - Freedom Park

Peak daily 8-hour averages using the fully adjusted and validated data sets were next compared with the County's collocated measurements. The average difference between the instruments was 0.26 and 0.29 ppm for Freedom Park and Crestwood, respectively, well within the accuracy of the equipment. The standard deviation of the differences was 0.55 and 0.53 ppm, respectively. Time series plots of the measurements are shown on **Figures 4-3 and 4-4**. It can be concluded that the Onset analyzers are comparable to the County's CO monitors over the range of ambient levels experienced during the study.

4.6 Data Capture

The overall data capture rate for the Saturation Network Static and Dynamic sites was 94.7 percent. Data capture in this study is defined as the number of valid hour average records in the data base as opposed to the maximum possible, based on the date and time of site startup. The capture rate for each individual site is given in **Table 4-4** along with the start date and time.

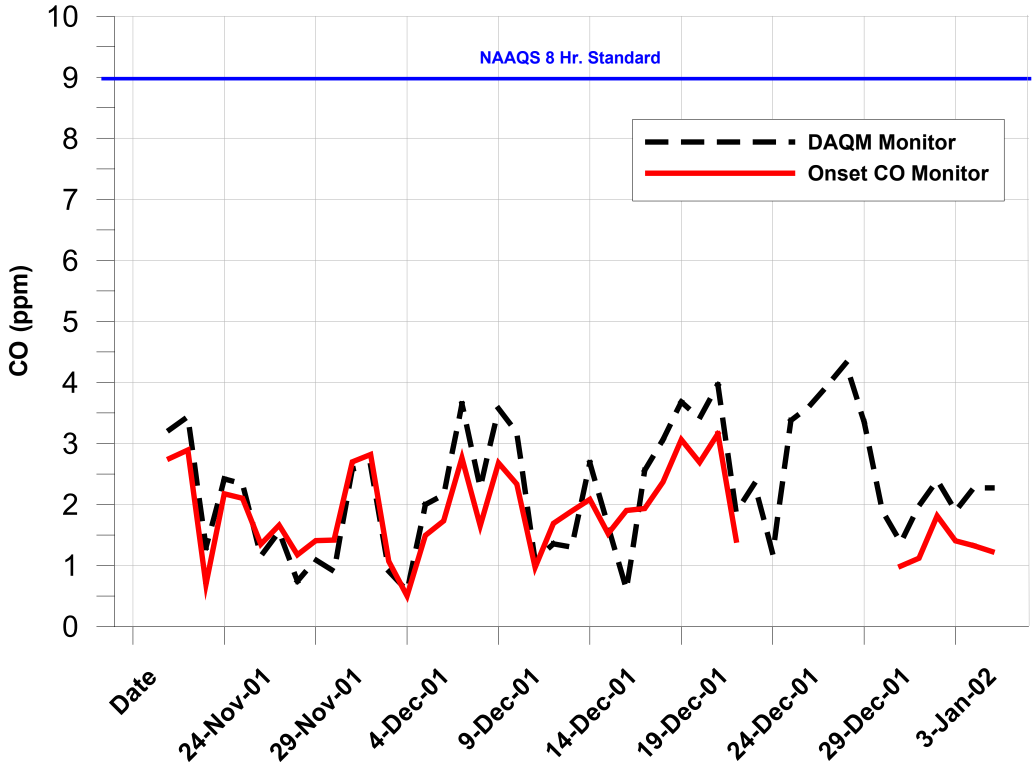


Figure 4-3. Freedom Park Collocated Measurements 8-Hour Average Daily Maximum

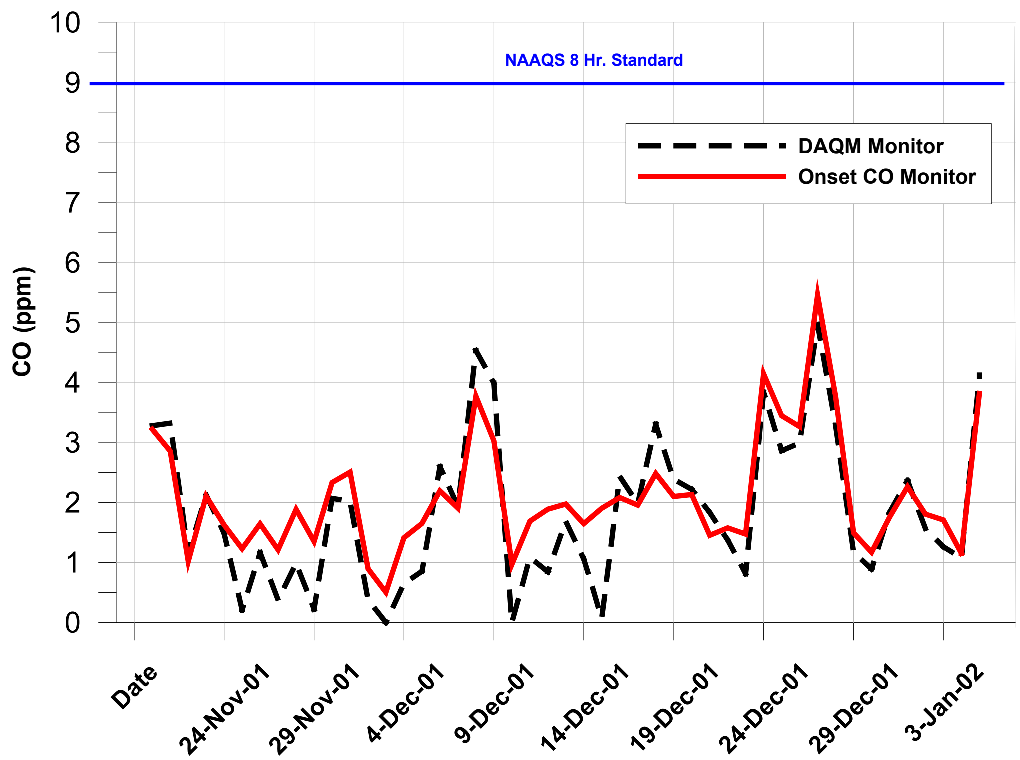


Figure 4-4. Crestwood Collocated Measurements 8-Hour Average Daily Maximum

Table 4-4. Hourly Data Capture Rates for the Saturation Network

Site	Start_Date	Valid Data Rec	Max Possible	Data Capture(%)
A17	27-Nov-01	870	943	92.3
AA8	7-Dec-01	502	707	71.0
BB5	20-Nov-01	1122	1125	99.7
BB9	20-Nov-01	1122	1125	99.7
D19	21-Nov-01	1015	1088	93.3
E13	20-Nov-01	1051	1125	93.4
G22	27-Nov-01	871	944	92.3
H17	27-Nov-01	940	943	99.7
J11	20-Nov-01	1052	1125	93.5
J29	30-Nov-01	821	873	94.0
L16	20-Nov-01	1122	1125	99.7
L20	20-Nov-01	1121	1125	99.6
M17	20-Nov-01	1121	1125	99.6
N14	20-Nov-01	1073	1125	95.4
P12	27-Nov-01	943	946	99.7
P23	20-Nov-01	1122	1125	99.7
P8	20-Nov-01	1124	1126	99.8
Q13	20-Nov-01	1122	1125	99.7
Q20	20-Nov-01	1121	1125	99.6
R15	8-Dec-01	682	684	99.7
R3	25-Nov-01	993	995	99.8
R8	20-Nov-01	1123	1125	99.8
S13	20-Nov-01	1121	1125	99.6
S16	20-Nov-01	1121	1125	99.6
S17	7-Dec-01	700	703	99.6
S18	30-Nov-01	867	871	99.5
SoH	30-Nov-01	815	869	93.8
T11	20-Nov-01	1122	1125	99.7
T14	20-Nov-01	1121	1125	99.6
T15	20-Nov-01	949	1125	84.4
T16	20-Nov-01	1120	1125	99.6
U-3	17-Dec-01	416	468	88.9
U19	20-Nov-01	1120	1125	99.6
U6	20-Nov-01	1122	1125	99.7
V13	20-Nov-01	1121	1125	99.6
V15	20-Nov-01	935	1125	83.1
V17	20-Nov-01	1121	1125	99.6
X10	20-Nov-01	1120	1125	99.6
X15	20-Nov-01	834	1125	74.1
X16	20-Nov-01	1001	1125	89.0
X23	30-Nov-01	819	871	94.0
Y14	20-Nov-01	934	1125	83.0
Z17	20-Nov-01	802	1125	71.3
Z19	20-Nov-01	1122	1125	99.7

Table 4-4. Hourly Data Capture Rates for the Saturation Network

Site	Start_Date	Valid Data Rec	Max Possible	Data Capture(%)
xBB12	7-Dec-01	610	707	86.3
xBB15	7-Dec-01	609	707	86.1
xBB18	7-Dec-01	608	706	86.1
xM19	17-Dec-01	461	463	99.6
xO16	8-Dec-01	640	684	93.6
xP11	27-Dec-01	225	225	100.0
xP13	27-Dec-01	224	225	99.6
xP15	19-Dec-01	414	416	99.5
xP17	19-Dec-01	413	415	99.5
xP19	19-Dec-01	414	415	99.8
xQ18	17-Dec-01	462	463	99.8
xR17	27-Dec-01	224	224	100.0
xU16	26-Dec-01	246	246	100.0
xV21	7-Dec-01	606	704	86.1
xW20	7-Dec-01	606	705	86.0
xX18	7-Dec-01	656	705	93.0
xY12	17-Dec-01	411	462	89.0
xZ10	27-Dec-01	222	222	100.0
xZ16	7-Dec-01	657	707	92.9
SUMMARY:		52144	55057	94.7

5. FIELD PROGRAM

Operational aspects of the field measurement program are provided in this section to further document the CO measurements taken during the Study.

5.1 Project Weather Conditions

Synoptic and local weather conditions were monitored and analyzed each day for the duration of the project beginning on November 18, 2001, and ending on January 5, 2002. The meteorological information routinely gathered during this period was used to determine the daily atmospheric dispersion conditions occurring in the Las Vegas Valley, and to generate dispersion forecast information that was used for planning Intensive Operating Period (IOP) deployment. Weather data that was routinely gathered included surface and upper air synoptic maps, satellite images, local (Desert Rock) upper air soundings, surface wind data from key valley sites and National Weather Surface (NWS) published discussions of forecast model output.

A ridge of high pressure dominated the weather over the Western U.S. for several days prior to November 20, and continued to influence dispersion conditions in the Las Vegas Valley into November 21. The result was relatively stagnant conditions with clear skies and light winds with significant low-level inversion development during the nocturnal hours, and only weak mixing during the daylight hours. Synoptic scale wind flow was minimal, thus enabling local valley transport patterns to predominate. Pollutant concentrations did elevate during this period particularly during the nocturnal periods, but the mixed layer deepened enough from diurnal surface heating during the daylight hours to allow moderate daytime dispersion, and not allow significant carryover of concentrations from one day to the next.

By the morning of November 21, the ridge had weakened and slid eastward as westerly flow aloft brought more moisture and less stability to the project area. The resultant deeper mixing conditions produced increased dispersion by afternoon and a corresponding significant drop in pollution concentrations by evening. This marked the beginning of a cooler and more unsettled period of weather that prevailed through the remainder of November. A series of alternating short-wave troughs and ridges migrated out of the Eastern Pacific and across the Western U.S. during that time. No precipitation occurred in the project area, but deep mixing layers and strong gradient winds resulted. Even during the short-lived short ridge events, synoptic-scale wind flow enhanced strong Colorado River regional flow to keep both thermodynamic and mechanical mixing optimal.

The unsettled pattern of late November continued into early December as fast moving short troughs and ridges migrated off the Pacific and across the Great Basin. However, by December 5 a somewhat broader and longer-lived ridge followed a short wave trough into southeastern California, Nevada, and Arizona. The ridge brought weaker gradient flow, warmer temperatures aloft, and generally stagnant dispersion conditions to the project area during the 5th and 6th. The IOP crew was alerted to this situation two days previously, but deployment was cancelled on the 5th because of forecast strong winds expected on 12/07/01. A strong surface high-pressure area developed in the northern Great Basin on the 7th and slipped southward into the southern area by December 8. The initial development of this ridge on the 7th increased the surface gradient considerably during that day resulting in strong enough winds in the project area to clean out any accumulated pollutants remaining from the quasi-stagnant conditions of the previous two-day. By the evening of December 8, surface and upper ridging had settled over the area again leading to poor dispersion conditions. However, those conditions only persisted through the morning of December 9, as greater mixing and less nocturnal stability associated with an approaching trough produced good dispersion by afternoon.

By the afternoon of December 9, a cold front associated with a long-wave eastern Pacific trough was moving across northern and central California. The effects of a lifting air mass ahead of this approaching system were felt in the project area by the afternoon of that day. The frontal system marked the beginning of a period of a broad-scale trough along the Pacific coast and associated good air quality in the project area that lasted through December 15.

A fast-moving storm system impacted southern Nevada late on December 14 and had moved eastward into the Inter-Mountain area by early on the 15th. This system signaled the end of the unsettled weather pattern that had dominated the project area during the previous week. A broad high-pressure area began to build over the region on December 15 initially bringing decreasing clouds but breezy and somewhat unstable conditions on that day. In anticipation of the development of stagnant conditions associated with this high-pressure ridge, the IOP crew was alerted on December 14, and deployed on December 16. By the evening of the 16th, pressure gradients had decreased and wind flow had diminished sufficiently to allow the air mass in the project area to stabilize. During the period from December 17 through 19, the broad ridge of high pressure was prominent enough to block the influx of several short wave troughs into the southern Great Basin, allowing the air mass over the project area to remain stable. Shallow nocturnal inversion layers and light surface flow characterized the dispersion conditions during the nighttime periods on the 17th, 18th, and 19th. Vertical mixing during the daytime periods were somewhat restricted, but surface heating from insolation deepened the boundary layer enough to inhibit the accumulation of CO from day-to-day carryover.

By late on December 19, the Great Basin ridge was flattening and a new Pacific trough was forming offshore. However, the limited dispersion conditions in the project area persisted through the 19th, and well into the 20th before the advancing weather system affected the area. In addition, overrunning high cloudiness during the daylight hours on the 20th inhibited daytime mixing and allowed the persistence of elevated CO readings well into the late morning. Limited dispersion conditions continued in the project area until the onset of stronger gradient wind flow that evening. The area then experienced the influx of colder, less stable air accompanied by windier conditions that persisted to December 24.

A very strong but narrow ridge of high pressure developed off the Pacific coast on December 23 behind the troughing pattern that was affecting the Great Basin at that time. The ridge moved onshore early on the 24th producing stable atmospheric conditions in the project area by late that evening. The new air mass was initially quite cold, and the daytime mixing layer was fairly deep with some leftover Colorado River regional drainage persisting on the 25th. Local radiation inversions formed during the evening of the 25th accompanied by diminished winds. The IOP crew was alerted on December 24 for possible deployment on the December 26. Intensive sampling began the evening of the 26th. Although the West Coast ridge produced relatively stable conditions in the project area through December 28, the center of the ridge never moved eastward out of California, and the area remained in northerly flow with relatively cool air advection aloft. As a result, dispersion conditions were poor at night, but the atmosphere destabilized enough during the daylight hours to prevent carryover during the IOP. By 12/28/01, the strength of the ridge had been significantly eroded, and sub-tropical moisture from a disturbance in the Pacific off Southern California was advecting aloft into the area. Dispersion conditions were still relatively poor during the morning of the 28th, but stagnant conditions were gone by that evening.

An upper level disturbance that caused the influx of sub-tropical moisture aloft moved through the project area during December 29, and was followed by a weak short wave ridge on December 31, 2001 and January 1, 2002. The ridge was rather diffuse and transitory, but it did allow some stabilization during the evening of the 31st and morning of January 1, 2002. A short wave frontal system moved through central California on January 2, and enhanced dispersion in the project area during the 2nd and 3rd. A somewhat stronger ridge of high pressure built in over the Great Basin on January 4th. The atmosphere did not immediately stabilize in the project area, however, because the incoming ridge induced a rather strong north-to-south pressure gradient, and the resultant breezy conditions kept the boundary layer relatively deep and well-mixed. By January 5, the gradient had relaxed, and the ridge stabilized the air mass in the Las Vegas Valley. Relatively stagnant dispersion conditions prevailed through January 9, but no carryover occurred due to sufficient daytime mixing. Dispersion conditions during that period were similar to those measured during the two IOP periods in December.

5.2 Continuous Monitoring

The operation of the Saturation Network took place in two phases. They were: 1) the siting and installation of the Static sites; and 2) the expansion, maintenance, and data recovery operations phase. The initial phase took place during the period from November 10 to November 22, and the second phase was accomplished from November 22 through January 20, including the five-day decommissioning period after the termination of monitoring on January 5.

5.2.1 Static Network Establishment (November 10 to 22, 2001)

Field site selection activities began shortly after November 10. The original 35 Static sites were installed by November 22. Site locations were determined using the criteria and philosophy discussed in Section 3 of this report. A typical installation consisted of attaching a mounting hook to an existing pole or structure at the locations determined during the siting process. An installation was considered complete when the instrument enclosure and operating Onset CO analyzer was installed at a site. **Table 5-1** presents a list of the original Static sites and the dates that valid data collecting started. During the installation, site GPS coordinates and elevation were determined. A map of the site locations is included in Section 3 of this report. Site Descriptions, which include coordinates, elevations, site objectives, physical descriptions and pictures, are given in Appendix A**.** Standard Operating Procedures (SOP) for the launching and deployment of the Onset CO analyzers are included in Appendix B. A complete summary table documenting all the site deployment activities is presented in Appendix C.

Table 5-1. Data Start Dates for Original Static Network

Site I.D.	Data Start Date
A17	20-Nov
BB5	20-Nov
BB9	20-Nov
E13	20-Nov
H17	20-Nov
J11	20-Nov
L16	20-Nov
L20	20-Nov
N14	20-Nov
M17	20-Nov
P23	20-Nov
P8	20-Nov
Q13	20-Nov
Q20	20-Nov
R8	20-Nov
S13	20-Nov
S16	20-Nov
T11	20-Nov

Site I.D.	Data Start Date
S18 (1st)	20-Nov
T14	20-Nov
T15	20-Nov
T16	20-Nov
U19	20-Nov
U6	20-Nov
V13	20-Nov
V15	20-Nov
V17	20-Nov
X16	20-Nov
X15 (1st)	20-Nov
X10	20-Nov
Y14	20-Nov
Z17	20-Nov
Z19 (1st)	20-Nov
D19	21-Nov
R3	22-Nov
U-3	22-Nov

Note: All sites operated through Jan. 5, ‘02.

The initial network of sites was discussed with the DAQM staff at the DAQM offices on November 21. As a result of that meeting, Static sites D19, R3, and U-3 were established and became operational on November 21 and 22. The addition of those sites to the Network of 32 that was operating by November 20, made the total number of original operational Static sites 35.

An internal performance and siting audit was conducted during the initial start up period. Multipoint calibration checks of the Onset CO analyzers were conducted, and 25 of the

Static sites were checked during the audit. Audit activities are discussed in Section 4.2 of this report.

5.2.2 Network, Expansion, Maintenance and Data Recovery (November 22, 2001 to January 20, 2002)

The base of knowledge of the dispersion characteristics of the project area was broadened as information was gathered from the initial Static Network, the DAQM Network measurements, and observations by field personnel. This additional insight enabled the expansion of the Saturation Network to more effectively measure the CO exposure. As a result, the original 35-site Static Network was expanded to 44 sites during the period from November 27 to December 8. The deployment crew made siting decisions for the addition of sites G22, P12, R15, S17 and S18. The new S18 site was relocated within the secure area at the M.A.S.H. facility after the original unit was stolen from its location on Foremaster Lane. In addition, a meeting between DAQM and study personnel on November 30 resulted in the establishment of the AA8, J29, SoH and X23 sites. **Table 5-2** lists the added sites and the operations start date. In addition, descriptions of the sites can be found in Appendix A.

In anticipation of a possible initial IOP event, the first eight Dynamic sites were established and installed during December 7 and 8. Siting decisions were once again made by the deployment crew, and were based on additional information obtained during the first two weeks of the monitoring program. Anticipated IOP conditions did not materialize, but it was decided to leave the eight Dynamic sites in operation in order to gain more information. The sites remained operational for the remainder of the program. In like manner, another six Dynamic monitoring sites were established during the first IOP operation on December 17 to 19, and five more were installed during the second IOP on December 26 and 27. All those sites also remained operational through the end of the study. Table 5-2 also lists all the Dynamic sites and the dates when data logging started. Note that Dynamic site names all contain a prefix lower case (x). Site descriptions for all the Dynamic sites can be found in Appendix A of this report.

Table 5-2. Data Start Dates for Expanded Static and Dynamic Network

Site I.D.	Data Start Date
Z19 (2nd)	23-Nov
G22	27-Nov
P12	27-Nov
J29	30-Nov
S18 (2nd)	30-Nov
SoH	30-Nov
X23	30-Nov
AA8	07-Dec
S17	07-Dec
xBB12	07-Dec
xBB15	07-Dec
xBB18	07-Dec
xV21	07-Dec
xW20	07-Dec
xX18	07-Dec
xZ16	07-Dec
R15	08-Dec
xO16	08-Dec
X15 (2nd)	15-Dec
xM19	17-Dec
xQ18	17-Dec
xY12	17-Dec
xP15	19-Dec
xP17	19-Dec
xP19	19-Dec
xU16	26-Dec
xZ10	27-Dec
xP11	27-Dec
xP13	27-Dec
xR17	27-Dec

Site I.D. Data Start Date

Notes: All sites operated through Jan. 5, 02
Prefix x denotes Dynamic sit

Maintenance of the Saturation Network consisted of periodic site visits by the field technicians to download data and repair or replace damaged equipment. A complete summary of the site visit and data recovery activity is available from the Deployment and Recovery Summary in Appendix C. During the initial period of monitoring, one sampler was stolen from the original S18 location on Foremaster Lane before any data could be recovered. In addition, four samplers failed to operate properly during the initial 10 days of monitoring resulting in data lose. Site vandalism also occurred at the original X15 site, resulting in data lose there despite eventual recovery of the Onset analyzer. The site was subsequently relocated. Three more analyzers failed to operate late in the project. Sites T15 and Z17 failed during the first IOP, and site AA8 collected no data after December 30.

In order to check and document the operational consistency of the Onset CO analyzers, three rounds of zero/span calibrations were run on each sampler during the field study. The first round of zero/span checks was performed at the T&B Systems field office during December 3 to 6; the second round took place after the first IOP during December 21 to 24; and the third run took place after the end of the monitoring program, on January 8 to 9. The checks, which are described in more detail in Section 4, were run using the same sealed controlled airflow chamber used during acceptance testing and the internal audit. Certified standard zero air and 43.3 ppm CO span gas were used in the chamber for durations of 30 minutes each. Appendix B contains the SOP's describing the zero/span procedure. The results are provided in tabular form in Appendix E.

Recorded CO data were downloaded from the Onset analyzers on an as-required basis during the period of field operations. No more than a 12-day interval between downloads occurred for any given sampler, and more often the interval was much shorter. A particular effort was made to download data just prior and after IOP operations, and also during the initial week of the project in order to assure that problems were identified early. See Appendix C for a complete summary of the sampler deployment and data downloading history.

Data was typically downloaded at the T&B Systems field office, where it then underwent initial processing and QC. The processing included the conversion of the raw data files to ASCII text format, and then to MS Excel format. An initial visual check of raw data plots was also performed immediately after the download. The Excel formatted data was then labeled and trimmed of extraneous data recorded outside of the valid monitoring period. The data set was then examined again, and invalid or suspect data were flagged. At that point, the data was considered to be at Validation Level 0.5, and it was sent to the T&B Systems main office for further processing. Appendix B in this report contains the SOP's for the field data recovery and initial data processing sequence.

5.3 Intensive Operations Period (IOP) Activities

The synoptic weather conditions during the field effort provided two periods when a full IOP effort including the operation of the sampling van (for instantaneous mobile measurements) and Saturation Network (continuous monitoring) was possible. These periods were December 16 through December 20, 2001, and December 26 through December 29, 2001.

Figure 5-1 shows time-series histogram plots of the daily peak CO 8-hour averages for two Saturation Network monitoring sites; one representative of the inner core area and the other representative of the outer fringe, away from direct urban influence. There were three distinct time periods when high CO loading in the inner core area was evident. The CO peaks were centered on December 8, December 19, and December 27. As discussed above, the latter two periods were IOPs and full operations were conducted. The period from December 4 through December 9 provided the first opportunity for an IOP operation, and in fact the IOP field crew was ready to travel to the field on the morning of the 5^{th} when the IOP was aborted due to forecast increasing winds for December 7. Stronger winds did materialize on the $7^{th,}$ as a short wave system slipped through the Great Basin. Another short ridge of high pressure built into the area on December 8 and 9, but that feature was cut short by more troughing activity by the 10^{th}. As can be seen from Figure 5-1, CO levels were building up on December 4-6, dropped significantly on December 7, then increased again on the 8th and 9th before CO levels dropped to background values again on the 10th. It is clear that IOPs were conducted during the most favorable conditions for producing high CO concentrations that occurred during the field study.

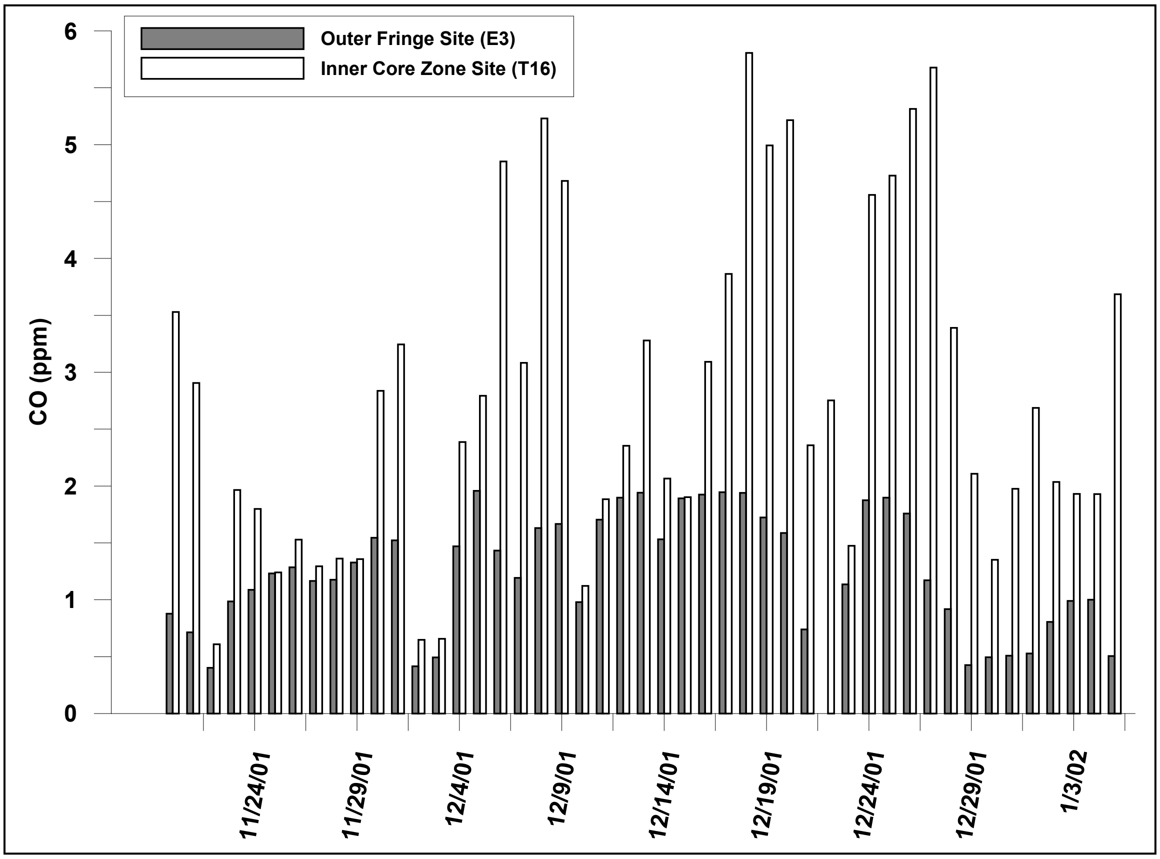


Figure 5-1. Time-Series of 8-hr Averaged CO Peaks from Saturation Network

5.3.1 IOP Coordinated Operations

The Saturation Network was expanded three times during the IOP periods to include Dynamic monitoring sites. Placement of the Dynamic sites was determined based on intelligence gained from stationary (Static sites) and mobile sampling. During the first IOP, 54 sites comprised the Saturation Network. Six Dynamic sites were added during the first IOP. At the start of the second IOP, the Saturation Network consisted of 63 sites.

The sampling van was maintained in a ready mode by the operators throughout the study and was mobilized once the decision for IOP sampling was made.

IOP field sampling operations were run out of the T&B Systems field office in Las Vegas. Sampling van instrumentation warm-up and shutdown, as well as zero/span calibration checks, was done at that location. The sampling strategy, including the routes and times, was determined based on the conditions existing during the operational days. Current weather and CO concentrations, available in near real-time from the DAQM Network, and real-time feed back of monitored data from the van were used to adjust operations sequence in a real-time while thus optimizing measurements.

5.3.2 Mobile Van Sampling

Data from the van served two purposes, to map the spatial distribution of CO throughout the Las Vegas Valley, and to aid in the selection of the regions to place the dynamic samplers. **Table 5-3** summarizes the mobile van sampling runs within the IOP periods and provides a brief overview of the goals of the sampling and an indication of the maximum observed CO concentrations during the mapping exercises. **Figure 5-2** is an example of a map showing the route of the sampling van and times when sampling was performed. Maps depicting the van routes for each sampling run are given in Appendix H.-

Table 5-3. Summary of Sampling Van Operations

Run #	Period of Operation	Description of Sampling Performed	Maximum CO (ppm)
1	12/16 1837-2200	• Evaluation of the system to sample on busy streets • Test and identify appropriate streets for traversing • Perform initial surveys of key identified areas	5.6
2	12/17 0731-0956	• Map extent of CO plume down Boulder Highway • Investigate CO levels in haze plume toward Henderson • Investigate the N/S extent of the CO values in 5-points area • Investigate the E/W extent of the CO plume along Charleston	9.6
3	12/17 1712-2218	• Map the E/W and N/S extent of CO plume in downtown and 5-points area • Implement a “confirmation loop” to verify higher CO levels along the major roadways by performing short trips through neighborhoods adjoining the primary traverse roads • Investigate the relationship of observed wood smoke smell to CO levels	8.0
4	12/18 0717-1029	• Focus on target areas and map neighborhoods around maximum concentrations near existing monitoring stations • Investigate the southern extent of the CO plume • Investigate the western extent of the CO plume	9.0
5	12/18 1807-2215	• Investigate the northwest extent of the CO plume during the evening rush hour traffic • Perform a detailed investigation of the higher CO levels in the target area and spatial extent of the highest concentrations	9.5
6	12/19 0708-1017	• Investigate the northwest extent of the CO plume during the morning rush hour traffic • Evaluate the N/S and E/W extent of the CO plume • Investigate the regions around select AQM stations to verify appropriate siting for high CO levels • Investigate the southeast extent of the CO plume to try and observe CO entrained in the drainage flow	8.3
7	12/19-12/20 1830-0009	• Evaluate the N/S extent of the CO carryover from the daytime • Characterize the evening profile along Rancho Road in the northwest • Identify the potential drainage flow pattern and track the path of the CO plume when drainage is established	8.5
8	12/26 2216-2330	• Evaluate the post-rush hour traffic to look at the spatial extent of the CO plume • Observe the somewhat reduced traffic city-wide during the holiday period • Evaluate the first day plume of a multi-day event	7.7
9	12/27 0703-1001	• Attempt to observe carry-over from previous evening • Evaluate the CO distribution during non-school and reduced work travel schedule • Identify other potential areas where CO may be present • Evaluate the entire valley CO from northwest to southeast • Explore areas south of Owens and west of Eastern for areas of elevated CO	7.9
10	12/27-12/28 1711-0206	• Perform extensive spatial mapping to find additional potential CO maximums • Identify if the drainage flow is draining CO toward Lake Mead • Investigate the CO levels in the northwest and around those Casinos	9.7
11	12/28-12/29 1814-0042	• Perform north to south traverse down strip to observe CO exposure to pedestrians • Evaluate NW area for CO during period of improved mixing • Perform additional neighborhood evaluations	8.3

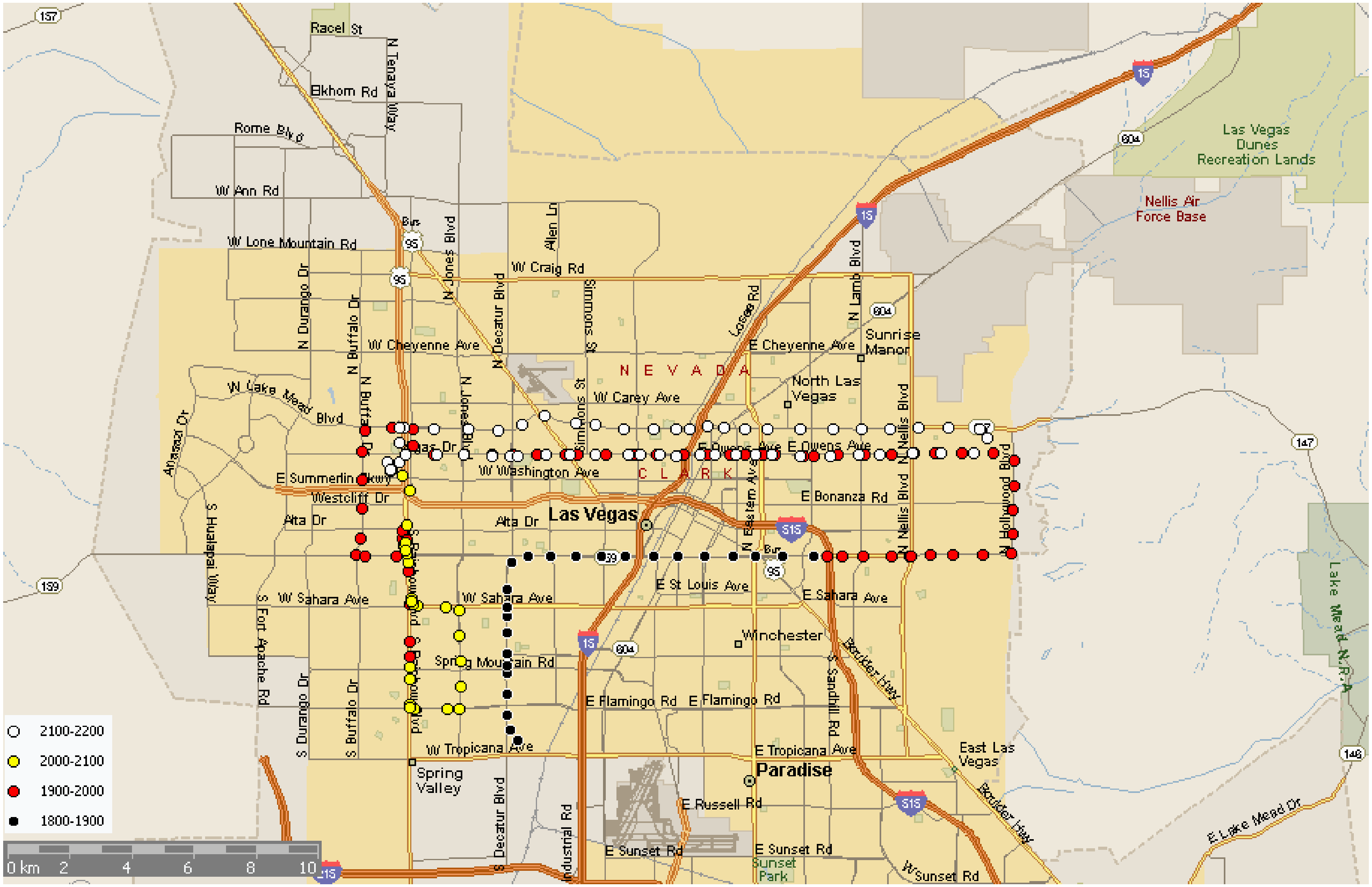


Figure 5-2. Sample Map of Mobile Sampling Times and Locations for the Evening of December 16, 2001

6. RESULTS

6.1 Saturation Network Sampling - Static and Dynamic Sites

The 1-hour and 8-hour averaged databases from the 63-site Saturation Network were examined to determine the geographic distribution of CO during peak periods. The Saturation Network included three sites that had been classified during the siting process as representative of the micro-scale, and were intended to measure impacts from very localized sources. Three other sites, although not originally classified as micro-scale, exhibited characteristics that suggest significant impacts from local sources on an intermittent basis. This subset of sites is addressed separately in the following discussion.

6.1.2 Maximum CO Levels

6.1.2.1 Maximum Over Period of Field Measurements

The major objective of this study is to determine if the DAQM CO Network captures peak CO ambient concentrations, and is representative of the CO exposure levels in the Las Vegas Valley. As can be seen from **Figure 6-1**, this appears to be the case. In the figure, isopleths of the peak running 8-hour averaged CO levels generated from the Saturation Network data for the period of the field study (November 20, 2001 to January 5, 2002) are shown. The locations of the existing DAQM sites that measure CO are shown as well. Of particular note is that there is a concentration of DAQM sites in the most severely impacted area. The Sunrise Acres (SA) site was ideally located to measure maximum levels as defined by the Saturation Network. Generally low CO concentrations (peaks <2.5 ppm) were experienced in the fringe areas outside the inner core. A sense of the CO gradient between the core and the outer areas in the Las Vegas Valley is provided on the time-series plots shown in Figure 5-1 of this report. A representative sample of peak concentrations at select locations throughout the Valley is given in **Table 6-1**.

Table 6-1. Peak 8-hour CO Concentrations (ppm) from Select Sites in the Saturation Network

Location	Site ID	Highest	2nd Highest	3rd Highest
Inner Core - Las Vegas	xU16	7.18	7.07	7.01
Airport Access Road	R8	2.92	2.88	2.88
New Development - So. Highlands	SoH	1.95	1.94	1.93
Westside Community - The Lakes	E13	1.96	1.95	1.94
Southside Community - Galleria Mall	BB5	2.29	2.28	2.26

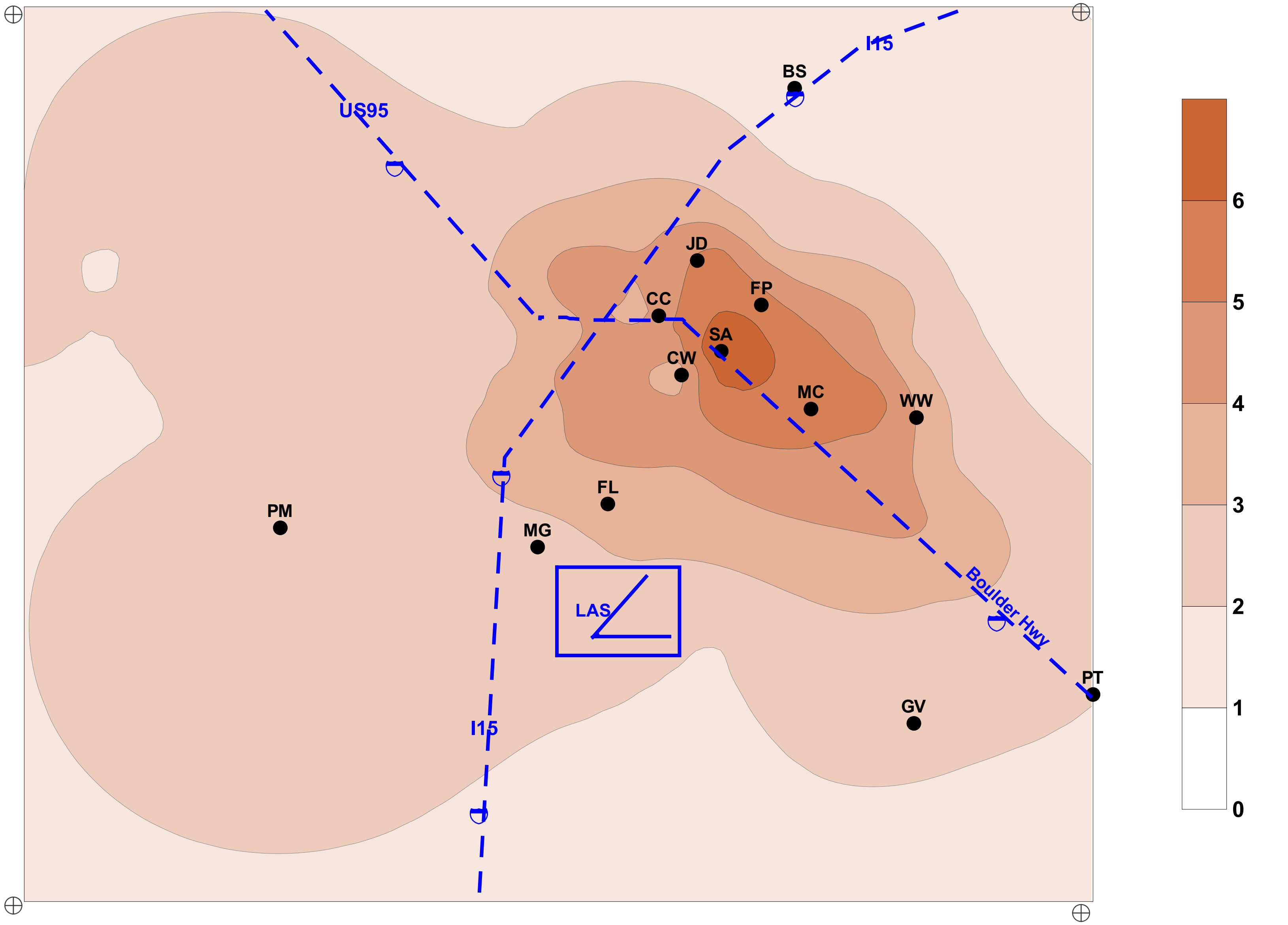


Figure 6-1. Peak 8-hour Average CO (ppm) for Period November 20 to January 5 Showing DAQM CO Sites

Figure 6-2 shows the Saturation Network sites that were used to develop the CO map on Figure 6-1. The philosophy associated with the selection of Saturation sites is discussed in Section 3 of this report. As can be seen from Figure 6-2, the Saturation Network included representative sites from throughout the developed areas of the Las Vegas Valley.

6.1.2.2 Maximum During IOPs

It should be noted that Figures 6-1 and 6-2 were constructed using the peak 8-hour concentrations experienced during the field study without regard to date. In fact, 50 percent of the peaks shown occurred on either December 26 or 27, and 80 percent during one of the two IOP's (December 17-20 and December 26-28). However, the number of sites in the Saturation Network increased from 36 on November 20 to 63 by the end of the second IOP. Ten additional sites were installed after reviewing the Static and mobile measurements acquired during the first IOP thus providing additional coverage in potential locations of elevated CO levels. The reader is referred to Tables 5-1 and 5-2 in this report for a complete list of the dates data acquisition started at sites in the Saturation Network.

The maximum or peak 8-hour CO concentrations occurring during the two IOP's are shown in **Figures 6-3 and 6-4**. All sites in the Saturation Network are included in the dataset from which the figures were developed, including micro-scale sites. Although all days that comprised the IOPs were included, the peak concentrations experienced during the first IOP were evenly distributed between the 17th and 18th, and mostly on the 27th during the latter IOP.

In general, the geographic distribution of CO was similar during both episodes in that the inner core area was impacted the greatest, and high concentrations tended to follow the terrain sloping southeastward parallel to the Las Vegas wash. The latter feature is due to transport by terrain-induced drainage flows during the nighttime. CO levels within the drainage flow were measured in more detail during mobile sampling that is discussed in Section 6.2.

Notable differences in the geographic distribution of CO between the two episodes are that high concentrations were more widespread and background levels throughout the Valley were somewhat lower during the late December IOP.

Although the DAQM Network covers the maximum impacted area, secondary areas to the southeast and northwest of the Las Vegas City Center where impacts owing to drainage-flow transport are not well defined.

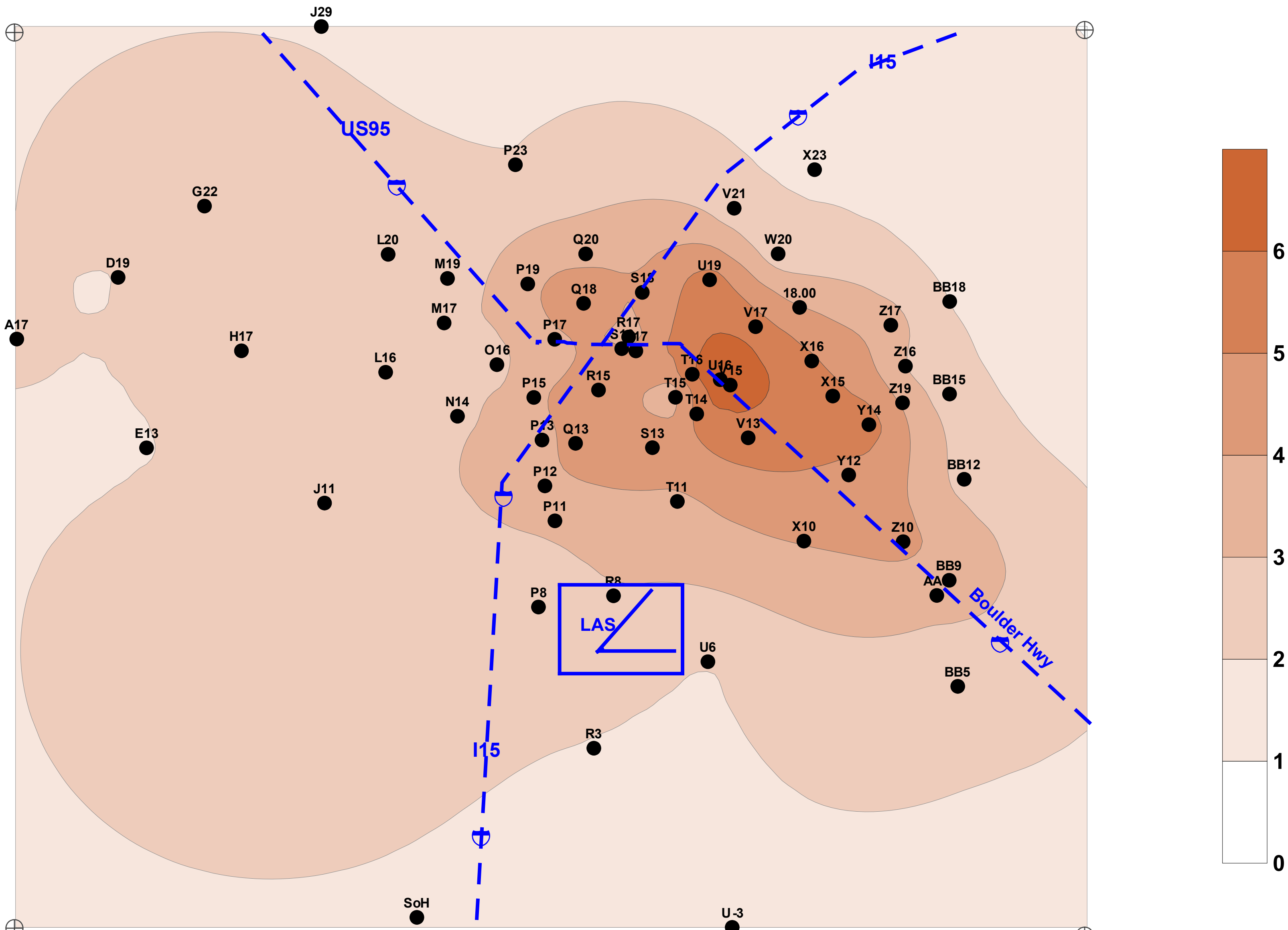


Figure 6-2. Peak 8-hour Average CO (ppm) for Period November 20 to January 5 Showing Saturation Network Sites

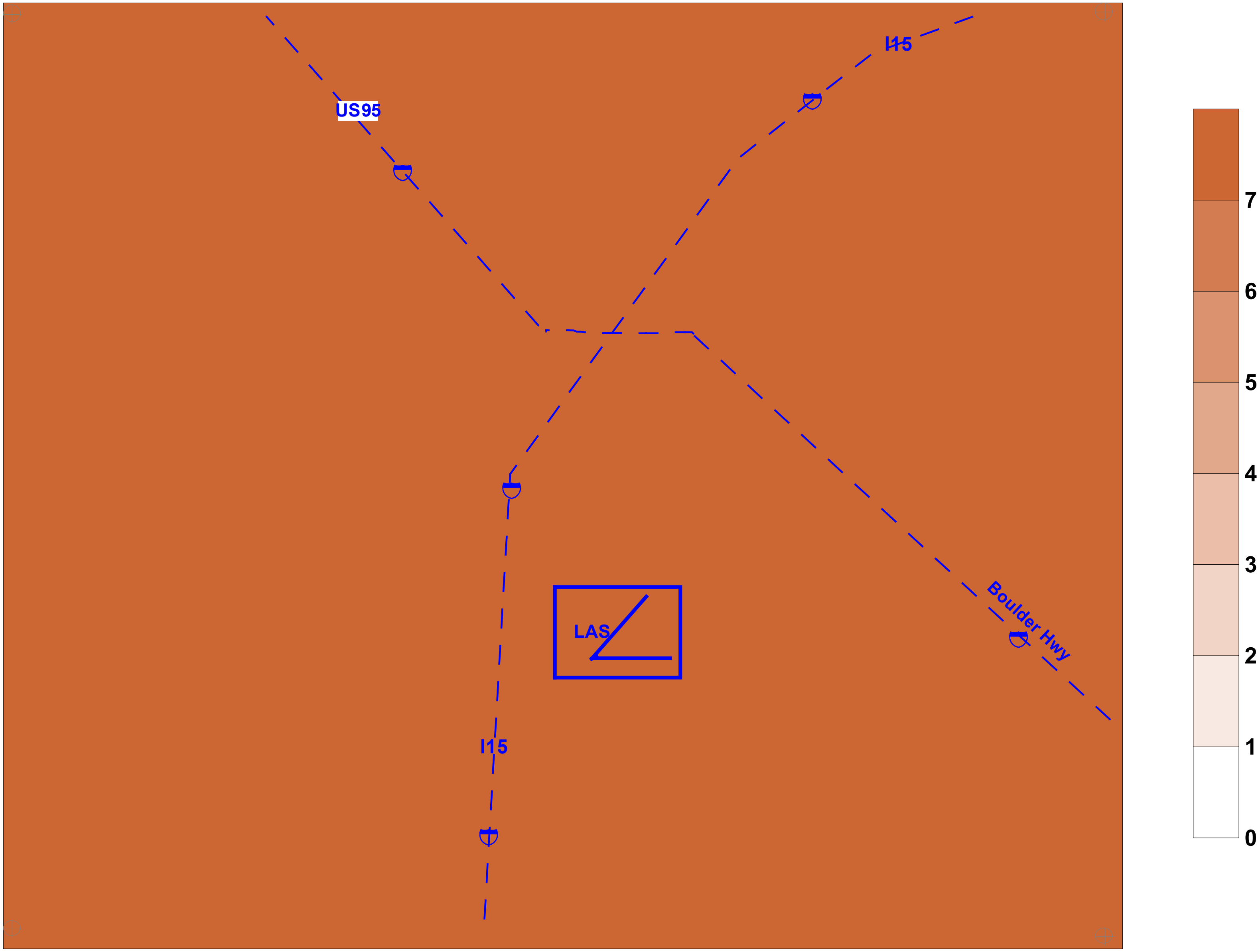


Figure 6-3. Peak 8-hour Average CO (ppm) for Period December 16 to 20, 2001 Showing DAQM Network Sites

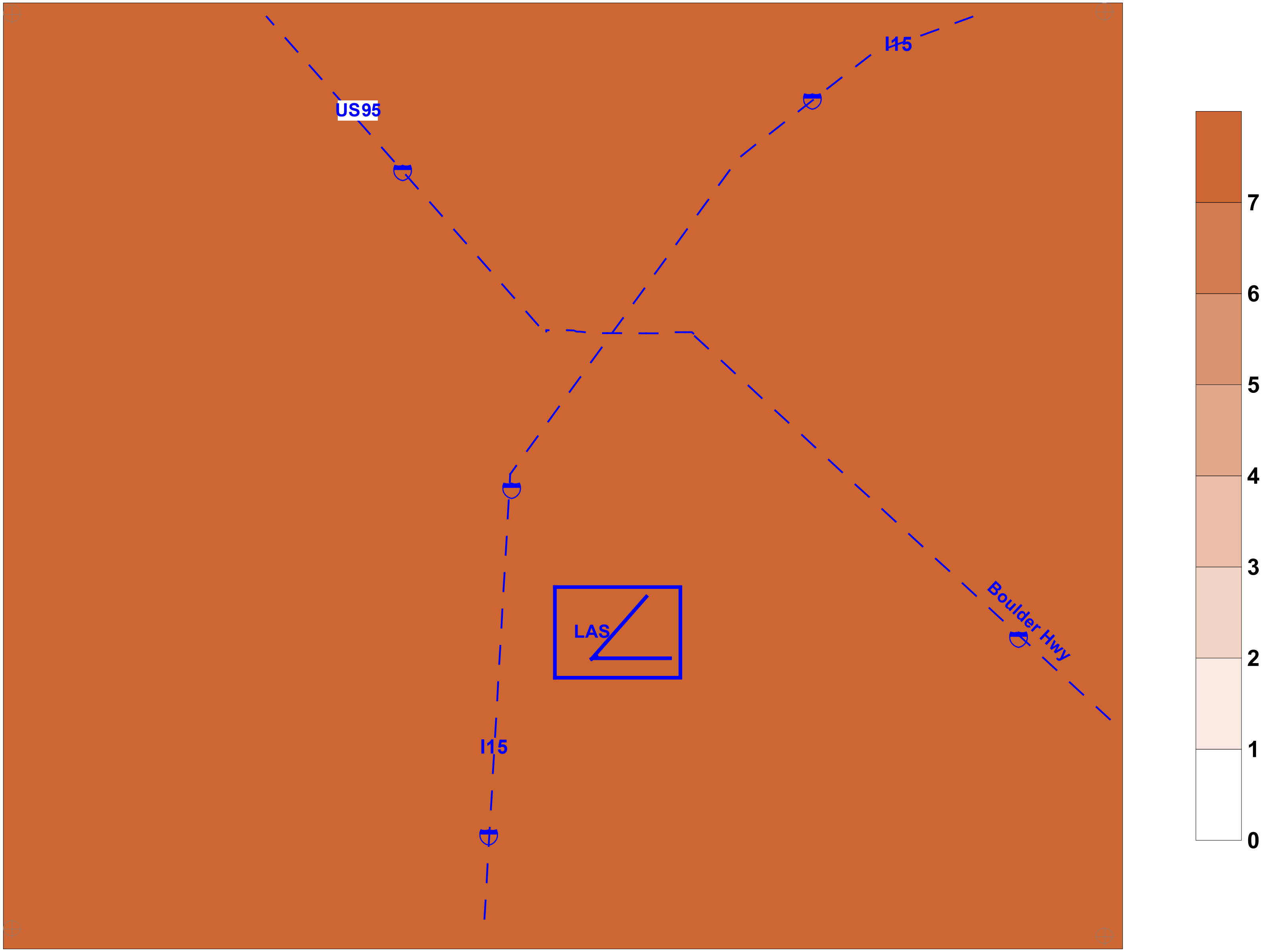


Figure 6-4. Peak 8-hour Average CO (ppm) for Period December 27 to 29, 2001 Showing DAQM Network Sites

6.1.3 Micro-scale Measurements and Aberrations

6.1.3.1 Micro-scale Sites

Three of the Saturation Network sites were classified as micro-scale and were included to aid in understanding the behavior of local sources. The S16 site was located at a taxi loading area adjacent to the Fremont Street Experience. A second site, Q13, was curbside to Las Vegas Blvd, in front of a theme park (Wet and Wild), and exposed to heavy vehicular traffic. The third site, V15, was located at the DAQM's designated Microscale site (MS) (CO monitoring has been discontinued at this site).

The highest CO levels experienced in the Saturation Network were at the S16 or "Taxi stand" site. Peak instantaneous levels in excess of 40 ppm were measured. Hourly averages ranged as high as 18.3 ppm. Both levels were the maximum measured in the Saturation Network. Owing to the more intermittent nature of the source activity (waiting taxis), S16 did not experience the highest 8-hour averages in the Saturation Network. The typical diurnal variation in hourly concentrations is shown in **Figure 6-5**.

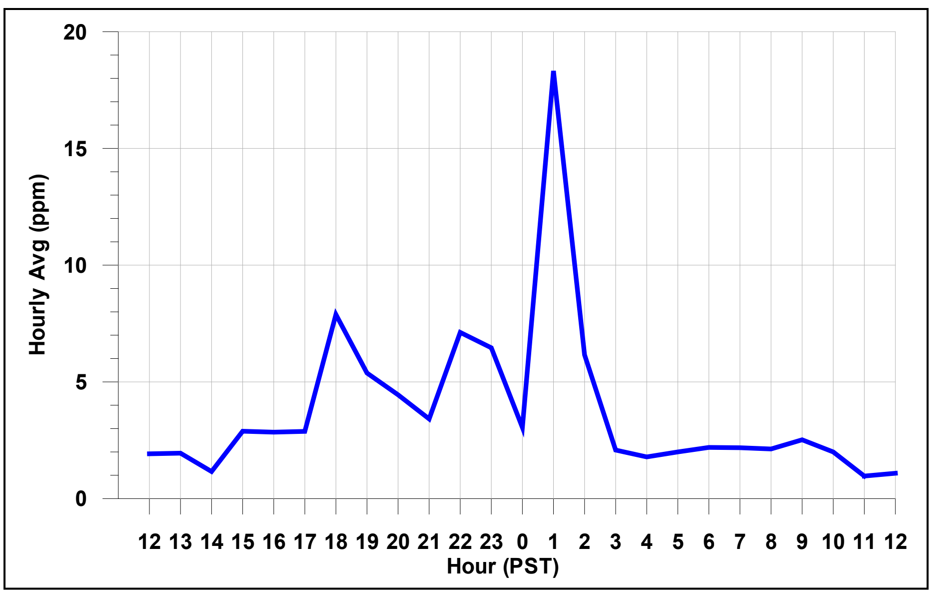


Figure 6-5. Diurnal Variation in Hourly CO at S16 (Taxi Stand)
December 11 to 12, 2001

6.1.3.2 Aberrations

Three other sites that were initially classified as either middle- or neighborhood-scale stood out as outliers when the measurements at those sites were compared to the other sites in the network. The sites, N14, L16, and P12 experienced isolated high CO levels that, from our examination of the high-resolution minute readings, were considered valid measurements. The former two are located in residential neighborhoods with only local traffic thus it can only be assumed that the high levels were caused by vehicles parking with engines running for extended periods (5-10 minutes). This resulted in unexpectedly high hourly averages on an occasional basis but did not appear to significantly affect the 8-hour averaged levels. The third site (P12) was located in front of the Fashion Show mall on Las Vegas Blvd. The analyzer was located approximately 35 meters from the intersection of Las Vegas Blvd. and Fashion Show Rd., near the front entrance to the Saks Fifth Avenue Department store. The site should be adequately distanced far enough away from Las Vegas Blvd. so as not be overwhelmed by vehicular traffic. Nevertheless, high CO levels were persistent to the extent that the hourly averages were elevated above those of the surrounding saturation sites. These three sites were excluded from hourly analyses but included in the results for 8-hour average CO readings.

An examination of the maximum concentrations experienced during the field program provides additional useful information. **Table 6-2** provides the peak 8-hour averaged CO levels measured by the Saturation Network ranked by concentrations. The data set used to produce the table itself was a subset of the total data consisting of the top five levels measured at each site in the Network hence the maximum entries possible in Table 6-2 is five. Also included is the site name, date and time of occurrence. Note that the peak levels in the table were experienced at four of the 63 sites in the Saturation Network. The S16 site at the taxi stand is a micro-scale site not necessarily representative of a significant health risk exposure to more than a small group of people. The three other sites, xU16, V15, and T16 are of primary interest. They are all located in the so-called inner core area. The V15 monitor was located at the DAQM Microscale site at which the routine measurement of CO was discontinued, as it was not considered representative of the general population exposure in that area. However, the Saturation Network xU16 site was located nearby in a neighborhood at a reasonable distance from heavy vehicle traffic or industrial sources. As can be seen from the data in the table, the highest levels were measured at that site. The Saturation T16 site was also located in a neighborhood several blocks west of the Sunrise Acres site. Measurements at the T16 site were among the highest levels experienced during the study.

The maximum 8-hour CO concentrations at all Saturation sites are shown in **Table 6-3**. The date and time of occurrence is also given. Note that most of the peak levels were measured during the two IOPs. Nearly all of the 10 sites that were exceptions are located outside the urban area. U19, situated near the county's J.D. Smith site, experienced maximum CO levels on December 8, which had been a candidate IOP day.

Table 6-2. Twenty 8-hour CO Concentrations Measured in the Saturation Network

Site ID	Date	Start_hr	Co(ppm)
xU16	27-Dec-01	18	7.18
xU16	27-Dec-01	17	7.07
S16	27-Dec-01	17	7.05
xU16	26-Dec-01	15	7.01
S16	11-Dec-01	18	7.01
S16	27-Dec-01	18	6.97
xU16	27-Dec-01	19	6.97
S16	27-Dec-01	16	6.95
xU16	26-Dec-01	18	6.94
S16	27-Dec-01	15	6.92
V15	27-Dec-01	18	6.56
V15	27-Dec-01	19	6.45
V15	27-Dec-01	17	6.41
V15	27-Dec-01	16	6.11
V15	26-Dec-01	18	6.08
T16	19-Dec-01	8	5.81
T16	18-Dec-01	19	5.68
T16	19-Dec-01	7	5.64
T16	27-Dec-01	19	5.61

Table 6-3. Maximum 8-hour CO Concentrations at All Saturation Network Sites

Site	Date	Start_hr	CO(ppm)
Z19	20-Dec-01	13	2.37
Z17	20-Dec-01	13	3.59
Y14	27-Dec-01	19	5.58
xZ16	22-Dec-01	19	2.91
xZ10	27-Dec-01	19	4.23
xY12	27-Dec-01	19	4.65
xX18	27-Dec-01	18	4.05
xW20	27-Dec-01	17	2.32
xV21	27-Dec-01	17	2.42
xU16	27-Dec-01	18	7.18
xR17	27-Dec-01	18	3.23
xQ18	27-Dec-01	18	5.25
xP19	27-Dec-01	18	3.78
xP17	01-Jan-02	18	3.66
xP15	19-Dec-01	18	3.94
xP13	27-Dec-01	20	3.57
xP11	27-Dec-01	19	3.19
xO16	27-Dec-01	19	2.62
xM19	27-Dec-01	18	2.47
xBB18	17-Dec-01	23	1.97
xBB15	27-Dec-01	19	2.49
xBB12	27-Dec-01	22	2.58
X23	17-Dec-01	23	1.96
X16	27-Dec-01	19	5.14
X15	27-Dec-01	19	5.21
V17	27-Dec-01	18	5.45
V15	27-Dec-01	18	6.56
V13	27-Dec-01	18	5.53
U6	17-Dec-01	23	1.98
U-3	17-Dec-01	23	1.95
U19	08-Dec-01	18	5.55

Site	Date	Start_hr	CO(ppm)
T16	19-Dec-01	8	5.81
T15	20-Dec-01	2	3.16
T14	26-Dec-01	19	5.33
T11	26-Dec-01	2	3.75
SoH	17-Dec-01	23	1.95
S18	27-Dec-01	18	4.05
S17	26-Dec-01	19	4.73
S13	20-Dec-01	2	4.63
R8	13-Dec-01	19	2.92
R3	26-Nov-01	1	1.99
R15	27-Dec-01	19	4.39
Q20	27-Dec-01	18	3.55
Q13	19-Dec-01	8	4.44
P8	18-Dec-01	1	2.29
P23	08-Dec-01	18	2.05
P12	29-Nov-01	4	3.78
N14	30-Nov-01	5	2.85
M17	19-Dec-01	3	2.95
L20	27-Dec-01	18	2.48
L16	05-Dec-01	3	2.90
J29	17-Dec-01	23	1.96
J11	28-Dec-01	18	2.94
H17	20-Dec-01	7	2.30
G22	20-Dec-01	6	2.36
E13	05-Dec-01	6	1.96
D19	16-Dec-01	3	1.99
BB9	27-Dec-01	19	3.92
BB5	19-Dec-01	3	2.29
AA8	27-Dec-01	18	3.29
A17	04-Dec-01	10	2.05

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6.2 MOBILE SAMPLING

The results of the sampling performed using the sampling van are presented in two sections. The first section describes the measurements during the first IOP from December 16 to 20. The second section describes measurements during the second IOP from December 26 to 29. Within each section are discussions for each of the periods when sampling was performed. Included with each discussion are color-coded maps depicting the observed spatial distribution of CO over the respective sampling period. As appropriate, more detailed discussions and finer resolution maps are provided to present the sampling results. One of the key areas of focus was in the inner core region around the intersection of Charleston Blvd., Eastern Avenue, and Fremont Street. For simplicity this area is referred to in the discussions below as the CEF area.

6.2.1 December 16 – 20

Seven sampling events were conducted during the first IOP. The results from each of the events are described below.

<u>December 16 Evening</u>

Figure 6-7 presents the overall CO observations during the sampling period. Key findings from the run include:

- While not high in relative concentration, there were several instances when rises in CO concentration were accompanied by the smell of wood smoke. These observations were made on Owens Avenue between North Pecos Road and North Lamb Drive.
- It appeared that heavy traffic, such as traffic along Decatur or Charleston in peak commute times, added about 1 to 2 ppm to the general background of CO in the area. Medium to light traffic, with no high emitting vehicles nearby, had little or no influence on the observed CO concentrations.
- Little CO was seen in the region west of I-15 and south of 95. Additionally, the region in the northwest from Charleston to W. Lake Mead and from Rainbow over to Buffalo saw no significant levels of CO.
- Of the east/west traverses made, the highest concentrations were observed in the areas around Eastern Avenue.

<u>December 17 Morning</u>

Figure 6-8 presents the overall CO observations during the sampling period. Key findings from the run include:

- Morning concentrations in the CEF area were greater than 6 ppm with some observations to over 9 ppm along Desert Inn Road, between Eastern and Boulder Hwy, south of this region.
- A traverse down Boulder Hwy showed the drainage flow had been established with concentrations above 4 ppm in the region northwest of Missouri Ave. Concentrations remained above 3 ppm down to Warm Springs Road.
- Traveling down toward Henderson to the region where the haze was observed showed relatively low concentrations of CO.
- The primary CO plume during the north/south traverse along Eastern showed the higher levels of CO to be between Lake Mead Blvd and Desert Inn Road.

December 17 Evening

Figure 6-9 presents the overall CO observations during the sampling period. Key findings from the run include:

- The region of highest concentrations was bounded on the east by Lamb Blvd and the north by Carey Ave.
- A traverse along Charleston Blvd. showed the highest concentrations centered in the CEF area. A north/south traverse along Eastern Ave. showed the highest concentrations in the vicinity of Stewart Ave.
- Multiple traverses along Vegas Drive/Owens Ave showed a peak in the vicinity of Rancho Drive (Business 95) and at about the crossing with Eastern Ave.
- Implementation of the "confirmation loop", where a short drive through neighborhoods adjoining the busy streets was performed, confirming the addition of about 1-2 ppm to the observations along heavily traveled streets.
- Traveling through some neighborhoods there was a wood smoke smell, but concentrations appeared to have no more than 1 ppm added as a result.

December 18 Morning

Figure 6-10 presents the overall CO observations during the sampling period. Key findings from the run include:

- General CO levels throughout the mapping area from the west through the CEF region and to about Lamb Blvd were in the 5 to 7 ppm range. Little CO was observed in the northeast area around Freedom Park. It appeared the primary CO plume was broad and may have been draining in the direction of Boulder Hwy.

- The highest concentrations were observed prior to 9:00 with levels throughout the neighborhoods surrounding the CEF region showing values upwards of 9 ppm.
- By 9:00 much of the overall CO was diminishing rapidly in concentration with the traverse south on Pecos Road from Cheyenne Ave. showing only a minor increase to about 5.5 ppm as Boulder Hwy. was crossed.
- The southern areas down to and around McCarren airport were mapped after 9:00 and little CO was seen. This was potentially due to the later hour and associated greater vertical mixing of the CO significantly reducing the surface level concentrations.

December 18 Evening

Figure 6-11 presents the overall CO observations during the sampling period. Key findings from the run include:

- Concentrations along Rancho Rd. in excess of 7 ppm were observed heading northwest. The elevated concentrations continued to about the North Las Vegas Air Terminal after which they dropped to under 5 ppm. By Craig Road the concentrations were under 4 ppm. The concentrations then dropped to under 3 ppm by the intersection of Rainbow Blvd and Rancho Road. Observations made by the sampling van in this southern part of Rancho Road prompted the addition of Saturation Network sites to characterize this area.
- Several traverses south on Eastern and in the neighborhoods within 2 km of the CEF area showed that to be the region of maximum CO concentration. **Figure 6-12** shows a map with this area ~~and~~ withand observed CO ~~numeric~~ concentrations ~~of the observed CO are~~ displayed. It is clear that while some of the highest CO concentrations were observed along Eastern Ave, the surrounding neighborhoods also showed significant concentrations.
- Observations made this evening with the sampling van prompted the addition of another Saturation Network site (Dynamic site) during the second IOP ~~to be added~~ within the neighborhood adjacent to the Sunrise Acres DAQM station. It appeared the higher levels of observed CO were due to a source other than vehicle emissions.

December 19 Morning

Figure 6-13 presents the overall CO observations during the sampling period. Key findings from the run include:

- The initial morning traverse up Rancho Road to the northwest showed elevated concentrations of CO up until just before Craig Road. ~~To~~ ~~c~~Confirming the neighborhood scale of the CO, rather than just representative of road type emissions, a trip through the housing development just south of Vegas Drive showed values over 7 ppm. Additionally, levels above 5 ppm were seen as far south as Flamingo Road while traversing Decatur on the west side. This showed a more general plume throughout the valley during the morning hours.
- The traverse from north to south along Martin Luther King Blvd showed relatively low concentrations (<4 ppm). This implied a region of lower concentrations of CO between the northwest and west regions, and the inner core area in the eastern portion of the valley. The subsequent traverses through the regions around Freedom Park and Sunrise Acres showed concentrations over 8 ppm.
- Traverses along Stewart Ave in the region of Eastern showed that area to have some of the highest concentrations, with the peak observed value over 8 ppm. Surveys around the DAQM sites showed them to be in the appropriate general region.
- A traverse down Boulder Hwy showed the CO plume to start tapering off between Tropicana Ave. and Russell Road, where concentrations fell below 4 ppm. This implied some of the CO had been entrained in the nighttime drainage flow.
- By the 9:00 to 10:00 hour the overall CO concentrations were dropping rapidly. This was a result of the mixed layer growing and diluting the morning CO.

December 19 – 20 Evening/Night

Figure 6-14 presents the overall CO observations during the sampling period. Key findings from the run include:

- Low concentrations (<3 ppm) were seen along the very western traverse up Durango Drive and then down Rancho Road to the south. The northwest area north of Vegas Drive and west of Decatur had concentrations less than 4 ppm.
- The north/south and east/west extent of the plume was more extensive during this period suggesting the Valley did not clean out during the daytime, and a general elevated CO background was carried over into the nighttime hours.

Concentrations in excess of 5 ppm were seen from Flamingo Road on the south to above Lake Mead Blvd in the north and from Decatur Blvd. on the west to Nellis Blvd. on the east.

- The higher concentrations of CO crossing Nellis Blvd to the southeast of the main CO area suggests that drainage flow was setting up to the southeast. This is further illustrated in **Figure 6-15** which shows the numeric values of the concentrations observed in the vicinity of Vegas Valley Drive and Nellis Blvd. Further downwind, concentrations east of Boulder Hwy and south of Stallion Mountain Golf Club suggested the plume was following the Las Vegas Wash toward Lake Mead. While relatively low, the values along the drainage path of 4 ppm, falling to around 3 within the wash, does support the drainage pattern. The reduction in concentration was most likely due to dilution from low CO concentration air draining from the hills to the east.
- On the basis of the mobile ~~van~~ observations, an additional ~~saturation~~ Saturation Network site was added in the vicinity of the Boulder Hwy intersection with Flamingo and Nellis, behind Sams Town. This site would help identify drainage flow concentrations heading toward the Las Vegas Wash. The site was added prior to the first sampling event of the second IOP.

6.2.2 December 26-29

December 26 Evening

Figure 6-16 presents the overall CO observations during the sampling period. Key findings from the run include:

- ~~Little~~ Only low concentrations of CO were~~as~~ observed west of I-15.
- The mapping of the CO plume showed the highest concentrations to be in the region of the CEF intersection and down Fre~~e~~mont Street toward Boulder Hwy. Concentrations over 7 ppm were observed.

December 27 Morning

Figure 6-17 presents the overall CO observations during the sampling period. Key findings from the run include:

- The highest observed concentrations were ~~in the vicinity of abou~~within~~t~~ an approximate 3 km radius of the CEF area. The highest values were seen along the Eastern Ave traverse and along Fre~~e~~mont from the intersection to the northwest. While the focus was on areas other than around the Sunrise Acres School, that area most likely was also seeing higher values. Prior mapping identified the additional ~~saturation~~ Saturation Network site that was installed at the start of this second IOP, so additional mapping was not performed.

- Given the reduced amount of traffic due to schools being closed, and overall lighter traffic due to the holiday period, much of the CO seen may have been due to carryover through the night period, or possibly locally produced from home or water heating.

December 27 – 28 Evening/Night

Figure 6-18 presents the overall CO observations during the sampling period. Key findings from the run include:

- Mapping performed on the west side around the new developments and ~~Casinos~~ casinos showed no significant concentrations of CO.
- The most significant concentrations of CO were not on either the extreme east or west side of the valley, they were found back in the region of the CEF intersection and in the region around Owens Drive between Main St. and Eastern Ave. **Figure 6-19** shows the numeric concentration values in the Owens region with some of the highest values seen off of the major streets. Given the lack of automobile sources, the CO may be more related to home or water heating related sources. Similarly, **Figure 6-20** shows the ~~numeric values~~CO measurements around the neighborhood near the Sunrise Acres site. Again, the high values were observed away from the major streets and was not related to adjacent vehicle sources.
- Along Boulder Hwy is a secondary peak in CO that was observed in the vicinity of Boulder Hwy and Nellis Blvd. This was in the vicinity of Sam's Town. **Figure 6-21** shows the measured CO~~numeric~~ concentrations.
- Traverses made down Boulder Hwy~~. did~~ showed the plume extending almost to Henderson. Tracing the plume out along East Lake Mead Drive and down into the low areas where drainage would occur ~~did~~ showed slightly elevated concentrations in the low areas that would be draining toward Lake Mead. **Figure 6-22** shows the observed CO concentrations along the southeast portion of the sampling van track~~ showing the numeric values~~.

December 28 – 29 Evening/Night

Figure 6-23 presents the overall CO observations during the sampling period. Key findings from the run include:

- The traverse down the Strip did show some elevated concentrations when traffic was heavy. However, concentrations were no higher than in the CEF region. The higher concentrations were seen down to approximately Tropicana Ave.

- The general concentrations throughout the study region were still relatively high, but values diminished significantly south of Tropicana Ave., as they did down the ~~strip~~Strip. Higher levels were also seen up to the northwest, potentially due to a change in the wind direction.
- Some of the highest levels were seen along an east/west traverse on Stewart Ave. from Nellis to Las Vegas Blvd. up to Bonanza and across Rancho to Vegas Drive and finally ending at Decatur Blvd.
- Surveying the area around Sunrise Acres showed that this site was not in the maximum CO region this night. The maximum region was more to the northwest. It is suspected that a wind direction from the southeast may have moved the overall plume in that direction.

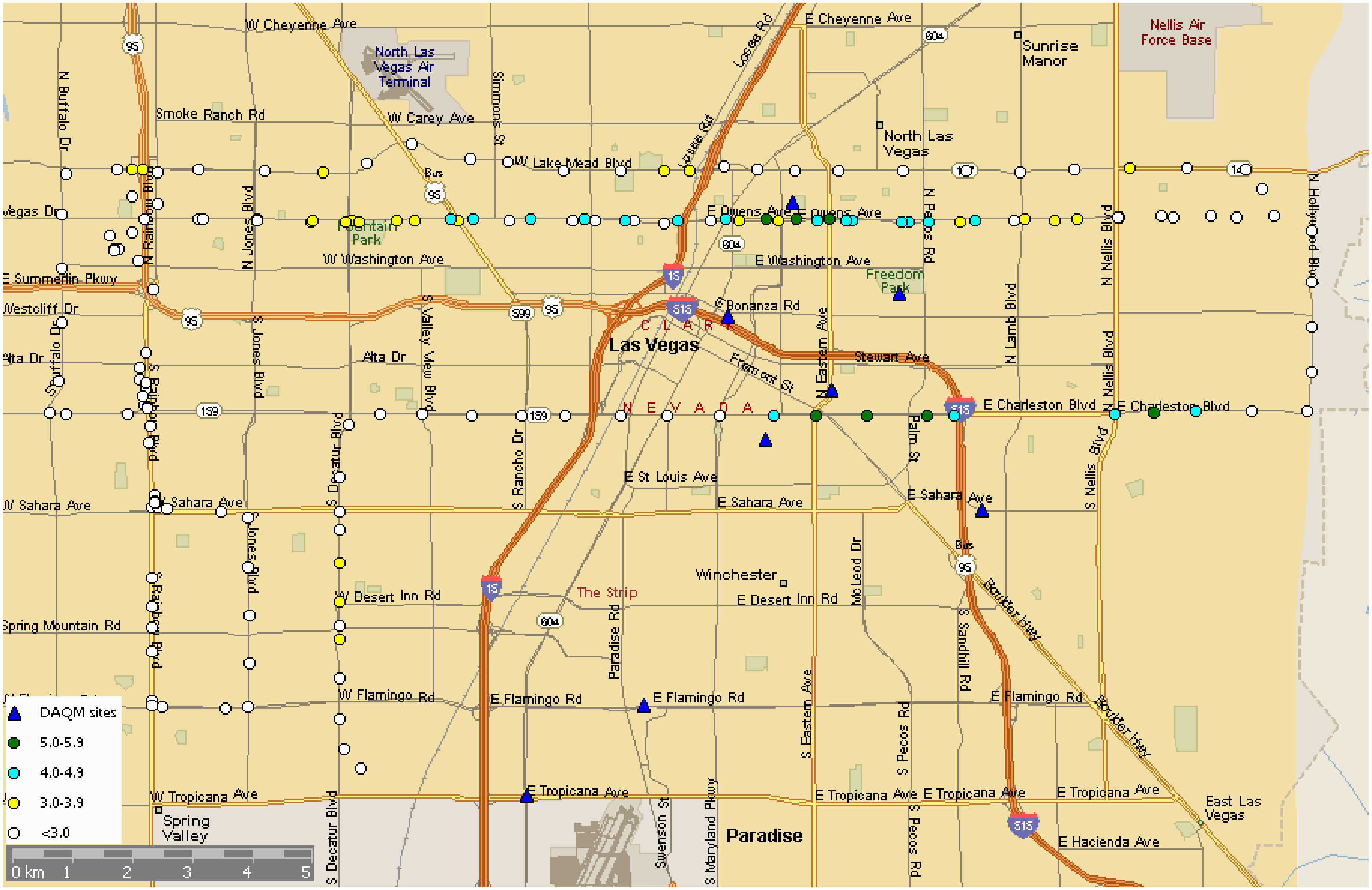

Figure 6-7~~x1~~. Observed CO Concentrations (ppm) During December 16 Evening Period

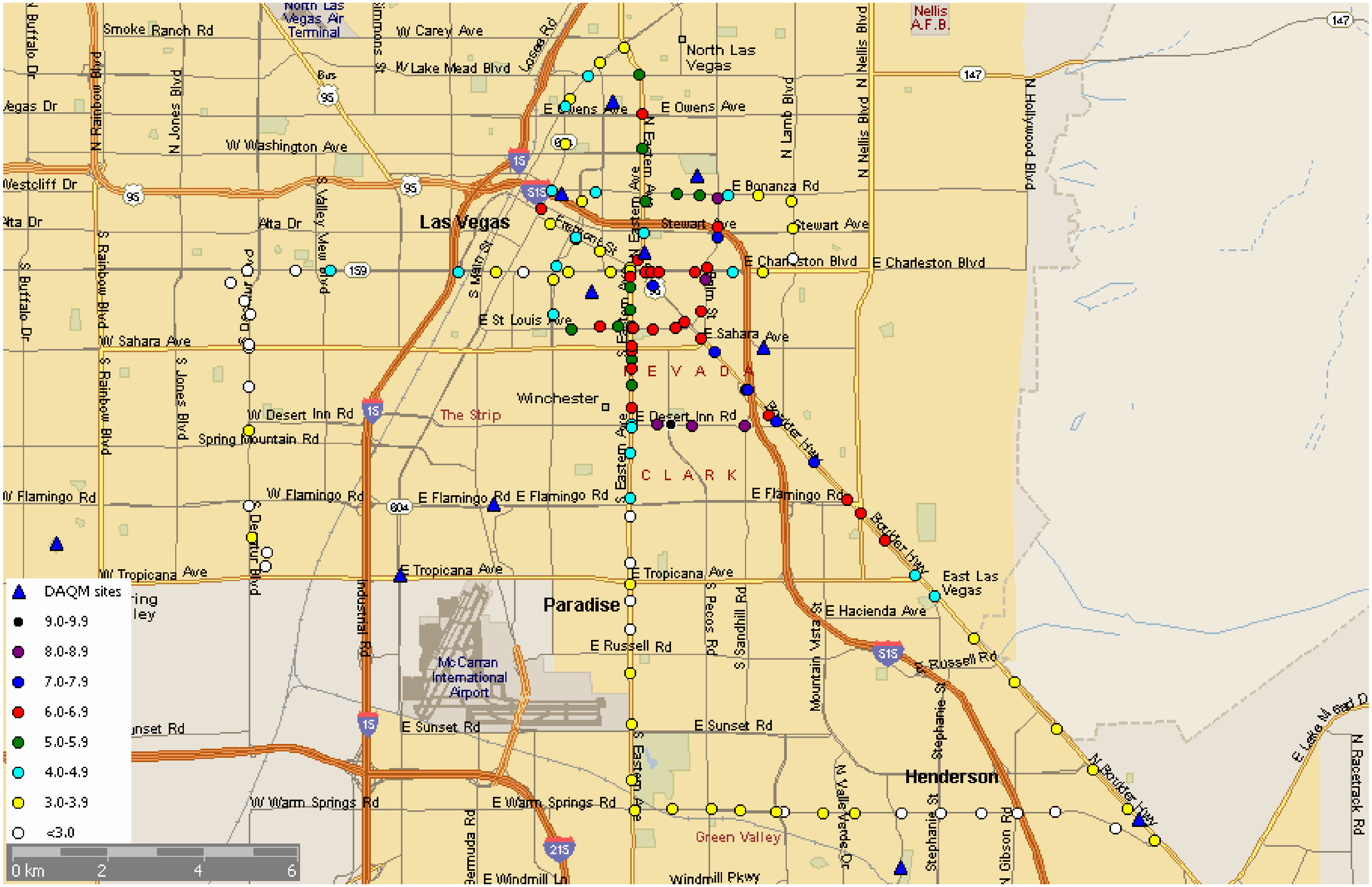

Figure 6-8. Observed CO Concentrations (ppm) During December 17 Morning Period

Figure 6-9. Observed CO Concentrations (ppm) During December 17 Evening Period

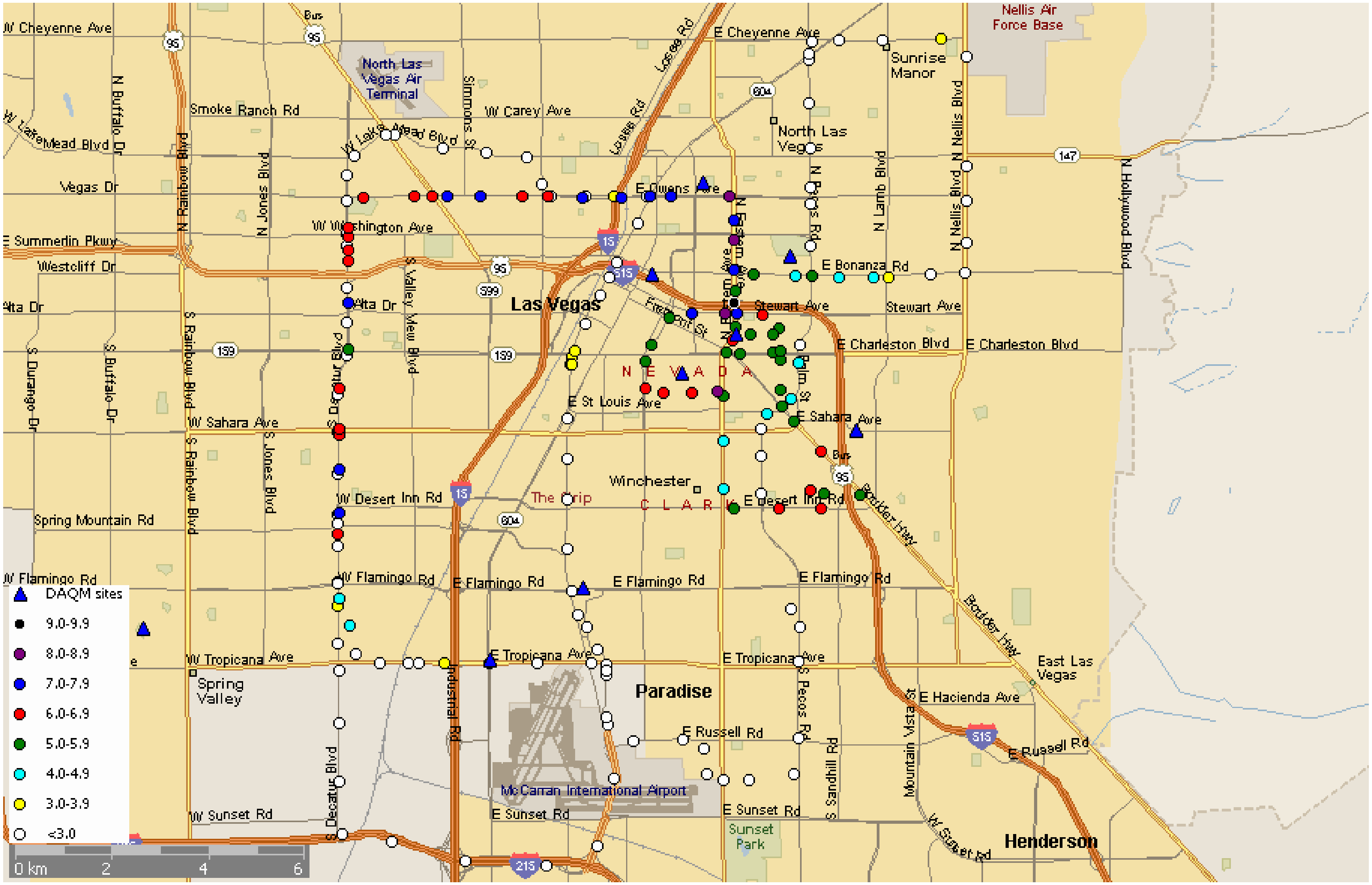

Figure 6-10 Observed CO Concentrations (ppm) During December 18 Morning Period

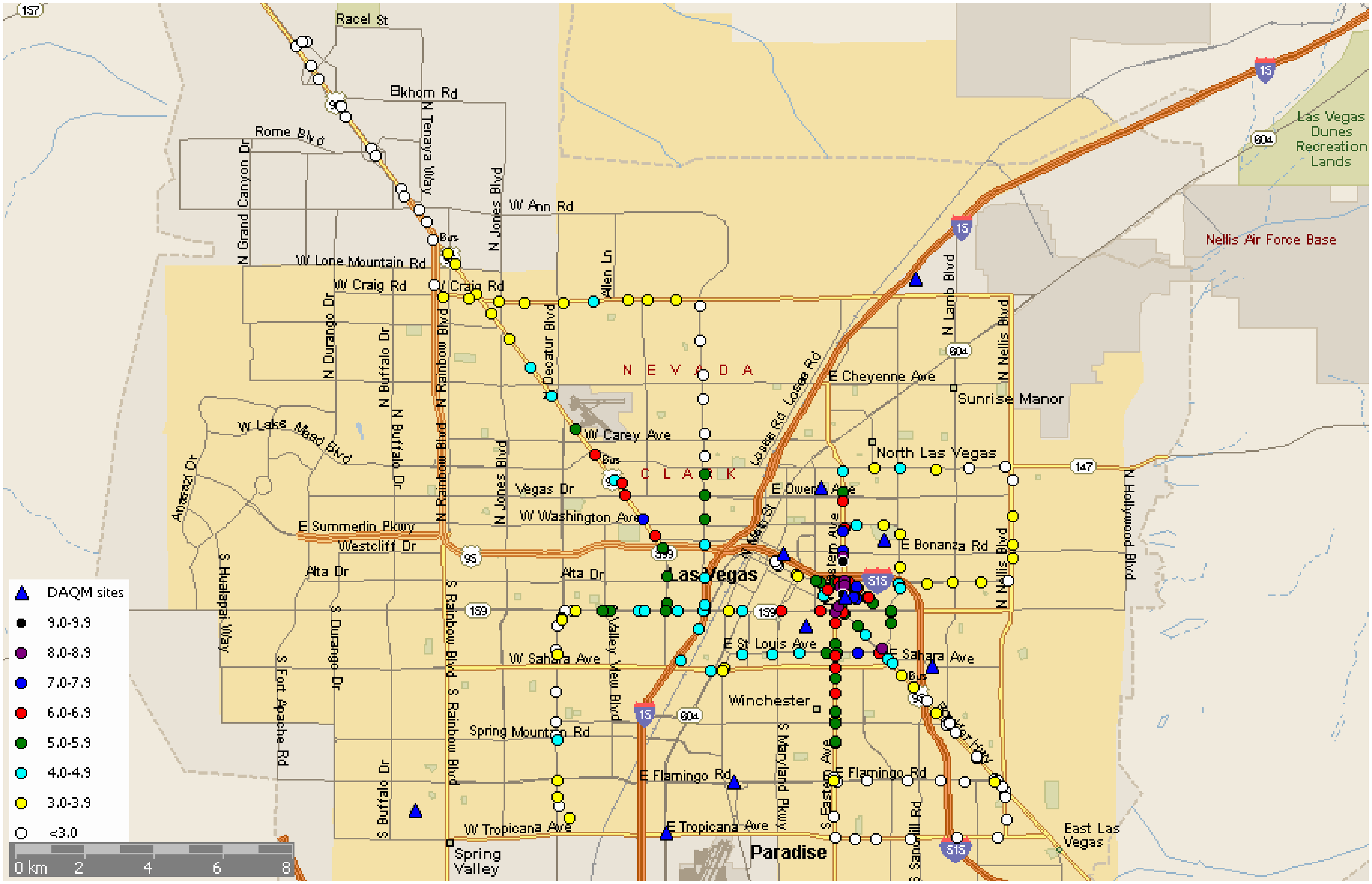

Figure 6-11. Observed CO Concentrations (ppm) During December 18 Evening Period

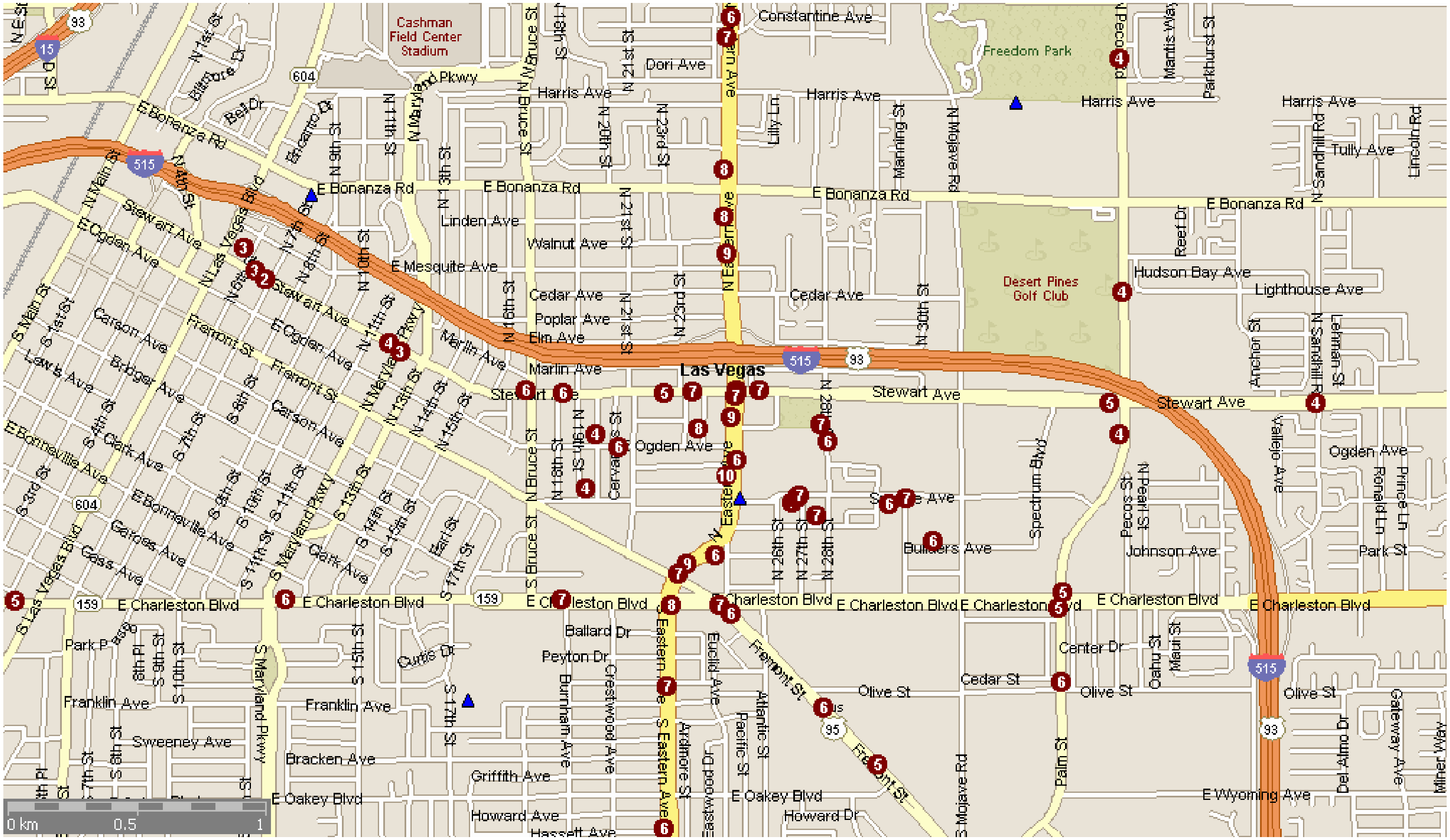

Figure 6-12. Observed Numeric CO Concentrations (ppm) During December 18 Evening Period in the CEF Region. (The DAQM sites are shown in blue triangles.)

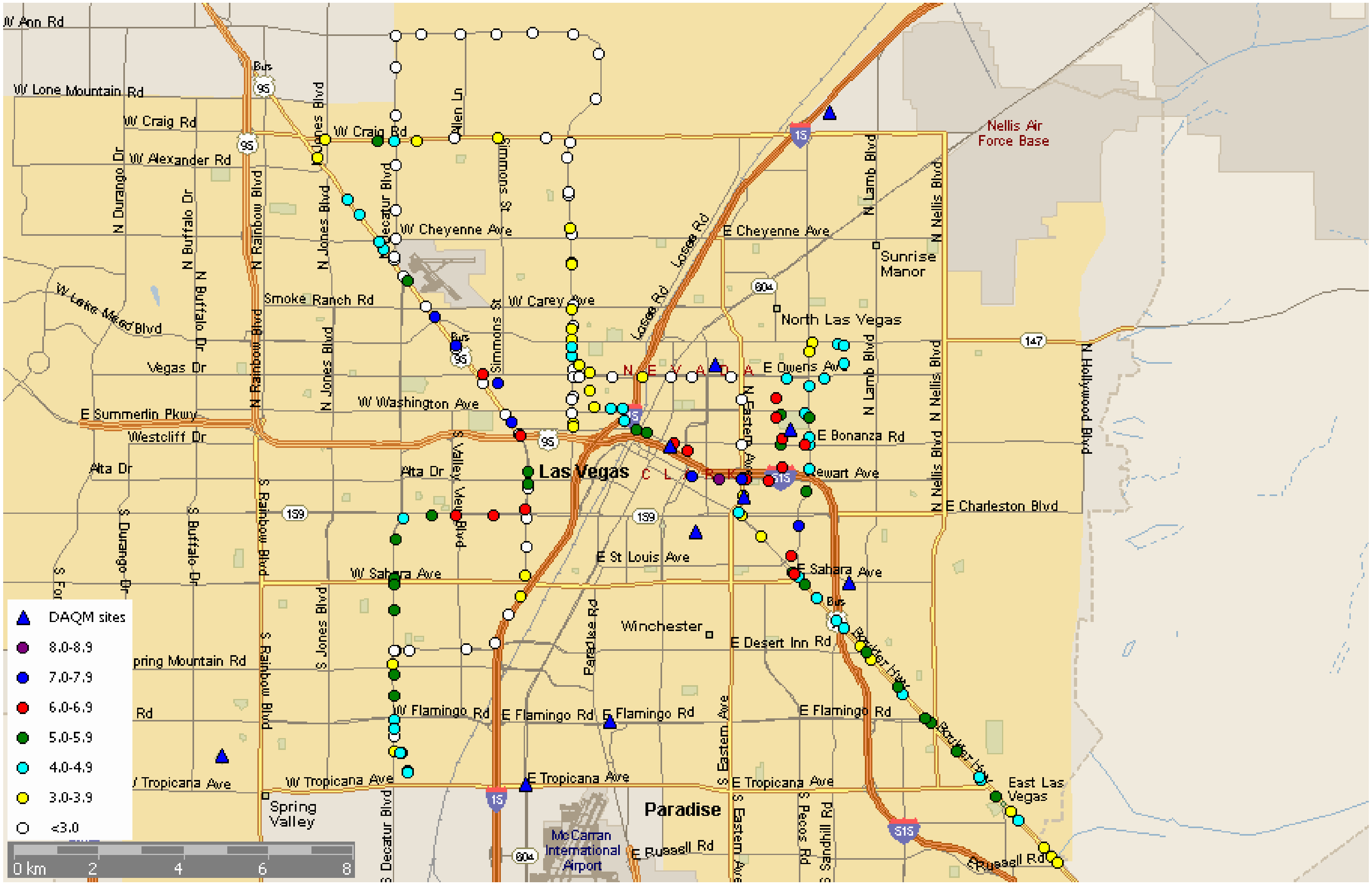

Figure 6-13. Observed CO Concentrations (ppm) During December 19 Morning Period

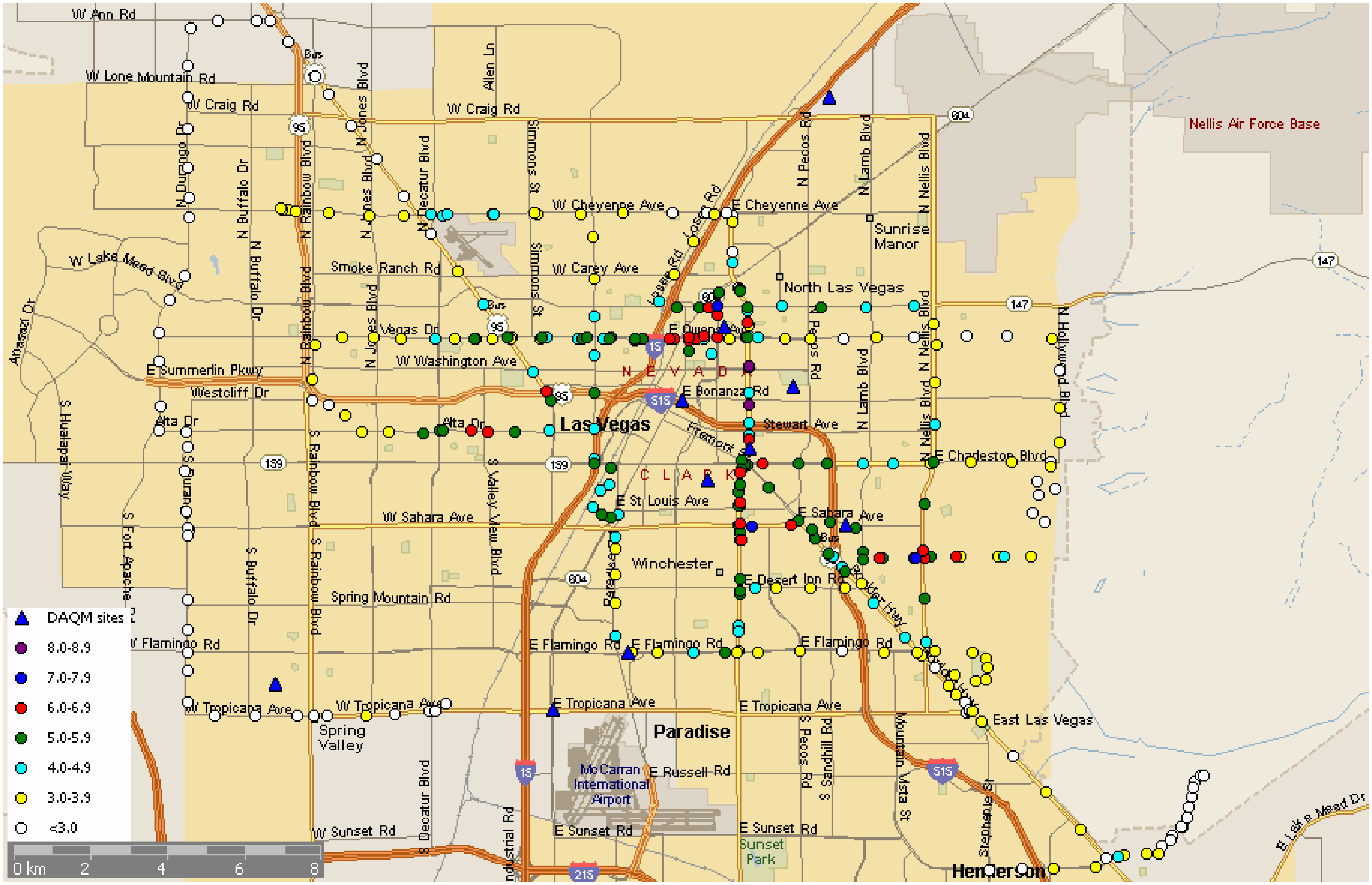

Figure 6-14. Observed CO Concentrations (ppm) During December 19 to 20 Evening/Night Period

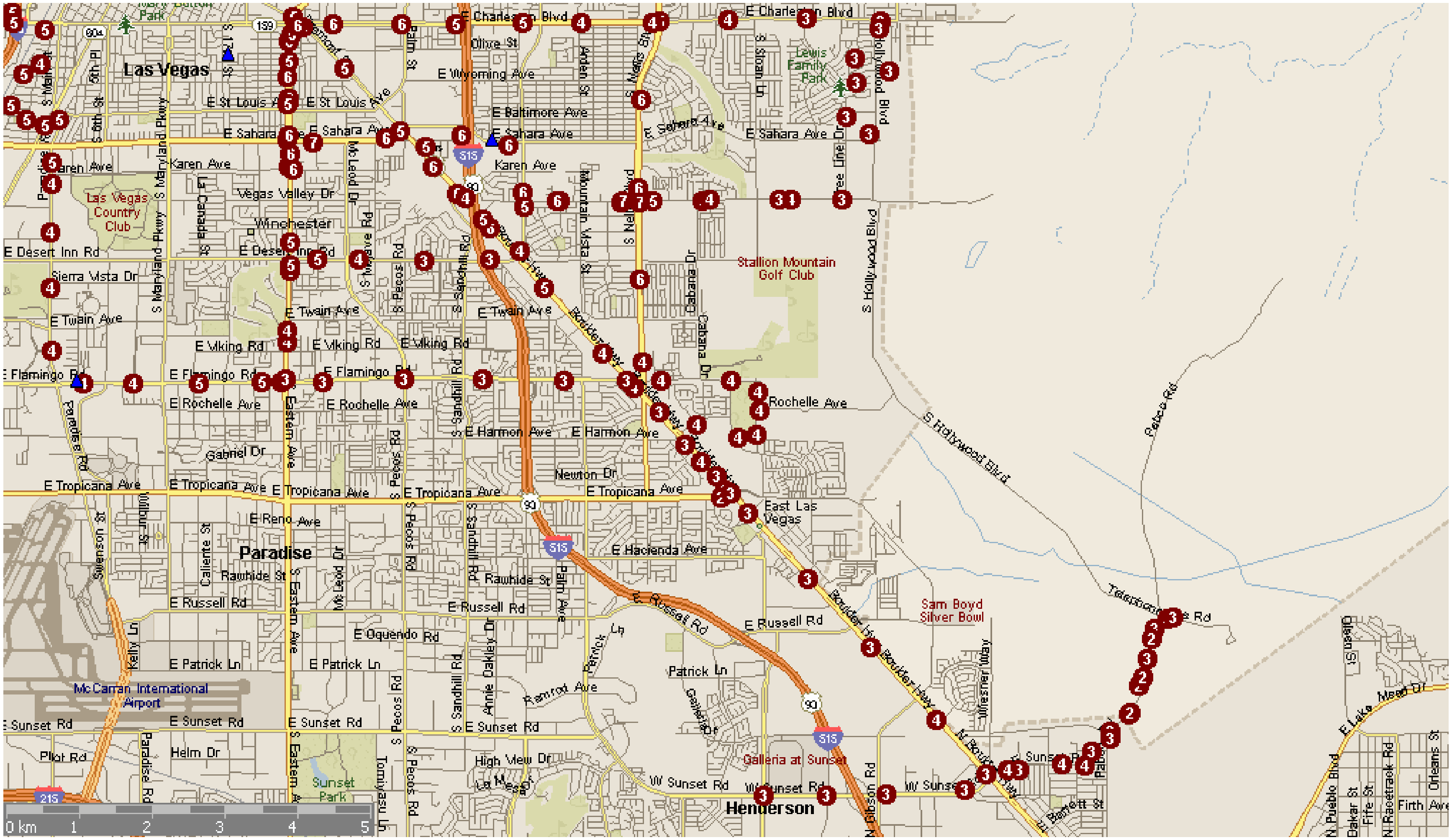

Figure 6-15. Observed Numeric CO Concentrations (ppm) During December 19 to 20 Evening/Night Period Concentrations illustrate the drainage flow. DAQM sites are shown in blue triangles.

Figure 6-16. Observed CO Concentrations (ppm) During December 26 Evening Period

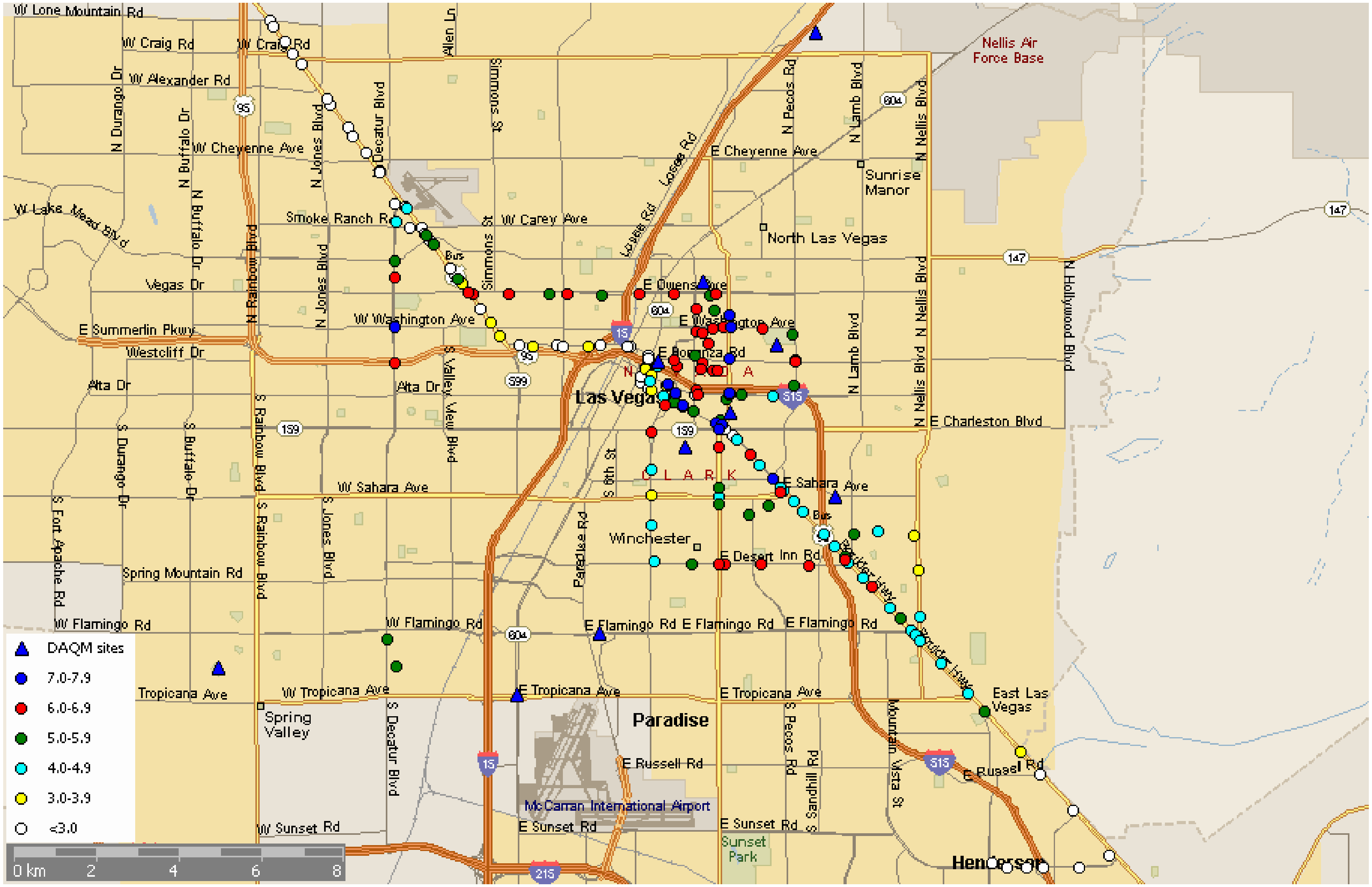

Figure 6-17. Observed CO Concentrations (ppm) During December 27 Morning Period

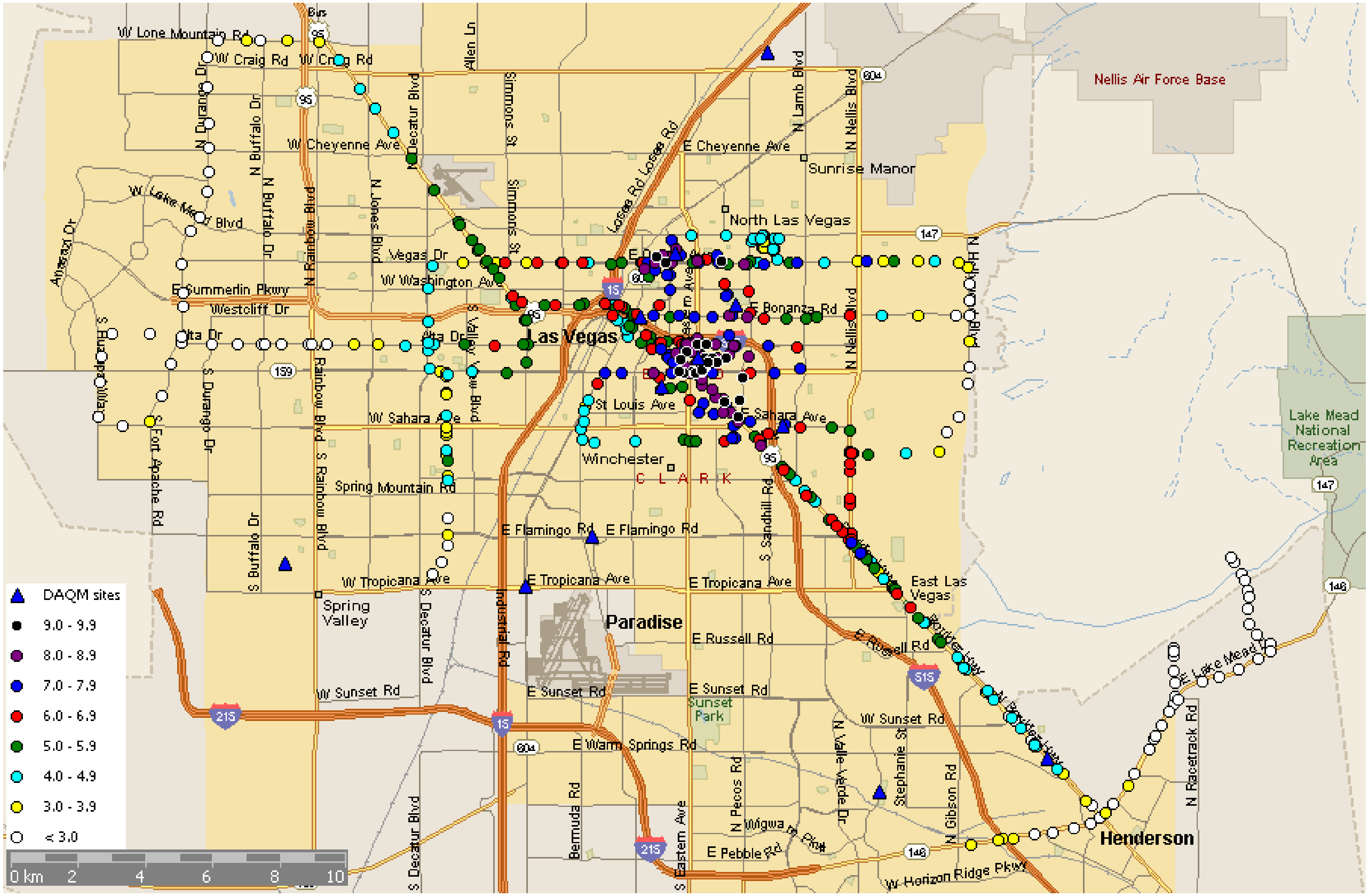

Figure 6-18. Observed CO Concentrations (ppm) During December 27 to 28 Evening/Night Period

Figure 6-19. Observed Numeric CO Concentrations (ppm) During December 27 to 28 Evening/Night Period in the Region of Owens Ave. DAQM sites are shown in blue triangles.

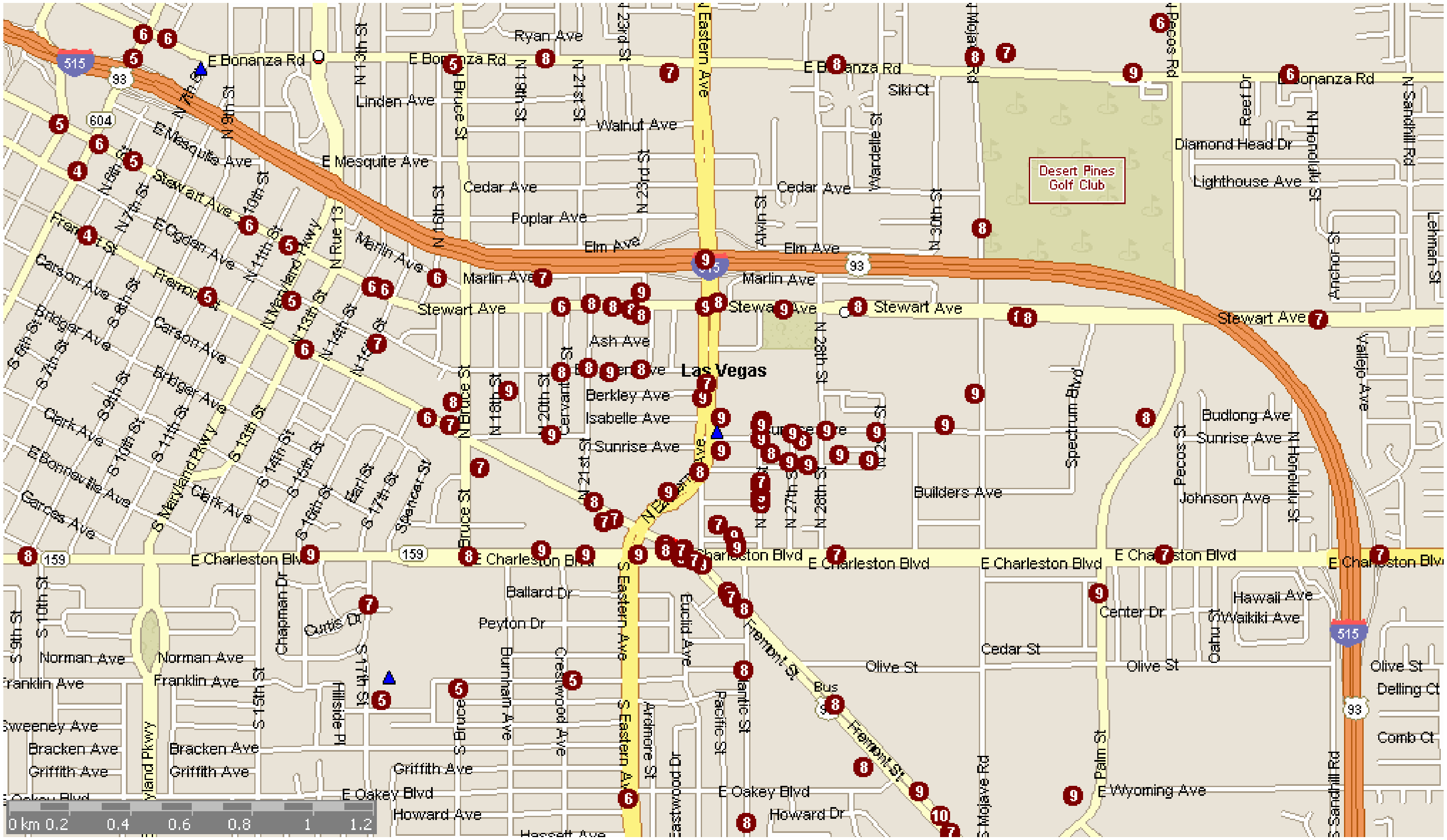

Figure 6-20. Observed Numeric CO Concentrations (ppm) During December 27 to 28 Evening/Night Period in the Region of the Sunrise Acres Site. The DAQM sites are shown in blue triangles.

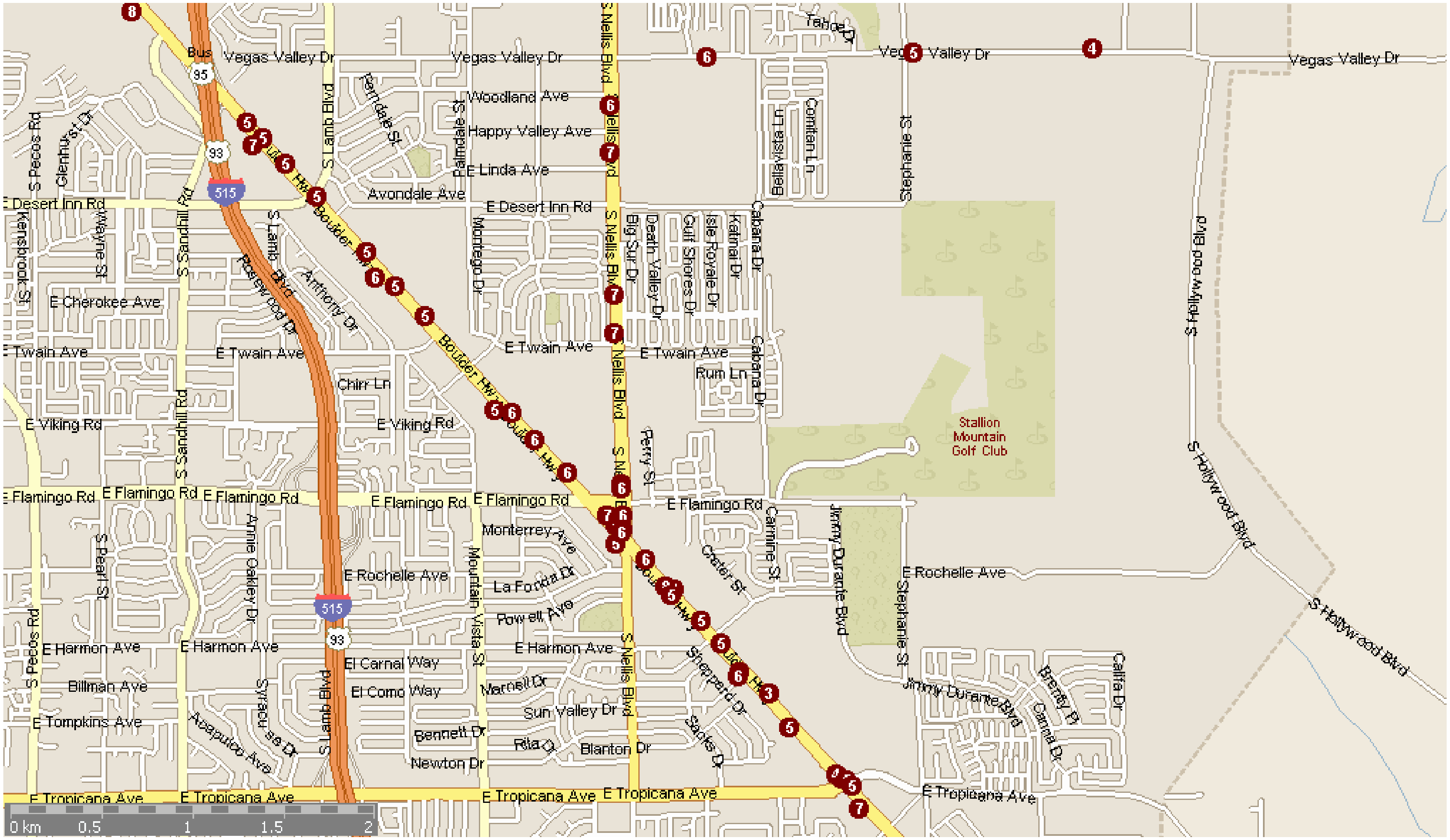

Figure 6-21. Observed Numeric CO Concentrations (ppm) During December 27 to 28 Evening/Night Period Showing the Concentrations in the Vicinity of Boulder Hwy and Nellis Blvd. There are no DAQM sites in this region.

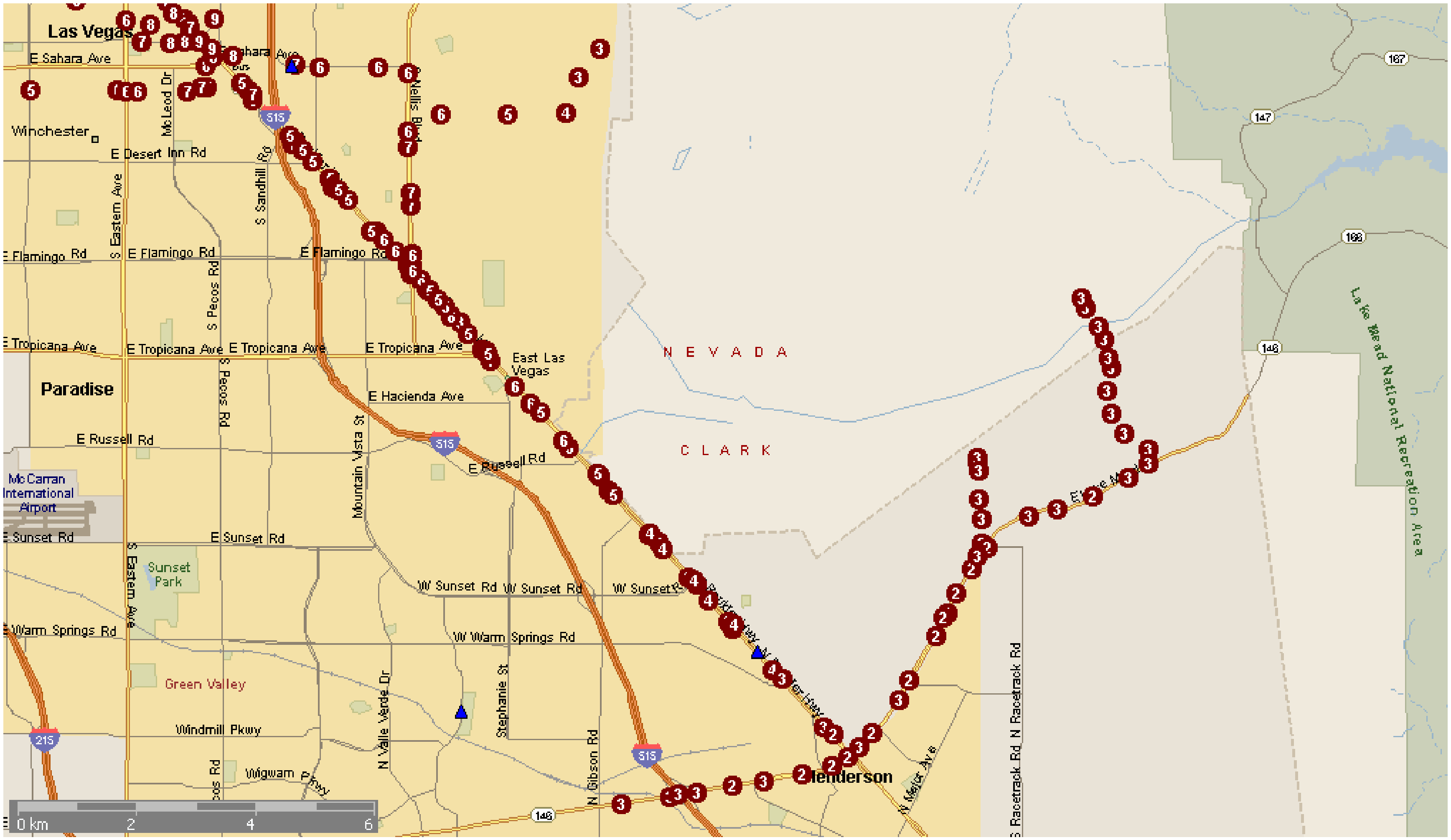

Figure 6-22. Observed Numeric CO Concentrations (ppm) During December 28 to 29 Evening/Night Period
The concentrations illustrate the drainage flow. The DAQM sites are shown in blue triangles.

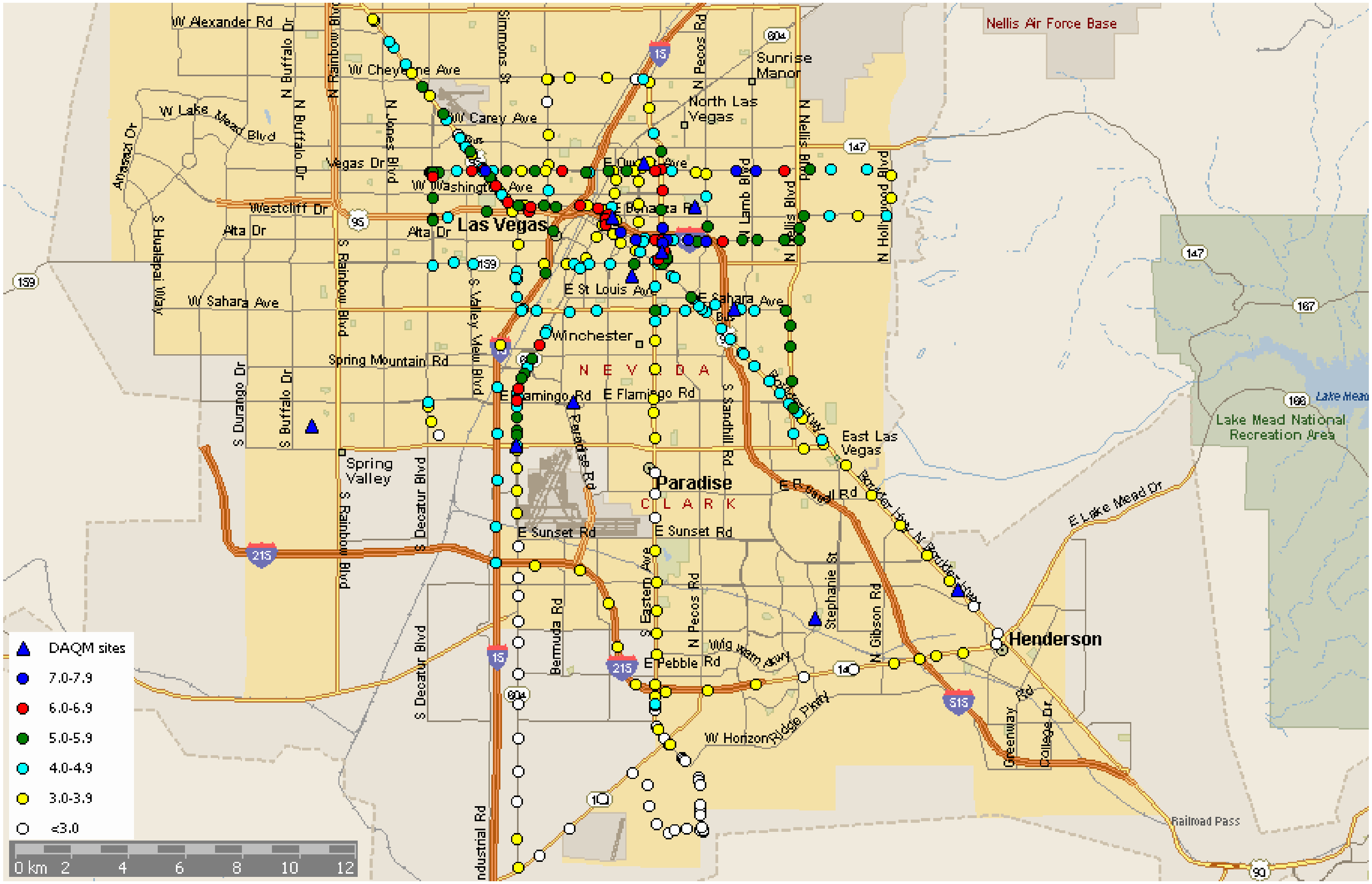

Figure 6-23. Observed CO Concentrations (ppm) During December 28 to 29 Evening/Night Period

7. KEY FINDINGS AND RECOMMENDATIONS

Key Findings

Six of the Clark County DAQM CO monitoring sites are located in the parts of the Las Vegas Valley that experience the higher CO levels, and the Sunrise Acres site is centered in the area of maximum impact. This observation leads to the conclusion that the DAQM CO monitoring sites are suitably located to identify the peak CO concentrations and the corresponding general area in which the higher levels occur.

Aside from the S16 micro-scale site in downtown Las Vegas, the highest CO concentrations measured during the Saturation Study occurred in the vicinity of the Sunrise Acres DAQM site. This site has experienced the highest concentrations in the DAQM network during recent years. The Saturation Network revealed that relatively high CO levels extend beyond the major streets in the area into the residential neighborhoods. Figures showing the peak 8-hour average CO concentrations indicate that the higher concentrations (above 5 ppm) extend about one mile to the north, south, and east of the peak area. This area includes six of the DAQM CO monitoring sites: CC, CW, JD, FP, SA and MC. Most of the area covered by the higher CO concentrations is east of Interstate 15.

The peak 1-~~one-~~hour average CO concentration measured at the Saturation Study sites was 18.3 parts-per-million (ppm); this occurred at the S16 micro-scale exposure site near Casino Center and Fremont Street. The peak 1-hour averages at the remaining sites were all less than 10 ppm. These levels are all well below the 1-hour National Ambient Air Quality Standard (NAAQS) of 35 ppm.

The peak 8-hour average CO concentration measured during the program was 7.2 ppm. This occurred at the U16 site, which is two blocks south of the DAQM monitoring site at the Sunrise Acres School near the intersection of Eastern Avenue, Charleston Boulevard and Fremont Street. This CO level is below the 8-hour NAAQS of 9 ppm. The peak 8-hour average occurring at the Sunrise Acres DAQM site (from November 20 through December 2001) was 6.0 ppm, which was during the same 8-hour time period as the maximum at U16.

At least two secondary CO peak areas were observed in the Saturation Network that are not as well covered by the existing DAQM. One area is just northwest of the I15/95 interchange. The other is along the Boulder Highway where elevated concentrations of CO entrained in the nocturnal drainage were observed.

In the outlying areas of the Las Vegas Valley where DAQM monitoring is sparse, measured levels within the Saturation Network were confirmed to be very low.

Higher than expected CO levels were observed in residential neighborhoods that are not immediately adjacent to major thoroughfares. These elevated concentrations may not be related to traffic patterns but instead, may be the result of other sources of CO, such as space or water heating. The areas where this was observed are high population density residential neighborhoods where CO exhaust from older heaters and water-heating appliances may be significantly higher than in newer neighborhoods.

Key Recommendations

While the Sunrise Acres site CO levels were close to the peak 8-hour averages observed in the Saturation Study network, the area east and south of that site experienced slightly higher concentrations during the peak nighttime episode of this Study period. The differences may be due in part to uncertainties in each of the sampling instruments, and partly due to differences in CO concentrations occurring under the specific emission and dispersion conditions occurring that particular night. Thus, CO monitoring near the Sunrise Acres site seems highly recommended to continue documenting maximum concentrations occurring in the Valley.

Two areas might be considered for possible future CO monitoring sites if the rapidly increasing population growth continues in the Las Vegas Valley. These are the area northwest of the downtown freeway interchange, and near Boulder Highway south of the intersection with Nellis Blvd. and north of the intersection with Tropicana.

To gain a better understanding of the CO transport and dispersion in the Las Vegas Valley, it is recommended that a database of the meteorology in the boundary layer be acquired and examined.

As the data suggest, the emissions inventory should be examined for contribution from non-vehicular CO sources, especially in high-density residential areas where older appliances may be in use.