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GUIDANCE FOR SITING AMBIENT AIR MONITORS AROUND STATIONARY LEAD SOURCES

Office of Air Quality Planning and Standards
Clean Air
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Emissions, Monitoring, & Analysis Division
Office of Air Quality Planning and Standards
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GUIDANCE FOR CONDUCTING AMBIENT AIR MONITORING FOR LEAD AROUND POINT SOURCES

1.0 INTRODUCTION

The Environmental Protection Agency (EPA) is revising the Ambient Air Quality Surveillance regulations (40 CFR Part 58) as they pertain to lead monitoring to better reflect the change in lead emissions sources from on-road mobile sources (emissions have essentially been eliminated due to the removal of lead from gasoline) to stationary lead sources. The purpose of this document is to provide supplemental information and guidance to State and local agencies for monitoring for lead around point sources. EPA's existing guidance for such monitoring[1] is replaced by this document. For clarity, references to the lead regulations in this document generally pertain to the recent revisions to the lead regulations. Currently promulgated lead monitoring requirements are referred to explicitly.

1.1 Summary of the Part 58 Lead Air Monitoring Regulations

The most significant change to the Part 58 monitoring regulations is the change in emphasis from monitoring primarily to determine the impact of automotive emissions, to establishing a network focused around point sources. This change reflects the drastic reduction in lead emissions from automotive sources over the last decade and the concurrent increase in the relative importance of lead air pollution emitted from point sources.[5]

The original regulations required two National Air Monitoring Stations (NAMS) in urbanized areas with populations greater than 500,000. Both of these stations were designed to measure the impact from roadways. One of the stations was intended to measure in areas of maximum lead concentrations, while the other station focused on measuring lead concentrations in highly populated, high traffic density areas. Because of the significant reductions in ambient lead concentrations due to the removal of lead from gasoline, the regulations have been modified to require only one NAMS as a maximum concentration type site in one of the two most populous Metropolitan Statistical Areas/Consolidated Metropolitan Statistical Areas (MSA/CMSA) within each of the ten U.S. EPA Regions. Descriptions of each Region and the current most populous MSA/CMSAs within each are listed in Table 1.

Table 1. EPA Regions & Current Largest MSA/CMSAs (using 1995 Census data)

Region (States)	Largest MSA/CMSA
I (Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, Vermont)	Boston-Worcester-Lawrence CMSA Hartford MSA
II (New Jersey, New York, Puerto Rico, U.S. Virgin Islands)	New York-Northern New Jersey-Long Island, CMSA San Juan-Caguas-Arecibo CMSA
III (Delaware, Maryland, Pennsylvania, Virginia, West Virginia, Washington, D.C.)	Washington-Baltimore CMSA Philadelphia-Wilmington-Atlantic City CMSA
IV (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee)	Miami-Fort Lauderdale CMSA Atlanta MSA
V (Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin)	Chicago-Gary-Kenosha CMSA Detroit-Ann Arbor-Flint CMSA
VI (Arkansas, Louisiana, New Mexico, Oklahoma, Texas)	Dallas-Fort Worth CMSA Houston-Galveston-Brazoria CMSA
VII (Iowa, Kansas, Missouri, Nebraska)	St. Louis MSA Kansas City MSA
VIII (Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming)	Denver-Boulder-Greeley CMSA Salt Lake City-Ogden MSA
IX (American Samoa, Arizona, California, Guam, Hawaii, Nevada)	Los Angeles-Riverside-Orange County CMSA San Francisco-Oakland-San Jose CMSA
X (Alaska, Idaho, Oregon, Washington)	Seattle-Tacoma-Bremerton CMSA Portland-Salem CMSA

In addition, one NAMS site must be located in each of the MSA/CMSAs (or in the city or county if outside a MSA/CMSA) where one or more violations of the quarterly lead NAAQS have been recorded over the most recent eight calendar quarters with available lead air quality data. This NAMS site must be located within a populated area, apart from the lead source, to assess area-wide lead air pollution levels. These NAMS sites should represent the maximum lead concentrations measured within the MSA/CMSA, city, or county that is not directly impacted from a single stationary lead source, and it may be either a mobile source oriented site or a neighborhood type site with adjacent heavily trafficked roadways. Data from this site will be used to assess national trends and progress toward continued attainment of the lead NAAQS with regard to area-wide sources such as mobile sources. The 1995-1996 Lead NAAQS Attainment Strategy monitoring report is included within Appendix A for a reference of the currently tracked stationary lead sources. Table 2 contains a listing of the MSA/CMSAs, cities, or counties that have one or more quarterly Pb NAAQS violations over the 1995-1996 period.

Table 2. MSA/CMSAs or Counties with 1 or more Lead NAAQS Violations in 1995-1996.

MSA/CMSA or County	Contributing Lead Source(s)
Philadelphia-Wilmington-Atlantic City CMSA	Franklin Smelter in Philadelphia County, PA
Tampa-St. Petersburg-Clearwater MSA	Gulf Coast Lead in Hillsborough County, FL
Memphis MSA	Refined Metals in Shelby County, TN
Nashville MSA	General Smelting in Williamson County, TN
St. Louis MSA	Chemetco in Madison County, IL, and Doe Run in Jefferson County, MO
Cleveland-Akron CMSA	Master Metals in Cuyahoga County, OH
Iron County, MO	ASARCO in/near Hogan, MO
Omaha MSA	ASARCO in Douglas County, NE
Lewis and Clark County, MT	ASARCO in/near East Helena, MT

2.0 BACKGROUND

This section presents general information related to lead air quality and trends in lead air pollution. Specifically, Section 2.1 describes the chemical and physical forms of atmospheric lead; Section 2.2 discusses the major source categories of lead emissions; and Section 2.3 describes observed lead air quality patterns and trends.

2.1 Airborne Lead Forms

The chemical and physical form of airborne lead is directly related to the type of emission source. Chemical forms of lead emitted into the atmosphere by anthropogenic sources include elemental lead (Pb), lead oxides (PbO, PbO_2, and PbO_3), lead sulfates and sulfides ($PbSO_4$ and PbS), lead chlorides and bromides ($PbCl_2$, PbClBr, and $PbBr_2$), and lead-alkyl compounds [$Pb(CH_3)_4$ and $Pb(C_2H_5)_4$].

The dominant forms of atmospheric lead from mines and smelters are lead sulfates and sulfides ($PbSO_4$, PbO•$PbSO_4$, and PbS). The main chemical forms of lead from ore handling and fugitive dust from open mounds of ore concentrate are lead sulfate, and the major chemical forms from sintering and blast furnace operations are $PbSO_4$ and PbO•$PbSO_4$.[2] In contrast to the chemical forms of lead emitted by point sources, the chemical forms of airborne lead from mobile sources are in the form of lead halides ($PbCl_2$, PbClBr, and $PbBr_2$), and as double salts (e.g., PbBrCl•$2NH_4Cl$, and alpha-2PbBrCl•NH_4Cl). Lead alkyl compounds are emitted from petroleum refineries.

Combustion and smelting processes emit submicron size particles due to the high temperatures at which these processes take place. Lead particles emitted by handling and mechanical processes (e.g., ore processing) are several times larger (greater than 2 microns) than particles emitted by combustion sources.

Airborne lead particles can be placed into three size ranges: (1) the nuclei mode (less than 0.1 μm); (2) the accumulation mode (0.1-2 μm); and (3) the large particle mode (greater than 2 μm). Lead particles are generally in the nuclei and large particle size range as emitted at the source. The large particles are removed by deposition close to the source, and the particles in the nuclei size range either diffuse to the earth's surface or agglomerate in the air to form particles in the accumulation size range which are then transported over long distances.[2]

Atmospheric lead particles found in both urban and rural areas are sized predominantly in the accumulation mode and appear mostly in the size range between 0.2 and 0.3 μm. Many studies of atmospheric lead concentrations in Europe, South America, and Asia have confirmed that ambient urban and rural air contains predominantly fine particles. A study of six U.S. cities showed that fine particle lead mass appears to be greater than coarse lead mass by approximately a factor of five.[2]

During atmospheric dispersion, lead transformations may occur and include physical changes in particle size distribution, organic to inorganic chemical phase changes, and chemical changes in the inorganic phase of lead particles. Within a few hundred meters of the source, the particle size distribution of lead stabilizes and remains roughly constant with transport into remote environments. The atmospheric concentration continues to decrease with distance from the source. Ambient concentrations of organic lead decrease more rapidly than inorganic lead. This suggests that the organic lead converts to the inorganic form during atmospheric transport. Inorganic lead forms also appear to undergo chemical transformations from lead halides and oxides to lead sulfates. Lead compounds may be removed from the atmosphere by wet or dry deposition.[2]

2.2 Sources of Lead Emissions[5]

The major sources of lead emissions and ambient lead levels are combustion sources and industrial sources. Combustion sources include mobile gasoline combustion sources and stationary combustion sources, with the latter category being dominant among combustion sources. Industrial sources include metallurgical and manufacturing processes.

Lead emissions from on-road and non-road mobile sources currently comprise approximately 10 percent of total lead emissions nationwide, with non-road sources (e.g., aircraft) contributing nearly all of these emissions. The lead content of gasoline has undergone a series of reductions beginning in the 1970s and continuing through 1995 when all lead was required to be removed as an on-road mobile source fuel in accordance with the 1990 Clean Air Act Amendments. Currently, ambient lead levels near roadways and in urban areas are extremely unlikely to exceed the current lead NAAQS.

Stationary combustion sources that emit lead include coal and oil combustion, waste oil combustion, and municipal waste and sewage sludge incinerators. Taken together, this source category amounts to somewhat more than 33 percent of nationwide emissions. Waste oil combustion, municipal waste incineration, and coal combustion comprise the majority of emissions in this category. Recent modeling studies[3] suggest that sources in this category are unlikely to pose a threat to the NAAQS.

Industrial manufacturing sources of lead now account for about 5 percent of total lead emissions. This category includes production of lead alkyl, lead-acid batteries, lead oxide and pigments, leaded glass, portland cement, solders and coatings, and other miscellaneous products. Some larger lead-acid battery manufacturing facilities may have the potential to cause high enough ambient lead concentrations to threaten the NAAQS.[3]

Metallurgical processes that may be sources of lead emissions include lead ore mining; smelting/refining of lead, copper, and zinc; and production of iron and steel, gray iron, brass and bronze. Taken together, this category of sources currently comprises about 50 percent of nationwide lead emissions. As industries, the largest contributors are primary and secondary lead smelters and producers of iron, gray iron, and steel.

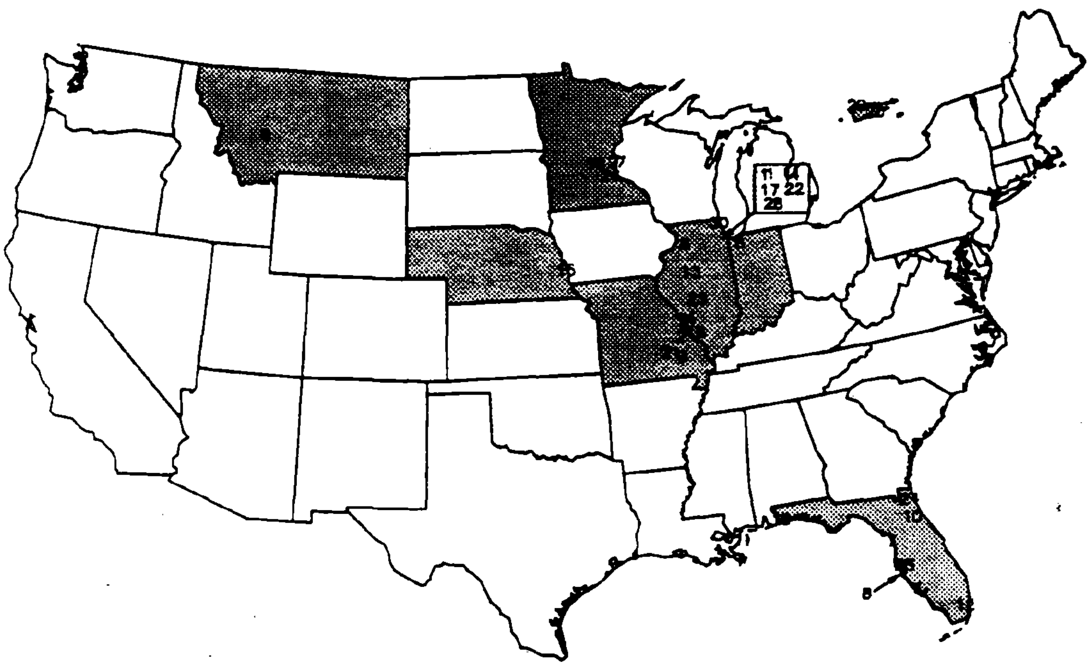
Results of dispersion modeling around various point sources suggest that metallurgical processes are the greatest contributors to high ambient concentrations of lead.[3] Observed maximum quarterly average lead concentrations near primary and secondary lead smelting and refining plants have exceeded the former NAAQS concentration of 1.5 $\mu g/m^3$. For primary lead smelters, both stack and fugitive emissions contribute to high predicted ambient impacts while fugitive emissions contribute the most at secondary smelters.

Overall, about 85 percent of the primary lead produced in the U.S. is from native mines which are often associated with minor amounts of zinc, cadmium, copper, bismuth, gold, silver, and other minerals.[2] In addition, a new source of lead emissions emerged in the mid-1960s when the "Viburnum Trend" or "New Lead Belt" was opened in southeastern Missouri. This area consists of eight mines and three accompanying lead smelters which makes it the largest lead-producing district in the world. This area has also made the U.S. the world's leading lead-producing nation. The Missouri lead ore mining operations account for about 80 to 90 percent of the domestic production of lead.

Figure 1 shows the relative locations of major lead operations in the U.S. including mines, primary and secondary smelters, refineries and alkyl lead plants. Maximum quarterly average lead concentrations for the nation in 1995 are illustrated in Figure 2. Sources of lead emissions are found throughout the entire U.S. Both mobile and point sources of lead emissions are found mostly in areas of high population density with the exception of lead smelters. Primary lead smelters are located mostly in rural areas. Secondary lead smelters are located mostly near large urban areas that produce large quantities of scrap lead (mostly used automobiles and truck batteries).

Figure 1. Locations of the 30 Largest Lead Emitters in the United States

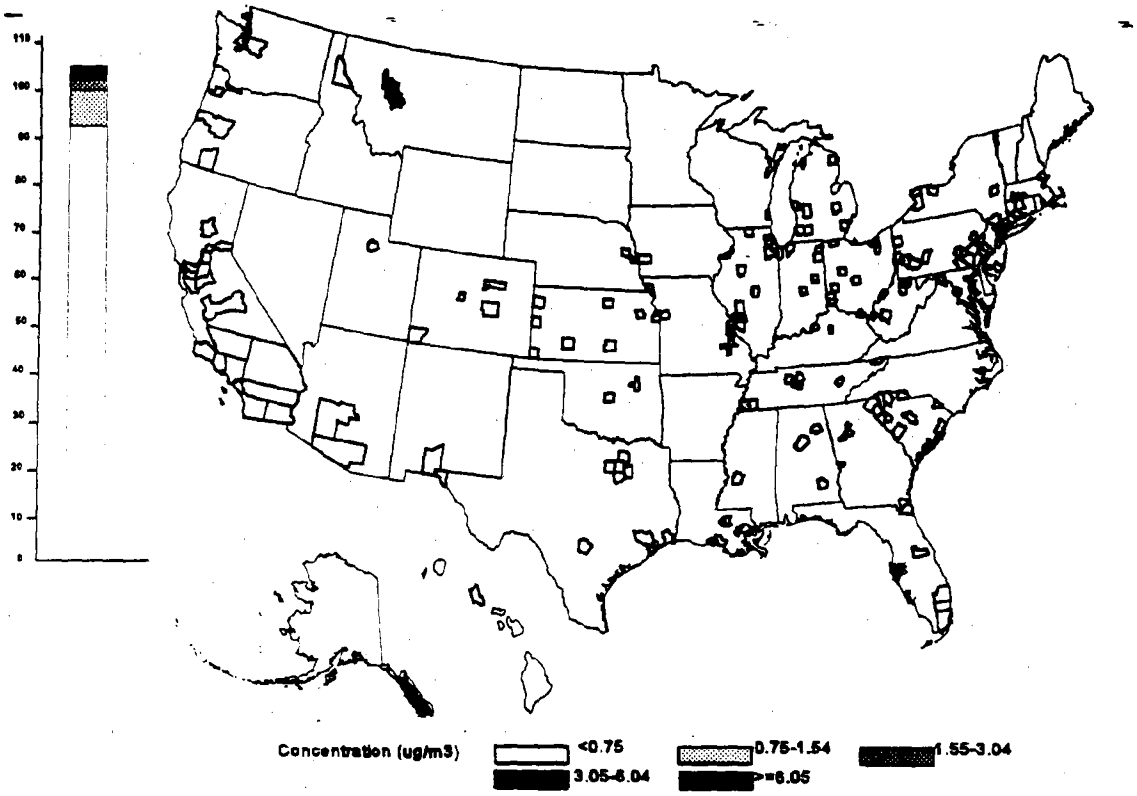
Sources are located in shaded states



ESTIMATED ANNUAL EMISSIONS

	TONS	(EMISSIONS INVENTORY YEAR)	
1	687	(96)	GRANITE CITY STEEL COMPANY
2	122	(93)	THE DOE RUN COMPANY
3	115	(93)	ASARCO
4	108	(96)	CHEMETCO, INC
5	81.6	(96)	NORTHWESTERN STEEL & WIRE
6	55.6	(95)	U S STEEL CO GARY WORKS
7	34.9	(93)	FLORIDA POWER
8	31.0	(93)	TECO—BIG BEND STA.
9	25.0	(96)	ASARCO INCORPORATED
10	21.3	(93)	SEMINOLE ELECTRIC COOP
11	19.3	(95)	NORTHWEST WASTE TO ENERGY
12	19.1	(93)	U S FOUNDRY MANUFACTURING
13	17.8	(96)	KEYSTONE STEEL & WIRE DIV
14	16.7	(96)	J—PITT STEEL MELT SHOP, INC
15	16.0	(94)	ASARCO, INC.
16	15.6	(96)	WIRCO CASTING
17	14.7	(96)	ACME STEEL COMPANY
18	14.5	(95)	NORTHERN STATES POWER
19	14.5	(93)	GULF POWER CO
20	14.0	(92)	GENERAL ELEC CO.
21	13.9	(93)	DOE RUN — BUICK RESOURCE
22	13.3	(96)	ACME STEEL COMPANY—CHICAGO
23	13.0	(93)	TECO—GANNON STA.
24	12.6	(93)	JACKSONVILLE ELECTRIC AUTH
25	12.0	(96)	COM ED — KINCAID GENERATING
26	11.4	(95)	GOPHER SMELTING & REFINING
27	11.3	(96)	NORTH STAR STEEL MN
28	11.0	(95)	ACME STEEL COMPANY
29	10.5	(92)	ART PRINTING
30	8.13	(96)	R. LAVIN & SONS, INC.

Figure 2. Maximum Quarterly Average Lead Concentrations, 1995 (reference 7)



3.0 RECOMMENDATIONS FOR MONITORING LEAD NEAR POINT SOURCES

State and Local Air Monitoring Station (SLAMS) monitoring networks are now encouraged to establish monitoring sites around point sources which have the potential to exceed the level of the lead standard (40 CFR Part 58). At a minimum, two sites are recommended for each source. Emissions from point sources which may emit over 5 tons per year (tpy) of actual lead including both stack and fugitive emissions are generally considered to have the potential to cause an NAAQS exceedance, and other smaller sources may need to be investigated, particularly if their facility boundaries are small and they are located in heavily populated areas where exposure may be high. Modeling may be necessary to determine if sources that emit between 1 and 5 tpy pose a threat to the standard.

More than two monitoring sites may be needed in order to adequately monitor the areas of expected maximum impact in the vicinity of a point source. The need for additional sites will depend on the level and degree of variability of the ambient lead concentrations attributable to the source as determined through monitoring and modeling analyses. Factors such as meteorological and topographical influences, and the spatial scale of representativeness of lead impacts should be considered.

When reviewing sources to determine the need for monitoring, total lead emissions should be based on the maximum allowable emission rate for the source as stated in the operating permit issued by the local air pollution control agency. If a source is not permitted or if permit information is unavailable or incomplete (e.g., does not account for fugitive emissions), total emissions should be based on the maximum emission rates achievable by the source. Emission data should be based on the current operating status of the source and should take into account any pending source modifications.

There may be situations when there is some question whether a source area should be considered for monitoring. For example, an area might contain several sources whose emissions are below the threshold where monitoring is recommended, but whose combined impacts might pose a threat to the air quality standard. Calculation of total lead emissions for such a source area should be based on expected ambient impacts. That is, if multiple lead sources are located within the same general area, total lead emissions should be summed unless the impacts of those sources are clearly separate.

4.0 SITE SELECTION METHODOLOGY

The goal of devising a site selection methodology for monitoring lead impacts near point sources is to optimize placement of monitors such that the probability of capturing maximum concentrations is maximized while the number of monitors, and associated cost, is minimized. Achieving this goal requires understanding the spatial distribution of airborne lead concentrations at the scale of representativeness appropriate to dispersion of lead in the ambient atmosphere. This entails acquiring knowledge of actual or predicted lead concentrations over the area of concern with resolution at the micro-, middle-, and neighborhood-scales. This knowledge is gained from a series of analyses utilizing available emissions, monitoring, and meteorological data combined with knowledge of local influences and an understanding of atmospheric dispersion and lead deposition processes.

A basic procedure has been traditionally outlined for this purpose and consists of the following steps:

- Determine the monitoring objectives and the spatial scale of representativeness
- Identify unique source characteristics
- Characterize topographic and land use influences
- Analyze available meteorological data
- Analyze existing monitoring data
- Conduct air quality modeling analysis
- Select monitoring locations

In practice, this is not a step-by-step procedure, but one in which information gathered or results obtained during one activity might provide insight or demonstrate a need that suggests that an earlier activity be revisited. An iterative process is thus established. In addition, saturation monitoring studies have been employed more recently as an additional option in this process.

In every case, monitoring objectives must be defined and source characteristics and local influences identified before other steps in the process can proceed. At that point, a site selection study plan should be established based on available data, resources, logistical and time constraints, and regulatory requirements. Such plans should reflect a careful study of the factors to be considered and an understanding of the methods available. They should allow for some dynamic elements, or midstream redirection, where appropriate. Ultimately, a decision is made based on the analyses conducted and the professional judgment of those involved.

4.1 Monitoring Objectives and Spatial Scale of Representativeness

The objective of monitoring for lead near point sources is primarily directed by the need to achieve and maintain the lead ambient air quality standard. Data collected will be used for making NAAQS attainment/nonattainment decisions, determining required levels of control, and obtaining data needed for control strategy development and SIP revisions. These data uses all imply a monitoring strategy where samplers are located to record maximum lead concentrations.

The spatial scale of representativeness of a monitor refers to an area where the expected variation in concentration in the area surrounding the monitor is small (less than 20 percent, for example). Lead concentrations tend to decline rapidly with distance from the source due to dispersion, settling, and deposition processes. Therefore, the spatial extent of the most significant lead impacts tends to encompass relatively small areas at a given time.

Under unstable or fumigation conditions, or when a plume impinges on elevated terrain, the ambient impact of a lead point source may vary significantly at the spatial scale affecting an area less than 100 meters across, or micro-scale. Such conditions, however, are unlikely to persist for long periods. More frequently, point sources are responsible for relatively consistent impacts over areas from 100 to 500 meters across, or at the middle-scale. Impacts may also occur at the neighborhood scale which encompasses an area extending from 500 to

4000 meters. Because the area representative of maximum lead impacts is likely to be relatively small, the precise location of lead samplers may be more critical.

4.2 Source Characteristics/Emissions Types

Once the need for monitoring near a point source has been established, certain source-specific data should be compiled to aid in the analyses necessary to select representative sampling locations. This also applies to sources where modeling is needed to establish the need for monitoring, since similar analyses will be conducted. Although data on total lead emissions were used to determine that a source be considered for monitoring, lead emissions data should be reviewed in detail before proceeding with site selection so that emission rates are verified and the contributions from various emission types (point, background, fugitive) are understood.

In addition to the amount and type of lead emissions, information should be obtained identifying source-specific influences on how the lead emitted is dispersed into the atmosphere. These influences include physical stack parameters, and the dimensions and locations of nearby buildings, and may also include process descriptions, and chemical and physical characteristics of the lead-containing emissions.

4.2.1 Source Characteristics

Stack height and diameter, and effluent exit temperature and velocity are used by air quality models to determine the effective plume centerline. Emission rates and other characteristics for roof vents, reentrainment areas, and other fugitive sources must also be provided to the model.

Since nearby buildings can create downwash and turbulent effects on the plume, dimensions and locations of nearby buildings may be required for dispersion modeling. Information on the particle size distribution characteristic of the emissions should be evaluated, if available, for its influence on the degree of settling and deposition that might be expected near the source. Similarly, the chemical composition of the emissions should be evaluated to determine if chemical transformations need to be treated in the analyses. If receptor modeling is employed, chemical and physical characteristics of the lead-containing emissions can be used to develop source fingerprints.[6]

Descriptions of the industrial processes taking place at the lead-emitting facility should also be obtained. This information should include operating schedules, material throughput rates, size and location of storage piles and waste holding areas, and any other information needed to characterize the resulting lead emissions. Such information is useful for interpreting monitoring data, estimating emission rates from non-point or fugitive sources, and selecting appropriate air quality models and modeling parameters.

4.2.2 Types of Emissions

Various types of lead emissions can be associated with a given point source or source area. Stack emissions are those that are vented through a smokestack to encourage dilution and minimize direct impact on the surrounding area. Stack emissions are often associated with a combustion process or furnace so that emissions are at elevated temperatures. Lead may also be captured by ventilation systems and emitted through vents at ambient temperatures. Data on emission rates for stacks and vents at sources large enough to require modeling should be available from emissions inventories or might be obtained from operating permit files. Alternatively, emission rates can be developed based on process information and published emission factors.[7]

Fugitive emissions refer to lead that escapes from an industrial process, storage facility, or mine that are not intentionally vented to the atmosphere. Ground level or reentrained emissions generally refer to lead that reenters the atmosphere due to wind action or a disturbance such as automobile traffic after having been deposited from the air at an earlier time. In some instances, reentrained lead alone may represent a significant emission source. This would also apply to areas near facilities that are no longer operating.

Techniques have been published for estimating emissions from various fugitive dust sources that may be applicable to estimating fugitive lead emissions in combination with data on the lead content of soils, dusts, and storage piles in the area.[8] Information on fugitive emissions from industrial processes might be obtained from permit files for the source in question or estimates could be based on the process type and size, and emission rates.[7]

Background lead levels are generally associated with distant sources, are regionally representative, and most often occur at relatively low levels. A conservative estimate of 0.1 $\mu g/m^3$ (monthly average) has been applied to sources across the U.S. This value represents a nationwide average of annual urban background concentrations, plus concentrations attributable to mobile sources, and diffuse minor point sources.[3] Area-specific background levels should be estimated if adequate monitoring data are available.

The total impact of all types of emissions on the surrounding area can result from combined effects at single receptors or separate impacts at multiple receptors. Each of the different emission types must be considered in the network design in order to ensure that monitors are located in maximum concentration areas and that all such areas are identified. A workable approach is to analyze the nature, strength, and dispersion patterns of each emission type individually and then consider the potential for combined impacts. Separate impacts should be considered for fugitive emissions that might be significant enough to threaten NAAQS attainment.

In general, stack emissions are of primary concern around point sources; however, their impact must always be considered in combination with background levels including roadway network emissions. The area of maximum impact from stack emissions should occur at some distance downwind from the stack depending on effective stack height and meteorology. The highest concentrations generally occur near the source when the plume is mixed to ground level under unstable conditions. The greatest air quality impact of ground level emissions should occur adjacent to the source area in the downwind direction. Fugitive and ground level emissions may or may not act in combination with stack emissions depending on the meteorology and topography of the area. Emissions from nearby sources must also be considered as appropriate.

4.3 Topographical and Land Use Influences

Topographic influences can exert profound effects on dispersion patterns and impacts of lead emissions from point sources. For example, plume impaction on elevated terrain can result in very high, localized lead concentrations. Local topography affects the dispersion of pollutants and can act to localize the air pollution climatology of the source area. Knowledge of local topographic influences is essential to assess the representativeness of available monitoring and meteorological data.

Topographic influences may include thermally-induced, diurnal air mass circulations as in mountain/valley or land/sea air flow cycles. In addition, there are direct, terrain-induced influences on wind direction and wind speed. These are related to the mechanics of aerodynamic diversion occurring as air flows over and around obstacles. For example, air tends to be channeled along valleys, affecting sources located near rivers. Wind speed increases as air flows up and over hills. Turbulent eddies are set up on the leeward side of hills.

The extent to which the stability of an air mass is disturbed as the air passes over the earth's surface is affected by the degree to which the surface is occupied by buildings, trees, and other obstacles. This is often referred to as surface roughness. In general, urban areas present more and larger obstacles to airflow than rural areas, resulting in greater instability.
Urban areas may also be subject to a "heat island" effect. Urban areas store heat and remain warmer than surrounding rural areas. The effect is most pronounced at night. When a heat island circulation exists, cool air from the surrounding rural areas converges toward the city, is heated, rises to the level of the inversion, and then returns to the outlying areas. Strong winds or more pronounced thermal circulations can destroy heat island circulation.

In complex terrain, special care must be taken in correctly applying modeling analyses and interpreting modeled results. Where feasible, model output relating to complex terrain situations should be substantiated with monitoring data. Saturation monitoring studies may be used to corroborate models and can serve as an alternate source of information for site selection purposes.

4.4 Meteorological Influences

Second to the emissions themselves, meteorology is the most important consideration in evaluating the impact of lead emissions on the area surrounding a point source. In order to understand source impacts, it is necessary to identify meteorological conditions associated with high ambient lead concentrations and to understand when, and how often, those conditions occur in the vicinity of the source. It is also important to characterize conditions occurring most frequently in the vicinity of the source. Because the lead standard is based on a quarterly mean concentration, the persistence of meteorological conditions associated with elevated lead levels is the most important consideration. High concentration events that occur infrequently, or for very short durations, will not significantly affect a quarterly standard.

Meteorological conditions associated with the highest ambient concentrations include fumigation, plume trapping by an elevated inversion, and plume coning with low wind speeds. Fumigation occurs when thermal turbulence occurring beneath an elevated inversion brings high concentrations from stack height to ground level. Less severe, but more frequent, elevated concentrations occur near point sources during periods of low wind speed under stable or unstable conditions.

Analysis of meteorological data should first determine the completeness and representativeness of available data. Meteorological data that may be useful for various modeling analyses may include the following measurements:[9,11,14]

- hourly wind speed and wind direction,
- hourly atmospheric stability based on wind fluctuations (σ_θ), or vertical temperature gradient combined with wind speed,
- hourly surface temperature for climatological comparisons and plume rise calculations.

Hourly relative humidity, precipitation, and solar radiation may also be recorded. Upper air data are useful to establish a vertical temperature profile and characterize the speed and direction of winds aloft. Data collected at several altitudes are especially useful for dispersion modeling in complex terrain situations. Analysis of monitoring data may then be used in conjunction with representative meteorological data to identify conditions associated with high ambient lead concentrations.[11]

Data obtained from the nearest National Weather Service (NWS) station are most often used for air quality analyses. The representativeness of these data for the source area will depend on the distance of the NWS station from the source and the local topography. Additional data may be available from other meteorological stations including those operated by private citizens, industry, State air pollution control agencies, colleges and universities, and federally funded monitoring networks such as the National Dry Deposition Network (NDDN).

Multi-station comparative analyses can be conducted to help determine the representativeness of available measurements over the impact area. When representative data are not available, it may be necessary to conduct on-site meteorological monitoring. Monitoring should preferably be conducted over at least one year but could be conducted during periods representative of conditions when maximum lead impacts are expected. Guidance is available for collecting and preprocessing on-site meteorological data[10] for use with air quality models.[11]

4.5 Analysis of Monitoring Data

Analysis of sufficient, representative monitoring data can identify general areas of maximum impact and can help to determine the spatial scale of representativeness of those impacts. Background concentrations and impacts from road networks and other diffuse sources can often be best estimated by monitoring. Due to the likely spatial sparseness of lead monitoring data near point sources, analysis of existing data is unlikely to conclusively identify maximum receptor points at the small spatial scales of concern for lead monitoring.

Analysis of monitoring data can, however, aid in model selection and application by supporting choices of receptor points to be modeled, and identifying circumstances that may need to be given special treatment in the modeling analysis. These include influences of terrain or meteorology, and source-specific emissions characteristics. In addition, the analysis of monitoring data should help to validate, corroborate, and interpret the model results.

In evaluating monitoring data, it is important to consider the likely source of high concentrations (stack, fugitive, background, reentrainment) as well as the meteorological and topographical influences particular to the area. It is preferable to obtain comparable data from multiple stations within and around the source area; however, analysis of data from single stations can provide much useful information.

4.5.1 Single Station Analysis

The goal of single station analysis is to identify factors that influence the observed lead concentration levels. This is accomplished through a sequence of comparisons between observed concentrations and concurrent emissions, and meteorological data. The analysis should focus on those conditions that persist long enough or produce high enough concentrations to influence monthly average concentrations. Care should be taken to ensure that data used in comparisons are quality assured and representative of the same areas and time intervals. Parameters to consider for comparisons include the following:

- Prevailing wind direction
- Scalar average wind speed
- Wind persistence (ratio of vector mean to scalar average wind speed)
- Height and magnitude of inversions (daytime and nocturnal)
- Range of Pasquill-Gifford stability categories[11]
- Emissions rates over time (if available)
- Facility operating schedules

The techniques that should be applied will depend on the available data, time, and resources. The goal is to utilize the data to obtain as much information as possible on the spatial distribution of lead concentrations surrounding the source. A recommended sequence of analyses is to consider the frequency distributions of concentrations and related parameters, then conduct time series analyses and case studies of peak values. If data are available from more than one monitor, comparing the results of similar analyses conducted for the different monitors can yield valuable information.

A good starting point for statistical analysis of monitoring data is to compile frequency distributions for observed concentrations and meteorological parameters. A graphical presentation of these distributions enables immediate understanding of the nature of any central tendency of the various parameters. Most frequently occurring lead concentrations might be related to the most frequently occurring meteorological conditions. Monitors exhibiting similar concentration frequency distributions, especially over a period of several years, might be considered to be in homogeneous areas.

Comparative time series analysis can help to explore the relationship between lead concentrations and the various influencing parameters. A graphical presentation of two or more variables plotted simultaneously against time can be extremely useful in identifying such relationships. Because historical lead measurements are generally integrated over a 24-hour period and are obtained only once in each six day period, it may be difficult to achieve meaningful comparisons between concentration and meteorological data; however, significant relationships should appear. Comparison of time series plots of data from different stations can quickly reveal if the factors influencing lead levels are the same. Regression analysis can be used to further explore and quantify apparent relationships.

After exploring interrelationships between concentrations and the various influencing factors, case study analyses of peak values and consistently elevated values should be conducted to thoroughly characterize conditions that could result in an exceedance of the monthly standard. Ideally, a limited set of conditions can be identified that corresponds to the most persistent conditions related to elevated concentrations and to the highest values recorded. This information will help to focus subsequent analyses and, in some cases, may provide adequate information for site selection.

4.5.2 Multi-station/Mapping Analysis

If data from a sufficient number of monitoring stations are available to provide adequate spatial coverage of the source impact area, mapping analysis can be conducted to identify maximum impact areas and their associated spatial scales of representativeness. This can be accomplished by estimating the locations of lines of uniform concentration (isopleths) on a map of the area. Computer graphics packages are available that provide a convenient and systematic method of establishing concentration contours. Data must generally be available from at least six sites concurrently in order to obtain useful information from a mapping analysis.[12] In order to obtain meaningful results, it is essential to ensure the comparability of data from different stations. This includes consideration of sampling and analysis methods, sampling intervals, and schedules. Data bases should be adequately validated and sufficient completeness criteria applied (e.g., 75 percent).

4.5.3 Adequacy of Analysis of Existing Monitoring and Meteorological Data

Two judgments are required to determine whether analysis of monitoring and meteorological data is sufficient to justify selection of permanent monitoring stations. The first is whether the available monitoring data accurately reflect the spatial distribution and temporal variation of lead concentrations over the area. The second is whether the resolution (detail) in that pattern is adequate to allow selection of permanent monitoring locations with sufficient assurance that they represent the maximum impact areas. Due to the steep concentration gradients typical of lead air pollution, maximum impacts may occur over relatively small areas that may not be represented in a more general pattern. High concentrations over a small area could occur due to plume impaction on elevated terrain, but would not be represented if no monitor were positioned to record those concentrations. Similar uncertainty could result if high concentrations occurred near a source due to fumigation conditions and, likewise, there was no monitor in position.

When the distribution and variability of lead concentrations are adequately defined, meteorological variation, topographical influences, and the distribution of sources should be consistent with the monitoring data. Any significant changes in these factors should be reflected in the monitoring data. If the lead air quality pattern is consistent over time (peaks in subsequent years occur under the same conditions at about the same time), this may be taken as evidence of a stable pattern which can be used for network design purposes. If the monitored lead air quality pattern varies over time, then these variations should be consistent with changes in the influencing factors. If there are unresolved inconsistencies, then more careful or detailed analyses should be conducted. If further analyses of existing data fail to resolve inconsistencies, then air quality modeling should be considered to explore further relationships.

When monitoring data are available from a few, widely dispersed monitoring stations, as is often the case, it is difficult to determine if small scale impacts are adequately represented. In such instances, it may be possible to benefit from knowledge of emissions characteristics, topographic influences, and prevailing meteorological conditions to draw conclusions regarding the location and scale at which maximum impacts are likely to occur. For example, impacts from resuspension and ground level fugitive sources will be adjacent to the source in the downwind direction. Ground level impacts from elevated stack emissions should be diffuse and remote from the source except under fumigation conditions. Adequate documentation that such conditions prevail, along with corresponding data from an appropriately located monitor, would provide sufficient justification for permanent site selection without the need for modeling.

Air quality models designed to predict concentrations at designated receptors under a variety of source configurations and meteorological conditions can be used to help resolve some of this uncertainty. Agreement between modeling and monitoring analyses, though not constituting proof, provides additional justification for decisions regarding site selection. In addition, if time and resources permit, saturation monitoring studies can be designed to specifically address the uncertainties particular to a given source area.

4.6 Air Quality Modeling

Air quality models are a limited mathematical representation of the processes of emission, transport, and deposition of pollutants in the atmosphere. Dispersion models allow computation of relative concentrations of air pollutants based on emission conditions, degree of atmospheric mixing, and distance from the source. Receptor models are designed to back-calculate source impacts using variability in ambient air data and unique source characteristics. All air quality models incorporate simplifying assumptions which produce varying degrees of uncertainty in the modeled results depending on the extent to which the actual situation is represented in the assumed conditions.

Dispersion models are of primary importance in network design since they yield data that can be used immediately to determine locations where maximum impacts might be expected. Further, dispersion models can be used to predict the degree of emissions reductions required to achieve an air quality standard. Receptor models are useful in situations where there are large uncertainties in dispersion model results and can be applied to help resolve inconsistencies between dispersion modeling and monitoring data.

4.6.1 Dispersion Modeling

Detailed guidance on the regulatory use of air quality dispersion models is available in the Code of Federal Regulations, Title 40, Part 51, Appendix W.[11] The most extensively applied method of modeling the dispersion of air pollution utilizes the Gaussian plume equations. These equations are derived from expressions representing the concentration of air pollutants within a cross section perpendicular to the plume at varying distances downwind from the source. Concentrations are assumed to decrease in proportion to increasing distance from the source, and the concentration profile along the vertical and horizontal axes within the plume is assumed to conform to a Gaussian (normal) distribution (Figure 3). Theoretical and experimental results support these assumptions.[13]

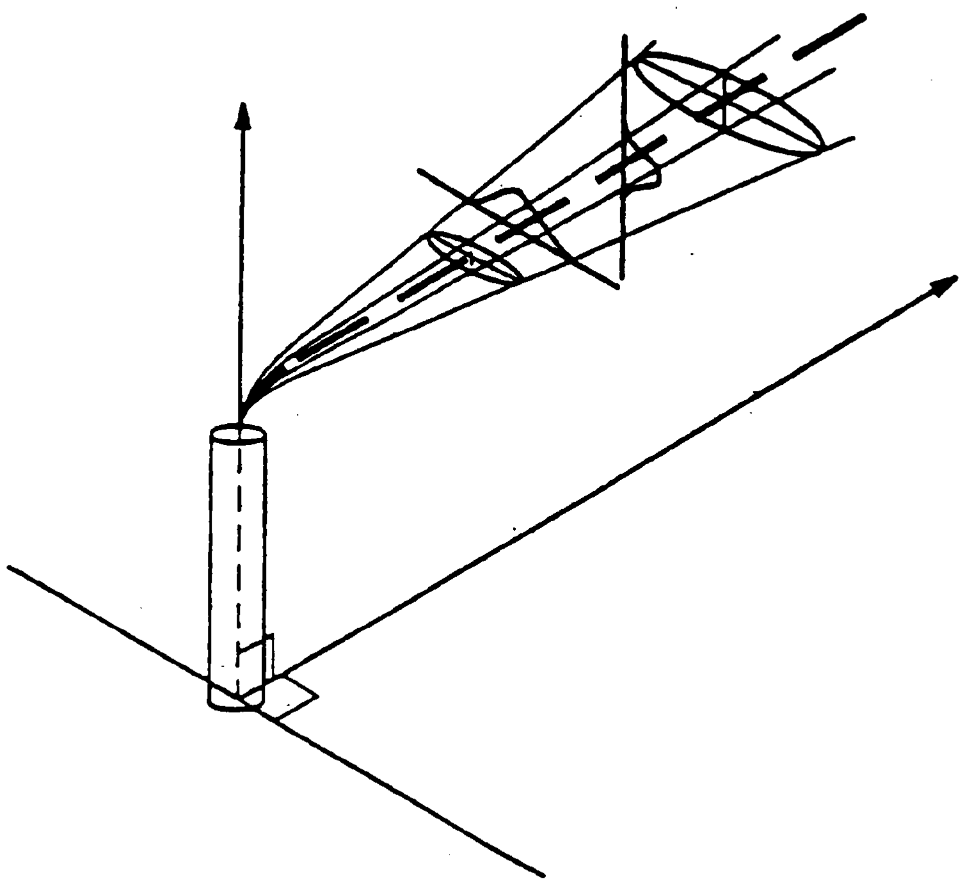


Figure 3. Gaussian Plume Dispersion Model

The spatial impact of a plume depends on wind speed and direction, and the rate and extent of vertical and horizontal dispersion of the plume. Plume dispersion depends on atmospheric stability as well as emission characteristics. Atmospheric stability has been categorized by Pasquill and others into classes defined according to wind speed, insolation, and vertical temperature gradient.[11,14] Diffusion coefficients expressing horizontal and vertical dispersion rates at varying downwind distances have been empirically derived for each stability category and are employed in dispersion models. In general, such models describe a cone shaped plume spreading out downwind from a point source over level terrain.

4.6.2 Recommended Modeling Approach

Dispersion models are required for demonstrations of attainment of the lead air quality standard around certain point sources and in areas with measured quarterly mean lead concentrations greater than 4.0 $\mu g/m^3$. Dispersion modeling is an appropriate analytical technique for network design for lead monitoring near point sources. In order to most effectively utilize resources, a three-phase approach to the use of dispersion models for air quality analysis has been developed and is recommended.[14]

The first two phases utilize screening procedures to determine relatively quickly which sources pose no threat to air quality and which sources might potentially generate an air quality problem. The screening procedures are designed to provide a conservative estimate of air quality impacts so that, if predicted concentrations are below the level of concern, no further analysis is necessary. Refined modeling techniques are utilized in the third phase. The refined models are designed to provide a more accurate assessment of air quality impacts by taking into account influences that are beyond the scope of the screening procedures.[14]

4.6.3 Screening Procedures

In the first phase, a simplified, step-by-step, procedure is used to apply the Gaussian dispersion equation to estimate the maximum ground level concentration near a point source. The simplified screening procedure can be carried out by hand or with a hand-held calculator. The procedure is primarily applicable to single point sources in level terrain; however, a method is provided to merge nearby point sources with similar characteristics so that they can be treated as a single source. The simplified procedure does not apply if aerodynamic downwash or plume impaction on elevated terrain are to be considered.[14]

More detailed, second phase screening procedures are warranted if concentrations predicted by the simplified procedure exceed the level of concern. Second phase computations account for a predetermined range of meteorological situations, and can be applied to estimate the impact at specific downwind locations. These calculations can also be done manually. The same assumptions of level terrain and no downwash generally apply when the basic second phase procedures are used. A computer application called SCREEN is available to help conduct more detailed second phase screening analyses. The SCREEN model facilitates second phase computations and is capable of providing corrections for downwash, fumigation, elevated terrain, and area sources.[14]

The available screening procedures are designed to provide maximum one-hour, 3-hour, 8-hour, 24-hour, or annual average concentrations. Maximum concentrations averaged over intervals longer than one hour will be lower than the one-hour values. The ratio of a longer term maximum to a one hour maximum depends on the averaging time, source characteristics, and the local climatology, topography, and meteorology.

Screening procedures can provide estimates of the rate at which maximum impacts decrease with distance from the source. This information is useful for designing appropriate receptor grids for refined modeling. Screening procedures can also be applied to various sources within a facility to obtain initial estimates of the relative contributions from each source. This information is useful in selecting refined model output and interpreting refined model results.

4.6.4 Refined Modeling

Where screening procedures fail to clearly eliminate a source from concern, the use of a refined model is called for. Refined modeling is also recommended if the source configuration is complex, emission rates are highly variable, or pollutant dispersion is thought to be significantly affected by terrain features or large bodies of water. Since available screening procedures do not readily predict quarterly average concentrations, refined modeling will often be required to determine if a source's emissions pose a threat to the standard.

The additional effort to run a refined model consists primarily of that required to construct the receptor grid and to prepare the more detailed meteorological data. The industrial source complex (ISC) model has been used to estimate lead impacts from a variety of sources [2,3,15] and is recommended for areas with significant sources of lead emissions. [16]

The ISC model allows the user to select a large number of receptor locations to be modeled. These can be located in a grid pattern or by individual coordinates. Polar or Cartesian coordinate systems may be used. Separate sources are likewise located according to a coordinate system. The ISC model accounts for many source/area specific influences including the following: particle settling and dry deposition; downwash; point, area, and volume sources; plume rise as a function of downwind distance; wind speed variation with height; and separation of point sources. [11,17] Fumigation is not treated and terrain adjustment is limited. Short-term and long-term versions of the ISC model are available. Both versions provide a variety of user-specified output options.

The short-term version (ISCST3) is designed to provide concentrations averaged over 1-hour to 1-month intervals using hourly meteorological input data. The short-term model can also provide a "period" concentration output calculated over the number of days of meteorological data processed. Either monthly averages, or period averages with 90 days of data, would be used for assessing whether a source constitutes a threat to the quarterly lead standard.

The long-term version (ISCLT3) uses meteorological data in the form of Stability Array (STAR) summaries and is designed to provide quarterly and annually averaged concentration outputs. STAR summaries are joint frequency distributions of wind speed, direction, and stability category. STAR summaries are available from the National Climate Data Center (NCDC); however, they can also be generated from site-specific data.[11] ISCLT3 could be used to generate quarterly averaged concentrations if quarterly STAR summaries were used. Quarterly concentrations generated from the short-term and long-term models might not agree precisely; however, the probable locations of maximum concentrations predicted by the two approaches should be reasonably similar.

4.6.5 ISC Model Application for Lead Sources

As previously noted, the ISC model is applicable to combinations of point, area, and volume sources. Thus, the model is applicable to a source configuration with separate or combined impacts from an isolated point source with nearby roadways (line or volume sources) and fugitive area sources. Similarly, the ISC model can address combined impacts from multiple nearby point sources.

Background lead concentrations should be obtained independently and added to the modeled concentrations.[11] Data on regional scale background lead concentrations may be available from monitoring data for the area of concern or an area that can reasonably be assumed to have similar background lead levels.[16] A monthly average value of 0.1 $\mu g/m^3$ has been used as a conservative estimate of background lead concentrations across the U.S.[3]

If a point source is located within a substantial highway network, lead emissions from the road network should be added to background concentrations and the source and nearby roadways should be modeled separately. If available, monitoring data that are representative of the roadway network, but are not influenced by the plant emissions, can be used to estimate the roadway background. If representative monitoring data are not available, data from a similar network can be substituted or emission estimates can be derived based on traffic volume.[16]

The ISC3 model incorporates a screening model (COMPLEX-1) for complex terrain. As a result, it may not adequately account for effects of complex terrain. Plume impaction on elevated terrain may cause high ground level concentrations. In addition, topography and land use can significantly alter the local wind field as compared to that predicted for level terrain. For modeling purposes, complex terrain is defined as having topographic features that exceed the stack height.

Other than COMPLEX-1, other screening models for complex terrain are available, including the Rough Terrain Dispersion Model (RTDM) and CTSCREEN. These may provide somewhat better estimates of concentrations than COMPLEX-1. The Complex Terrain Dispersion Model (CTDM Plus) is a refined model for complex terrain. This can make use of digitized contour data and meteorological data at several levels up to plume height. Receptor location is highly critical. The very dense array of receptors potentially required suggests that the models be applied in two stages. The model would first be applied to a moderate number of carefully selected receptors in order to identify areas with potential for high concentrations. A more dense array of receptors could then be selected within the areas of concern. The CTDM may be too involved for site selection purposes, and even CTSCREEN will require some detail of terrain data. A model such as Complex-1 may suffice and does not require substantially different input data than ISC3. Screening and refined analytical techniques for modeling in complex terrain are discussed in recent revisions to the Guideline on Air Quality Models.[11]

4.6.6 Interpretation of Model Results

Modeling is a primary analytical tool for selecting monitoring locations for lead around existing point sources and, in some cases, may be the only practical means of formally analyzing the distribution of lead air pollution. As noted above, results of air quality models are subject to a relatively large degree of uncertainty. Modeled concentrations typically differ from observed concentrations by as much as ±50 percent.[11] Nevertheless, modeled estimates of the highest concentrations occurring at some time, somewhere in an area are thought to be reasonably reliable. In general, the maximum modeled concentration is the best estimate as to whether the quarterly NAAQS may be violated.

At present, there is no standardized means of determining and reporting modeling uncertainty and expressing confidence levels in decisions based on modeling. It is important, however, to attempt to identify and document the reliability of the model estimates for each application. It is the responsibility of the modeler to provide a reasonable justification for interpretation of modeling results. Therefore, it is important that modeling be conducted by experienced air pollution meteorologists.

4.6.7 Receptor Modeling

Receptor models use monitoring data to apportion the contributions of sources by comparing observed air quality characteristics to known emissions characteristics of sources in the area. The Chemical Mass Balance (CMB) method for receptor modeling has been in use for over two decades. CMB8 will be released in 1998 and should be used in conjunction with its application and validation protocol.[22] For CMB applications, data from both sources and receptors are required, and these data should be collected in accordance with an approved quality assurance protocol. Ambient lead sampling for CMB work is ideally done with membrane filters (i.e., Teflon) followed by appropriate analysis by X-ray fluorescence spectroscopy. Although not predictive, CMB is useful to help bridge the gap between monitoring data and dispersion model predictions.

In situations where there are multiple contributing sources that can be differentiated chemically or physically, CMB analysis may be used to apportion the contribution from the various sources. This technique can also be used to differentiate between stack, fugitive, ground level (reentrained) and background emissions. In cases where there are multiple sources and/or source types, complex terrain, or other factors which adversely affect the degree of uncertainty in dispersion model results, receptor models can be applied to help resolve the contribution from the various sources without the need to directly account for the influence of complicating factors. Receptor modeling has also been applied in air sheds for which the meteorological regime is dominated by calm wind conditions, and for which Gaussian plume models are ill suited.

If adequate monitoring data are available, (from properly collected and analyzed samples), CMB analysis can be used to validate and corroborate the results of dispersion modeling. If dispersion models fail to predict ambient concentrations, then CMB modeling may help to resolve the differences by accounting for the contributions from sources that were not modeled in the dispersion analysis. This usually leads to an adjustment of the emission inventory used in the analysis, followed by a rerun of the dispersion model. When dispersion model results do agree with measured concentrations, there is still little evidence of the dispersion model's ability to predict the impact of a single source within a group of sources or of variations within the source makeup without the help of some form of receptor model analysis.

4.7 Saturation Monitoring

Saturation monitoring refers to an air quality monitoring approach directed at achieving finely detailed spatial and temporal resolution of air quality impacts in an area. This can be accomplished through a rigorous program design employing a large number of portable samplers. Saturation monitoring studies are typically conducted over relatively short intervals during the part of the year in which maximum impacts are expected to occur. A successful saturation study provides a wealth of data that can complete information lacking in traditional monitoring and modeling approaches.

4.7.1 Saturation Monitoring Applications for Lead Point Source Monitoring Network Design

Saturation data can be used to resolve spatial concentration gradients and identify distinct impact areas associated with different source types. In addition, saturation data can provide missing background and area/mobile source baseline characterizations. Dispersion and receptor model performance can be evaluated using data obtained from saturation studies. Saturation studies may be particularly valuable in complex terrain situations where existing monitoring data are likely to lack the necessary spatial resolution, and modeling results are subject to the greatest uncertainties. In some cases, it may be appropriate to use a saturation study to independently provide a basis for site selection.

4.7.2 Saturation Monitoring Study Design

Saturation study designs are, by their nature, highly dependent on the area and monitoring objectives under consideration. The design of a saturation monitoring network shares many of the same considerations necessary for design of a network near lead point sources or any other sampling network. That is, historical meteorological and monitoring data need to be analyzed and area-specific source emissions and topographic influences need to be considered.

Study Interval

An appropriate study interval must be chosen to capture the time period when maximum impacts occur and span the required temporal scales of variation. This entails review of historical monitoring, meteorological, and emissions data. The interval must be long enough to allow collection of sufficient valid samples for statistical integrity of the data. Logistical considerations, including regulatory deadlines, manpower, and resources, are also likely to play a significant role in study design.

Sampling Schedule

The daily sampling schedule must be addressed in terms of monitoring objectives. For lead monitoring, a 24-hour sampling period would be consistent with the reference sampling schedule for lead. Finer time resolution is probably unwarranted and not likely to provide useful information since the lead standard is based on a quarterly average. Potential use of a longer sampling interval could be evaluated in terms of comparability with composite samples collected by a reference high volume sampler. A longer sampling period might improve the sensitivity of portable samplers which are able to achieve flow rates far lower than those achieved by the high volume. Whatever sampling period is chosen, it is important to devise a scheme for sample changes to ensure that samples are collected over comparable intervals at different locations. The saturation study design can also incorporate multiple or dynamic sampling periods, if appropriate.

Site Selection

The likelihood of small scale impacts of lead air pollution suggests a site selection strategy that attempts to identify representative monitoring locations within relatively small areas. If such areas have previously been identified through modeling studies or analyses of monitoring data, saturation samplers can be clustered within a few areas thought to be the most heavily impacted. Alternatively, saturation samplers can be scattered over a larger number of areas to determine where maximum impacts occur. It is also possible to change the site configuration within the study period based on the data obtained or changes in meteorological or emission conditions. Once again, existing air quality, meteorological, and emissions data are consulted. Previous monitoring and/or modeling studies may be available and can be studied for suggestions of appropriate monitoring locations.

Methods and Quality Assurance

Battery operated, portable particulate samplers are available that are relatively inexpensive, convenient to operate and deploy, and exhibit detection limits and operating ranges comparable to reference methods. A limited number of intercomparison studies have been conducted to validate portable sampling methods.[18] If possible, the study design should include a set of samples from a portable sampler collocated with a high volume so that an assessment of the relative accuracy of the data can be obtained. In addition, a duplicate set of measurements should be obtained from collocated portable samplers so that operational precision can be assessed. A quality assurance plan should be prepared and adhered to as with any monitoring program.

4.8 Site Selection Without Monitoring or Modeling Data

There may be situations when useable information from existing lead monitors will not be available and modeling analysis is not feasible because of logistical or resource constraints, or limitations of the available models. It may be possible to identify representative lead monitoring sites based on information available on emission sources, and the area's topography and climatology. In addition, measurements or modeling analyses conducted in similar locations under similar source influences might be available and could provide some insight into locating representative sites. Such decisions could depend rather heavily on the best professional judgment of those involved. Location of monitors based on population density, industrial growth expectations, or exposure to sensitive populations might also be a consideration.

Except in the simplest and most direct of circumstances, siting monitors without substantial supporting information is unlikely to satisfy SLAMS network design requirements. In such circumstances, a saturation monitoring study could be considered, or steps might be taken to obtain the data and resources necessary to conduct a modeling study.

4.9 Number and Location of Monitors

The recent revisions to the air surveillance regulations (40 CFR 58 Appendix D) recommend at least two monitors near sources that are believed to have the potential to cause air quality problems.. The monitors should be located in the two locations most likely to receive maximum lead concentrations as determined from the foregoing analyses. These might be located, for example, at an appropriate distance downwind from the source in the first and second most predominate wind directions that occur when meteorological conditions favor high ground level concentrations.

In some cases, it may be determined that separate threats to the standard may be presented by different source types in the same source area. For example, stack emissions might impinge upon a hillside while a separate area near the source is impacted by significant fugitive and ground level emissions. In such instances, one monitor should be dedicated to monitoring stack impacts while the other is located to capture the fugitive impacts.

The monitoring requirements suggest that more than two monitors may be needed in some circumstances. Generally, the number of monitors will be greater where the expected spatial variability of lead concentrations is larger. This would typically occur when there are multiple sources or source types located in the same area or when background concentrations are occasionally significant and highly variable. Examples include multiple point sources; combined impacts of point and mobile sources; and separate or combined impacts of stack and ground level or fugitive emissions where fugitive emissions are sufficient to pose a threat to the standard.

number needed. After analysis options have been exhausted, a decision is made based on the available information by the agency involved with the support and approval of the local EPA regional office. The final determination of whether more than the minimum number of monitors should be installed will depend on the outcome of this process.

4.10 Site Selection Study Report

In addition to the preparation of the network description, a formal record should be maintained summarizing the study conducted to arrive at final site selections. Documentation should be maintained that supports study activities and allows results to be reproduced if necessary. Such documentation might include monitoring data files, model input and output files, maps, memoranda, references consulted, and procedures followed. A recommended outline of a site selection study report would contain the following sections.

Introduction, Goals, and Objectives

Background on the circumstances and information leading to the need to undertake the network design study should be provided in this section. The study design should be outlined and the specific, technical objectives that shaped the study should be summarized.

Description of Study Area

A description of the study area should be given that outlines matters and features of concern and references maps, emissions data files, and other information sources that provide necessary details.

Study Design/Activities

The overall study design should be described, and activities and analyses that were conducted as part of the study should be detailed.

Study Interpretation

The reasoning that was applied to synthesize information gathered from the various study activities and arrive at final site selections should be presented. Data interpretation and uncertainty issues and a description of how these were addressed should be included.

Site Descriptions

The physical location and features of the selected sites including their roles in satisfying monitoring objectives should be enumerated.

5.0 LEAD MONITORING

Sampling for ambient concentrations of lead must be done in accordance with the lead reference method prescribed in Appendix G of 40 CFR Part 50. The sampling schedule and reporting requirements are codified in 40 CFR Part 58. Quality assurance and siting criteria appear in Appendices A and E to Part 58. This Section reviews existing requirements and significant changes to the ambient lead monitoring regulations resulting from the revisions to 40 CFR Parts 50 and 58.

5.1 Placement of Lead Samplers

Lead samplers should be placed so that a representative measurement of the lead concentration over the impact area of concern will be obtained. In order to assure optimum sampler placement and network consistency, criteria for siting the lead sampler are codified as given in Section 7.0 to Appendix E of Part 58. The primary concerns involve consideration of the vertical and horizontal lead concentration gradients near roadways, airflow obstructions, and unrepresentative localized sources or sinks. In general, considerations for locating ambient lead monitoring stations around point sources are confined to micro-scale and middle-scale areas.

The following summarizes the basic sampler siting criteria that State/local agencies must consider in the proper placement of the lead sampler at lead monitoring sites (40 CFR 58, Appendix E):

- The sampler inlet must be 2-7 meters above ground level in micro-scale areas. For middle-scale areas, the sampler inlet must be 2-15 meters above ground level.
- The distance between samplers and obstacles must be at least twice the height that the obstacle protrudes above the sampler.
- There must be an unrestricted airflow in an arc of at least 270° around the sampler and this must include the predominant direction for the season with the greatest pollutant

concentration. This criteria applies to micro-scale, street canyon, and similar restricted sites. This would also apply to a maximum concentration fugitive emissions site.

- No furnaces or incinerator flues should be nearby.

- Any tree(s) that act as obstructions between the source of the lead emissions and the sampler should be at least 20 meters and must be at least 10 meters distant.

- The roadway setback criteria is not generally applicable to point source oriented sites. Given that roadway concentrations are now generally near background or even the reference method's minimum detection limit, a good site location should not be rejected due to proximity to a roadway unless the roadway is a significant source of lead (e.g., resuspension).

5.2 Sampling Method

The use of high-volume samplers for collecting lead ambient air samples continues to be required. During the most recent review of the lead NAAQS, the EPA investigated using the PM_{10} sampler as the reference method sampler. Results from this work showed that the use of a high-volume air sampler was effective at capturing 80 to 90 percent of the total mass of lead in a hypothetical particle size distribution air sample using the particle size distribution specified in the PM_{10} methodology requirements (52 FR 24634, July 1987).[19] EPA also demonstrated that high-volume air samplers could capture on average, two times as much lead mass as PM_{10} samplers.[19,20,21] The PM_{10} sampler, by design, excludes particles larger than respirable size. Such particle sizes may be collected, however, by the high-volume sampler. Exposure to lead not only occurs through inhalation, but also through ingestion of particles which may be too large to be inhaled, especially by young children. Therefore, the high-volume sampler provides a more complete measure of exposure to airborne lead than the PM_{10} sampler.

The high-volume sampler remains as the monitoring option for the lead standard because (1) it will provide a reasonable indicator for determining compliance with quarterly standards; (2) the measurement technology is in place; (3) it is simple and inexpensive to operate; and (4) its continued use will result in historical continuity in the lead air quality database.

The reference method now allows for lead samples to be collected on quartz fiber filters in addition to glass fiber filters. Historically, glass fiber filters were used in conjunction with high-volume total suspended particulate (TSP) samplers. The option of using a quartz substrate for lead sampling was added to allow such agencies to use a single filter substrate in their overall monitoring network. In addition, X-ray fluorescence (XRF) analysis is widely used in receptor modeling. Samples collected on glass fiber filters are inappropriate for XRF analysis. Thus, quartz filters may also be preferred for this reason.

5.3 Sampling Schedule

Samplers intended to monitor ambient impacts from point sources are required to be operated at a minimum schedule of one-in-6 days; however, many monitoring agencies have increased this frequency to once every 3rd day or every day when monitoring around point sources in order to obtain a more complete database. Roadway monitors should generally be operated on a one-in-six day sampling schedule.

5.4 Analytical Method

The reference method procedure for determining lead in suspended particulate matter collected from ambient air is provided in 40 CFR Part 50 Appendix G. In general, Appendix G requires that lead in particulate matter be solubilized using extraction procedures involving nitric acid (HNO_3) and hydrochloric acid (HCl) with subsequent analysis using atomic absorption spectrometry. In addition, ambient lead concentrations must be determined as elemental lead. Equivalent methods designated in accordance with 40 CFR Part 53 may be used in lieu of the Appendix G method for determining the ambient lead concentrations. A current list of designated reference and equivalent methods is available from the following address:

National Exposure Research Laboratory
Dept. E. U.S. EPA, (MD-77)
Research Triangle Park, NC 27711

Updated listings are also available on the U.S.EPA's Ambient Monitoring Technology Information Center accessible through the Internet address http://www.epa.gov/ttn.

Individual filter samples or composites of as many as eight filter samples collected over a consistent one-week, two-week, or one-month period during a calendar month may be analyzed for lead content to derive a monthly average concentration. EPA's National Exposure Research Laboratory (NERL) recommends the use of eight filter samples for compositing. As such, U.S.EPA allows for individual analysis of all lead samples collected during the quarter or an average of three monthly composite samples for determining the quarterly average.

Compositing procedures must be approved in accordance with procedures contained in Section 2.8 of Appendix C to 40 CFR Part 58 -- Modifications of Methods by Users.

5.5 Quality Assurance Requirements

Quality assurance programs for SLAMS monitoring networks and minimum quality assurance requirements are codified in Appendix A to 40 CFR Part 58. Complete quality assurance procedures for determining sampling precision, sampler flow rate accuracy, and accuracy of the lead reference method are contained in the "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II--Ambient Air Specific Methods", EPA-600/R-94/038b. This Quality Assurance Handbook is available through the Center for Environmental Research Information, 26 W. Martin Luther King Drive, Cincinnati, Ohio, 45268, (513) 569-7562, fax (513) 569-7566.

5.6 Data Completeness and Reporting Requirements

At least 75 percent of the lead samples must be available in order for the quarterly average to be considered valid. For monthly composite sampling, the sampler must have been properly operating on at least 75 percent of the sampling days in a month. Alternatively, if fewer than

75 percent of the scheduled samples for the quarter are available, the quarterly average shall be considered valid if this average, computed as the sum of all available measured concentrations in the calendar quarter divided by the number of scheduled samples, exceeds the level of the standard. That is, a NAAQS exceedance can be recorded using fewer than 75 percent valid data capture, while at least 75 percent valid data are required to demonstrate NAAQS attainment.

The quarterly average concentration measured at any single lead ambient air monitoring station must not exceed the level of the standard. A quarterly average concentration, rounded to one decimal place, is considered to exceed the standard if it is greater than 1.5 $\mu g/m^3$. No violations can be measured for a given two year period (eight quarters) in order to demonstrate attainment of the NAAQS.

Precision and accuracy data must be submitted to the Aerometric Information Retrieval System (AIRS) under 40 CFR Part 58.35. Previously, only data summary reports for SLAMS data were submitted; however, SLAMS data are now also to be submitted according to the schedule for submitting NAMS data. SLAMS and NAMS lead monitoring data, along with the associated precision and accuracy data, should be reported to EPA within 90 days after the end of each calendar quarter.

6.0 CASE STUDIES

6.1 General Considerations

This section discusses three case studies that were developed to illustrate the application of the general guidance for selecting monitoring locations near lead point sources. This work was completed during the time period when the U.S.EPA was reviewing the quarterly lead NAAQS and considering the merits of a monthly lead NAAQS; however, the basic principles within are applicable for either the quarterly or the monthly forms. The case studies are based on emission rates and source configurations for a hypothetical lead acid battery plant, secondary smelter, and primary smelter. Meteorological and topographical characteristics of the hypothetical source locations are based on actual data. The approach to determining optimum monitoring locations for the case studies follows the general outline provided in Section 4.0. The following paragraphs discuss general considerations for each step of the procedure for locating lead monitors near lead sources as applied to the case studies. A discussion of the results of such analyses for each case study follows.

Monitoring Objectives and Spatial Scale of Representativeness

For lead monitoring near point sources, the primary monitoring objective is to measure maximum ambient impacts. This is necessary to document compliance or noncompliance with the lead standard. If ambient concentrations and population density near the source are large enough, it may be advisable to site an additional monitor or monitors to document population exposure. This may be especially important when sensitive populations, such as children concentrated at a school, are likely to be exposed. All three case studies focus on locating maximum concentration sites. It is assumed that the Case 2 and 3 sources are located in rural, low population density areas. For Case 1, lead concentrations decrease rapidly enough that the source could be located in a semi-urban area and would still be unlikely to require exposure oriented monitoring.

The spatial variability of point source lead impacts is such that the spatial scale of representativeness for a lead monitor is likely to be on the order of several hundred meters. Once modeling and/or other analyses have suggested general areas where maximum impacts are expected, it is desirable to site the monitor to maximize the spatial coverage of the measurements. Probe siting requirements contained in Appendix E of 40 CFR Part 58 provide guidelines for avoiding influences of local obstructions; however, each situation should be examined independently. For all three case studies, monitor locations are suggested by model predictions. Details of precise probe siting are not discussed.

Source Characteristics

Case study source characteristics were determined uniquely for each facility. Source configurations include emission rates and locations for point (stack), and area and volume (fugitive) sources within each facility. Characteristics of each source within each facility were provided as input to ISC. Model inputs for point sources included stack height, diameter, temperature, and exit velocity. Stack downwash effects and buoyancy induced dispersion were considered. In addition, building dimensions were provided so that building downwash effects could be calculated by the model. Particle size distributions and associated settling velocities were considered for Cases 2 and 3. For the case studies, background lead concentrations were conservatively estimated at 0.1 $\mu g/m^3$.

Accurate source data are most readily obtained by surveying the source directly. Organizations representing particular industry groups may also be consulted. In many cases, especially for larger sources, the EPA's AIRS Facilities Subsystem will be able to provide the needed information. State and local SIP emission inventories and/or operating permits may also be used. Within the decade, all lead sources large enough to require monitoring will be required to obtain Title V permits. These permits should serve as a comprehensive reference for source related information.

Topographic and Land Use Influences

The terrain was assumed to be rolling or flat for all three case studies. For Case 1, there were some topographic features elevated above stack height; however, this complex terrain was too far from the source to experience significant impacts. Analyses required to characterize significant impacts in true complex terrain are beyond the scope of the general studies presented here.

Meteorological Data

Meteorological data for all three cases were assumed to have been collected at an airport within a representative region containing the source. Representativeness might have been established by examining meteorological data from surrounding stations and determining that there were no persistent, significant spatial gradients across the area containing the source and the airport. One year of hourly meteorological data was used for each case study. For regulatory compliance purposes, five years of data are required; however, for network design purposes, a single year's data can suffice provided that the year is reasonably representative of the regional climate.

Analysis of meteorological data for the case studies consisted of examination of windroses to determine dominant wind direction(s) and consideration of statistical summaries of the frequency of occurrence of stability classes for various wind directions. Identical meteorological data were used for Cases 1 and 3. This year's data are characterized by two dominant wind directions. Meteorological data for case 2 are characterized by a dominant southerly wind.

Ambient Monitoring Data

Existing ambient monitoring data should be examined for monitors likely to be affected by point source emissions. Cases 1 and 2 represent smaller sources where monitoring is unlikely to have been conducted in the past. Case 3 is a large source, and it is assumed that there is an existing record of one year's data from a monitor located approximately in the predominate downwind direction from the source. For purposes of the case study, daily lead measurements for the Case 3 monitor were simulated using ISC output.

Air Quality Modeling

ISC was applied to each case study to predict monthly average impacts for an array of receptor locations surrounding each source. The model was set to produce a composite arithmetic mean for each month in the year. Hourly meteorological data are used by the model to predict hourly ambient concentrations which are then averaged into daily concentrations and, subsequently, averaged into monthly concentrations.

Model options (ISW switches) for ISC were, for the most part, set at the regulatory defaults. Particle settling was not considered for Case 1 since no size category data were available. Particle settling was modeled for Cases 2 and 3. Case 3 stacks were good engineering practice (GEP) height, so it was not necessary to consider building wake effects. Building wake effects were modeled for Cases 1 and 2.

In each case, a screening analysis was used to examine the expected rate of decrease of predicted concentrations with distance from the source. This information was used to aid designing receptor grids for refined modeling and to provide estimates of the relative contributions from various sources within each facility.

SCREEN predicts maximum hourly concentrations for a single, or appropriately grouped, source over a range of downwind distances. SCREEN output is based on 33 categories of meteorological conditions based on wind speed and stability class (Table 4). Alternatively, ISC can be run under screening conditions to produce similar output. The advantage of using ISC for the screening analysis is that it is more convenient to handle complex facilities with multiple sources. SCREEN was run for each of the 3 stacks for Case 1. ISC was run in screening mode for Cases 2 and 3.

Table 3. Wind Speed and Stability Class Combinations Used by SCREEN

Stability Class	Wind Speed at 10 Meters								
	1	2	3	4	5	8	10	15	20
A	1	2	3						
B	4	5	6	7	8				
C	9	10	11	12	13	14	15		
D	16	17	18	19	20	21	22	23	24
E	25	26	27	28	29				
F	30	31	32	33					

"Screening Procedures for Estimating the Air Quality Impact of Stationary Sources," Appendix A, USEPA, Office of Air Quality Planning and Standards, EPA-450/4-88-010, August 1988.

Hourly averages predicted in the screening analyses are about 50 times as high as monthly average concentration predicted by refined modeling. For the case study model runs, monthly averages predicted by ISC were 2.0 to 2.5 percent of hourly averages predicted by SCREEN. Although concentrations predicted by SCREEN cannot be compared directly with the NAAQS, SCREEN output provides initial estimates of which sources within each facility are most likely to produce the highest ambient impacts.

Monitoring Locations

Monitoring locations for the case studies were suggested by the refined model output. The modeled results were interpreted based on knowledge of the source configuration and understanding gained from examination of the meteorological and available monitoring data. Population exposure was also considered when multiple monitoring locations were suggested with equal weight by the model. Specific probe siting criteria should be followed to avoid influences of local obstructions. In addition, there are practical limitations such as property ownership, availability of electrical service, and ease of operator access that must be considered in finally siting a monitor.

6.2 Case #1 - Lead Acid Battery Plant

<u>Source Characteristics</u>

There are approximately 90 lead acid battery plants in the U.S. with emissions ranging from 0.25 to 3.5 tpy.[3] In this type of facility, lead particulate matter is generated by grid casting, lead paste mixing, battery assembly, and lead reclamation processes. Emissions are typically captured by ventilation systems and controlled using baghouses or impingement scrubbers.

Case 1 represents a large, lead acid battery plant. Total emissions are 3.4 tpy. Because total emissions are between 1 and 5 tpy, modeling is needed to determine the need for monitoring. If model results indicate that the source poses a threat to the standard, then monitoring should be established.

All emissions are from three stacks located on one building. Stack heights are low (11, 11, and 13 meters) and are not elevated significantly above the building height. Stack temperatures are near ambient for stacks #1 and #2, suggesting that these sources emit ambient air ventilated from the building. The largest emission rate is from stack #1. Stack #3 has an elevated stack temperature and a relatively low emission rate. There are no lead emissions from nearby sources.

<u>Topographic and Land Use Influences</u>

The Case 1 facility is located in rolling terrain in a rural to suburban area. Land use near the source is primarily agricultural; however, some land is used for residential and recreational purposes. Because of the relatively sparse population density near the source, no special consideration of siting an exposure oriented monitor is warranted. The area is not heavily industrialized; therefore it is not necessary to consider combined impacts from nearby sources. There is some terrain elevated above stack height 4 kilometers from the source; however, SCREEN indicates that concentrations fall off rapidly enough with distance from the source that no special modeling is needed to account for complex terrain effects. ISC truncates elevated terrain to the level of stack height.

Meteorological Data

One year of hourly meteorological data was obtained from a nearby airport. The data are considered to be representative of conditions near the source since there is no record of a significant spatial gradient in meteorological conditions in the area and there are no terrain features that are likely to create such a gradient. The data are also considered to be representative of the air quality climate for the area.

The annual wind rose indicates bi-directional predominant winds (Figure 4). This bi-directionality persists for three quarters of the year. Southerly winds clearly dominate during the second quarter of the year; however, during the remaining quarters, northerly winds make up a substantial proportion. Figure 6 provides the four quarterly wind roses. The model predictions reproduce the wind rose. Highest impacts are predicted for receptors both North and South of the source.

Figure 4. Annual Wind Rose - Case 1

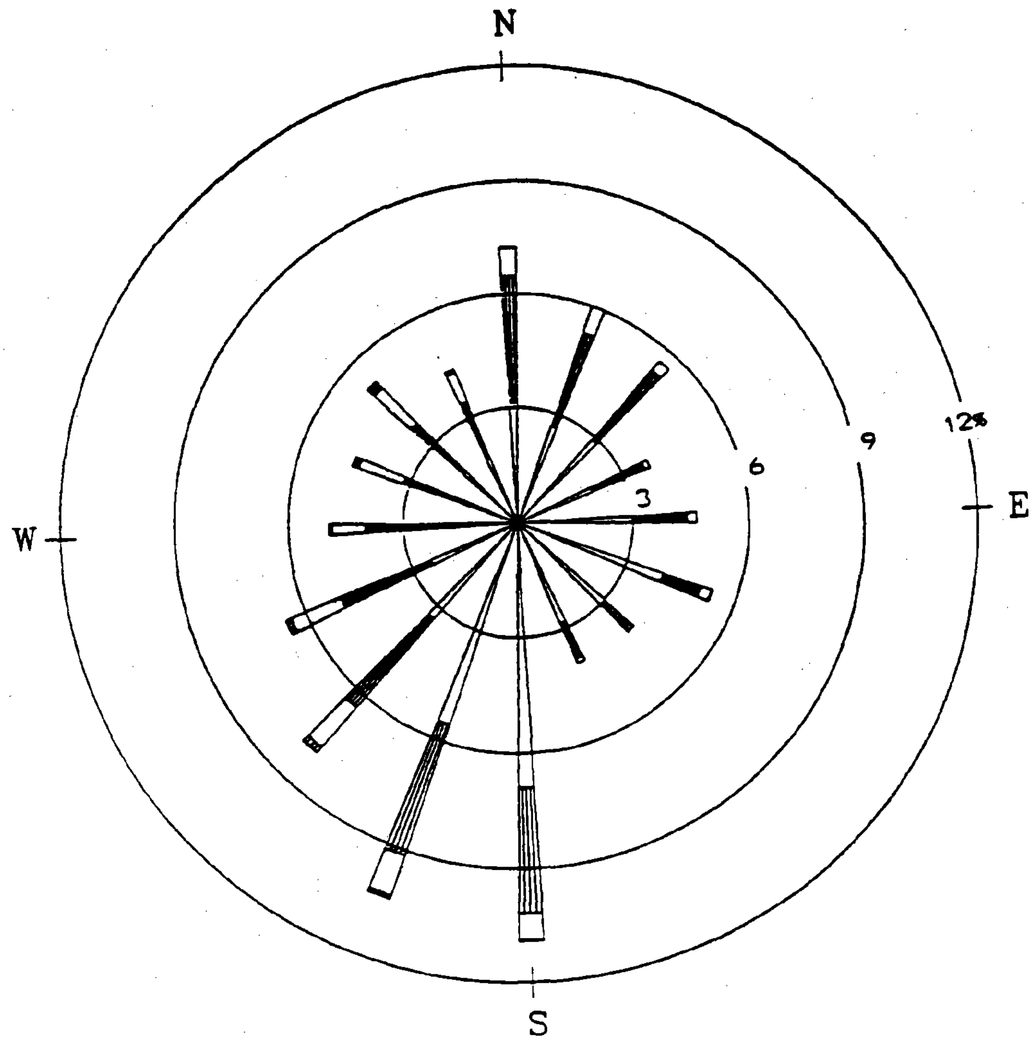
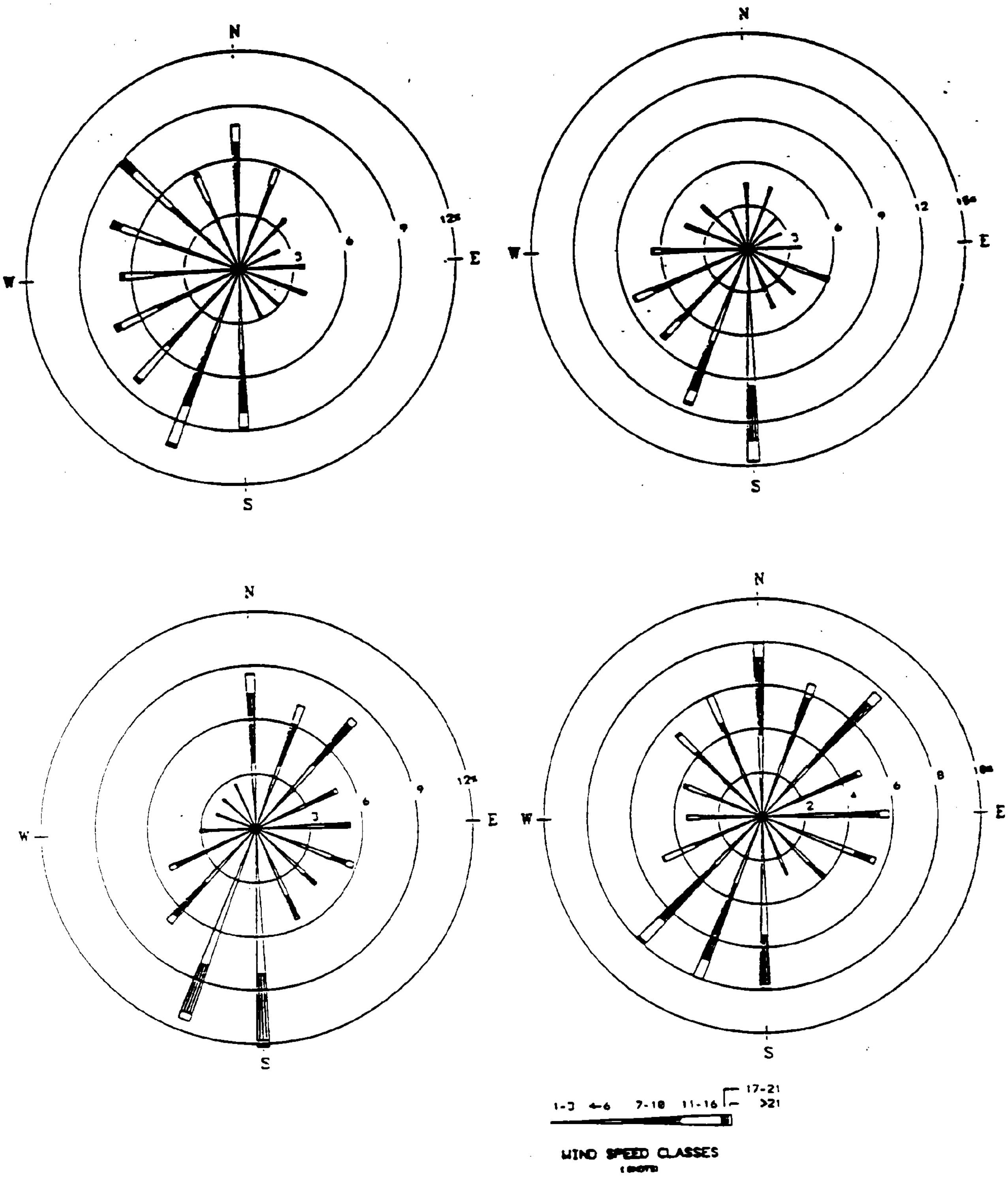


Figure 5. Four Quarterly Wind Roses - Case 1



Ambient Monitoring Data

No ambient monitoring data are available for the area impacted directly by this facility. Roadway lead monitors at the nearest urban area suggest that background concentrations are lower than the 0.1 $\mu g/m^3$ default background.

Air Quality Modeling

Screening analysis shows that stack #1 is the most significant contributor to ambient impacts. In addition, ambient impacts predicted by SCREEN indicate that the concentration gradient begins to level off at a distance of 900 meters from the source. At this distance, predicted impacts are one fifth of the highest impacts near the source and should be well below the NAAQS. Concentrations were one tenth of their highest values at a distance of 4000 meters. A sample of SCREEN output for source #1 is provided as Figure 6.

The receptor grid for refined modeling was spaced at 100 meter intervals beyond the fenceline out to 500 meters and at 500 meter intervals out to 4000 meters. Elevations exceeding stack height are located more than a kilometer from the plant. Since concentrations at this distance are quite low, complex terrain was not treated in the analysis. Particulate settling was not modeled for Case 1 since no size distribution data were available. Note however, that had settling been included, the maximum impacts might have been nearer to the plant.

The highest predicted impact was 0.73 $\mu g/m^3$ excluding background and occurs south of the facility at coordinates [-200, -200]. When very modest background concentrations are added, NAAQS exceedances are predicted. Figure 8 shows ISC-ST model results for Case 1. In this Figure, a high non-exceedance is defined as a maximum monthly concentration between 0.50 and 0.75 $\mu g/m^3$ or a concentration greater than 0.25 $\mu g/m^3$ persisting for more than 6 months of the year. The three stacks are located very near to one another at the center of the Figure (coordinates [0,0]). A low concentration is defined as a maximum month below 0.5 $\mu g/m^3$ and monthly averages below 0.25 $\mu g/m^3$ for more than half the year. If a background concentration as low as 0.05 μg/m^3 is added, a receptor located north of the facility at coordinates [100, 300], in addition to the maximum receptor, will exceed the standard.

Given a maximum acceptable predicted impact (including background) at 90 percent of the standard, 4 of the 7 high, non-exceedances illustrated in Figure 6 might be considered to pose a threat to the standard. The majority of these are located south of the plant. It is interesting to note that, while the predominant wind direction is from the south, the highest concentrations are downwind from the plant in the secondary, northerly wind direction. This is because the southern fenceline is nearer to the stacks than the northern fenceline and concentrations are decreasing rapidly in this region.

Monitoring Locations

Monitoring will be needed for this facility since predicted impacts, including background, clearly pose a threat to the standard. The monitors should be placed at the locations representative of areas where maximum impacts are expected. Based on the modeling analysis, these are on the fenceline in the primary and secondary predominant wind directions. Monitors should be placed at or near coordinates [-200, -200], and [100, 300].

2600.	6.903	6	1.0	1.1	5000.0	24.0	80.9	25.3	NO
2700.	6.665	6	1.0	1.1	5000.0	24.0	83.7	25.8	NO
2800.	6.439	6	1.0	1.1	5000.0	24.0	86.5	26.3	NO
2900.	6.224	6	1.0	1.1	5000.0	24.0	89.2	26.8	NO
3000.	6.019	6	1.0	1.1	5000.0	24.0	92.0	27.3	NO
3500.	5.156	6	1.0	1.1	5000.0	24.0	105.7	29.3	NO
4000.	4.483	6	1.0	1.1	5000.0	24.0	119.2	31.1	NO
4500.	3.947	6	1.0	1.1	5000.0	24.0	132.6	32.8	NO
5000.	3.513	6	1.0	1.1	5000.0	24.0	145.7	34.4	NO
5500.	3.155	6	1.0	1.1	5000.0	24.0	158.7	36.0	NO
6000.	2.856	6	1.0	1.1	5000.0	24.0	171.6	37.4	NO
6500.	2.602	6	1.0	1.1	5000.0	24.0	184.4	38.8	NO
7000.	2.385	6	1.0	1.1	5000.0	24.0	197.0	40.2	NO
7500.	2.203	6	1.0	1.1	5000.0	24.0	209.6	41.4	NO
8000.	2.044	6	1.0	1.1	5000.0	24.0	222.0	42.5	NO
8500.	1.904	6	1.0	1.1	5000.0	24.0	234.4	43.5	NO
9000.	1.781	6	1.0	1.1	5000.0	24.0	246.6	44.6	NO
9500.	1.671	6	1.0	1.1	5000.0	24.0	258.8	45.6	NO
10000.	1.572	6	1.0	1.1	5000.0	24.0	270.9	46.6	NO
15000.	.9661	6	1.0	1.1	5000.0	24.0	388.4	55.0	NO
20000.	.6943	6	1.0	1.1	5000.0	24.0	501.0	60.4	NO
25000.	.5365	6	1.0	1.1	5000.0	24.0	609.8	65.0	NO
30000.	.4343	6	1.0	1.1	5000.0	24.0	715.6	68.9	NO
40000.	.3151	6	1.0	1.1	5000.0	24.0	920.2	74.6	NO
50000.	.2457	6	1.0	1.1	5000.0	24.0	1117.4	79.3	NO

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND 1. M:

100.	53.39	6	4.0	4.2	5000.0	12.1	4.1	7.0	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

```
*** CAVITY CALCULATION - 1 ***          *** CAVITY CALCULATION - 2 ***
 CONC (UG/M**3)      =   .0000           CONC (UG/M**3)      =   .0000
 CRIT WS @10M (M/S)  =   99.99           CRIT WS @10M (M/S)  =   99.99
 CRIT WS @ HS (M/S)  =   99.99           CRIT WS @ HS (M/S)  =   99.99
 DILUTION WS (M/S)   =   99.99           DILUTION WS (M/S)   =   99.99
 CAVITY HT (M)       =   10.32           CAVITY HT (M)       =   10.06
 CAVITY LENGTH (M)   =   36.02           CAVITY LENGTH (M)   =   30.00
 ALONGWIND DIM (M)   =   30.00           ALONGWIND DIM (M)   =   42.40
```

CAVITY CONC NOT CALCULATED FOR CRIT WS > 20.0 M/S. CONC SET = 0.0

****
*** SUMMARY OF SCREEN MODEL RESULTS ***
****

CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)
SIMPLE TERRAIN	53.39	100.	0.

****
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
****

10-17-91
11:53:43

*** SCREEN-1.1 MODEL RUN ***
*** VERSION DATED 8[illegible]300 ***

CASE STUDY #1; STACK #1 ✓

SIMPLE TERRAIN INPUTS:

```
   SOURCE TYPE                =   POINT
   EMISSION RATE (G/S)        =   .7570E-01
   STACK HEIGHT (M)           =   11.00
   STK INSIDE DIAM (M)        =   .82
   STK EXIT VELOCITY (M/S)    =   13.00
   STK GAS EXIT TEMP (K)      =   294.00
   AMBIENT AIR TEMP (K)       =   293.00
   RECEPTOR HEIGHT (M)        =   .00
   IOPT (1=URB,2=RUR)         =   2
   BUILDING HEIGHT (M)        =   10.00
   MIN HORIZ BLDG DIM (M)     =   30.00
   MAX HORIZ BLDG DIM (M)     =   42.40
```

max 1-hour concentrations
max annual < 1%
max 24-hour ~4%
max monthly ~ 2%

BUOY. FLUX = .07 M**4/S**3; MOM. FLUX = 28.31 M**4/S**2.

*** FULL METEOROLOGY ***

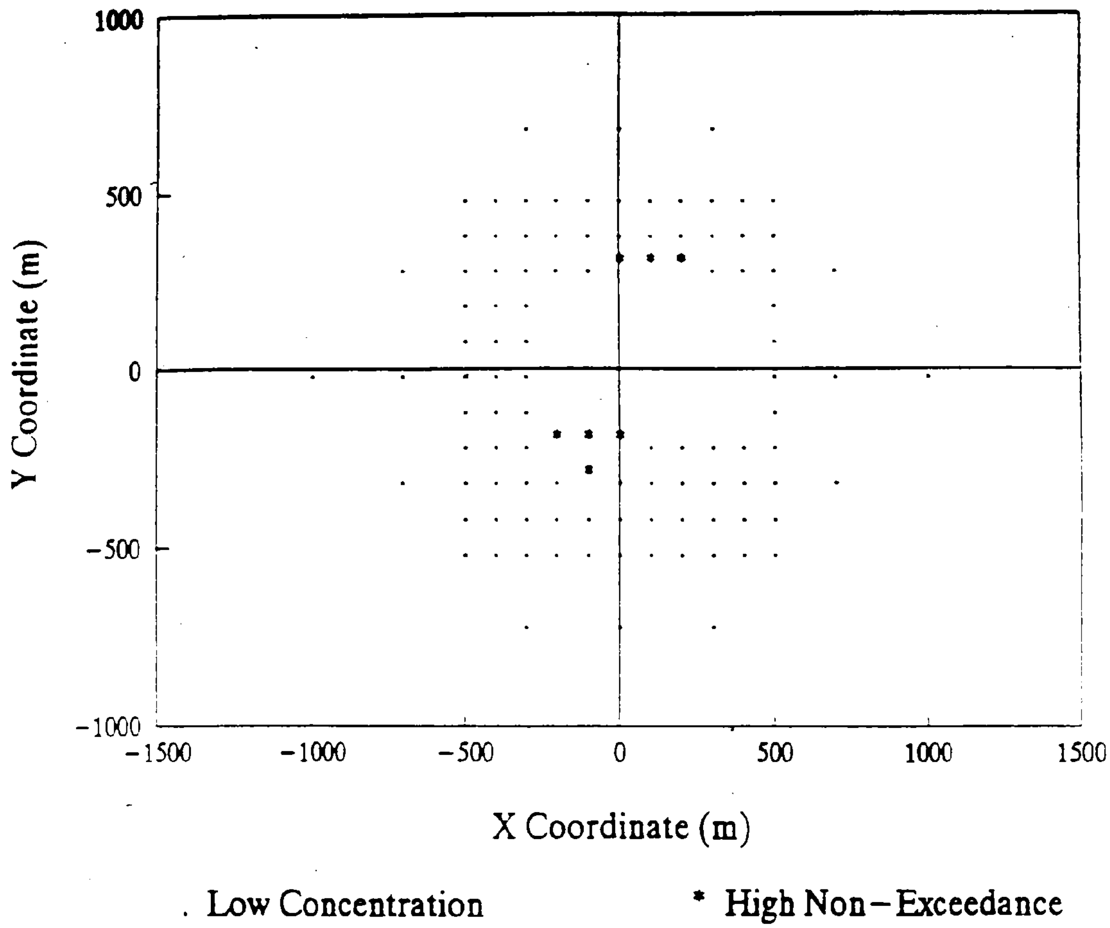
****
*** SCREEN AUTOMATED DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
1.	.0000	0	.0	.0	.0	.0	.0	.0	NA
100.	53.39	6	4.0	4.2	5000.0	12.1	4.1	7.0	SS
200.	33.35	6	4.0	4.2	5000.0	12.1	7.7	9.1	SS
300.	24.71	6	4.0	4.2	5000.0	12.1	11.2	10.4	SS
400.	20.37	6	3.0	3.2	5000.0	14.0	14.6	10.9	SS
500.	17.37	6	3.0	3.2	5000.0	14.0	18.0	11.3	SS
600.	15.24	6	3.0	3.2	5000.0	14.0	21.2	12.3	SS
700.	13.43	6	3.0	3.2	5000.0	14.0	24.5	13.3	SS
800.	11.92	6	3.0	3.2	5000.0	14.0	27.6	14.0	SS
900.	10.73	5	1.0	1.0	5000.0	26.3	46.5	20.4	NO
1000.	10.66	6	1.0	1.1	5000.0	24.0	34.1	14.8	NO
1100.	10.81	6	1.0	1.1	5000.0	24.0	37.2	15.3	NO
1200.	10.79	6	1.0	1.1	5000.0	24.0	40.2	16.1	NO
1300.	10.66	6	1.0	1.1	5000.0	24.0	43.2	16.9	NO
1400.	10.45	6	1.0	1.1	5000.0	24.0	46.2	17.7	NO
1500.	10.18	6	1.0	1.1	5000.0	24.0	49.2	18.5	NO
1600.	9.890	6	1.0	1.1	5000.0	24.0	52.1	19.3	NO
1700.	9.576	6	1.0	1.1	5000.0	24.0	55.1	19.9	NO
1800.	9.255	6	1.0	1.1	5000.0	24.0	58.0	20.6	NO
1900.	8.933	6	1.0	1.1	5000.0	24.0	60.9	21.3	NO
2000.	8.612	6	1.0	1.1	5000.0	24.0	63.8	22.0	NO
2100.	8.293	6	1.0	1.1	5000.0	24.0	66.7	22.6	NO
2200.	7.987	6	1.0	1.1	5000.0	24.0	69.5	23.1	NO
2300.	7.696	6	1.0	1.1	5000.0	24.0	72.4	23.7	NO
2400.	7.418	6	1.0	1.1	5000.0	24.0	75.2	24.2	NO
2500.	7.154	6	1.0	1.1	5000.0	24.0	78.0	24.7	NO

Figure 6. SCREEN Model Run - Case 1

Figure 7. Model Results - Case 1



6.3 Case #2 - Secondary Lead Smelter

Source Characteristics

There are approximately 23 secondary lead smelters in the U.S. Total emissions (stack and fugitive) per plant range from 3 to 60 tpy. Secondary lead smelters process lead bearing scrap and residue to produce lead ingots, battery lead oxide, and lead pigments. Processing typically involves scrap pretreatment, smelting, refining, and casting. Reverberatory and blast furnaces account for the majority of lead emissions from secondary smelters; however, fugitive emissions from loading and holding areas, or reentrainment can contribute significantly to ambient impacts.

The Case 2 smelter is a small smelter with total emissions of 3.9 tpy. Fugitive lead from area and volume sources accounts for 20 percent of total emissions; however, fugitive emission sources are the largest contributors to ground level ambient impacts. The source configuration for the Case 2 facility is shown in Figure 8. There are 3 stacks located on the west side of the controlling building. Sources numbered 4 through 6 are treated as volume sources and are related to various processing and handling areas. Sources numbered 7 and 8 are area sources such as storage piles, or resuspension areas surrounding the site.

Topographic and Land Use Influences

The terrain surrounding the Case 2 facility is flat. Land use is primarily agricultural. In addition to the smelter, there is some other heavy industry in the area; however, lead emissions from these other sources are not significant, and they are located outside of the maximum impact area for emissions from the Case 2 smelter. Thus, combined emissions do not present any added impact. Background emissions are expected to be within the assumed 0.1 $\mu g/m^3$.

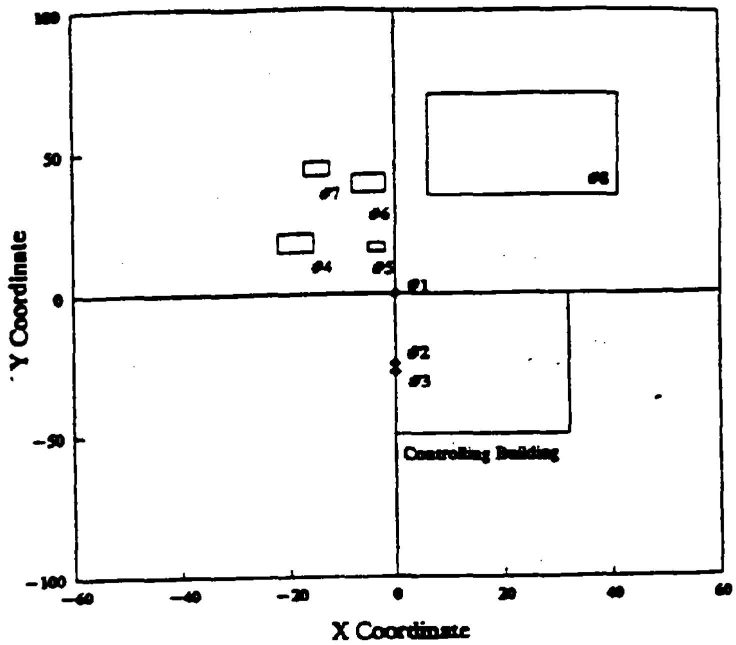


Figure 8. Source Configuration - Case 2

Meteorological Data

One year's meteorological data was obtained from the nearest airport. These data may be considered to be spatially representative and consistent with the prevailing air quality climate. The annual wind rose is uni-directional with predominant winds from the south (Figure 9).

Ambient Monitoring Data

There are no existing measurement data available for the Case 2 impact area.

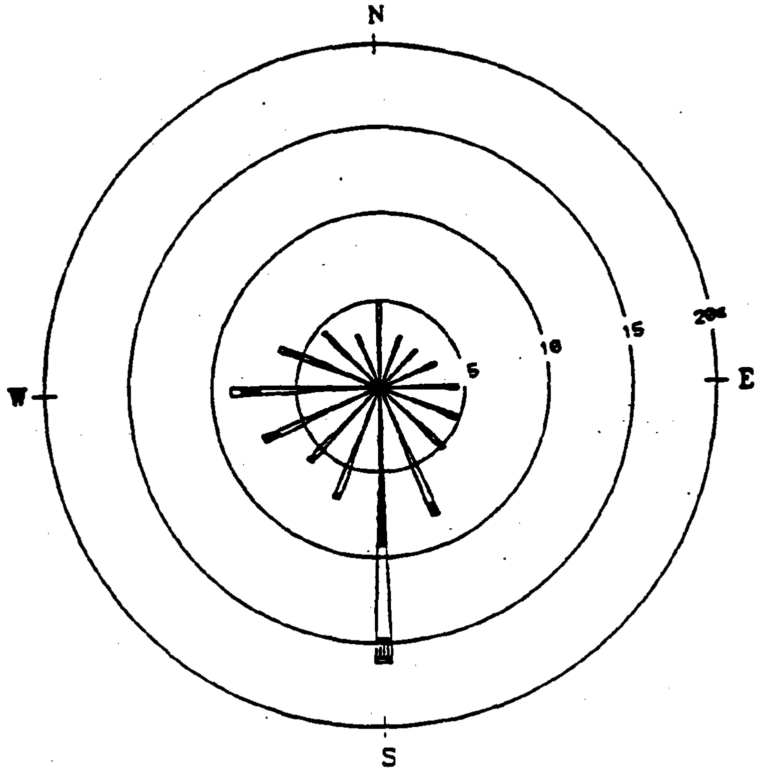


Figure 9. Annual Wind Rose - Case 2

Air Quality Modeling

Screening analyses show that area source #8 is clearly the largest contributor to ambient impacts and is responsible for perhaps 50 percent of the total. While accounting for only 20 percent of emissions, area and volume sources account for 90 percent of ambient impacts. This is because the greatest impacts are close to the source where fugitive emissions are most important. Except under fumigation conditions, the ground level impact from elevated stack emissions will be diffuse, and distant from the source. With increasing distance from the source, fugitive emissions become relatively less important compared to stack emissions.

The rate of decline of ambient impacts begins to level off within 500 meters from the source. Thus, the receptor grid for refined modeling was designed to be most dense (100 meter intervals) within 500 meters from the source and less dense (250 meter intervals) beyond 500 meters from the source. Between 2000 and 4000 meters from the source, receptors were added at 1000 meter intervals to account for any potential long range impacts.

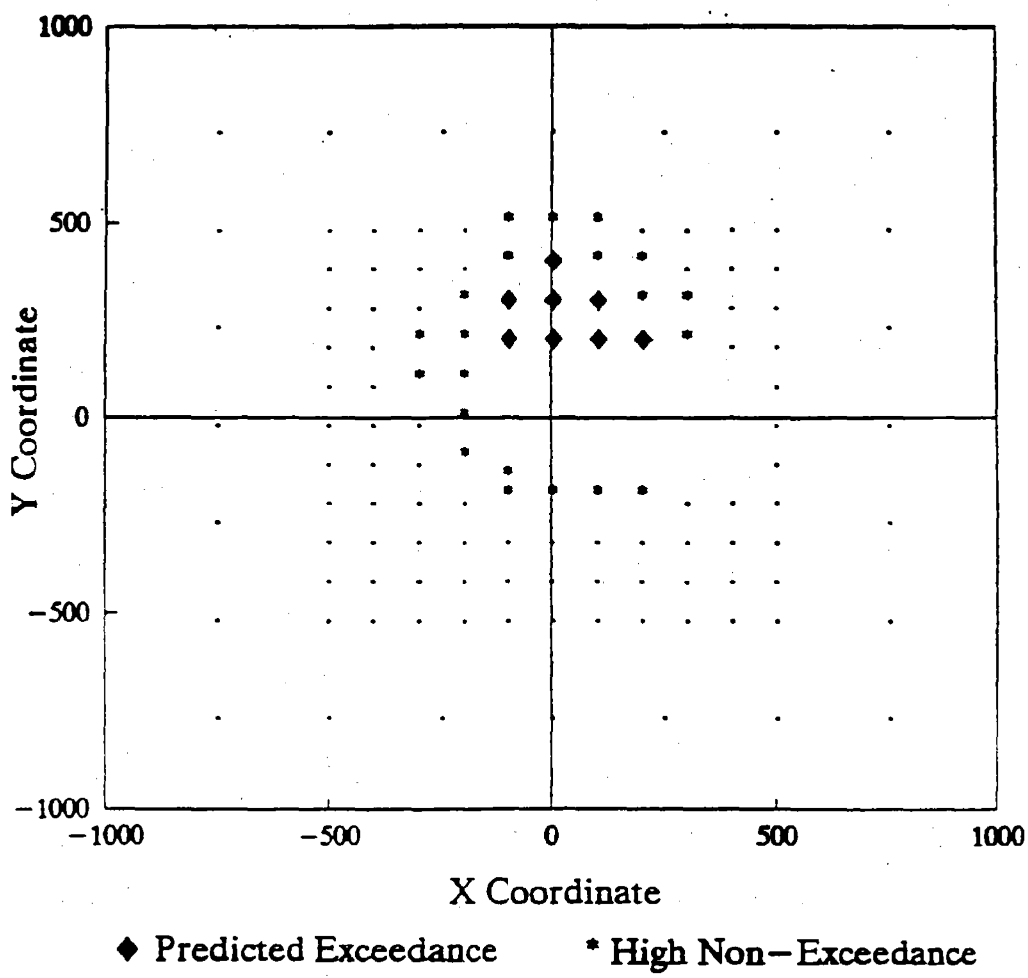
Figure 10 shows the results of refined modeling for Case 2. Exceedances are defined as predicted monthly maximum concentrations greater than 0.75 $\mu g/m^3$ (excluding background). High nonexceedances are defined as monthly maximum concentrations exceeding 0.5 $\mu g/m^3$ or monthly averages exceeding 0.25 $\mu g/m^3$ for more than 6 months of the year. Otherwise, the point is plotted as a low concentration receptor. The highest predicted impact was 2.3 $\mu g/m^3$ which occurred during July at the fenceline receptor with coordinates [0, 200]. Concentrations at this receptor exceed the standard for all 12 months of the year. Other receptors where exceedances are predicted are clustered around this receptor. These model predictions are consistent with a predominant southerly wind direction and major impacts from ground level, fugitive sources. Highest impacts are close to the source in the predominant downwind direction.

Figure 10 shows some high nonexceedances on the southern and western fencelines. The highest predicted impact is 0.72 $\mu g/m^3$ at the receptor with coordinates [-200, 100]. If a background value of 0.1 $\mu g/m^3$ is added to this concentration, an exceedance would be predicted. Thus, concentrations at receptors on the southern fenceline may also pose a threat to the standard. Concentrations predicted for receptors on the western fenceline were slightly below the 90 percent threshold (0.68 $\mu g/m^3$ including background) required to pose a threat to the standard.

Monitoring Locations

Total emissions for the Case 2 facility are between 1 and 5 tpy; however, modeling clearly shows that the source may pose a threat to the standard. Thus, monitoring should be established at a minimum of two locations. The primary monitoring location should represent the area of maximum impact. This is on the northern fenceline near the point with coordinates [0, 200].

Figure 10. Model Results - Case 2



Two options present themselves for locating the second monitor. The first option is to back up the first monitor by locating either beyond the fenceline in the same direction, or elsewhere on the northern fenceline. The northerly receptor where the second highest impacts were predicted is located at [100, 200]. This option provides additional confidence that maximum impacts will be recorded throughout the year.

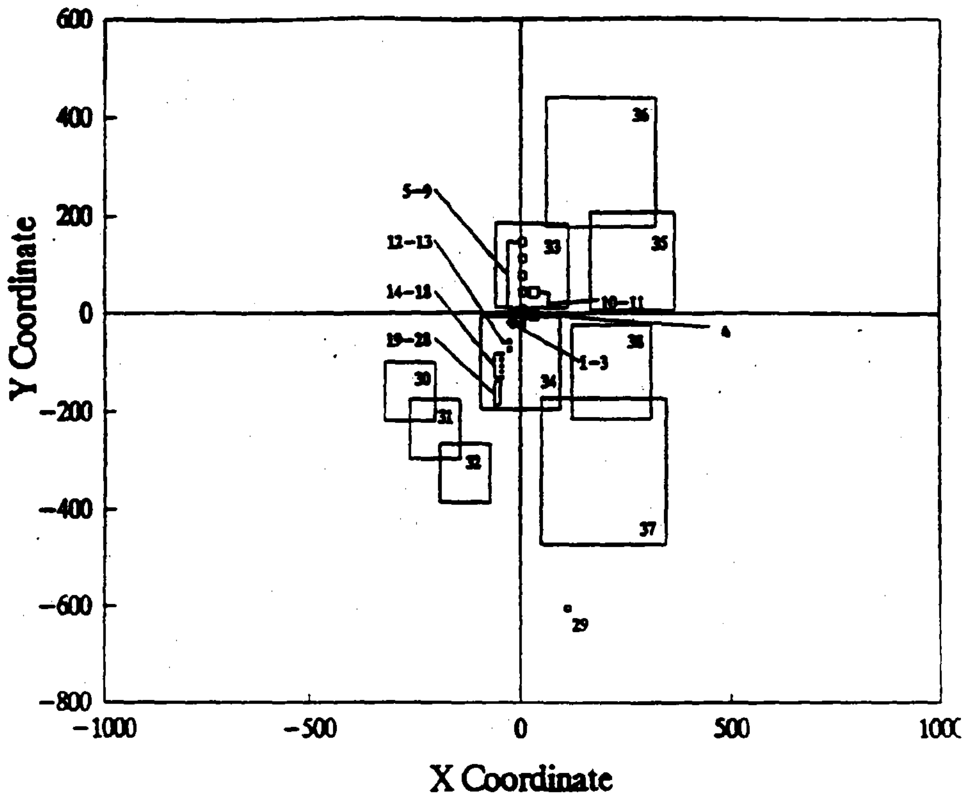
The second option is to locate the second monitor on the southern fenceline where concentrations, while significantly lower than on the northern fenceline, were high enough to pose a threat to the standard. This second option provides greater spatial coverage. The decision where to locate the second monitor may ultimately depend on additional considerations, such as proximity and direction of populated areas.

6.4 Case #3 - Primary Lead Smelter

Source Characteristics

Four primary lead smelters operating in the U.S. in 1989 had lead emissions ranging from 21 to 291 tpy.[3] Primary smelters take mined lead ore containing 3 to 8 percent elemental lead and produce a refined concentrate containing 55 to 70 percent lead (ref AP-42). Processing involves sintering, reduction, and refining. Lead is emitted from the sintering machines and furnaces used in the reduction and refining processes. Fugitive lead is emitted from ore handling, crushing and storage, and resuspension.

Case 3 addresses locating monitors for a hypothetical primary lead smelter emitting 160 tpy. Similar considerations might be applied to a large secondary smelter. Figure 11 shows the source configuration for Case 3. Case 3 is a large and complex facility with very high ambient impacts. There are 4 point sources comprising 62.3 percent of emissions (100.1 tpy); 24 volume sources comprising 19.9 percent of emissions (32 tpy); and 10 area sources comprising 17.8 percent of emissions (28.6 tpy).



Point Sources

1. Sinter Machine (Main Stack)
2. Sinter Crushing
3. Sinter Preparation
4. Blast Furnace/Dross Kettles

Volume Sources

5-9. Concentrate Storage/Handling
10-11. Sinter Building
12-13. Blast Furnace Area
14-18. Drossing Area
19-28. Refinery Area

Area Sources

29. Concentrate Truck Unloading
30-32. Granulated Storage Pile
33-38. Resuspension

Figure 11. Source Configuration - Case 3

Topographic and Land Use Influences

The Case 3 facility is located in flat terrain. Land use is rural, largely undeveloped, and consists primarily of lead mining operations. There are no specific topographic or land use influences that would effect the dispersion of lead emissions from the source and demand special treatment in the modeling analysis.

Meteorological Data

The same meteorological data were applied to Cases 1 and 3. Once again, it is assumed that there is adequate justification for concluding that data collected from a nearby airport are representative of the meteorology near the source both spatially and temporally. The annual wind rose is bi-directional with predominant southerlies and a significant proportion of northerlies except in the second quarter of the year (see Figures 5 and 6).

Ambient Monitoring Data

Due to the large emissions from the Case 3 facility, a monitor was placed in the predominant downwind direction, north of the facility, just over a year before the study was conducted. Thus, one complete year's monitoring data were available for examination. Daily measurements were obtained. The measurements show that ambient concentrations near the plant consistently exceed the standard by a very large margin.

Figure 12 is a boxplot comparison of the daily measurements data for each month of the year. The dotted line is plotted at the level of the standard (0.75 $\mu g/m^3$). The boxplots show the range and variability of the data using statistics that are not sensitive to the distribution of the data. This is important since monitoring data are unlikely to be normally distributed. The center of each box represents the median. The upper and lower boundaries of each box represent the 75th and 25th percentiles respectively. The upper and lower extensions (whiskers) represent the 90th and 10th percentiles. Values exceeding 1.5 times the interquartile range (VERIFY) are plotted as outliers. Monthly median concentrations exceed the standard during all but three months of the year

(February, September, and October). Monthly mean concentrations exceed the standard during all months of the year.

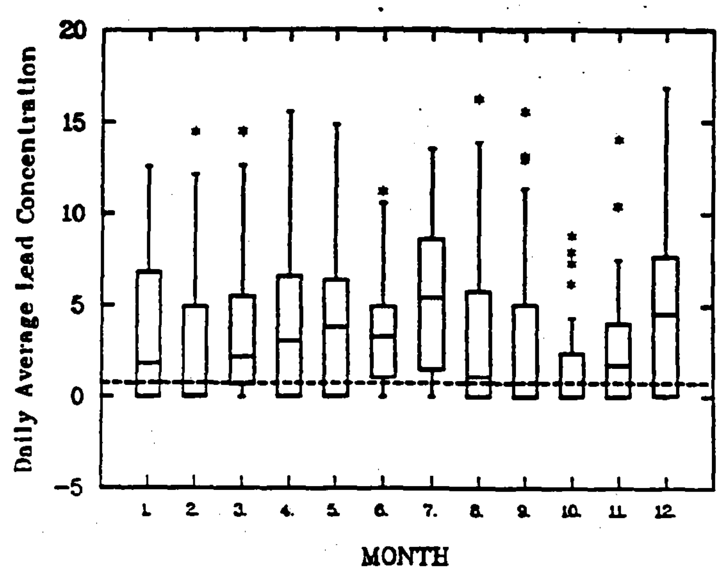


Figure 12. Monitoring Data - Case 3

Air Quality Modeling

The relative contributions of stack, volume, and area sources to ambient impacts depends on the prevailing meteorological conditions. Tall stacks contribute maximally to ambient impacts under conditions of low wind speed and strong instability (strong insolation). Volume sources and short stacks contribute maximally under conditions of low wind speed and moderately unstable to stable conditions. Contributions from ground level area sources may be somewhat independent of wind speed and are maximized under stable overcast, or night-time conditions. Resuspension area sources are maximized with high wind speed and stable conditions.

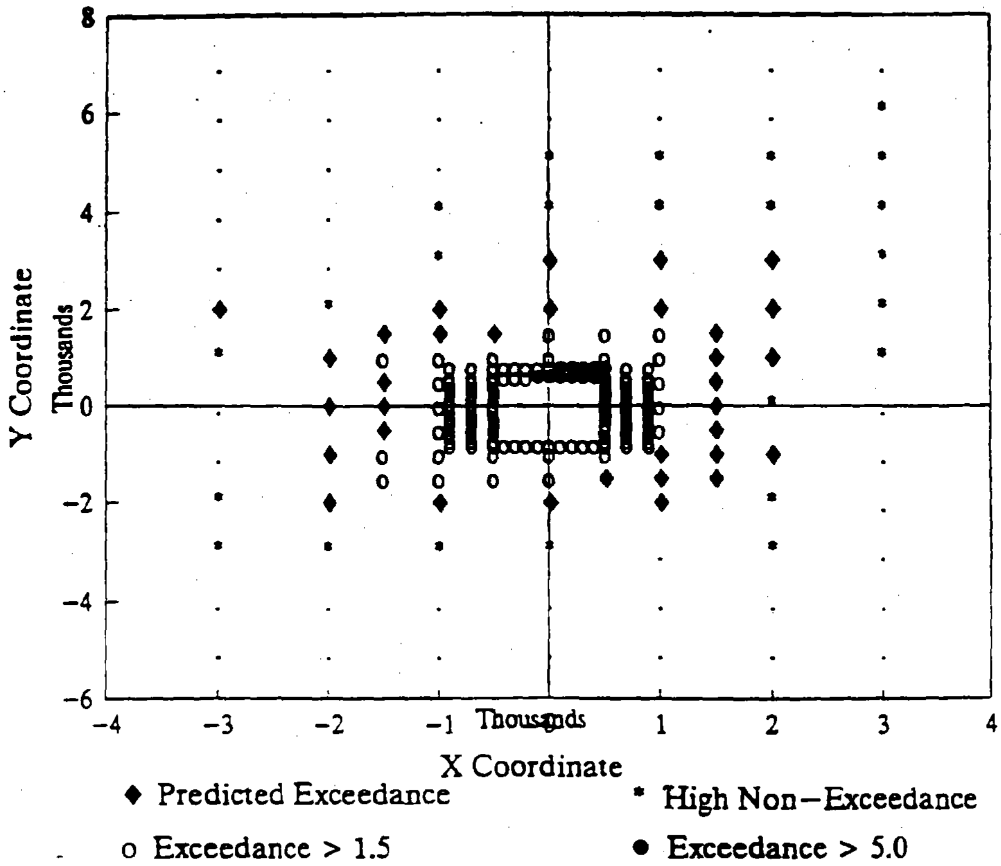
For Case 3, ISC was used under screening conditions to provide the 50 highest hourly concentrations for the total facility, and for stack, volume, and area sources. Each predicted value is associated with one of 33 meteorological categories depending on stability class and wind speed (see Table 4). Analysis of this output shows that area and volume sources are the most important contributors to ambient impacts under all conditions.

Although stacks comprise over 60 percent of total emissions, they contribute less than 10 percent of the total ambient impact under the most favorable conditions (unstable and low wind speed). Except with high wind speeds, area and volume sources contribute equally to ambient impacts. Resuspension sources dominate with high wind speeds.

Figure 13 summarizes the ISC-ST model results for Case 3. Because of the large number and wide distribution of exceedances, concentrations greater than 1.5 and 5.0 $\mu g/m^3$ are plotted separately. The highest concentrations are along the eastern side of the northern fenceline. Maximum monthly average concentrations in this area are predicted to be in the range from 6 to 9 $\mu g/m^3$, or one order of magnitude above the standard. The receptor where the highest concentrations are predicted is located at coordinates [200, 600].

The second most heavily impacted area is along the southern portion of the eastern fenceline. Predicted maximum concentrations in this area are 4 to 5 $\mu g/m^3$. The highest concentration in this area is predicted at coordinates [-500, -400].

Figure 13. Model Results - Case 3



Exceedances are predicted in every direction as far as 1000 meters from the source. Some exceedance may occur as far as 3000 meters from the source. Maximum concentrations along a square at 1000 meters from the center of the facility range from 1.4 to 3.8 μg/m^3. The highest concentrations at this range are northeast of the source [500, 1000], with the second highest concentrations occurring to the southeast [-500, -1000]. This is approximately in line with the highest and second highest concentrations occurring at the fenceline, suggesting that the more distant impacts are attributable to the same sources within the facility.

Concentrations on a square perimeter at 2000 meters from the source range from 0.5 to 1.4 μg/m^3. The highest concentrations are predicted north and northeast of the facility. Concentrations high enough to pose a threat to the standard are also predicted at southeastern receptors. The maximum impact receptor is located at coordinates [0,2000].

Monitoring Locations

Due to the extremely high concentrations and the large number of receptors where exceedances are predicted for this facility, more than the minimum of two monitors should be sited. In order to ensure sufficient spatial coverage, it is recommended that 3 to 5 monitors be sited around this facility.

The first two monitors would be located in the areas of maximum and second highest concentration on the fenceline. These locations are predicted to occur at coordinates [200, 600] and [-500, -400], respectively. The existing monitor is currently located near coordinates [300, 800] and is not far from the coordinates where maximum impacts were predicted. This monitor should be relocated to the maximum impact location.

The third and possibly the fourth monitor should be located at a distance of 1000 meters from the source near where the maximum and second highest concentrations are predicted. The fifth monitor should be located at a distance of 2000 meters from the facility at the coordinates where the maximum impact is predicted for this distance.

This monitoring strategy is designed to measure maximum concentrations and to account for different degrees of reduced impact with distance from the plant as emissions from different sources come under control. For example, if stack emissions are reduced, then impacts further from the plant should be affected. If area source emissions are controlled, then impacts nearer the plant should be reduced. The strategy also provides data that can be used to determine human and environmental exposure with increasing distance.

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16. ABSTRACT

This document provides technical guidance to air montoring agencies on how to determine the network design for measuring lead air pollution concentrations emitted from stationary lead sources.

17. KEY WORDS AND DOCUMENT ANALYSIS

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