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Air

ENHANCED OZONE MONITORING NETWORK DESIGN AND SITING CRITERIA GUIDANCE DOCUMENT

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ENHANCED OZONE MONITORING NETWORK DESIGN AND SITING CRITERIA GUIDELINE DOCUMENT

FINAL REPORT

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Mr. Neil Berg

Office of Air Quality Planning and Standards

Technical Support Division

Monitoring and Reports Branch

U.S. Environmental Protection Agency

Research Triangle Park, North Carolina 27711

PREPARED BY:

Radian Corporation

P.O. Box 13000

Research Triangle Park, North Carolina 27709

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LIST OF ABBREVIATIONS AND ACRONYMS

CAAA	-	Clean Air Act Amendments
CBD	-	Central Business District
EKMA	-	Empirical Kinetic Modeling Approach
CMSA	-	Consolidated Metropolitan Statistical Area
MSA	-	Metropolitan Statistical Area
NAAQS	-	National Ambient Air Quality Standards
NAMS	-	National Air Monitoring Stations
NMOC	-	Non-methane Organic Compounds
NO_x	-	Oxides of nitrogen
PAMS	-	Photochemical Assessment Monitoring Stations
ROM	-	Regional Oxidant Model
SIP	-	State Implementation Plan
SLAMS	-	State and Local Air Monitoring Stations
UAM	-	Urban Airshed Model
VOC	-	Volatile Organic Compounds
RFP	-	Reasonable Further Progress

1.0 INTRODUCTION

1.1 REGULATORY BACKGROUND AND PURPOSE

Under Title I, Section 182, of the Clean Air Act Amendments of 1990 (CAAA), the Environmental Protection Agency (EPA) is proposing a rule to revise the current ambient air quality surveillance regulations (40 CFR Part 58). The driving forces behind the proposal are the lack to date of successful attainment of the ozone air quality standard and the desire to obtain an improved air quality database for ozone and ozone precursors. Included in the proposal are provisions for (1) enhanced ambient air monitoring of ozone and oxides of nitrogen (NO_x); (2) monitoring of volatile organic compounds (VOC) (including aldehydes); and (3) measurement of meteorological parameters.

The proposed rule would require implementing a national network of enhanced ambient air monitoring stations. States with metropolitan statistical areas (MSA's) or consolidated metropolitan statistical areas (CMSA's) classified as serious, severe, or extreme for ozone nonattainment would be required to establish photochemical assessment monitoring stations (PAMS) as part of their State Implementation Plan (SIP).

The general objectives of the PAMS are outlined below.

- NAAQS Attainment and Control Strategy Development
  - -- Provide an air quality database to help air pollution control agencies assess ozone attainment status;
  - -- Extend the air quality database for future attainment demonstrations;
  - -- Characterize ozone and precursor transport; and

-- Support photochemical model input requirements and model performance for future attainment demonstrations and control strategy development.

- SIP Control Strategy Evaluation
  - -- Evaluate effectiveness of various control strategies; and
  - -- Assist in developing cost-effective VOC and NO_x reductions and control strategies.

- Emissions Tracking
  - -- Assist in tracking VOC and NO_x emission inventory reductions;
  - -- Provide additional information to demonstrate Reasonable Further Progress (RFP) toward the attainment of the National Ambient Air Quality Standard (NAAQS) for ozone; and
  - -- Corroborate and assess accuracy of VOC and NO_x emission inventories.

- Trends
  - -- Prepare long-term ozone, VOC, NO_x, and toxic air pollutant trends; and
  - -- Improve effectiveness of the trends database.

- Exposure Assessment
  - -- Characterize population exposure to ozone and toxic air pollutants.

The main purposes of this document are to familiarize State and local air authorities with the enhanced ozone monitoring program and to recommend network design strategies for the PAMS. EPA is also preparing a guidance document on PAMS measurement methods for ozone and ozone precursor compounds entitled

"Technical Assistance Document for Sampling and Analysis of Ozone Precursors."[1] The user is encouraged to refer to this document for information on manual and automated sampling techniques for VOC's and non-methane organic compounds (NMOC), and methodologies for measuring NO_x.

1.2 GENERAL APPROACH

Design criteria for the PAMS network are based on the selection of an array of data collection sites that satisfy the monitoring objectives in Appendix D, Section 4, of 40 CFR Part 58. These sites would allow ambient data on ozone precursor source areas and predominant wind directions associated with high ozone events to be developed and made accessible through the Aerometric Information Retrieval System (AIRS) National database. Specific monitoring objectives are associated with each site location or combination of site locations. The PAMS network design will enable characterization of precursor emission sources within an MSA/CMSA, transport of ozone and ozone precursors into and out of an MSA/CMSA, and photochemical processes that result in ozone exceedances.

Section 2.0 of this document describes the PAMS network design and includes network requirements, site types, and the site type selection procedures. Section 3.0 defines monitoring methods and network operations. Section 4.0 describes how data from the PAMS will be used. Section 5.0 contains references. Appendix A contains information on those PAMS data applications of interest for photochemical grid modeling.

2.0 NETWORK DESIGN

2.1 INTRODUCTION

New ozone monitoring sites are required by the CAAA to enhance the existing ambient air monitoring network currently composed of State and Local Air Monitoring Stations (SLAMS), the National Air Monitoring Stations (NAMS), and Special Purpose Monitors (SPM) stations. These enhanced monitoring sites, called photochemical assessment monitoring stations (PAMS), will measure ozone, VOC (including aldehydes), and NO_x concentrations, and meteorological parameters.

The proposed PAMS network array will enable EPA to acquire data needed for National Ambient Air Quality Standards (NAAQS), and aid in characterizing precursor emission sources within an area, evaluating transport of ozone and its precursors into and out from an area, and understanding photochemical processes related to ozone nonattainment. The PAMS will also assist in developing an initial urban air toxic pollutant database.

As the PAMS will become part of the SLAMS network, they will be subject to specific siting, quality assurance, analytical methodology, sampling interval, and instrument requirements. This guidance document provides a description of the PAMS sites, and the requirements for siting and configuring the sites. A companion guidance document[1] describes the requirements for ozone precursor data to be gathered and the techniques used to acquire this data.

The network design information presented in this section is organized as follows: PAMS site types are described in Section 2.2. The criteria and procedures for selecting site type locations are give in Section 2.3. Section 2.4 describes minimum

PAMS network requirements. Guidance for the transition period during which PAMS will be phased in is presented in Section 2.5 Finally, information on meteorological and air toxics monitoring is found in Sections 2.6 and 2.7, respectively.

2.2 PAMS SITE TYPES

PAMS site types and general uses of the data from each site type are described in this section (Section 4.0 describes data uses in detail). Unlike SLAMS and NAMS, which focus on specific pollutants, PAMS focus on site requirements. Specific PAMS monitoring objectives are associated with each site location or with combinations of site locations. Specific monitoring objectives and how they relate to precursor emissions, maximum ozone locations, background air quality, and pollutant transformation, require five PAMS site types:

Site Type (1)	-	Upwind background.
Site Type (2)	-	Downwind edge of maximum precursor emissions.
Site Type (3)	-	Downwind fringe of MSA/CMSA.
Site Type (4)	-	Maximum ozone concentration - primary downwind direction.
Site Type (5)	-	Maximum ozone concentration - secondary downwind direction.

To meet the PAMS monitoring objectives, site distribution within and in the proximity of MSA's/CMSA's should be based on design criteria described in this guidance document. The PAMS design criteria and site locations include considerations of ozone precursor source areas, ozone "hot-spot" areas, ozone/ozone

precursor background areas, and downwind areas prevalent during high ozone episodes.

Predominant wind direction associated with ozone exceedances must be determined in order to designate PAMS site types. Predominant wind direction should be chosen based on several considerations. Available historical data should be reviewed for the predominant winds during: (1) the sampling period, (2) ozone episodes, and (3) the daily ozone formation period. The intent is to focus on the predominant wind direction during the sampling period (June-August), when the highest ozone concentrations are expected to occur. It is recognized that wind directions will vary between the beginning and the end of a particular sampling period, and they will also vary between different parts of the country. Individual areas are encouraged to perform additional reviews of available meteorological data for shorter periods (i.e., ozone episodes and/or diurnal variations) as necessary to ensure effective siting.

PAMS are sited relative to the most predominant wind direction during the sampling period (U1) and the second most predominant wind direction (U2). (Although U1 and U2 are the first and second most predominant wind directions, other wind directions may play a role in determining which PAMS will provide data to meet regulating objectives.) The relative locations of site types and their relationship to predominant wind flow for a single urban area are illustrated in Figure 2-1. The relative locations of site types for multi-area/transport region (or an urban corridor) are shown in Figure 2-2.

Data uses from the site types (see Section 4.0) will vary, depending on the predominant wind flow patterns during the ozone episode under review. Meteorological parameters and monitoring data must be evaluated together in order to address the

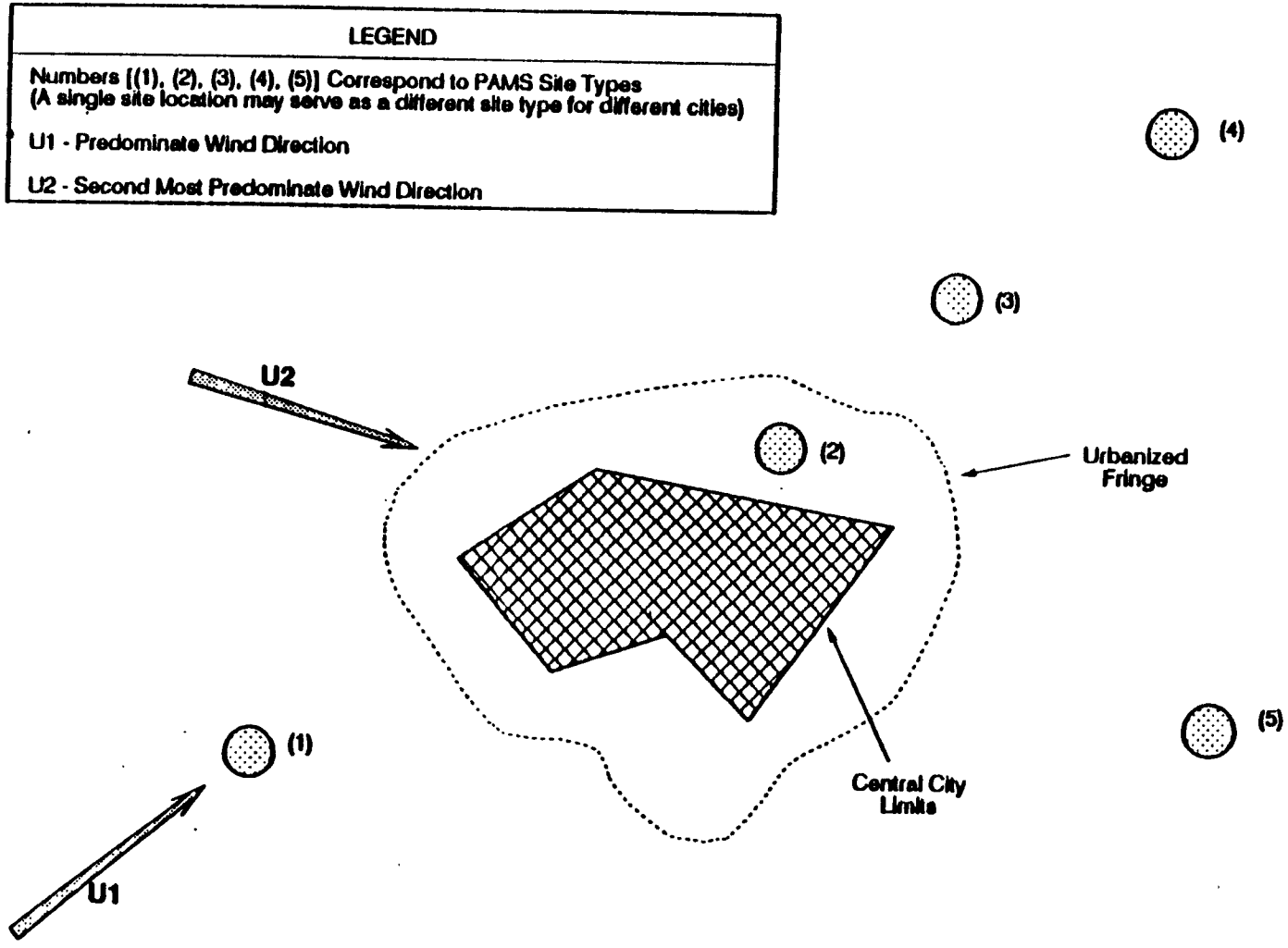


Figure 2-1. PAMS Network Design for an Isolated Area

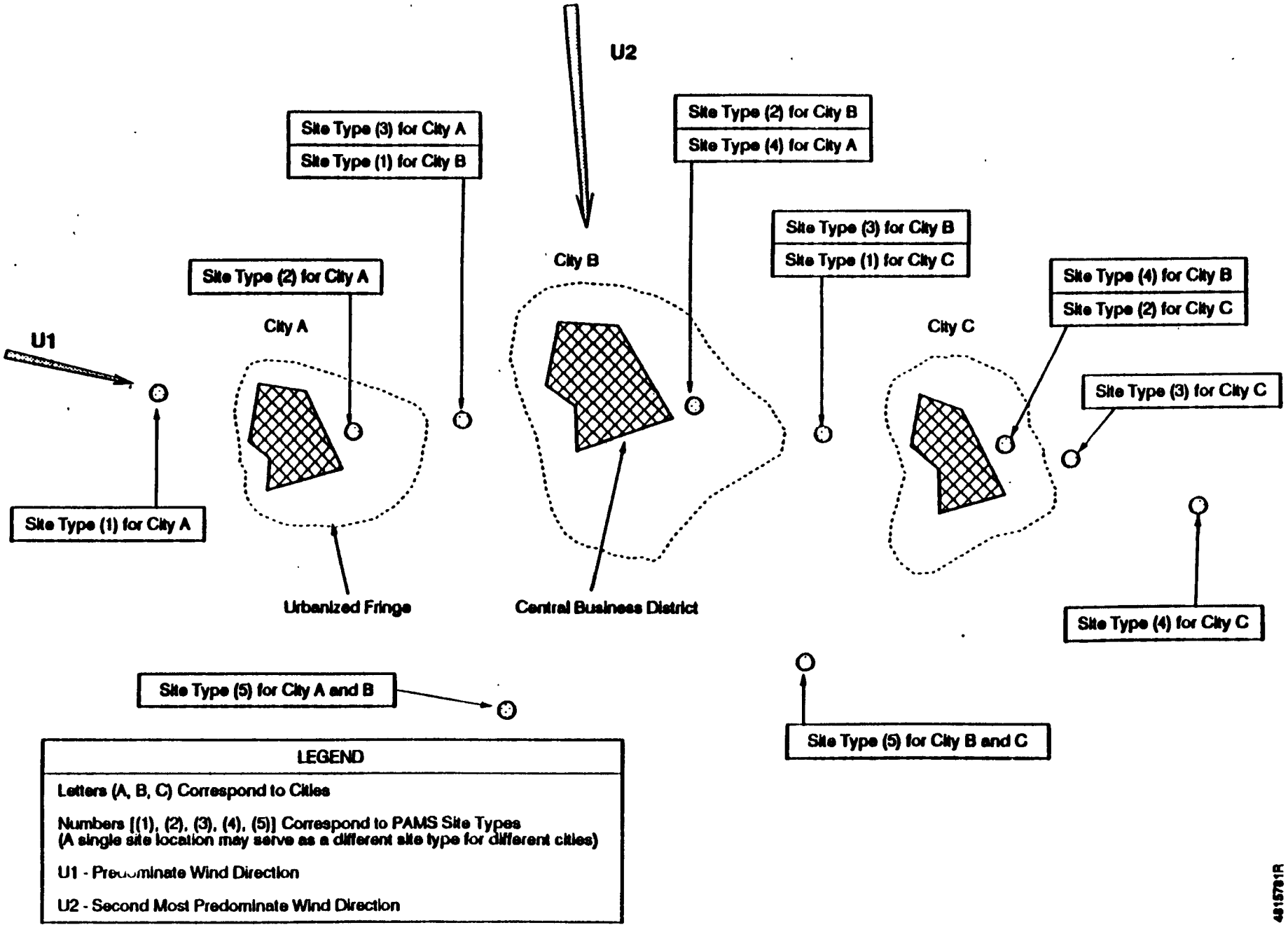


Figure 2-2. PAMS Network Design for a Multi-Area/Transport Region
(PAMS for Each City A, B, and C Will Serve Duplicate Functions)

objectives of the PAMS, regardless of the original siting criteria and intended use of the data.

The following subsections describe the purpose and general location of each site type.

2.2.1 Site Type (1) - Upwind Background

The purpose of Type (1) sites is to characterize background and transported ozone and ozone precursor concentrations entering the MSA or CMSA. Type (1) sites should be located in the predominant upwind direction from the local area of maximum precursor emissions during the sampling period. They should be located at a distance sufficient to ensure that urban scale measurements are obtained, as defined elsewhere in this section. Typically, Type (1) sites will be located 10 to 30 miles from the city limits or fringe of the urbanized area, in the predominant upwind direction during the sampling period.

2.2.2 Site Type (2) - Downwind Edge of Maximum Precursor Emissions

The purpose of Type (2) sites is to determine the magnitude and type of precursor emissions for areas where highest emissions are expected. Precursor emissions will be characterized and apportioned using measurements of different types of ozone precursors (e.g., volatile hydrocarbons, volatile carbonyl compounds). Type (2) sites should be located immediately downwind of the area of maximum precursor emissions during the sampling period and are typically placed near the downwind boundary of the central business district (CBD) to ensure that neighborhood scale measurements are obtained.

The site location should not be unduly influenced by single emission sources. Site locations immediately downwind of the CBD

are recommended because maximum precursor emissions typically occur within the CBD. Some urban areas may have very little industry within the CBD; rather, industrial emissions may be concentrated along the outer fringe of the CBD or urban core. In this case, a more suitable Type (2) location may be downwind of this industrial area.

2.2.3 Site Type (3) - Downwind Edge of MSA

Type (3) sites are established to measure changes in precursor concentrations downwind of emission sources that are located within city limits or at the fringe of the urbanized area. Precursor concentration ratios will also be determined from these measurements. Type (3) sites should be located in an intermediate position between the area of maximum precursor emissions and the downwind area where maximum ozone concentrations would be expected. These sites are intended to ensure that neighborhood scale measurements are obtained [between Sites Types (2) and (4)] (see Section 2.3.1 for further explanation). Typically, Type (3) sites are located 10 to 20 miles from the CBD or at the fringe of the urbanized area, in the predominant downwind direction during the sampling period.

2.2.4 Site Type (4) - Maximum Ozone Concentration - Primary Downwind Direction

Type (4) sites are intended to measure maximum ozone concentrations resulting from an upwind area of precursor emissions. These sites should be located directly downwind of the highest ozone precursor emissions sites [i.e., Type (2) sites]. Type (4) sites should be located downwind of urban areas, along the most predominant wind direction during the sampling period. The location should be chosen so that urban scale measurements are obtained. Typically, Type (4) sites should be placed 10 to 30 miles from the urban fringe or the

location of a Site Type (3), in the predominately downwind direction during the sampling period.

2.2.5 Site Type (5) - Maximum Ozone Concentration - Secondary Downwind Direction

The purpose of Type (5) sites is similar to that of Type (4) sites, except that Type (5) sites should be located downwind of urban areas, along the second most predominant wind direction during the sampling period. The location of Type (5) sites should be chosen so that urban scale measurement are obtained. Typically, Type (5) sites should be placed 10 to 30 miles from the fringe of the urbanized area or the location of a Site Type (3) and, as noted, in the second most predominant downwind direction during the sampling period.

2.3 PAMS SITE SELECTION

Site selection is one of the most important tasks associated with monitoring network design and must result in the most representative location to monitor the air quality conditions being assessed. General recommendations for site selection are provided in this document. Detailed site selection guidelines for monitoring ozone and precursor pollutants are given in "Site Selection for the Monitoring of Photochemical Air Pollutants."[2] PAMS site selection will follow the general guidance found in that reference. It is further recommended that photochemical models be used to assist in the design of the network.

2.3.1 Spatial Scales

The basis for monitor site selection, according to the referenced guidelines, is to first match each site-specific monitoring objective to an appropriate scale of spatial representation, and to then choose a monitoring location that is

characteristic of that spatial scale. Five spatial scales are commonly applied to air pollution monitoring: microscale, middle scale, neighborhood scale, urban scale, and regional scale. The spatial scales that are most relevant to the enhanced ozone monitoring network are the regional, urban, and neighborhood scales.

The regional scale defines conditions within an area of reasonably homogeneous geography and extends in distance from tens to hundreds of kilometers. This scale is most relevant to Type (1) monitoring sites.

The urban scale characterizes city-wide conditions with dimensions on the order of 4 to 50 km. Measurements on an "urban" scale represent concentration distributions over a metropolitan area. Monitoring on this scale relates to precursor emission distributions and control strategy plans for an MSA/CMSA. Site Types (4) and (5) are characteristic of the urban scale.

The neighborhood scale defines conditions within some extended areas of the city that have a relatively uniform land use and range from 0.5 to 4 km. Measurements on a neighborhood scale represent conditions throughout a homogeneous urban subregion. Precursor concentrations, on this scale of a few kilometers, will become well mixed and can be used to assess exposure impacts and track emissions. Neighborhood data will provide information on pollutants relative to residential and local business districts.

VOC sampling sites, including Site Types (2) and (3), are characteristic of neighborhood scales. Measurements of these reactants are ideally located just downwind of the edge of the urban core emission areas. The urban core is defined as "a clearly defined industrialized area with a high emission

density."[3] Further definition of neighborhood and urban scales is provided in Appendix D of 40 CFR, Part 58[4] and "Site Selection of the Monitoring of Photochemical Air Pollutants."[2]

2.3.2 General Monitoring Area

After choosing the appropriate spatial scale of representation, a general monitoring area must be selected that is characteristic of the required spatial scale and consistent with the monitoring objectives (micrositing). This is done by reviewing certain background information, including area land use patterns, emissions inventories, population densities, traffic distributions, climatological and meteorological data, and any existing monitoring data. The use of gridded photochemical models is especially useful in defining expected areas of steep low concentration gradients and important source/receptor relationships. Candidate monitoring sites are then selected from within the general monitoring area by eliminating from consideration all locations that might be unduly influenced by emissions from specific non-representative pollution sources or by non-representative topography.

Using the previous guidance, a close examination should be made of the MSA's or CMSA's under review before selecting the monitor locations. A distinction should be made between MSA's that are isolated and those that are consolidated into a corridor of urban areas. The possibility of multi-day transport should be considered in defining isolated urban areas or corridors of urban areas. Table 2-1 shows all areas in the United States listed as serious, severe, or extreme, grouped as Isolated or Transport areas.

Meteorological factors are used to identify which general monitoring areas qualify for upwind or downwind PAMS sites. In

TABLE 2-1. OZONE NONATTAINMENT AREAS FOR ISOLATED AND TRANSPORT AREAS

Isolated Areas	Population	Region/State	Ozone Non-Attainment Designation
Parkersburg-Marietta	< 5,000,000	WV-OH	Serious
Muskegon		MI	Serious
Huntington-Ashland		WV-KY-OH	Serious
El Paso	500,000 - 1,000,000	TX	Serious
Baton Rouge		LA	Serious
Sacramento	1,000,000 - 2,000,000	CA	Serious
Atlanta	> 2,000,000	GA	Serious
Transport Areas		**Region/State**	**Ozone Non-Attainment Designation**
L.A.-Anaheim-Riverside		CA	Extreme
San Diego		CA	Severe
Fresno		CA	Serious
Bakersfield		CA	Serious
Houston-Galveston-Brazoria		TX	Severe
Beaumont-Pt. Arthur		TX	Serious
Chicago-lake County		Lake Michigan	Severe
Milwaukee-Racine		Lake Michigan	Severe
Sheboygan			
N.Y.-No.N.J.-Long Island		Northeast	Severe
Baltimore		Northeast	Severe
Philadelphia-Wilm.-Trenton		Northeast	Severe
Hartford-Nw.Brit.-Middl.		Northeast	Serious
Springfield		Northeast	Serious
Boston-Lawren.-Salem		Northeast	Serious
Washington, D.C.		Northeast	Serious
Ports.-Dover-Roches.		Northeast	Serious
Providence-Pawt.-Fall River		Northeast	Serious

general, these areas will be remotely located. The wind patterns, combined with the length of time required to form ozone, are important factors in locating the monitors for measuring both maximum precursor and maximum downwind ozone concentrations. The idealized network design described in Section 2.2 is partly based on consideration of meteorological conditions. Meteorological data measurements from existing sites or from National Weather Service (NWS) stations can be used to determine the influence of prevailing wind patterns on major sources in order to pinpoint optimum monitor locations. If available, gridded photochemical air quality models should be utilized to assist in the siting process.

2.3.3 Probe Siting and Exposure Criteria

The probe siting and exposure criteria for PAMS monitors are similar to those for NAMS/SLAMS monitors for such items as the minimum distance of the inlet probe from obstructions, vertical and horizontal probe placement, minimum distances from trees, and spacing from roadways. These criteria are given in the following subsections. More detailed guidance can be found in "Site Selection for the Monitoring of Photochemical Air Pollutants,"[2] "Quality Assurance Handbook for Air Pollution Measurements,"[5] and "Technical Assistance Document for Sampling and Analysis of Ozone Precursors."[1]

Vertical and Horizontal Probe Placement

To achieve comparability with NAMS/SLAMS ozone monitoring data, the height of the inlet probe for PAMS monitors should be as close as possible to the breathing zone, but must be located 3 to 15 meters above ground level. Since PAMS involve multi-pollutant measurements, this range serves as a practical compromise for finding suitable probe positions in the siting

area. The probe must also be located more than 1 meter vertically or horizontally away from any supporting structure. Since VOC's are not routinely measured as part of NAMS/SLAMS monitoring programs, additional siting criteria comparable to those required for PSD monitoring of noncriteria pollutants should also be applied. These criteria include a minimum separation distance of 2 meters between the inlet probe and any walls, parapets, penthouses, etc. for probes located on roofs or other structures. In addition, probes should be located far from any furnace or incineration flues.

Spacing from Obstructions

The probe must be located away from obstacles and buildings such that the distance between any obstacle and the inlet probe is at least twice the height that the obstacle protrudes above the sampler. There must be unrestricted airflow in an arc of at least 270° around the inlet probe, and the predominant and second most predominant wind direction during the sampling period must be included in the 270° arc. If the probe is located on the side of a building, 180° clearance is required.

Spacing from Roads

Motor vehicle emissions constitute a major source of both ozone precursors and scavenger compounds. It is important, therefore, to maintain a minimum separation distance between roadways and PAMS monitoring sites such that the representation of the resulting monitoring data is not compromised. Table 2-2 gives the required minimum separation distances from roadways for various traffic volumes. The minimum separation distance must also be maintained between an PAMS station and other similar areas of automotive traffic, such as parking lots. Nearby roads should be far enough away from Site Types (2) and (3) probe

TABLE 2-2. MINIMUM SEPARATION DISTANCES BETWEEN ROADWAYS AND PAMS

Average Daily Traffic (Vehicles/Day)	Minimum Separation Distance[a] (meters)
<10,000	>10
15,000	20
20,000	30
40,000	50
70,000	100
>110,000	>250

[a]Interpolation of these distances should be made for intermediate traffic data.

inlets to avoid producing localized ozone sinks. Likewise, nearby roads should not be located near Site Types (1), (4), and (5) probe inlets, as precursor pollutants could have a local influence on these regionally representative sites.

Spacing from Trees

Trees can provide surfaces for adsorption and/or reactions, and can also affect normal wind flow patterns. To limit these effects, probe inlets should be placed at least 20 meters from the dripline of any trees and must certainly be more than 10 meters from the dripline of any trees that are located between the urban city core area (or other area of maximum ozone precursors) and the monitoring station along the predominant sampling period daytime wind direction.

Exposure of Meteorological Instruments

The 10-meter meteorological tower at each PAMS site should be located such that the resulting measurement data are representative of the meteorological conditions that affect pollutant transport and dispersion within the area that the monitoring site is intended to represent. Meteorological instruments should be located away from the immediate influence of trees, buildings, steep slopes, ridges, cliffs, and hollows.

Additional guidance for siting meteorological instruments is given in the EPA's "Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD),"[6] "On-Site Meteorological Program Guidance for Regulatory Modeling Applications,"[7] "Technical Assistance Document for Sampling and Analysis of Ozone Precursors."[1]

2.3.4 Practical Considerations

This section highlights practical considerations regarding the design of PAMS networks, particularly for those States under budget constraints. Costs are a strong driving force in selecting and implementing PAMS site types. Multiple uses of the data from various PAMS site types may result in lower program implementation costs. However, alternative uses of the data are subject to review and approval by the Administrator.

Some PAMS objectives have a higher priority than others. Cost can be minimized by prioritizing objectives as follows:

For Type (1) sites:

1. Maximum background ozone concentration.
2. Model verification.
3. Transport of ozone precursors.

For Type (2) sites:

1. Characterize maximum VOC emissions.
2. Characterize maximum NO_x emissions.
3. Characterize maximum concentration of urban air toxics.
4. Verify model.
5. Characterize population exposure.

For Type (3) sites:

1. Determine VOC/NO_x ratios.
2. Speciate VOC's.
3. Determine transport and reactivity of ozone precursors.
4. Verify model.
5. Determine population exposure.

For Type (4) and (5) sites:

1. Determine maximum downwind ozone concentration.
2. Verify model.
3. Determine spatial extent of reactivity through measurement of VOC.

Although network minimizations have been incorporated into the PAMS design, States planning to implement the PAMS may find some of these network design requirements to be impractical and/or an economic burden. States facing budget limitations may not be able to obtain suitable data without using existing SLAMS sites or acquiring additional monitoring data from industry-sponsored programs.

States may be able to add or improve monitoring capabilities at existing SLAMS sites or private monitoring sites. An evaluation should be made of existing monitoring sites to determine which, if any, would potentially qualify as PAMS. Some site locations may qualify on the basis of their location in MSA's/CMSA's. After carefully confirming that these sites are properly located and will meet PAMS objectives, review and addition of the appropriate PAMS monitoring techniques should be performed.

Although private monitoring sites are primarily established to measure maximum pollutant levels from a specific source, the site may be suitable, depending on the utilization of the data retrieved. Two types of private monitors may exist:

1. Monitors designed for preconstruction or post construction purposes. Most are in operation for 1 year and are primarily intended for background measurements.

2. Monitors designed to measure maximum impacts from sources possibly under permit restrictions. These sites can be in operation for 6 months to several years and are intended to reflect air quality concentrations associated with a single source.

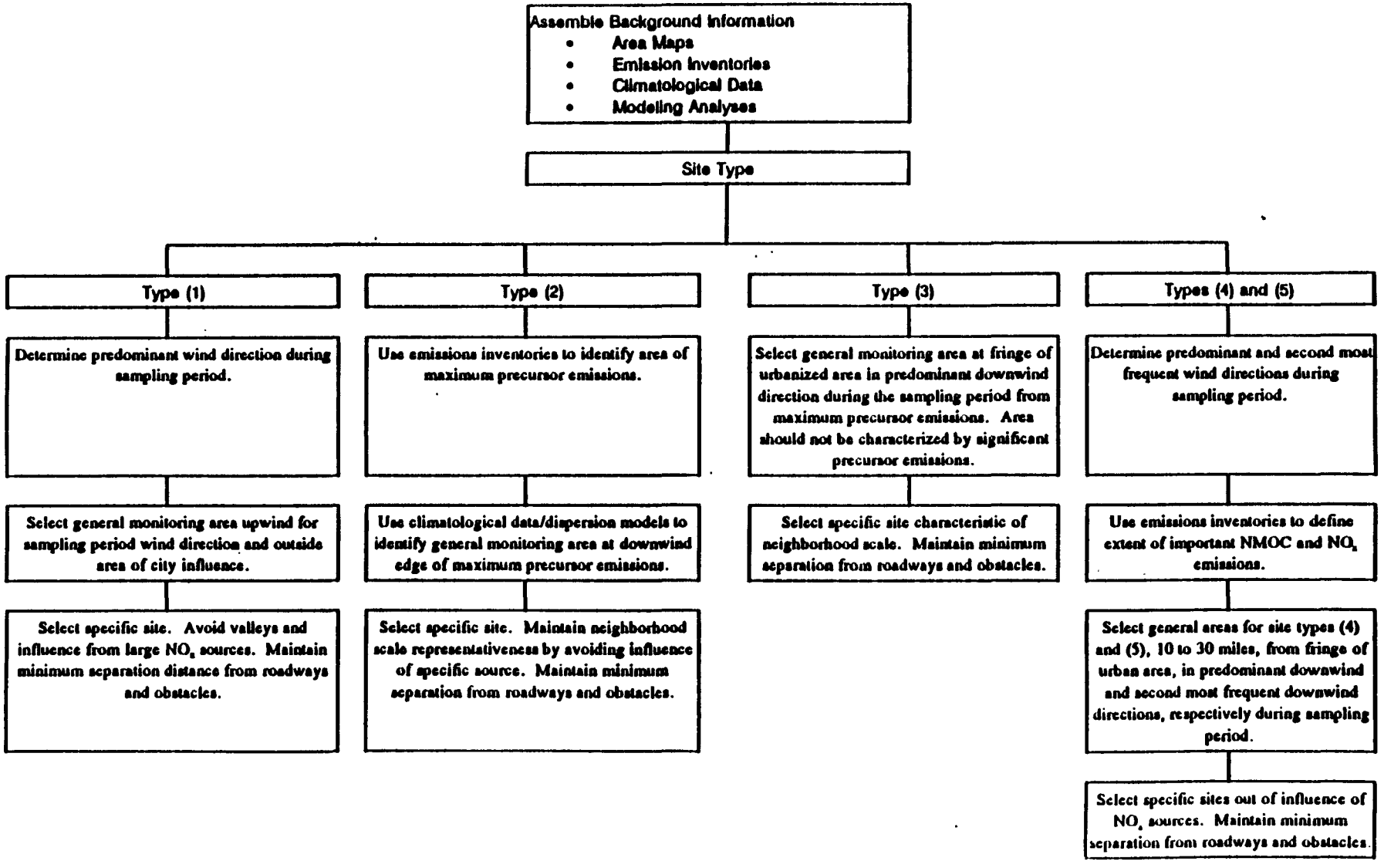
Some preconstruction monitoring sites may have measurement data for ozone and meteorological parameters. These data have limitations, however, as sites are sparse and monitors are in operation for varying time periods.

2.3.5 Specific PAMS Site Selection Procedure

A summary of the steps for selecting PAMS sites is given in Figure 2-3. Specific site selection guidance relevant to each PAMS site type is given in the following subsections. This guidance is based on the idealized network design that was described in Section 2.2. In situations where the following guidance is impractical because of the uniqueness of the source distribution, land use patterns, or geography, alternative network designs are allowed by federal regulations. Alternative network designs, however, must demonstrate that they satisfy the monitoring data uses and fulfill the overall PAMS objectives described in Section 1.1.

Note that in some cases, monitoring stations operating as NAMS or SLAMS may already exist within the general monitoring area. In these cases, if the site is properly located as a PAMS, federal regulations require that existing monitoring stations only be supplemented with the additional instruments necessary to comply with the PAMS monitoring requirements.

FIGURE 2-3. STEPS FOR SELECTING PAMS SITE LOCATIONS



Type (1) Monitoring Sites

The basic objective of Type (1) sites is to characterize upwind background and transported ozone and ozone precursor concentrations. Measurements conducted at these sites should be representative of the regional scale in the direction that is predominantly upwind from the MSA during conditions that are most conducive to ozone formation during the sampling period.

To select a Type (1) monitoring site, one must first determine the predominant wind direction associated with strong photochemical activity. One must then select the general monitoring area in the predominant upwind direction from the MSA, and outside the area of influence of the MSA. Typically, Type (1) sites should be located approximately 10 to 30 miles from the city limits or fringe of the urbanized area.

To obtain measurements that are most representative of background conditions, Type (1) monitoring sites should ideally be located on a small hill or knoll where the surface destructive effects of trees and other nearby obstacles on ozone will be minimal. Type (1) sites should also be sufficiently far from roads and other major sources of NO_x and NMOC emissions so that the data truly represent the region. The specific monitoring locations should comply with the probe siting and exposure criteria given in Section 2.3.3.

Minimum separation distance between roadways and PAMS monitoring locations are discussed in Section 2.3.3. Other types of NO_x and NMOC's sources that may affect the regional representation of a monitoring site are shown in Tables 2-3 and 2-4[8], respectively. These tables indicate total U.S. annual emissions of NMOC and NO_x from various anthropogenic source categories. More detail regarding emission sources and their

TABLE 2-3. U.S. 1985 ANTHROPOGENIC NO_x EMISSIONS

Source Category	NO_x Emissions[a]					
	Area Sources		Point Sources		All Sources	
	(kTPY[b])	%	(kTPY[b])	%	(kTPY[b])	%
Transportation						
On-road vehicles[a]	6811.0	61.6	0.0	0.0	6811.0	33.1
Off-road vehicles	2023.3	18.3	0.0	0.0	2023.3	9.8
Subtotal	8834.3	79.9	0.0	0.0	8834.3	42.9
Stationary fuel combustion						
Electric utilities	0.0	0.0	6769.6	71.2	6769.6	32.9
Other	2022.3	18.3	1800.8	18.9	3823.1	18.6
Subtotal	2022.3	18.3	8570.4	90.1	10592.7	51.5
Solid waste (Subtotal)	69.2	0.6	18.3	0.2	87.5	0.4
Industrial processes						
Chemicals	0.0	0.0	171.7	1.8	171.7	0.8
Metals	0.0	0.0	76.7	0.8	76.7	0.4
Other	0.0	0.0	371.6	3.9	371.6	1.8
Subtotal	0.0	0.0	620.0	6.5	620.0	3.0
Miscellaneous						
Unplanned fires	39.0	0.4	0.0	0.0	39.0	0.2
Agricultural activities	0.0	0.0	4.8	0.1	4.8	0.0
Controlled burning	90.4	0.8	0.0	0.0	90.4	0.4
Waste disposal	0.0	0.0	0.0	0.0	0.0	0.0
Organic solvents	0.0	0.0	8.3	0.1	8.3	0.0
Oil and gas production and marketing	0.0	0.0	289.7	3.0	289.7	1.4
Other	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	129.4	1.2	302.8	3.2	432.2	2.0
Total	11055.2	100.0	9511.5	100.0	20566.7	99.4

[a]Source of data - Network Design and Site Exposure Criteria for Non-Methane Organic Hydrocarbons-SYSAPP - 89/138.

[b]kTPY - Kilotons per year.

TABLE 2-4. U.S. 1985 ANTHROPOGENIC NMOC EMISSIONS

Source Category	NMOC Emissions[a]					
	Area Sources		Point Sources		All Sources	
	(10^3 TPY)	%	(10^3 TPY)	%	(10^3 TPY)	%
Transportation						
On-road vehicles[b]	5866.6	29.5	0.0	0.0	5866.6	26.3
Off-road vehicles	1421.1	7.1	0.0	0.0	1421.1	6.4
Subtotal	7287.7	36.6	0.0	0.0	7287.7	32.7
Stationary fuel combustion						
Electric utilities	0.0	0.0	56.9	2.4	56.9	0.3
Other	2433.7	12.2	162.8	6.9	2596.5	11.7
Subtotal	2433.7	12.2	219.7	9.3	2653.4	12.0
Solid waste	608.8	3.1	11.1	0.5	619.9	2.8
Industrial processes						
Chemicals	359.0	1.8	518.3	21.9	877.3	3.9
Metals	0.0	0.0	77.3	3.3	77.3	0.3
Other	0.0	0.0	144.7	6.1	144.7	0.6
Subtotal	359.0	1.8	740.3	31.3	1099.3	4.8
Miscellaneous						
Unplanned fires	205.9	1.0	0.0	0.0	205.9	0.9
Agricultural activities	50.0	0.2	50.5	2.1	100.5	0.5
Controlled burning	348.1	1.7	0.0	0.0	348.1	1.6
Waste disposal	1430.5	7.2	0.0	0.0	1430.5	6.4
Organic solvents	4631.3	23.3	825.2	34.8	5456.5	24.5
Oil and gas production and marketing	2353.4	11.8	522.1	22.0	2875.5	12.9
Other	191.9	1.0	0.0	0.0	191.9	0.8
Subtotal	9211.1	46.2	1397.8	58.9	10608.9	47.6
Total	19900.3	99.9	2368.9	100.0	22269.2	99.9

[a]Source of data - Network Design and Site Exposure Criteria for Non-Methane Organic Hydrocarbons-SYSAPP-89/138.

[b]Based on MOBILE4 emission factors.

influences on site selection can be found in "Network Design and Site Exposure Criteria for Non-Methane Organic Hydrocarbons."[9] Next to motor vehicles, the largest source types of NMOC's and NO_x, are petrochemical facilities and electric power plants, respectively. The minimum separation distances between such sources and Type (1) sites depends primarily on the magnitude of emissions from the sources and on meteorological factors. Dispersion modeling should be conducted to evaluate whether or not any local emission sources have the potential to disturb the regional representation of a prospective monitoring site.

Type (2) Monitoring Sites

Type (2) sites are established to monitor the impact of maximum precursor emissions. The sites should be suited for monitoring urban air toxic pollutants, and should be located near the predominantly downwind edge of the central business district or area of maximum precursor emissions from a large industrial area.

To select the general monitoring area for Type (2) sites, emissions inventories should be reviewed to identify the area of greatest emissions density within the MSA. Monitoring should be conducted near the predominantly downwind edge of this area. Although Type (2) sites are intended to monitor the impacts during the sampling period of maximum ozone precursor emissions, they should be representative of the neighborhood scale and not be unduly influenced by any single localized emission source. In some cases, dispersion modeling of source emissions may be helpful in identifying areas of uniformly high ozone precursor concentrations. The specific micrositing of Type (2) sites should comply with the probe siting and exposure criteria given in Section 2.3.3, and should be sufficiently remote (several hundreds of meters) from local sources of VOC's, such as gasoline stations and dry cleaning establishments.

Type (3) Monitoring Sites

Type (3) sites are intended to measure precursor concentrations sufficiently downwind of the predominant source area so that the transport and reactivity of precursor compounds may be assessed. The general monitoring area for Type (3) sites is less strictly defined than for other PAMS site types. The principal siting criterion for Type (3) monitoring locations is that they be located at an intermediate distance between the area of maximum precursor emissions and the downwind area where, during the sampling period, maximum ozone concentrations are expected to occur [between Type (2) and Type (4) monitoring sites]. They should also be representative of the neighborhood scale in an area not characterized by significant precursor emissions.

Typically, Type (3) sites will be located approximately 10 to 20 miles from the CBD of the MSA or at the fringe of the urbanized area, in the predominant downwind direction during the sampling period. The specific monitoring location should not be impacted by any nearby source of ozone precursors, and should comply with the specific probe siting and exposure criteria given in Section 2.3.3.

Type (4) and (5) Monitoring Sites

Type (4) and (5) sites are intended to monitor maximum ozone concentrations occurring downwind from the area of maximum precursor emissions in the first and second most frequently occurring wind directions, respectively, during the sampling period. These sites should typically be located approximately 10 to 30 miles downwind from the fringe of the urban area or from a Type (3) site.

Usually, it would not be possible to determine the point of maximum ozone concentration with confidence without, perhaps, the aid of complex photochemical modeling. In general, this point would be outside the region of major NO_x emissions, but within about 30 miles of the fringe of the urbanized area.

To select Type (4) and (5) monitoring sites, one must first determine the first and second most frequent wind directions associated with the sampling period. The general monitoring areas should then be selected from within an angular segment of approximately 45° centered on the two most important wind directions and extending from approximately 10 to 30 miles from the fringe of the urbanized area. The specific monitoring location should be sufficiently remote from significant emission sources of nitrogen oxide (NO), particularly roadways, and should comply with the probe siting and exposure criteria given in Section 2.3.3. Existing monitoring data would be helpful in choosing appropriate locations for Type (4) and (5) sites.

There is considerable flexibility in the micrositing of each PAMS type within a qualifying zone or area. After considering the previously discussed selection criteria, the recommended zone areas illustrated in Figure 2-4 should be considered for final selection of site type location. These zone areas allow flexibility in selecting sites for each site type. As shown in Figure 2-4, a zone area is drawn for each site type and is defined by a 45° sector centered on the predominant wind directions U1 and U2. The hatched segments within each sector serve as a guide for locating specific PAMS site types. The segment range (45°) allows flexibility while keeping the site locations within the framework of design recommendations. The narrowest segments are for Site Types (2) and (3) because of their proximity to urbanized areas. The other Site Types [(1), (4), and (5)] have a larger range to work with.

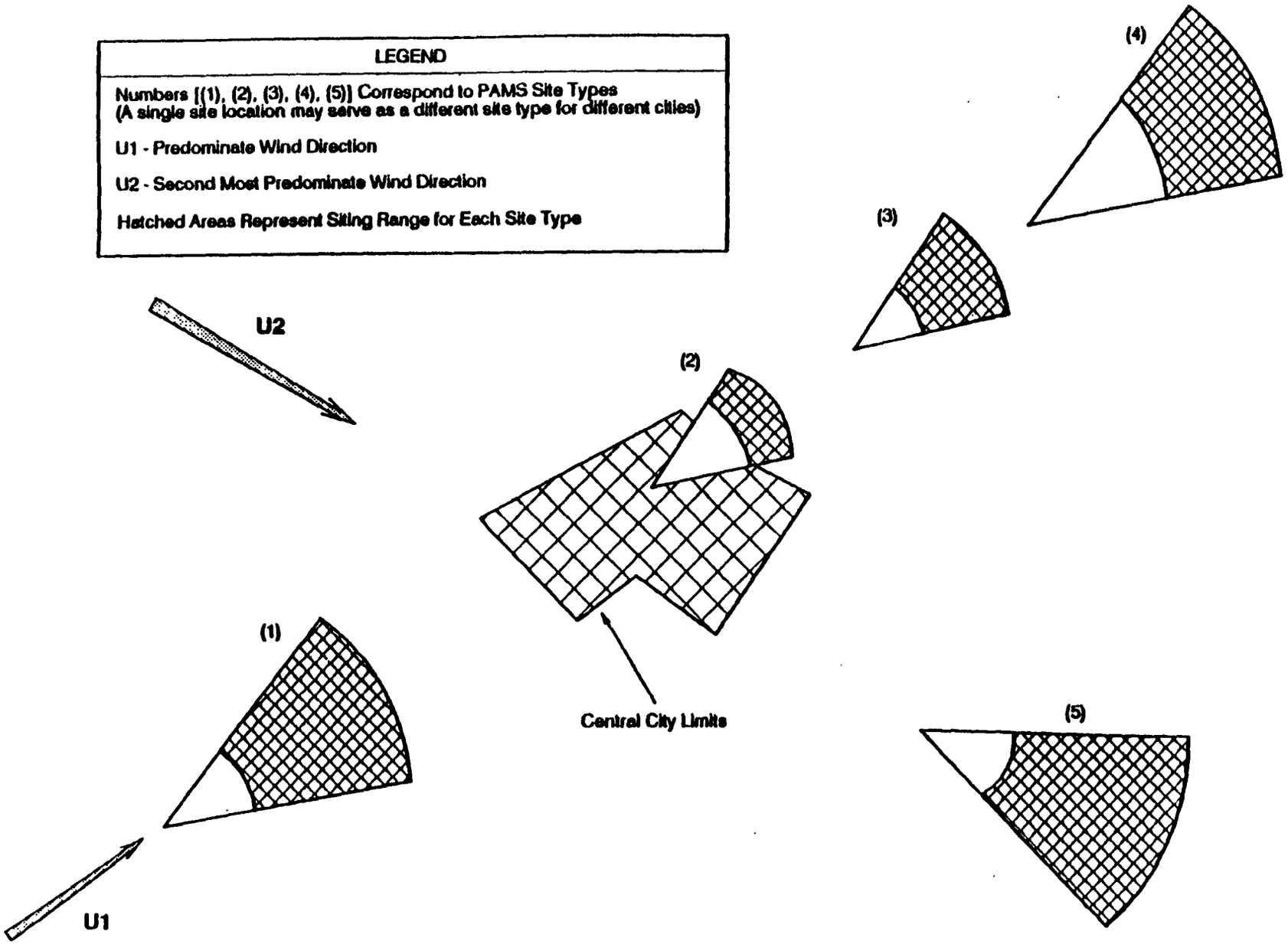


Figure 2-4. Approximate Sector Locations for PAMS Site Types (1) to (5) Based on Predominant Wind Flow U1 and U2 for an Isolated Area

2.4 MINIMUM NETWORK REQUIREMENTS

A minimum required number and type of PAMS sites and sampling requirements have been defined for selected population ranges. The population sizes are associated with an MSA or CMSA. The MSA/CMSA basis for monitoring network requirements was chosen because it typically is a good identifier of the most representative area that encompasses the emissions sources contributing to ozone nonattainment. Population figures for an MSA/CMSA can be used as a surrogate in representing MSA/CMSA emissions density. However, in some cases, nonattainment areas or counties may be larger than MSA's/CMSA's; therefore, the PAMS network design should be based on the larger of the MSA/CMSA, the county, or the nonattainment area. Preferably, network specifications will be designed on a case-by-case basis and will consider the interrelated factors of meteorology, source density and distribution, demographics, and other appropriate factors. Population figures must reflect the most recent decennial U.S. census population report. The minimum network requirements for each population range are identified in Table 2-5.

MSA's or CMSA's may be grouped to geographically cover an extended urban corridor. One characteristic of an urban corridor is that its observed ozone exceedances may be largely due to long range transport of pollutants. Grouped MSA's or CMSA's may require fewer total PAMS than the same number of MSA's/CMSA's considered individually (see Figure 2-2) but each MSA/CMSA must meet the skeleton network requirements shown in Figure 2-2. In meeting the urban area minimum requirements (see Figure 2-1), an PAMS may function as more than one site type.

2.5 TRANSITION PERIOD

Guidance is provided in this section on the implementation priority of each PAMS site so that a smooth transition can be

TABLE 2-5. MINIMUM NETWORK REQUIREMENTS

Population Range (MSA/CMSA, County or Nonattainment Area)[a]	Required Site Type(s)[b]	Minimum VOC Sampling Frequency[c]	Minimum Aldehyde Sampling Frequency[c]
Less than 500,000	(1)	A	-
	(2)	A	D
500,000 to 1,000,000	(1)	A	-
	(2)	B	E
	(4)	A	-
1,000,000 to 2,000,000	(1)	A	-
	(2)	B	E
	(3)	C	E
	(4)	A	-
More than 2,000,000	(1)	A	-
	(2)	B	E
	(3)	C	E
	(4)	A	-
	(5)	A	-

[a] Whichever is largest.

[b] See Figure 2-1.

[c] Frequency requirements are as follows:

A = Eight 3-hour samples every third day and one 24-hour sample every sixth day during the monitoring period.

B = Eight 3-hour samples every day during the monitoring period and one 24-hour sample every sixth day year-round.

C = Eight 3-hour samples every day and one 24-hour sample every sixth day during the monitoring period.

D = Four 6-hour samples every third day during the monitoring period.

E = Four 6-hour samples every day during the monitoring period.

made to a total enhanced ozone monitoring program. The phase-in order for each PAMS Site Type, and the reason for the order are as follows:

1. Site Type (2) - Provides the most comprehensive data reflecting ozone precursor emissions and toxic air pollutants.

2. Site Type (1) - Delineates the effect of incoming precursor emissions and concentrations of ozone.

3. Site Type (4) - Provides maximum ozone measurements and total conversion of ozone precursors.

4. Site Type (3) - Depicts the spatial changes in concentrations of ozone and precursors as the pollutants travel across an MSA/CMSA.

5. Site Type (5) - Serves a similar purpose as Site Type (4) in the second most predominant wind direction.

A variable period of time is proposed for phasing in the operation of all required PAMS. Within 1 year of the effective date of promulgation of the rule, or designation or reclassification of an area as serious, severe, or extreme for ozone nonattainment (whichever is later), a minimum of one Type (2) site must be operating. Operation of the remaining site types must, at a minimum, be phased in over the subsequent 4 years, according to the schedule shown in Table 2-6.

2.6 METEOROLOGICAL PARAMETER MONITORING

Upper air and surface meteorological monitoring are important to the success of the PAMS program. Combined upper air

TABLE 2-6. TRANSITION PERIOD FOR PAMS OPERATIONS

Years After Promulgation/ Redesignation	Minimum Number of Sites In Operation	Operating Site Types (by phase-in order)
1	1	(2)
2	2	(2),(1)
3	3	(2),(1),(4)
4	4	(2),(1),(4),(3)
5	5	(2),(1),(4),(3),(5)

and surface meteorological measurements will be used to support monitoring objectives associated with model inputs and performance evaluations, assessing source/receptor interactions, and determine pollutant transport fluxes. In particular, meteorological data are needed to determine the impact of climate on the relationship between emission data and air quality changes.

Meteorological monitoring is required at each PAMS to diagnose the behavior of photochemical grid models and to trace emission sources. The meteorological data collected will be most useful in the development of wind fields for photochemical grid models. The data will also be used to estimate mixing heights, vertical wind and temperature structure, and atmospheric stability. The following requirements should be met in order to achieve these goals:

- Surface meteorological monitoring of wind speed/direction, temperature, relative humidity, barometric pressure, and solar radiation should be measured at sites that measure VOC data.

- Operations for collecting meteorological data should be established coincident with site establishment.

- Upper air meteorological monitoring is encouraged at a representative site in each nonattainment area. Upper air data should be collected for approximately 10 to 20 key days per year, corresponding to model input requirements.

Surface meteorological monitoring will be required at each PAMS. Surface meteorological measurements should begin coincident with site establishment. Measurements of surface meteorological data should be acquired at a level of 10 meters

above ground level for each PAMS site. The 10-meter tower should be located so that surrounding structures and trees do not have an immediate influence on measurements. These meteorological data should reflect the origins of, and the conditions within, the air mass containing pollutants which the inlet probe will be sampling. These data should correspond to, or have the capabilities of converting into, photochemical model input requirements. For example, wind speed and direction should be reported over a 1-hour averaging time.

Upper air sites are not required to operate at the same locations as the surface PAMS sites, although it is preferred because the meteorological data will be used to reflect the origins of each pollutant measured and the meteorological conditions within the air mass advected across the PAMS sites. Upper air meteorological measurements should be initiated for areas where existing upper air data are not available. The location of upper air measurements should be selected in an area representative of the nonattainment area under review. Upper air measurements are strongly encouraged, but not required. Upper air meteorological data should be measured for approximately 10 to 20 key days per year. Model input requirements will dictate which meteorological parameters need to be derived from the upper air data.

More specific guidance on meteorological measurements can be found in "On-Site Meteorological Program Guidance for Regulatory Modeling Applications,"[7] "Technical Assistance Document for Sampling and Analysis of Ozone Precursors,"[1] and "Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Meteorological Measurements."[5]

2.7 AIR TOXICS MONITORING

Urban air toxics monitoring is required for VOC species and other hazardous air pollutants under Title III, Section 301, of the 1990 CAAA. Measurements of these species could be collocated with measurements of other pollutants as part of the enhanced national ozone monitoring network. PAMS Type (2) sites could serve simultaneously as urban air toxics monitoring sites, as well as ozone and ozone precursor monitoring sites.

Methods typically used for air toxics measurement are not addressed in this guidance document (see "Technical Assistance Document for Sampling and Analysis of Ozone Precursors"[1]). However, manual methods, such as canister sampling for VOC species, will be used for both quality assurance purposes to check the continuous VOC measurement data and to provide estimates of annual means for air toxics assessment purposes. Air toxics monitoring will include data gathered for semivolatiles and polar compounds. Other hazardous compounds, including metals, pesticides, and products of incomplete combustion (PICS) will be measured, provided resources are available.

3.0 MONITORING METHODS AND NETWORK OPERATIONS

3.1 MONITORING METHODS

Table 3-1 summarizes the measurement requirements that satisfy all PAMS monitoring objectives. To maintain comparability with measurements being obtained as part of NAMS/SLAMS monitoring networks, all PAMS measurements of ozone and NO_x should be conducted using automated, EPA designated reference or equivalent methods. No such reference methods exist for meteorological parameters or VOC's. However, as certain minimum uniform criteria concerning these measurements need to be maintained, selection of monitoring methods for these parameters should be performed in accordance with guidance documents such as "Technical Assistance Document for Sampling and Analysis of Ozone Precursors"[1] and "Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV. Meteorological Measurements."[5] States are required to use these documents in selecting and conducting measurements at PAMS. Consecutive hourly average measurements of ambient concentrations of both criteria and non-criteria pollutants are required. Because this sampling frequency is higher than typical for manual canister programs, automated VOC monitoring is highly recommended.

Alternative methods for conducting VOC measurements may be allowed by EPA, however, they must be described in detail in the network description and subjected to public comment and approval by the EPA Administrator.

Special care must be taken in monitoring VOC's at SLAMS designated as PAMS. FEP Teflon is unacceptable as the probe material because of VOC adsorption and desorption reactions on the FEP Teflon. Borosilicate glass, stainless steel, or their equivalent are the acceptable probe materials for VOC and

TABLE 3-1. MEASUREMENTS NECESSARY TO MEET MONITORING OBJECTIVES

MONITORING OBJECTIVES			NECESSARY MEASUREMENTS																								
			SITE TYPE																								
			(1)					(2)					(3)					(4)					(5)				
			OZONE	VOC	NOX	ATOX	MET	OZONE	VOC	NOX	ATOX	MET	OZONE	VOC	NOX	ATOX	MET	OZONE	VOC	NOX	ATOX	MET	OZONE	VOC	NOX	ATOX	MET
NAAQS ATTAINMENT AND CONTROL STRATEGY DEVELOPMENT	OVERWHELMING TRANSPORT		*	*	*		*	**	**	**		**															
	PHOTOCHEMICAL GRID MODELS	BOUNDARY CONDITIONS	*	*	*		*						**	**	**		**	*	*	*		*	*	*	*		*
		MODEL INPUT REQUIREMENTS	*	*	*		*	*	*	*		*	*	*	*		*	*	*	*		*	*	*	*		*
		MODEL PERFORMANCE	*	*	*		*	*	*	*		*	*	*	*		*	*	*	*		*	*	*	*		*
	ATTAINMENT DECISIONS		**		**		**	*		**		**	*		*		**	*		*		**	*		*		**
SIP CONTROL STRATEGY EVALUATION	EVALUATE EFFECTIVENESS OVER LONG-TERM		*	*	*		*	*	*	*		*	**	**	**		**	*	*	*		*	*	*	*		*
EMISSIONS TRACKING	CORROBORATE NOX AND VOC EMISSION INVENTORIES		**	*	*		*	**	*	*		*	**	*	*		*	**	*	*		*	**	*	*		*
	TRACK NOX AND VOC EMISSION INVENTORY REDUCTIONS			*	*	*	*		*	*	*	*		*	*	**	*		**	**	**	*		**	**	**	*
TRENDS			*	*	*	*	*	**	*	**	*	*	*	*	*	*	*	*	**	**	**	*	*	**	**	**	*
EXPOSURE ASSESSMENT			**	**	**	**	**	*	**	**	*	*	*	**	**	*	*	*	**	**	**	*	*	**	**	**	*

DEFINITIONS:

VOC - VOLATILE ORGANIC COMPOUNDS
NOX - OXIDES OF NITROGEN (NO, NO2, & NOX)
ATOX - TOXIC AIR POLLUTANTS ALSO MEASURED AS VOC

* - PRIMARY OBJECTIVE
** - SECONDARY OBJECTIVE

aldehyde sampling. Care must be taken to ensure that the sample residence time is minimized.

3.2 OPERATING SCHEDULE AND SAMPLING FREQUENCY

To maintain comparability with NAMS/SLAMS networks, uniform monitoring frequencies have been established. The operating schedule for continuous measurements being conducted as part of PAMS (i.e., ozone, NO_x, and VOC's, using automated gas chromatography) is the same as that required by federal regulations for SLAMS continuous analyzers. This schedule requires collection of consecutive hourly averages except during periods of routine maintenance, instrument calibration, and periods or seasons exempted by the Regional Administrator.

Typically, PAMS monitoring will be conducted annually at least throughout the months of June, July, and August, when peak ozone concentrations are expected to occur. A longer monitoring period is preferred for sites that have extended ozone seasons. With regard to SLAMS monitoring, the ozone monitoring season varies on a State by State basis, typically extending from April through October. It is preferable, although generally not required, that PAMS monitoring be conducted during the entire ozone monitoring period for the area. Table 3-2 gives the ozone monitoring season for each state in the United States. VOC sampling done in conjunction with PAMS monitoring is planned for June, July, and August at a minimum to coincide with peak ozone periods.

Manual ozone precursor and aldehyde sample collection should be conducted during the same operating period as PAMS ozone and NO_x measurements. Other VOC sampling for toxics, however, should be for any 3-month period during the year. The required frequency and duration of each sampling period for manual methods

TABLE 3-2. OZONE MONITORING SEASON BY STATE[a]

State	Begin Month	End Month
Alabama	March	November
Alaska	April	October
Arizona	January	December
Arkansas	March	November
California	January	December
Colorado	March	September
Connecticut	April	October
Delaware	April	October
District of Columbia	April	October
Florida	January	December
Georgia	March	November
Hawaii	January	December
Idaho	April	October
Illinois	April	October
Indiana	April	October
Iowa	April	October
Kansas	April	October
Kentucky	April	October
Louisiana	January	December
Maine	April	October
Maryland	April	October
Massachusetts	April	October
Michigan	April	October
Minnesota	April	October
Mississippi	March	November
Missouri	April	October
Montana	June	September
Nebraska	April	October
Nevada	January	December
New Hampshire	April	October
New Jersey	April	October
New Mexico	January	December
New York	April	October
North Carolina	April	October
North Dakota	May	September
Ohio	April	October
Oklahoma	March	November
Oregon	April	October
Pennsylvania	April	October
Puerto Rico	January	December
Rhode Island	April	October
South Carolina	April	October
South Dakota	June	September
Tennessee	April	October
Texas AQCR 4,5,7,10,11	January	December
Texas AQCR 1,2,3,6,8,9,12	March	October
Utah	May	September
Vermont	April	October
Virginia	April	October
Washington	April	October
West Virginia	April	October
Wisconsin	April	October
Wyoming	April	October
American Samoa	January	December
Guam	January	December
Virgin Islands	January	December

[a]40 CFR 58, Appendix D

tls.030

depends on the PAMS site type and population of the MSA. Measurements are typically conducted over 24-hour periods; however, in many cases, it is required that the 24-hour period be comprised of either four separate 6-hour sample or eight separate 3-hour samples. Table 2-4 (Section 2.4) presents the minimum sampling frequency requirements for PAMS manual methods sampling.

3.3 ANALYSES

The analyses required of discreet samples for ozone precursors and aldehydes are discussed in a separate technical assistance document entitled "Technical Assistance Document for Sampling and Analysis of Ozone Precursors" (EPA Contract No. 68-D0-0125, Work Assignment 22, October, 1991). This technical assistance document should be consulted for the descriptions and considerations of the monitoring methodologies, including analyses.

4.0 PAMS DATA USES

Data from the PAMS network will serve several purposes, including evaluation of attainment of the National Ambient Air Quality Standards (NAAQS), SIP control strategy development and evaluation, corroboration of emissions tracking, preparation of trends appraisals, and population exposure assessment. Each of these data uses is described in more detail in this section. Measurement requirements by site type for PAMS objectives are summarized in Table 3-1 (Section 3.1). Potential application of PAMS data to various ambient modeling applications (e.g., UAM, ROM, EKMA, TRAJECTORY) is provided in Appendix A.

4.1 NAAQS ATTAINMENT AND CONTROL STRATEGY DEVELOPMENT

The data from PAMS, combined with data from existing SLAMS and NAMS monitors, will be used to monitor ozone exceedances and provide input for attainment/nonattainment decisions. In addition, PAMS data will help resolve the roles of transported and locally emitted ozone precursors in producing observed exceedances and may be used to identify specific sources contributing to observed exceedances and excessive concentrations of ozone precursors.

PAMS data will also assist in characterizing the concentrations of ozone and ozone precursors occurring on days when high ozone levels are measured, thereby extending the database available for future attainment demonstrations. These demonstrations will be based on photochemical grid modeling and other approved analytical methods and will provide a basis for prospective mid-course control strategy corrections. PAMS data will provide (1) information concerning which areas and episodes to model in order to develop appropriate control strategies; (2) boundary conditions required by the models to produce quantifiable estimates of needed emissions reductions; and (3) a

means to evaluate the predictive capability of the models used. PAMS data are not designed to be the sole source of air quality data for input and evaluation of photochemical grid models.

Site Types (4) and (5), which measure ozone and, in some cases, VOC and NO_x concentrations downwind of the affected MSA or CMSA, will be used for ozone attainment demonstrations and control strategy development.

4.2 SIP CONTROL STRATEGY EVALUATION

Long-term PAMS data will be used to evaluate the effectiveness of SIP control strategies. Data from PAMS sites can validate the impact of emission reductions on air quality levels for ozone if retrieved at the end of a time period during which control measures were implemented. Additionally, ambient monitoring data from PAMS will be used to determine diurnal patterns of VOC emissions.

Speciation of measured VOC data will allow determination of which organic species are most affected by emissions reductions and assist in developing cost-effective, selective VOC reduction control strategies. All VOC species have different reactivities; therefore, the influence of control measures on specific species may have a bearing on the degree of ozone reductions achieved. A State or local air pollution control agency may use this information in developing strategies for its particular nonattainment area that are best suited for that area and can achieve the greatest emissions reductions at the least cost.

Site Types (2) and (3), which measure VOC and NO_x air quality concentrations, will be used to measure and document changes in ozone precursor emissions in order to evaluate control strategy effectiveness.

4.3 EMISSIONS TRACKING

Development of emission inventories for VOC's, NO_x, and CO in ozone nonattainment areas is required as part of the 1990 CAAA. PAMS data will be used to corroborate the quality of VOC and NO_x emission inventories. Although a perfect mathematical relationship between emission inventories and ambient measurements does not yet exist, a qualitative assessment in terms of the relative distribution of various compounds in the ambient air could be roughly compared to current emission inventory estimates to judge the accuracy of the emission inventories. The importance of collecting ambient data to verify emission inventory estimates has been shown through comparative studies involving predictive methods and measured data.

PAMS data will allow tracking of VOC and NO_x emission reductions and corroborate emissions trends analyses. VOC and NO_x emission inventory reductions for baseline emissions are required as part of the CAAA-mandated Reasonable Further Progress (RFP) demonstrations. While the regulatory assessment of progress will be made in terms of emission inventory estimates, the ambient data can provide independent trends analyses and corroboration of these assessments. The ambient assessments, using speciated data, can provide insight into whether the estimated emission improvements are supported by ambient measurements.

Speciated data can also be used to assess the adequacy of assumptions used for speciated emissions input during photochemical grid modeling exercises and to identify urban air toxic pollutant problems that deserve closer scrutiny. The speciated VOC data will be used to determine changes in the species profile resulting from the emission control program, particularly those resulting from fuel reformulation.

PAMS data from Site Types (2) and (3) will be used to corroborate and assess the accuracy of VOC and NO_x emission inventories. Long-term PAMS data from Site Types (2) and (3) will be used to track VOC and NO_x emission reductions and support RFP demonstrations.

4.4 AIR QUALITY TRENDS APPRAISALS

Long-term PAMS data will be used to establish VOC, NO, NO_2, NO_x, and toxic air pollutant trends, and supplement the ozone trends database. Multiple statistical indicators will be tracked, including ozone and its precursors on the 10 days during each year with the highest ozone concentration, the seasonal means for these pollutants, and the annual means at representative locations.

Surface meteorological parameters monitoring at each PAMS will help maximize the utility of these trends analyses by comparisons with meteorological trends and transport influences. The meteorological data will also help interpret ambient air pollution trends. In terms of overall ozone level increases or decreases nationwide, historical data have shown that meteorological conditions can play a major role in determining contributing factors to ozone level trends.

Long-term PAMS data from Site Types (2) and (3) will be used to establish VOC and NO_x trends, and data from all site types will be used to supplement existing ozone trends databases.

4.5 EXPOSURE ASSESSMENT

PAMS data will be used to better characterize exposure of populations living in serious, severe, or extreme ozone nonattainment areas to ozone and toxic air pollutants. Because

ozone and its precursors are by-products of numerous large and small stationary sources and motor vehicle emissions, the distribution and magnitude of ozone and ozone precursor concentrations within MSA's/CMSA's needs to be determined, utilizing as many monitors as possible. Knowledge of the spatial distribution of measured levels of these pollutants, in relation to demographics, will help determine ozone pollutant levels to which populations are typically exposed. Annual mean toxic air pollutant concentrations will be calculated to determine the risk to the population associated with individual VOC species in urban environments.

Site Types (2) and (3), located in populated areas, are suitable for this purpose. Ozone, VOC's, and NO_x would be measured at these sites. Urban air toxics information would be most meaningful from Site Type (2) locations.

4.6 PAMS SITE TYPE DATA USES

Specific monitoring objectives associated with each PAMS site location are described below.

4.6.1 Site Type (1)

Type (1) sites will characterize upwind background and transported ozone and its precursor concentrations entering an area and will identify those areas that are subjected to overwhelming transport. Data collected from Type (1) sites will be used to:

- develop and evaluate future control strategies;
- identify incoming emissions;

- establish boundary conditions for future photochemical grid modeling and mid-course control strategy changes;

- determine NAAQS attainment for ozone and NO_2; and

- analyze pollutant trends.

4.6.2 Site Type (2)

Type (2) sites will monitor the magnitude and type of precursor emissions in the area where maximum emissions are expected, and they are ideally suited for monitoring urban air toxic pollutants. Data collected from Type (2) sites will be used to:

- develop and evaluate future control strategies;

- corroborate NO_x and VOC emission inventories;

- augment RFP tracking;

- verify photochemical grid model performance;

- characterize ozone and toxic air pollutant exposures (maximum site for toxic emissions impact);

- analyze pollutant trends, particularly toxic air pollutants and annual ambient VOC trends to compare with trends in annual VOC emission estimates; and

- determine NAAQS attainment for ozone and NO_2.

4.6.3 Site Type (3)

Type (3) sites will monitor changes in precursor concentrations and ratios downwind of the emissions sources. Data collected from Type (3) sites will be used to:

- determine NAAQS attainment for ozone and NO_2 (this site type may coincide with an existing maximum NO_2 NAMS monitoring site);
- measure transport and reactivity of precursors;
- verify photochemical grid model performance;
- characterize ozone exposures; and
- analyze pollutant trends.

4.6.4 Site Types (4) and (5)

Types (4) and (5) sites will monitor maximum ozone concentrations occurring downwind from the area of maximum precursor emissions in the first and second most frequently occurring wind directions, respectively. Data collected from Type (4) and (5) sites will be used to:

- determine NAAQS attainment for ozone and NO_2 (this site type may coincide with an existing maximum concentration ozone or a population exposure NO_2 NAMS monitoring site);
- establish boundary conditions for photochemical grid modeling;
- develop and evaluate future control strategies; and

- analyze pollutant trends, particularly for VOC and ozone.

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APPENDIX A

PAMS DATA APPLICATIONS FOR PHOTOCHEMICAL GRID MODELING

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PAMS DATA APPLICATIONS FOR PHOTOCHEMICAL GRID MODELING

This section provides a detailed description of applications of each Site Type in terms of monitoring objectives pertaining to photochemical grid modeling.

A.1 OVERWHELMING TRANSPORT

Enhanced ozone monitoring data will be used to characterize transported ozone and its precursor concentrations entering MSA's/CMSA's and will identify those nonattainment areas that are subject to overwhelming transport.[1]

Exceedance episodes may be discounted based on overwhelming transport (contribution of local emissions to an observed exceedance is relatively minor). If overwhelming transport is a factor, an analysis of culpable upwind sources areas has to be made. The analysis would include the use of an urban scale photochemical model supported by monitoring information representing regional scale transport of ozone and precursors into the urban area under evaluation.

For a given MSA/CMSA under review, the following monitoring site types will be required to help verify that transported ozone and ozone precursors are of sufficient levels to be responsible for ozone violations in the downwind nonattainment areas. The upwind Site Type (1) would be used to measure O_3. A Type (2) site located near the fringe of the CBD, would be used to measure VOC and NO_x. Measurement data obtained to verify overwhelming transport should be from Sites Types (1) and (2) located near culpable MSA/CMSA upwind of the nonattainment area where the ozone exceedances occur.

A.2 URBAN AREAS INFLUENCING OZONE NONATTAINMENT AREAS

Enhanced ozone monitoring data will be used to provide input to, and verification of, future photochemical grid modeling analyses. Emission reductions needed to achieve the national ambient air quality standard (NAAQS) for ozone must be evaluated for urban areas contributing to ozone exceedances. Source areas responsible for contributing to ozone exceedances are primarily found within urbanized areas. Photochemical air quality models provide the most practical means of determining needed reductions of VOC and/or NO_x emissions. For serious, severe, and extreme nonattainment areas, photochemical grid models are required to demonstrate the effectiveness of control measures in achieving the NAAQS for ozone. The Urban Airshed Model (UAM)[2,3] is recommended for this purpose. The modeled area or domain will have to be large enough to include the contributing urban sources, available air quality monitoring sites, and the nonattainment area under review.[1,4] Data from the PAMS will provide needed information for model input and will assist in model performance evaluations.

A.3 MODEL INPUT

This section provides a description of the input requirements for photochemical grid modeling. Meteorological and air quality monitoring data provide multiple uses: (1) scoping modeling domains and episodes, (2) inputs needed to drive the models, and (3) evaluating the predictive capabilities of selected models.

Input to the urban scale models can be provided through regional scale modeling results or ambient measurements. Regional scale modeling results will be generated through the application of the Regional Oxidant Model (ROM).[1,3] Ambient

measurements of ozone and ozone precursor concentrations and meteorological parameters could also be obtained from PAMS. PAMS data, particularly from Site Types (1) and (4), could prove useful in assessing and enhancing the ROM-derived boundary conditions.

A UAM designed preprocessor program and a diagnostic wind field model using measurements from the PAMS will provide appropriate inputs to the urban modeling analysis. Surface measurements of ozone, NMOC, NO_x, and CO can be used for characterizing initial and boundary conditions for UAM.

A.3.1 Urban Airshed Model (UAM)

Enhanced ozone monitoring data will assist in providing inputs for urban scale models such as UAM. Ambient measurements are used for developing initial and boundary conditions, and gridded fields of meteorological parameters. The boundary conditions required during the application of UAM are shown in Table A-1[1]. Air quality data will include measurements of ozone and ozone precursor concentrations. Meteorological data will include measured wind speed and direction, temperature, humidity, atmospheric pressure, and solar radiation.

Because UAM uses a three-dimensional grid, there are practical limitations to collecting monitored data for individual boundary grid cells. PAMS data will be useful for developing boundary conditions; however, in most cases, only one PAMS site will be available.

Site Types (1), (4), and (5) located in areas outside of the MSA/CMSA under review are the most appropriate PAMS for providing boundary conditions.[1] Based on predominant meteorological conditions (U1), Type (1) is the most preferable site for

TABLE A-1. BOUNDARY CONDITIONS REQUIRED IN EKMA AND UAM

POLLUTANT	SOURCE ENOMS[a]	SOURCE DEFAULTS	METEOROLOGICAL PARAMETERS	SOURCE ENOMS[a]
NMOC:	(1),(4),(5)	30 ppbc	(Hourly):	1 - 5
Carbon Bond IV Speciation		Carbon Fraction	Wind Speed Wind Direction	
1) PAR		0.498	Temperature	
2) ETH		0.034	Humidity	
3) OLE		0.020	Atmospheric	
4) ALD2		0.037	Pressure	
5) FORM		0.070	Solar	
6) TOL		0.042	Radiation	
7) XYL		0.026		
8) ISOP		0.000		
9) MEOH		0.273		
10) ETOH		0.000		
O_3	(1),(4),(5)	40 ppb		
NO_2	(1),(4),(5)	2 ppb		
NO	(1),(4),(5)	0 ppb		
CO		350 ppb[b]		

[a]ENOMS Site Type.
[b]Source: PEPE/NEROS Study.

characterizing boundary conditions. Site Type (5) is the second most preferable site based on the second most predominant meteorological conditions. Data from Site Type (4) may supplement those from Site (1) in establishing boundary values. Application of Site Types (1), (4), and (5) for these purposes is acceptable, provided the data from each site are regional in scale. Boundary conditions based on VOC monitoring data should be obtained from Site Types (1) and (4) using 3-hour values taken every 3 to 6 days. These sites should be situated outside of the MSA/CMSA under review. It should be understood that these are general recommendations and that case-specific analyses using UAM modeling to assist in monitor placement is advised.

All site types can provide data to characterize gridded initial conditions. Some site types, such as Types (2) and (3) situated within the urban modeling domain, will be particularly useful for formulating initial conditions. Meteorological parameters obtained from all site types will assist in the development of gridded wind fields, as well as other gridded meteorological data fields.

Monitoring needs for evaluating the performance of UAM include measurements of ozone and ozone precursor concentrations at selected urban scale sites. Potentially, most, if not all, sites may be useful data sources for assessing model performance.

A.3.2 Empirical Kinetic Modeling Approach (EKMA)

Enhanced ozone monitoring data will assist in providing inputs for urban scale models such as city-specific EKMA.[5] Air quality measurements are needed to specify initial conditions, and meteorological measurements are needed to estimate mixing heights, reaction rates, and atmospheric moisture content. Air quality data will include measurements of ozone and ozone precursor concentrations. Meteorological data will include

measured wind speed and direction, temperature, humidity, atmospheric pressure, and solar radiation representative of the urban area.

The boundary conditions required during the application of EKMA are shown in Table A-1.

Use of upwind surface air quality monitors meeting PAMS siting criteria is recommended for estimating present boundary conditions for EKMA. Site Types (1), (4), and (5) are recommended for estimating present boundary conditions for ozone, NO_x and NO_2. Complete monitoring needs for determining boundary conditions for EKMA include measurements of ozone, VOC, NO_x, and CO. Boundary condition values for VOC may be estimated from a single 3-hour sample taken between 6 and 9 LCT every 3 to 6 days.

A.3.3 U.S. EPA TRAJECTORY Model

This model computes a trajectory using surface wind data from National Weather Service stations and other suitable monitoring sites to assist in locating culpable MSA's/CMSA's upwind of nonattainment areas. The model is intended to characterize mesoscale winds. Hourly daytime (8:00 am - 8:00 pm) data are needed as input to the model. The TRAJECTORY model[6] is not applicable to nighttime meteorological conditions, as surface wind data at night are not always representative of winds aloft. It is desirable to use as many wind observations as possible to construct these trajectories. PAMS will serve to provide additional surface wind speed and direction data.

Surface meteorological data will be obtained from all site types for upwind regions where back trajectories are calculated. These data will help supplement existing surface meteorological data within the upwind region. Upper air meteorological data

associated with the enhanced ozone monitoring program, along with the surface meteorological data will be used in verifying the back trajectory calculations.

A.4 MODEL PERFORMANCE EVALUATION

PAMS will provide more adequate data for evaluating the performance of UAM. The EPA guidelines for using UAM recommend a model performance evaluation in conjunction with attainment demonstrations. This performance evaluation will determine how well the model characterizes processes involved in case-specific ozone exceedances. The PAMS will provide data useful for conducting model performance assessments. As performance evaluations of ROM will be based on extensive areas covering ROM modeling domains, the PAMS network design should be such that an adequate spatial distribution of regional ambient measurements can be obtained for this purpose.

Surface ozone and upper air wind measurements are useful supplementary data for TRAJECTORY. Time sequences of observed ozone data, upwind along the path of the trajectory, can be used to evaluate TRAJECTORY's hypothesis.

Upper air wind measurements can be used to test whether the model has made appropriate adjustments to surface wind observations used as input to the model. These adjustments are intended to make hourly wind data more representative of the wind flow throughout the mixed layer. Surface and upper air ambient measurements from PAMS will provide data for evaluation purposes.

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16. ABSTRACT

New ozone monitoring sites are required by the CAAA to enhance the existing ambient air monitoring network currently composed of State and Local Air Monitoring Stations (SLAMS), the National Air Monitoring Stations (NAMS), and Special Purpose Monitors (SPM) stations. These enhanced monitoring sites, called photochemical assessment monitoring stations (PAMS), will measure ozone, VOC (including aldehydes), and NO_x concentrations, and meteorological parameters. As the PAMS will become part of the SLAMS network, they will be subject to specific siting, quality assurance, analytical methodology, sampling interval, and instrument requirements. This guidance document provides a description of the PAMS sites, and the requirements for siting and configuring the sites.

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