Ambient Air Quality Monitoring Networks

Muleshoe Ranch Visibility Monitoring Site located at 4,400 feet elevation in the Galiuro Wilderness Area east of Tucson

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Introduction

The federal Clean Air Act of 1970 required EPA to assist states and localities in establishing ambient air quality monitoring networks to characterize human health exposure and public welfare effects of conventional pollutants. The 1977 federal Clean Air Act amendments required each state to implement a visibility monitoring network to cover specified national parks and wilderness areas. The Phoenix and Tucson metropolitan areas also have year-round visibility monitoring networks to assess urban hazes. All of these networks are composed of individual monitoring sites, they are operated to collect ambient air quality data to ensure that Arizona citizens are able to know local air quality conditions and help ADEQ and local air quality control districts identify the causes of polluted air.

Conventional Pollutant Monitoring Networks

The conventional pollutants are presently defined as sulfur dioxide (SO_2), total particulate lead (Pb), suspended particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and carbon monoxide (CO). These pollutants are monitored with federal reference or equivalent methods that EPA has certified. EPA defined particulate matter monitoring in 1987 to measure particles less than or equal to 10 microns in aerodynamic diameter (PM_{10}), and again in 1997 to measure both PM_{10} and, separately, particles less than or equal to 2.5 microns in aerodynamic diameter ($PM_{2.5}$). Networks operated to monitor the nature and causes of visibility impairment use some of the same sampling methods and are described in more detail later in this section. Ambient monitoring networks for air quality are established to sample pollution in a variety of representative settings, to assess the health and welfare affects, and to assist in determining air pollution sources. These networks cover both urban and rural areas of the state. Sampling networks are designed to satisfy monitoring objectives and measurement scales defined in Tables 1 and 2.

For each conventional pollutant, EPA specifies monitoring objectives that define the parameters by which health exposure and public welfare are assessed and measurement scale classifications that describe the influence of atmospheric movement at given location.

The types and scales of monitoring sites described above are combined into networks, which a number of government agencies and regulated companies operate. These networks are composed of one or more monitoring sites, whose data are compared to the national ambient air quality standards, statistically analyzed in various ways. The agency or company operating a monitoring network also tracks data recovery, quality control and quality assurance parameters for the instruments operated at their various sites. The agency or company also often measures meteorological variables at the monitoring site.

Table 1. Monitoring Objectives for Air Quality Monitoring Sites	
Number	**Definition**
1	Determine highest concentrations expected to occur in the area covered by the network
2	Determine representative concentrations in areas of high population density
3	Determine the impact on ambient pollution levels of significant sources or source categories
4	Determine general background concentration levels
5	Determine the extent of regional pollutant transport among populated areas and in support of secondary standards
6	Determine the welfare-related affect in more rural and remote areas (such as visibility impairment and vegetation effects)

Table 2. Measurement Scales for Air Quality Monitoring Sites						
Measurement Scale *represents concentrations in air volumes within areas defined below*	**Conventional Pollutant**					
	Carbon Monoxide (CO)	**Sulfur Dioxide (SO_2)**	**Ozone (O_3)**	**Nitrogen Dioxide (NO_2)**	**Lead (Pb)**	**Particulate Matter (PM_{10}, $PM_{2.5}$)**
Micro (0 to 100 m)	X				X	X
Middle (~100 to 500 m)	X	X	X	X	X	X
Neighborhood (~0.5 to 4 km)	X	X	X	X	X	X
Urban (~4 to 50 km)		X	X	X	X	X
Regional (~10 to 100s of km)		X	X		X	X

Some of the agencies do special continuous monitoring for the optical characteristics of the atmosphere and manual sampling of ozone-forming compounds and other hazardous air pollutants. Maricopa, Pima and Pinal counties operate networks primarily to monitor urban air pollution. In contrast, the industrial networks are operated to determine the effects of their emissions on local air quality. The National Park Service's network tracks conditions in and around national parks and monuments. The state network monitors a wide variety of pollutant and atmospheric characteristics, including urban, industrial, rural and background surveillance.

The monitoring networks and their characteristics are shown in Table 3. A list of individual sites and monitoring parameters, based on the best available information at the time of publication, is presented in Supplement A, which begins on Page 111.

Table 3. Monitoring Networks Operating in Arizona				
Network Operator	**Geographic Area Monitored**	**Monitoring Objective***	**Measurement Scale(s)****	**Pollutant(s) Monitored**
Arizona Dept. of Environmental Quality	Statewide	1, 2, 3, 4, 5, 6	Micro, Middle, Neighborhood, Urban, Regional	SO_2, Pb, O_3, NO_2, CO, PM_{10}, $PM_{2.5}$
Arizona Portland Cement Company	Rillito	1, 3	Neighborhood	PM_{10}
ASARCO, Inc.	Hayden	1, 2, 3	Middle , Neighborhood	SO_2
Maricopa County Environmental Svcs Dept.	Phoenix Urban Area, Maricopa County	1, 2, 3, 4, 5, 6	Micro, Middle, Neighborhood, Urban, Regional	SO_2, Pb, O_3, NO_2, CO, PM_{10}
National Park Service	National Parks and Monuments	3, 4, 5, 6	Urban, Regional	SO_2, O_3, NO_2, PM_{10}, $PM_{2.5}$
Phelps Dodge Miami Inc. (PDMI)	Miami	1, 2, 3	Neighborhood	SO_2, PM_{10}, $PM_{2.5}$
Phoenix Cement Company	Clarkdale	1, 3	Neighborhood	PM_{10}, $PM_{2.5}$, Pb
Pima County Dept. of Environmental Quality	Tucson Urban Area, Pima County	1, 2, 3, 4, 5, 6	Micro, Middle, Neighborhood, Urban, Regional	SO_2, Pb, O_3, NO_2, CO, PM_{10}, $PM_{2.5}$
Network Pinal County Air Quality Control District	Pinal County , Phoenix Urban Area	1, 2, 3, 4, 5	Middle, Neighborhood, Urban, Regional	O_3, CO, PM_{10}, $PM_{2.5}$
Praxair, Inc.	Kingman	1, 3	Middle	PM_{10}
Salt River Project	Page	1, 3	Urban, Regional	NO_2, O_3, SO_2, PM_{10}, $PM_{2.5}$
Southern California Edison Company	Bullhead City, AZ and Laughlin, NV	1, 2, 3, 4	Neighborhood, Urban, Regional	SO_2, NO_2, PM_{10}

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Network Operator	**Geographic Area Monitored**	**Monitoring Objective***	**Measurement Scale(s)****	**Pollutant(s) Monitored**
Tucson Electric Power Company	Tucson and Springerville	1, 2, 3	Middle, Regional	SO_2, NO_2, PM_{10}, $PM_{2.5}$

** See Table 1 for a list of objectives*
*** See Table 2 for a definition of the scales*

Visibility Monitoring Networks in National Parks and Wilderness Areas

The intent of the Class I visibility monitoring program is to characterize long-term trends as completely as possible using ambient visibility measurements within constraints of an area's size, terrain or logistics for each of the 12 federally protected Class I areas in Arizona. The visibility monitoring network is designed to have a long-term monitoring strategy, to track short-term and long-term trends in Arizona Class I areas, to assist in identifying any reasonably attributable visibility impairment affects and to provide monitoring data if necessary for new or major modifications of categorical major sources.

Arizona continues to participate in the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program as part of the overall national visibility monitoring effort. IMPROVE is a cooperative measurement effort between EPA, federal land management agencies and state air agencies. The objectives of IMPROVE are:

- To establish current visibility and aerosol conditions in mandatory Class I areas
- To identify chemical species and emission sources responsible for existing man-made visibility impairment
- To document long-term trends for assessing progress towards the national visibility goal
- With the enactment of the regional haze rule, to provide regional haze monitoring representing all visibility-protected federal Class I areas

Class I areas were designated based on an evaluation required by Congress in the 1977 federal Clean Air Act amendments. The evaluation, which the U.S. Forest Service and National Park Service performed, reviewed the wilderness areas of parks and national forests which were designated as wilderness before 1977, were more than 6,000 acres in size and have visual air quality as an important resource for visitors. Of the 156 Class I areas designated across the nation, 12 are located in Arizona.

The Arizona Class I visibility network consists of a combination of visibility monitoring sites established by ADEQ and those established by the IMPROVE committee. Monitoring was conducted or is planned at the following sites (see Figure 1 for the monitoring objectives of air quality monitoring sites).

Grand Canyon National Park, Hance
Grand Canyon National Park, Indian Gardens
Petrified Forest National Park
Mt. Baldy Wilderness, Greer Water Treatment Plant
Sycamore Canyon Wilderness, Camp Raymond
Mazatzal Wilderness, Humboldt Mountain
Mazatzal/Pine Mountain Wildernesses, Ike's Backbone
Sierra Ancha Wilderness, Pleasant Valley Ranger Station
Superstition Wilderness, Tonto National Monument
Superstition Wilderness, Queen Valley
Saguaro National Park, West Unit
Saguaro National Park, East Unit
Chiricahua National Monument, Entrance Station
Galiuro Wilderness, Muleshoe Ranch
Chiricahua Wilderness, Rucker Canyon

Each IMPROVE site includes $PM_{2.5}$ sampling with subsequent analysis for the fine particle mass and major aerosol species, as well as PM_{10} sampling and mass analysis. Many of the sites also include optical monitoring with nephelometers or a transmissometer and color photography to document scenic appearance.

More information about the IMPROVE procedures, sites and data can be found on the IMPROVE Web site at http://vista.cira.colostate.edu/improve/ and on the National Park Service Web site at www.aqd.nps.gov/ard/impr/.

Urban Haze Networks

ADEQ monitors urban haze in the Phoenix and Tucson metropolitan areas using a network of instruments to characterize and quantify the extent of urban haze. There are no established federal or state standards for acceptable levels of urban haze. ADEQ began studying the nature and causes of urban hazes by conducting a study in the winter of 1989-90 in Phoenix and the winter of 1992-93 in Tucson. These studies recommended long-term, year-round monitoring of visibility. In 1993, ADEQ began deploying visibility monitoring equipment in Phoenix and Tucson. These visibility monitoring data are needed to provide policymakers and the public with information, track short- and long-term trends, assess source

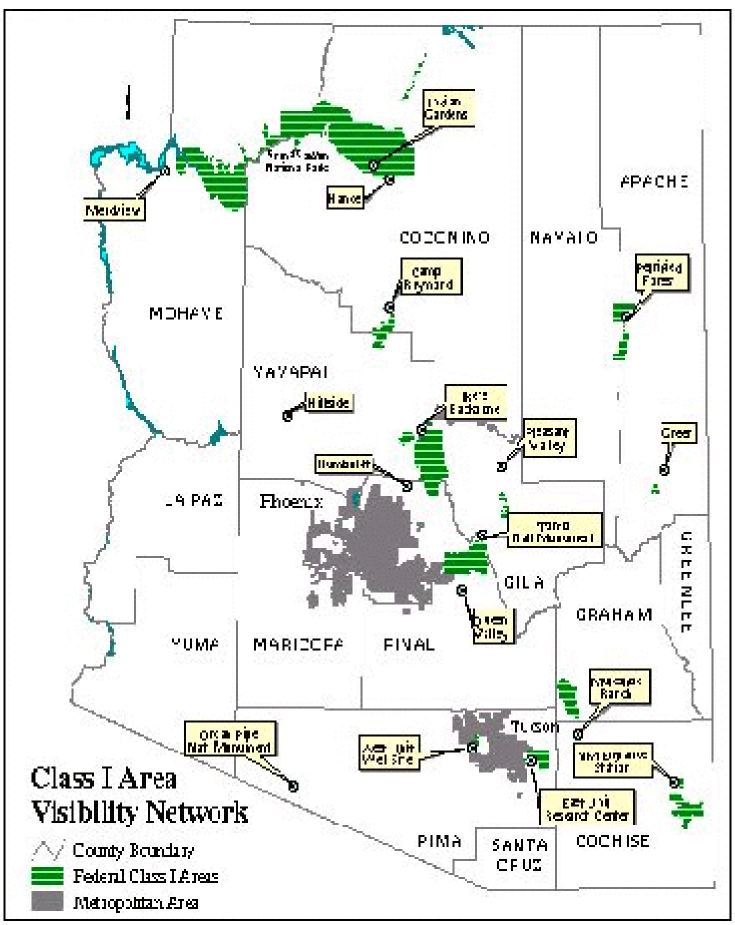

Figure 1. Class I Area Visibility Networks

contributions to urban haze and better evaluate the effectiveness of air pollution control strategies.

The urban haze networks include transmissometers for measuring light extinction along a fixed path length of about 5 kilometers, nephelometers for measuring light scattering, and particulate filters for quantifying and characterizing particulate matter. Data from urban PM_{10} and $PM_{2.5}$ samplers are characterized for chemical composition and seasonal variation.

Photochemical Assessment Monitoring Stations (PAMS) Monitoring

Section 182(c)(1) of the 1990 Clean Air Act amendments required the administrator to promulgate rules for the enhanced monitoring of ozone, oxides of nitrogen (NOx) and volatile organic compounds (VOCs) to obtain more comprehensive and representative data on ozone air pollution. Immediately following the promulgation of such rules, the affected states were to commence such actions as were necessary to adopt and implement a program to improve ambient monitoring activities and the monitoring of emissions of NOx and VOCs. Each state implementation plan (SIP) for the affected areas must contain commitments to implement the appropriate ambient monitoring network for such air pollutants. The subsequent revisions to Title 40, Code of Federal Regulations, Part 58 (40 CFR 58, 1993) required states to establish PAMS as part of their SIP monitoring networks in ozone nonattainment areas classified as serious, severe or extreme. The principal reasons for requiring the collection of additional ambient air pollutant and meteorological data are the nationwide lack of attainment of the ozone national ambient air quality standards and the need for a more comprehensive air quality database for ozone and its precursors.

The chief objective of the enhanced ozone monitoring requirements is to provide air quality data that will assist air pollution control agencies in evaluating, tracking the progress of and, if necessary, refining control strategies for attaining the ozone national ambient air quality standards. Ambient concentrations of ozone and ozone precursors used to make attainment and nonattainment decisions, aid in tracking VOC and NOx emission reductions, better characterize the nature and extent of the ozone problem, and examine air quality trends. In addition, data from the PAMS network provide an improved database for evaluating photochemical model performance, especially for future control strategy mid-course corrections as part of the continuing air quality management process. The data are particularly useful to states in ensuring the implementation of the most cost-effective regulatory controls.

The PAMS network array for an area should be fashioned to supply measurements that will assist states in understanding and solving ozone nonattainment problems. EPA has determined that for larger areas, a network that will satisfy a number of important monitoring objectives should consist of the following five sites.

Type 1 Site: Upwind and Background Characterization

These sites are established to characterize upwind background and transported ozone and its precursor concentrations entering the area. They will also identify areas that are subjected to overwhelming incoming transport of ozone. Type 1 sites are located in the predominant morning upwind direction from the local area of maximum precursor emissions and at a distance sufficient to obtain urban scale measurements. Typically, these sites will be located near the upwind edge of the photochemical grid model domain.

Type 2a and 2b Sites: Maximum Ozone Precursor Emissions Impact

These sites are established to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions representative of the metropolitan statistical area/consolidated metropolitan statistical area (MSA/CMSA) are expected to affect and are suited for the monitoring of urban air toxic pollutants. Type 2 sites are located immediately downwind (using the same morning wind direction as for locating the Type 1 site) of the area of maximum precursor emissions and are typically placed near the downwind boundary of the central business district or primary area of precursor emissions mix to obtain neighborhood scale measurements. A second Type 2 site may be required depending on the size of the area, and should be placed in the second-most predominant morning wind direction.

Type 3 Site: Maximum Ozone Concentration

These sites are intended to monitor maximum ozone concentrations occurring downwind from the area of maximum precursor emissions. Locations for Type 3 sites should be chosen so that urban scale measurements are obtained. Typically, these sites are located 10 to 30 miles from the fringe of the urban area.

Type 4 Site: Extreme Downwind Monitoring

These sites are established to characterize the extreme downwind transported ozone and its precursor concentrations exiting the area and will identify those areas that are potentially contributing to overwhelming ozone transport into other areas. Type 4 sites are located in the predominant afternoon downwind direction from the local area of maximum precursor emissions at a distance sufficient to obtain urban scale measurements. Typically, these sites will be located near the downwind edge of the photochemical grid model domain.

PAMS data include measurements of O_3, NOx, a target list of VOCs including several carbonyls, and surface and upper air meteorology. Most PAMS sites measure 56 target hydrocarbons on either an hourly or three-hour basis during the ozone season. The Type 2 sites also collect data on three carbonyl compounds (formaldehyde, acetaldehyde and acetone) every three hours during the ozone monitoring period. Included in the monitored VOC species are 10 compounds classified as hazardous air pollutants (HAPs). All stations must measure O_3, NOx and surface meteorological parameters on an hourly basis. ADEQ has installed two PAMS monitoring sites to date, the ADEQ Supersite (located near 17^{th} Avenue and Campbell) in central Phoenix (a Type 2 site) and the wind profiler (upper air meteorology) site. A time line describing proposed installation dates of additional sites is provided in Table 4.

Table 4. PAMS Installation Time Line		
Type of Ozone		**Proposed Installation**
PAMS	**Season**	
Type 1	**2002**	Palo Verde – Wintersburg Area
Type 2	**1999**	Supersite – 17th Avenue and Campbell, Phoenix
Type 2a	**2001**	South Phoenix Area
Type 3	**2001**	Queen Valley
Type 4	**2002**	Roosevelt Lake

Annual Ambient Air Monitoring Network Review

ADEQ expanded the 1999 and 2000 annual ambient air monitoring network reviews beyond the state and local air monitoring stations (SLAMS) to include all state networks. The Code of Federal Regulations (CFR), Title 40, Section 58.20(d), requires states to complete and submit to the U.S. Environmental Protection Agency an annual network review.

States are required to commit to and explain the air quality surveillance systems in their state implementation plans. The air quality surveillance systems consist of various sites designated as SLAMS, national air monitoring stations (NAMS) and PAMS. To provide a complete review of the air monitoring network, ADEQ chose to include additional stations classified as special purpose monitoring stations (SPM), which includes urban haze monitoring sites, IMPROVE sites, ADEQ visibility stations located in or near mandatory Class I areas and source-oriented monitoring sites operated independently by the permittee.

The annual network review determines conformance with the requirements of 40 CFR Part 58, Appendix D (*Network Design Criteria*) and Appendix E (*Probe and Path Siting Criteria*) for sites classified as SLAMS, NAMS, PAMS and SPM. Class I monitoring sites are subject to specific siting and operational guidance developed by the IMPROVE Steering Committee.

Results of the annual network review are used to determine how well the network is achieving its required air monitoring objectives, how well it meets data users' needs and how it should be modified (through termination of existing stations, relocation of stations, establishment of new stations, monitoring of additional parameters, and/or changes to the sampling schedule) in order to continue to meet its objectives and data needs. The main purpose of the review is to improve the network to ensure that it provides adequate, representative and useful air quality data.

During 2001-2002 ADEQ anticipates developing or refining existing network plans for the national ambient air quality standards and urban haze ambient monitoring programs that will define specific program goals and objectives. The initial monitoring plans will use recommendations made in the annual network review and will go through a review every two to three years considering factors such as data results and completeness, site representativeness, and data representativeness. The monitoring plan review will also tabulate network review results accumulated over the prior three-year period and will recommend changes to the monitoring plans and instrument or operating requirements. A Phase II network review, aimed at addressing site representativeness, will be conducted during 2001 for each conventional pollutant and the results will be integrated into future network monitoring plans.

Monitoring Methods

The gaseous conventional pollutants – SO_2, O_3, NO_2, CO, PM_{10} (TEOMs) and optical characteristics of the atmosphere (total light extinction, light absorption by gases, light scattering by particles and light absorption by particles) – are monitored with continuous analyzers taking approximately one pollutant sample per second. These values are averaged on an hourly basis and recorded to the correct number of significant digits, based on the form of the air quality standards and the detection limits of the instrument. In most cases, the hourly data are summarized into the appropriate multihour averages. Regular checks of the stability, reproducibility, precision and accuracy of these instruments are conducted by the agency or company network operators. Precision and accuracy of ambient data are assessed across an entire network using statistical tests that EPA requires.

Particulate lead (Pb), PM_{10} and $PM_{2.5}$ are usually sampled for 24 hours, from midnight to midnight, most often on every sixth day. Using a timer, ambient air is drawn through an inlet of a specified design at a known flow rate onto a filter that collects all PM less than a diameter specified by the inlet design. The filters are weighed before and after the sample period to determine the difference in mass and then divided by the product of the flow rate with the elapsed time to arrive at a mass per unit volume concentration. In the case of Pb, the filter is then subjected to chemical analysis to determine the amount of Pb particulate and integrated with the flow rate and timer information to calculate the concentration. These data are summarized into the appropriate quarterly or annual averages. These samplers are also certified as federal reference or equivalent methods. Regular checks of the stability, reproducibility, precision and accuracy of the samplers and laboratory procedures are conducted by the agency or company network operators. Again, precision and accuracy of ambient data are assessed across an entire network using statistical tests that EPA requires.

Visibility monitoring methods are generally divided into the three groups of optical, scene and aerosol (PM). Monitoring of visibility requires qualitative and quantitative information about the causes of haze (what is in the air, e.g., the formation, transport and deposition of pollutants) and the nature of haze (what are the optical effects of those pollutants to the observer). Scene conditions of visual air quality associated with hazes are recorded with a color video camera, which uses a Super-VHS format and is programmed to advance at the rate of one frame every four minutes during daylight hours. The video recording system is set to start just before sunrise and to stop just after sunset each day. Scene information can also be obtained from 35 millimeter slides, which are taken at the same times each day to establish baseline conditions, and track variations in haze.

Quantitative measurement of light extinction (B_{ext}) has four components:

- Light scattering by gases (B_{sg})
- Light absorption by gases (B_{ag})
- Light scattering by particles (B_{sp})
- Light absorption by particles (B_{ap})

Mathematically, the relationship is expressed as follows:

$$B_{ext} = B_{sg} + B_{ag} + B_{sp} + B_{ap}$$

where the units are inverse megameters (Mm^{-1}), or the amount of light removed per million meters of distance a viewer looks through.

Total optical light extinction (B_{ext}) is measured directly with a device called a transmissometer. The transmissometer generates visible light in the same wavelength (550 nanometers) as the human eye detects and then transmits that light beam over a sight path of several kilometers to a photocell detector. The transmissometer's design and operation allow its data to be directly correlated with human perception of visibility through the atmosphere. Transmissometer data are also used to check the general accuracy of the sum of the components of light extinction as measured by other continuous monitors. Two monitors have been operated in Phoenix and Tucson since 1993.

Light scattering by gases (B_{sg}) is a function of air density and is unrelated to air pollution sources. This parameter is derived and does not require measurement. In contrast, the other three components of light extinction are human-caused and require measurement with continuous monitors. Light absorption by gases (B_{ag}) is determined by continuously measuring nitrogen dioxide (NO_2) since it is the only gas normally present in urban or Class I Areas that absorbs significant quantities of visible light. Several EPA reference or equivalent method NO_2 monitors are deployed to verify maintenance of the national ambient air quality standards throughout the Tucson and Phoenix metropolitan areas, while the National Park Service network tracks NO_2 at several national parks in Arizona.

Light scattering by particles (B_{sp}) is determined by continuously, directly measuring particle scattering variation in a calibrated ambient sampling chamber called a nephelometer. The nephelometer samples air at ambient temperature and relative humidity conditions. Routine monitoring with this instrument began in both the Class I Area and urban haze networks during 1996. Light absorption by particles (B_{ap}) is determined by continuously measuring the quantity of light transmitted through a filter tape or intermittently through a filter from a PM sampler. Data from these analyses are reported in micrograms per cubic meter ($\mu g/m^3$) of elemental carbon and are converted to the B_{ap} units of Mm^{-1} using a laboratory-derived light absorption coefficient. Routine data collection using a continuous instrument, the aethalometer, began in December 1996 in Phoenix and February 1998 in Tucson. B_{ap} is also measured intermittently using the PM sample filters collected in both the Class I Area and urban haze networks.

In monitoring visibility, it is also essential to collect and analyze particulate samples to define and to understand the chemistry of aerosols present before, during and after haze events. The chemical speciation data can be used to determine the contributions of each source category to the observed optical haze data. From these filter data, the chemical components are used to calculate light extinction for the filter sample period and compare with continuous measurements as a check. Finally, the samplers used in the urban haze networks also monitor compliance with PM_{10} and $PM_{2.5}$ national air quality standards, and provide information on the categorical source contributions to observed PM_{10} and $PM_{2.5}$ concentrations. Sampling frequency for PM in the urban networks is generally every sixth day and every third day in the ADEQ and IMPROVE Class I Area networks. Every day sampling at all monitoring sites would be cost-prohibitive and personnel-intensive using current particulate sampling technologies.

To more fully understand the causes of hazes often associated with certain atmospheric conditions, it is necessary to monitor certain meteorological parameters. For these reasons, each network includes meteorological data such as temperature, relative humidity, wind speed and direction. Routine measurements of upper air temperature and water vapor are not made in the Phoenix area but information from the twice-daily rawinsonde launches by the National Weather Service at Tucson, Flagstaff, Las Vegas, NV and El Paso, TX are used to characterize the air masses over Arizona.