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Guidance For Estimating Ambient Air Monitoring Costs For Criteria Pollutants And Selected Air Toxic Pollutants

GUIDANCE FOR ESTIMATING AMBIENT AIR MONITORING COSTS FOR CRITERIA POLLUTANTS AND SELECTED AIR TOXIC POLLUTANTS

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LIST OF ACRONYMS

AAS	atomic absorption spectrophotometer
AIRS	Aerometric Information Retrieval System
CO	carbon monoxide
CPTL	capital expenditures
DNPH	dinitrophenylhydrazine
ECD	electron capture detector
EPA	United States Environmental Protection Agency
GC/FID	gas chromatography with flame ionization detection
GC/MS	gas chromatograph/mass spectrometer
HPLC	high performance liquid chromatography
ICAP-OES	Inductively coupled argon plasma optical emission spectrometry
IMPROVE	Interagency Monitoring of Protected Visual Environments
MSA/CMSA	Metropolitan Statistical Area/Consolidated Metropolitan Statistical Area
NAA	neutrons activation analysis
NAAQS	National ambient air quality standards
NAMS	National Air Monitoring Stations
NaOH	sodium hydroxide
NDMA	nitrosodimethylamine
NIST	National Institute of Science and Technology
NO_x	nitrogen oxides
O_3	ozone
O/M	operating/maintenance
OM	oscillating microbalance
PAMS	Photochemical Assessment Monitoring Stations
Pb	lead
PC	personal computer
PCBs	Polychlorinated Biphenyls
PM-10	particulate matter with an aerodynamic diameter equal to or less than a nominal 10 micrometers
PRO1	Professional I
PRO2	Professional II
PRO3	Professional III
PRO4	Professional IV
PUF	polyurethane foam
QA	quality assurance
QA/QC	quality assurance/quality control
RASS	radio acoustic sounding system
SIP	State Implementation Plan
SLAMS	State and Local Air Monitoring Stations
SO_2	sulfur dioxide
SSI	size selective inlet
SVOCs	semi-volatile organic compounds
TEC1	Technician I
TEC2	Technician II
TSP	total suspended particulates

LIST OF ACRONYMS (continued)

UV	ultraviolet
VOC	volatile organic compound
XRF	X-ray fluorescence

SECTION 1.0

INTRODUCTION

Since 1979, the United States Environmental Protection Agency (EPA) has issued three documents for estimating costs of ambient air quality monitoring. The first of these, *Cost of Monitoring Air Quality in the United States* (1979), provided capital, operation and maintenance costs for criteria pollutants and selected meteorological parameters.[1] This document was updated in 1985 by the document *Cost of Ambient Air Monitoring for Criteria Pollutants and Selected Air Toxic Pollutants*.[2] The 1985 document updated the previous cost estimates and developed new costs for measurements of selected air toxic compounds and visibility related parameters. Costs for criteria pollutant measurements only were updated in 1987 in the document *Cost of Monitoring for Selected Criteria Pollutants (An Internal Report)*.[3]

The purpose of this document is to update the previous cost estimates and to develop cost estimates for the following additional measurement categories:

- Additional air toxics methods to cover, to the extent currently possible, measurement of the 189 compounds identified in Title III of the amended Clean Air Act
- Methods related to Photochemical Assessment Monitoring Stations (PAMS)
- Saturation sampling for PM-10 and carbon monoxide (CO) using portable samplers

This document also describes the design and implementation of a model to be used in developing and presenting costs across different measurement methodologies. This approach has a number of advantages over developing cost estimates using different cost structures for different measurements. Details of the approach and its advantages are discussed in Section 2 of this document.

Sections 1 (Introduction) and 2 (Approach) outline the philosophy and methodology used for developing monitoring cost estimates. These sections provide the perspective needed to understand the discussions and presentations throughout the document.

Section 3 discusses general cost considerations associated with the range of activities that make up a complete monitoring system. This section provides a description of each activity as defined for this document and discusses general cost considerations and specific dollar costs as appropriate.

Sections 4 through 9 provide cost estimation criteria and detailed cost tables for each measurement category. Each of these sections presents background information sufficient to outline the most prevalent monitoring requirements and monitoring applications for each type of measurement. Costs are presented in detailed tables organized by activity. Costs are then summarized as total capital and annual operation and maintenance expenses, and lifetime annualized cost.

Section 10 provides an example cost calculation for a hypothetical monitoring network.

1.1 REFERENCES

1. PEDCo Environmental, Inc. *Cost of Monitoring Air Quality in the United States*. United States Environmental Protection Agency, Monitoring and Data Analysis Division. November 1979.

2. PEI Associates, Inc., *Cost of Ambient Air Monitoring for Criteria Pollutants and Selected Air Toxic Pollutants*. EPA-450/4-85-004. U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards. May 1985.

3. *Cost of Monitoring for Selected Criteria Pollutants (An Internal Report)*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Technical Support Division, Monitoring and Reports Branch. November 1987.

SECTION 2.0

APPROACH

The overall philosophy for the revised guideline is to provide a structure for an agency to use in calculating its own monitoring costs by giving a detailed breakdown of costs for each measurement type. Costs presented in the guideline should be reasonably accurate; however, a given agency should modify these costs as appropriate.

It is reasonable to expect that the estimated level of effort needed to conduct similar monitoring activities will vary significantly across various agencies. Some of this variability will result from differences in the way in which State and local agencies account for level of effort expenditures; however, the disparity is also likely to be due largely to actual differences in effort expended. States should apply their own level of effort estimates as needed in place of those adopted for the guideline.

Capital costs and expenses for consumables should remain reasonably constant across agencies. The guideline should serve effectively as a reference for these costs. Cost estimates in the guideline are based on the most likely methods, materials, and equipment to be used for each monitoring system.

2.1 COST MODEL

A generalized cost model was used to provide a consistent cost structure to be applied in developing cost estimates for each monitoring system presented in this guideline. This gives an overall structure to the cost estimates provided that should increase ease of use. Using a consistent format to develop and present costs across different monitoring systems should also enable States to more easily accumulate costs across the range of measurements that make up their total monitoring program. Other advantages of this approach include the following:

- A comprehensive list of major activities and cost elements is addressed for each monitoring system. This helps ensure that all relevant costs are considered.
- The generalized cost model imposes a consistent format for developing cost structures. This format provides a basis for compatibility with computerized database structures and the capability to use the current document as a basis for future development of an automated cost estimation software package.
- Ancillary data, such as the cost estimation criteria, references and methods, are documented in a consistent fashion. This provides quality assurance (QA) for the cost estimates and should facilitate future updates and revisions to the cost document.

The model developed for this document organizes network costs in a hierarchical structure. The overall monitoring network is divided into individual monitoring systems. The costs of setting up, operating and maintaining each monitoring system are divided among generalized monitoring activities. Costs are incurred for unique elements within each activity.

2.1.1 Network

The overall network is comprised of one or more types of monitoring. Monitoring types are generally defined by a physical or regulatory grouping of pollutants or parameters. Monitoring types include criteria pollutant monitoring, air toxics monitoring, meteorological monitoring, photochemical assessment monitoring, visibility monitoring, saturation monitoring, and remote sensing.

2.1.2 Monitoring System

The next level at which costs are accumulated is individual monitoring systems. Monitoring systems are complete systems that are used to measure one or more pollutants or parameters. Monitoring systems are defined by a unique combination of the type of monitoring, the pollutants or parameters measured, and the sampling and analytical methods used. Each monitoring type is associated with a specific list of pollutants or parameters. Each pollutant or parameter might be routinely measured by one or more sampling and analytical methods. Unique combinations of these factors make up individual monitoring systems that incur distinct costs. Monitoring system costs include all of the activities required to conduct monitoring from network design through data reporting.

2.1.3 Activity

The costs for each monitoring system are addressed in terms of a fixed list of general activities that incur costs. These include network design and siting, station installation, sampling, analysis, maintenance, data management and reporting, quality assurance/quality control (QA/QC), and supervision. This list covers the range of activities required to set up, operate, and maintain a monitoring station, and collect and report quality assured data.

The level of effort required to conduct some activities can be considered somewhat independently from individual monitoring system costs. That is, the costs are similar regardless of the pollutant or parameter being measured. For example, data management costs might depend more on whether the data are collected by a continuous analyzer or by an intermittent sampler than on the type of measurement. The costs for other activities may be more directly linked to particular monitoring systems and incur very different costs depending on the pollutant or parameter measured. Sampling and analytical costs, for example, are pollutant/method specific.

2.1.4 Cost Element

The costs for each activity are broken down into specific cost elements that incur cost directly. These costs may be for labor, durable goods (equipment), consumables and/or purchased services. The model provides for two levels of cost elements, which means that costs may be identified for a number of sub-elements under a single element. For example, equipment costs may be broken down into costs for the various components purchased. This provides a sufficient level of detail to the cost breakdowns without becoming overly burdensome. For clarity, the cost tables presented in this document do not distinguish between the two levels of cost elements used in the model.

While there are a fixed number of well-defined methods and activities used in the model, each individual activity may include a variety of cost elements, determined by the specific circumstances. This provides the flexibility necessary to adapt the model to the various methods. The cost elements should be clearly defined. To help ensure this, cost elements were reviewed for clarity and consistency before actual dollar cost estimates were obtained. The cost breakdowns should be similar enough from method to method to allow determining costs across several methods.

Supplemental data including the amortization period, the basis for annualization, references, and comments are provided for each unique cost element. These data provide additional information necessary for cost estimation and QA purposes. These supplemental data are not presented in the cost tables, but are discussed in the text. They will be retained for use in revising and updating the document. The cost tables are footnoted for clarity.

2.2 COST CALCULATIONS

Cost estimates are based on existing literature and direct monitoring experience. Current costs for equipment and supplies are verified with vendors. Level of effort estimates are verified with selected State and local agencies.

Costs for each monitoring system are presented in detailed tables by activity and cost element. This provides a logical and complete breakdown of costs that can be used directly or used as a structure for accumulating an agency's actual costs for more refined estimates. Each monitoring system will incur costs for labor and purchases of durable goods, consumables, and services. Some of these costs are one time, capital expenditures, and some are annual operation and maintenance costs. Total capital expenditures and annual operation and maintenance costs are summed. Capital expenditures are also annualized over the appropriate amortization periods and combined with annual operation and maintenance costs to give an average annualized cost over the lifetime of the system. This document assumes that the lifetime of most monitoring systems is 5 years.

Operation and maintenance costs are annualized based on a typical sampling schedule assuming that the monitor is operated throughout the year. Some monitoring systems, however, may not be operated throughout the year. For example, PAMS are only required to operate for 3 months during the primary ozone season. In such instances, cost estimates are presented as appropriate. If a monitor will not be operated throughout the year, cost estimates presented in this document should be adjusted accordingly.

The individual cost tables reflect costs for a single, complete monitoring station. When more than one monitor is located at a single site, there are obvious cost savings in several categories including land use, site preparation, shelters, and power. Further savings may be realized for certain combinations of monitors at a single site. When total network costs are accumulated, costs should be adjusted accordingly. This issue is addressed in the example network cost calculation in Section 10 of this document.

Services can be contracted outside the monitoring agency to conduct activities ranging from limited laboratory work to operation and maintenance of a complete monitoring program. In many cases, the proportion of capital versus operation and maintenance expenses depends on whether work is conducted in-house by the monitoring agency, or contracted to a service provider. For example, laboratory services contracted on a per sample basis would be considered an operation and maintenance cost, while laboratory work conducted in-house would involve significant initial capital equipment expenditures. The totals for the two options can be compared by reviewing the total annualized cost including amortized capital expenditures. The cost estimates presented in this document are intended to reflect a reasonable combination of in-house and contract services. Costs for multiple options are presented where appropriate. Cost estimates should be adjusted as needed to reflect the amount and type of contract assistance used.

For the purpose of this document, labor rates are divided into four professional and two technical levels. These levels are described including the necessary education, training and experience.

Technician I (TEC1) A technician I, or junior technician, has the training required for routine site operations. The technician is capable of keeping accurate records and making and recording correct observations of events that may have an impact on data quality. Good writing, arithmetic, and communication skills are required; however, no formal education beyond high school is necessary. An associate's degree is preferred.

Technician II (TEC2) In addition to the skills required of a technician I, a technician II has the training, education, and experience necessary to install, calibrate, and maintain most types of monitoring equipment. The technician understands the mathematics applied to statistical QC, linear regression, and unit conversions. In addition, a sound understanding of QA principles is required. In most cases, a technician II would have at least 2 to 6 years of work experience or an associate's degree along with 1 to 3 years of training and work experience.

Professional I (PRO1) A professional I would be assigned responsibility for fairly routine tasks such as QC data processing, and operational data validation (level I). A professional I might also serve as a laboratory technician. A bachelor's degree or equivalent would be required in a suitable scientific area and up to 3 years of work experience.

Professional II (PRO2) A professional II would have responsibility for more critical tasks requiring experience and judgement. These would include participation in network design and QA planning, supervision of site operations, statistical data validation (level II), and report preparation. An experienced laboratory technician might also be at the professional II level. A bachelor's degree or equivalent in a suitable scientific field and a minimum of 3 to 8 years of work experience or a master's degree and 1 to 6 years of work experience would be required.

Professional III (PRO3) A professional III is a senior technical staff member with key responsibility for management and direction of monitoring programs. The professional III would participate actively in the technical labor effort required for planning, development, and day to day management of the monitoring network, sharing many of these tasks with the professional II. The professional III should have a bachelor's degree and a minimum of 8 to 14 years of work experience or a master's degree and 6 to 12 years of work experience.

Professional IV (PRO4) The professional IV is a senior management and/or senior technical staff member. The professional IV would be responsible for overseeing the overall monitoring program and establishing policy to ensure compliance with the relevant regulations. This person would also consult with and review the work of the lower level professionals. The professional IV would coordinate with industry and other agencies in defining the direction and role for the agency's air monitoring program. The professional IV should generally have a master's degree and more than 12 years of work experience or a doctoral degree and more than 10 years of work experience.

Fully loaded labor rates are used in this document for technical and professional labor hours. Loaded rates include benefits and overhead costs, using a factor of 2.5 times the hourly rate paid to the employee. Table 2-1 lists the loaded rates for each professional and technical level.

TABLE 2-1. LABOR RATES

Professional/Technical Level	Labor Rate ($/hour)	Loaded Labor Rate ($/hour)
Junior Technician (TEC1)	12.00	30.00
Senior Technician (TEC2)	13.20	33.00
Junior Professional (PRO1)	14.40	36.00
Mid-level Professional (PRO2)	16.80	42.00
Staff Professional (PRO3)	20.00	50.00
Senior Professional (PRO4)	26.40	66.00

SECTION 3.0

GENERAL COST CONSIDERATIONS

This section describes the range of activities that make up a complete monitoring program and discusses the costs associated with each. To avoid redundancy in the presentations for individual monitoring systems, detailed cost estimates are provided for eight general monitoring activities whose costs do not depend on the specific monitoring systems used. These eight activities are (1) network design and siting, (2) station installation, (3) sampling, (4) analysis, (5) maintenance, (6) data management and reporting, (7) QA/QC, and (8) management and supervision. Activities whose costs are highly system specific are discussed briefly in this section, but are discussed in detail in the section for the specific monitoring systems involved.

3.1 NETWORK DESIGN AND SITING

Network design and siting costs depend on regulatory requirements and the emission, transport, and dispersion characteristics of the pollutants being measured. For criteria pollutants (and some non-criteria pollutants), network design criteria are outlined in the 40 CFR Part 58 regulations. This does not apply to all pollutants and parameters that might be part of an agency's monitoring program. Network design criteria are tailored to specific monitoring programs. In addition to site locations, the sampling schedule, averaging interval, and QA criteria may be predetermined by regulatory requirements, as in the case of the criteria pollutants. In the absence of specific regulations, it may be necessary to include consideration of these factors as part of the network design study. If an area requiring monitoring spans several States and/or EPA regions, the administrative complexity of an integrated network design will have an upward impact on costs.

A general network design procedure consists of the following steps:[1]

- Determine the monitoring objectives and the required spatial scales of representativeness
- Review emissions information and identify unique source characteristics
- Characterize topographic and land use influences
- Analyze available meteorological data
- Analyze existing monitoring data
- Perform air quality modeling analysis
- Select monitoring locations

In some situations, saturation monitoring or receptor modeling might also be conducted as part of a network design.

Each network design study must accommodate the requirements and circumstances peculiar to the area and the monitoring objectives. Thus, it is difficult to provide a generally applicable cost formula. It is important to consider these costs, however, because they can be significant. This document presents some rough approximations of the actual cost of network design.

To estimate the network design cost for a single monitoring system, total network design costs are divided by the number of stations in the network. Alternatively, in instances where multiple monitoring systems are usually collocated at a single station (as in visibility or PAMS monitoring), network design costs are estimated separately from individual monitoring system costs. In this document a network size of five sites is used where appropriate for cost estimation. Otherwise, the network size is discussed in terms of specific monitoring requirements for the pollutant or parameter to be measured.

Network design costs can be estimated in terms of burdened labor hours, which include overhead. These estimates include labor required for actual site selection. This usually involves a field trip to the area required by the network design to locate a point that meets specific probe siting criteria and allows for access, electricity and security. Network design costs are generally one time costs that would be amortized over the useful life of the network. Network lifetime is generally assumed to be 5 years for the purposes of this document. The cost of periodic network design reviews could be incorporated into this category as an additional, annual cost.

A relatively simple network design study involving a review of existing data might be accomplished in 100 to 200 hours at the PRO2 and/or PRO3 level, depending on the extent of the review, the availability and quality of the data, and other factors. A more involved analysis of the data could double this estimate. If existing data are insufficient, it may be necessary to gather the needed data, requiring additional time and resources.

A study involving dispersion modeling would add 100 to 200 hours at the PRO2 and PRO3 level, depending on the availability of high quality emissions and meteorological data suitable for model input. In complex terrain, or another situation where dispersion modeling estimates might not be as reliable, a saturation monitoring and/or receptor modeling study might be required.

Portable saturation monitors are currently available for particulate matter less than 10 microns in diameter (PM-10) and carbon monoxide (CO). A saturation study would require 400 to 600 hours for design, implementation, data analysis, and report presentation. This effort would be distributed among technicians and professionals from TEC1 (site operation) through PRO3 (network design). A receptor modeling study would probably require special monitoring, followed by modeling. The cost could range from several hundred to several thousand hours, in addition to any capital expenditures necessary to conduct the monitoring.

3.2 STATION INSTALLATION

Station installation costs include site acquisition, preparation, and procurement and installation of the monitoring equipment. The land for the site may be purchased, leased, or in some cases used without cost. Site preparations include providing access, electricity and security. Costs may include grading or leveling a site for a shelter or instrument platform, grading and paving or graveling an access road, providing electrical power and phone service for the site, and constructing fencing and installing lighting as necessary to prevent theft or vandalism. After the site is prepared, the shelter or platform and equipment must be transported to the site and installed. The equipment must then be made operational, calibrated, and prepared for routine monitoring.

Station installation costs include expenditures for durable goods, purchased services, and labor. These are one time capital costs that will be amortized over the lifetime of the monitoring station. For the purposes of this document, the lifetime of a monitoring station is assumed to be five years. The total costs for station installation are somewhat independent of the pollutant or parameter being measured. This is because site preparation costs can sometimes be significantly larger than equipment costs. While equipment costs are directly related to the pollutant being measured, site preparation costs may be more related to logistical factors. Site preparation costs are also dependent on factors specific to individual monitoring systems, such as whether a shelter is required or whether monitoring is conducted in a remote or populated area.

A plot of land sufficient for a monitoring site can be leased in some rural or suburban areas of the country for about $100 per month. Other areas may be significantly higher. In urban areas, sites may be located within buildings, on rooftops, or in parks. Sites located on public land or on land owned by universities, churches, or schools can often be leased for a nominal fee or used without cost. In some cases, the land or an easement on the land may have to be purchased. Real estate prices vary widely depending on the site location.

The cost of clearing, grading and providing an access drive to a site depends on the site's location and condition, and on the criteria for probe placement for the monitoring system to be installed. Bulldozing services can generally be obtained for between $60 and $100 per hour. Gravel for the roadbed would cost an additional $100 to $150 per 100 feet. For a site that is reasonably close to an existing roadway (within 300 feet), an access road can probably be graded and graveled for $500 to $1000. This assumes that the terrain is not unreasonably steep or rocky and that the area is not heavily forested.

The cost of clearing and grading an area large enough for a shelter or monitor platform (about 1000 square feet) is about $250 to $500 including the cost of reseeding the area in grass. This assumes that there are few large trees to be removed and that the surrounding area does not require additional clearing in order to satisfy probe placement criteria. If a larger area needs to be cleared and large trees removed, the cost could be much higher. Accurate estimates should be obtained from local contractors.

The local electric utility company will provide and install the cable, equipment and poles (or underground service) needed to connect the site to the electric grid. If the site is within a certain maximum distance from an existing power line, the utility should charge only a nominal application and hook-up fee ($50 to $100). For longer power drops, the utility will charge a hook-up fee based on the distance covered. Rates can be obtained from the local utility company. An electrician will be needed to install wiring from the weather head to the shelter or instrument platform. A typical wiring application using a pre-wired shelter should cost about $500 to $1,000. There will be additional expense if underground wiring is to be run to several instrument locations around the site. Estimates can be obtained from local electrical contractors.

If telephone lines are required at the site, the local telephone company will install telephone cable to the shelter for a nominal connection fee (about $50). A monthly service charge (approximately $25) will also be assessed.

Security fencing adequate to keep out intruders should be chain link, 6 to 8 feet high and topped by three strands of barbed wire. Fencing of this type to enclose a 30-foot square should cost about $1,200 to $1,800 installed. This includes a 12-foot gate, allowing an equipment shelter to be removed without being lifted over the fence. Security lighting should also be installed when necessary. A dusk to dawn security lamp can be leased from the electric utility for about $10/month (including power usage) or purchased and installed for about $100. Monthly power usage should be about 60 kilowatt hours. At 10 cents per kilowatt hour, the security lamp costs $6 per month to operate.

Total site preparation costs, including access, electricity and security, should range between $2,500 and $5,000. The lower end of this range represents the cost for a site located in a more developed area with ready access, while the higher end represents cost where access, clearing, and grading must be provided. In addition, there may be expenses for land lease or purchase. The estimates assume that the site is reasonably accessible, located near existing power lines, and does not require clearing a large area.

Equipment costs and the labor required to install, test, and calibrate the equipment depend on the particular monitoring system. These costs are addressed in detail in the cost tables for individual monitoring systems.

3.3 SAMPLING

Sampling costs include the labor and travel expense required for periodic field service of the monitoring station and the sampling media, and supplies and power required by the monitoring system. Field service consists of routine sampling media exchanges and routine periodic maintenance that can be performed by a junior technician (TEC1). Costs for more technically involved maintenance, both routine and remedial, are addressed under a separate activity for maintenance. Costs for routine calibrations and audits are addressed under the QA/QC activity.

Sampling costs depend on the monitoring system and on the amount of travel required to reach the sites. Different monitoring systems require different field service activities, sampling media, and supplies. Some systems, for example continuous analyzers for ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), do not use sampling media. Labor costs are estimated based on the frequency and activities required for individual monitoring systems. Specific costs are given in the cost tables for the individual monitoring systems.

For the purposes of this document, travel costs are generally estimated assuming a round trip to the site at 27.5 cents per mile. Travel distances are estimated based on the likely distance to the site for a particular monitoring system. For example, visibility stations are typically located in remote areas. This figure can be adjusted as appropriate. Annualized travel costs depend on the frequency of visits required for the monitoring system.

3.4 ANALYSIS

Analysis costs apply when separate laboratory analyses are conducted on samples collected in the field. Continuous monitoring systems, such as those for O_3, NO_2, and SO_2, do not incur analysis costs since the sampling and analysis are both conducted on-site by the analyzer. However, PM-10 and lead samplers expose a filter on-site, which must then be sent to a laboratory for analysis.

Analysis costs are measurement specific. Annualized costs depend on the number of samples collected in a year. Analyses can be conducted in-house by an agency laboratory or purchased from a contract laboratory. This document assumes that if laboratory work is conducted in-house, trained laboratory personnel and basic laboratory facilities will already be available. That is, no explicit cost estimates are provided for training personnel or building and furnishing a laboratory. Training costs are, however, reflected in the salary rate of the laboratory technician. Current costs for equipment and supplies needed for specific monitoring systems are provided in the cost tables.

The agency will need to total all the expenses required for in-house analysis and derive a cost per sample based on the total expenditures and the number of samples to be processed over the lifetime of the network. This calculation can be quite complex and will depend on the individual agency's overall analytical program.

The cost for in-house analyses can be compared to the cost of contract laboratory services on a per sample basis. Per sample analysis costs are presented in the cost tables based on current quotes from contract laboratories and a limited number of contacts with agency laboratories. The totals provided in the cost tables reflect a per sample analysis cost based on the most economical selection of in-house versus contract laboratory analytical services.

3.5 MAINTENANCE

Maintenance costs represent the cost of routine and remedial maintenance and repairs of the monitoring equipment. The specific maintenance activities are determined by the monitoring system used. Costs include labor, travel, equipment, spare parts and supplies. Maintenance is conducted by a senior technician (TEC2). After a sampler or analyzer is repaired, it must often be recalibrated. Remedial calibrations of this sort are also included under maintenance costs. Routine calibrations are accounted for under QA. The need for and cost of maintenance and repairs is determined by the particular monitoring system. A description of the required maintenance activities is provided in the text describing each monitoring system. Specific maintenance costs are included in the cost tables for the individual monitoring systems.

3.6 DATA MANAGEMENT AND REPORTING

Data management and reporting costs are incurred through the activities and resources necessary for data acquisition, data processing, data validation, and data reporting. Air quality data can be segregated into two broad categories: continuous data and intermittent data. Continuous data are collected by continuous analyzers and meteorological equipment. Data from continuous instruments are most often retrieved as an hourly average. Intermittent concentration data are the result of a calculation based on a flow rate or accumulated volume of air measured on-site and a mass of sampled material determined at a laboratory. Samples are generally collected over time intervals of 24 hours or longer, which may or may not be consecutive. The cost of data management depends on the volume of data handled, whether the data are continuous or intermittent, the level of computer automation employed, and on the operational characteristics of the particular monitoring system.

Data management can be achieved by manual or automated methods. In practice, most data management systems are computer based; however, they may not be completely automated. For example, such systems may require manual data entry and data editing. This document estimates data management costs primarily in terms of the level of effort (technical labor) required. These estimates include economies of scale that would be realized from a network containing a total of 12 or more continuous and intermittent monitors. The cost of the necessary computer resources is not explicitly estimated for each data management activity and monitoring system. Computers are often multi-use machines, and their costs may be divided among a number of activities conducted at the agency. Computers and other support equipment and services are considered part of general overhead, and their costs are reflected in the burdened labor rate. Where computers are required on-site, as part of the sampling or analytical equipment, their costs are included explicitly in the cost tables. For example, the automated gas chromatograph used for continuous VOC monitoring requires an on-site computer.

Most data management activities can now be conducted on a personal computer with a modem, adequate disk storage, and tape backup. The current hardware cost for such a system is $3,000 to $5,000. Software may be developed at the agency, provided by equipment vendors, or purchased separately. Software costs vary widely depending on the system implemented; however, software adequate to run a data management system on a personal computer should be available commercially for $1,000 to $2,000. This includes a communications system, a database system, and a statistical/graphics data analysis system.

Level of effort estimates in this document assume that an automated data management system is in place. Such a system would include data loggers on-site that are polled remotely by computer so that manual data entry is not required. Similarly, laboratory data should be received in an electronic format. Programs should be in place to automatically process and load data into a central database system. Statistical, graphical and error checking routines should be available to aid in data validation. Routine data reports should be generated automatically. Data should also be automatically uploaded to the national Aerometric Information Retrieval System

(AIRS). The cost of developing an automated data management system is not estimated in this document. System design is in an evolving state at most agencies. For practical reasons, existing equipment and software must continue to be operated as new systems are put into place. It is generally infeasible to implement a completely newly designed system. Since such circumstances vary greatly from agency to agency, it is not practical to use a generalized cost estimate for system design and implementation.

3.6.1 Data Acquisition

Data acquisition may be accomplished manually or automatically. Continuous data can be recorded using a data logger. The data logger can record on cartridges which are removed periodically and read at the monitoring agency, or the data can be automatically uploaded from the data logger via a telephone line and modem. Continuous data can also be plotted on strip charts and converted manually to numerical form. Strip charts are often used as a backup system to a data logger. Criteria pollutant monitoring costs for the gaseous pollutants CO, NO_2, O_3, and SO_2 include a strip chart recorder and data logger for each analyzer. Flow rates for an intermittent analyzer can also be recorded continuously using a data logger or strip chart. Flows may also be recorded manually by the site operator at the start and end of each sampling period. Analytical data will be delivered by the laboratory either electronically or as hard copy.

A fully integrated, automated data collection system can streamline the effort required for data acquisition; however, an initial investment is required to design and implement the system. The cost benefits of such a system are maximized when large volumes of data are involved. An automated system also provides superior QC to a system where human transcription is required. As a practical matter, most air agencies are currently in transition between a manual and a fully automated system.

In a survey of nine State and local agencies conducted in 1990,[2] the level of effort required to acquire data ranged from about 12 to 48 hours per monitor per year for continuous data and from 1 to 24 hours per monitor per year for intermittent data. The level of effort required to obtain intermittent data varied according to the pollutant being measured mainly as a function of laboratory data reporting procedures. Level of effort estimates for intermittent data were based on 15, 24-hour samples per quarter. One source of variability in the level of effort estimates in the survey is the accounting practices used at the various agencies. Data acquisition activities are defined differently at different agencies. At some agencies, initial data screening costs could not be separated from the data acquisition costs.

As more agencies adopt automated data handling systems, the level of effort required for data acquisition should move towards the lower end of the range presented in the survey. A generally applicable estimate is 12 to 24 hours per monitor per year for continuous data acquisition and 12 to 16 hours per monitor per year for intermittent data acquisition. These estimates assume that automated data acquisition systems are used where applicable. The estimates also include the effort required for an initial screening to detect any obvious errors such as formatting errors, date/time errors and data gaps.

3.6.2 Data Processing

Data processing costs include the effort to properly format the data and upload it to the agency's central database. This might involve computer file format conversions, application of initial error and missing data codes, and generation of summary reports for use in data validation. Data processing is the link between the agency's data acquisition and database systems. In a fully automated system, this link might be transparent to the system user and require very little effort to operate and maintain. Specific data processing activities will depend on the data management system in use at a particular agency.

Data processing costs ranged from 2 to 24 hours per monitor per year for continuous data and 1 to 6 hours per monitor per year for intermittent data in the 1990 survey of nine State and local agencies.[2] This range reflects the variability in the configuration of each agency's data handling systems and also variability in accounting for how various data management tasks are performed. A reasonable estimate for data processing costs is 6 to 12 hours per monitor per year for continuous data and 2 to 4 hours per monitor per year for intermittent data. The cost reflects the effort needed to monitor the system and verify its proper operation.

3.6.3 Data Validation

Costs are given in this document for two levels of data validation. These are referred to as operation data validation (Level I) and statistical data validation (Level II). Operational data validation constitutes a review of all available field information and application of appropriate data screening criteria. Operational data validation checks may include the following: power failure, instrument off line, instrument undergoing calibration, zero/span check or maintenance activity, instrument out of calibration, date/time errors, instrument malfunction, data logger malfunction, missing data, and unusual local sources. Data quality flags can be applied to indicate the occurrence of one or more of these conditions. Once operational checks have been completed, the data can be reviewed using statistical and graphical methods. Level II validation checks may include the following: control limit exceedance, excessive rate of change, spike, abnormal stability (persistence), inter-parameter tests, outlier tests, and data below the limit of detection.

According to the 1990 survey of nine agencies,[2] the level of effort required for data validation is 4 to 36 hours per monitor per year for continuous data and 2 to 8 hours per monitor per year for intermittent data. The range reflects variations in the degree of automation and in accounting practices. A reasonable estimate is about 12 hours per monitor per year for continuous data and 6 hours per monitor per year for intermittent data.

3.6.4 Data Reporting

Data reporting costs represent the cost of generating routine air data reports and transmitting air quality data to AIRS. This includes preparing any necessary data formats and summaries. This should be an automated procedure. According to the 1990 survey,[2] the level of effort for required data transmission to AIRS is about 1 to 4 hours per monitor per year for continuous and intermittent data. A reasonable estimate would be 2 to 4 hours per monitor per year to generate routine data reports and transmit data to the AIRS.

3.6.5 Combined Data Management Costs

The total level of effort costs for a data management program range from 30 to 50 hours per monitor per year for continuous data and 20 to 30 hours per monitor per year for intermittent data. For example, a network containing 26 continuous monitors and 40 intermittent monitors would require about one full-time equivalent position for data management. Data acquisition, data processing, Level I data validation and data reporting should be performed by a junior or mid-level professional (PRO1 to PRO2). Level II data validation should be performed by a mid- to senior level professional (PRO2 to PRO3). For example, approximately 50 percent of the work would be at the PRO1 level, 25 percent at the PRO2 level, and 25 percent at the PRO3 level. These proportions vary according to the staff mix and system characteristics at each agency. Note that these level of effort estimates do not address costs for system development and maintenance, or hardware and software expenditures.

3.7 QUALITY ASSURANCE AND QUALITY CONTROL

QA is a system designed to ensure that the data collected by the monitoring system are of known quality, and that the data quality objectives are met. QC is a system of routine procedures and checks designed to implement a QA program. A QA program involves planning and organizing a QC program and implementing procedures to verify proper QC and document data quality. QA is required for every monitoring program.

QA costs include planning and coordination, calibrations and certifications, audits, training, and data review and reporting. A QA plan must be prepared for each monitoring program. The QA plan should be prepared in accordance with guidelines contained in the *Quality Assurance Handbook for Air Pollution Measurement Systems*.[3] Monitoring instruments must be calibrated regularly, and the calibration standards must be certified. Performance and systems audits must be conducted on a regular schedule to document proper operations. Data recovered by the monitoring system and from calibrations, checks and audits must be evaluated for conformance with data quality objectives. A training program must be implemented.

The QA program will require expenditures for labor (planning and coordination), durable goods (calibration equipment), consumables (calibration standards), and purchased services (contract audits). Some of these costs are one time capital expenditures (equipment purchases, QA plan preparation), and others are annual expenses (routine calibrations, audits). Data validation is generally viewed as a QA activity; however, for cost estimation purposes, data validation is addressed under the activity of data management. QA costs are generally specific to a given monitoring system. Costs are addressed in the cost tables for each monitoring system.

3.8 MANAGEMENT AND SUPERVISION

Management and supervision of a monitoring program involves overall planning of the scope of the monitoring program, coordinating implementation of the monitoring program, supervision of routine activities, and periodic review of practice and procedure. The monitoring program must be administered in view of local, State, and Federal policies requiring monitoring. The program must be updated to reflect current changes in regulations and technology.

The cost of management and supervision is estimated in terms of burdened labor hours for a senior professional (PRO3 to PRO4). The number of hours required to manage a monitoring program depends on the size and complexity of the program. Costs per monitoring system are estimated based on the administrative and operational complexity of the system. Total management costs are divided by the number of monitors to arrive at a cost per monitoring system.

In general, costs are estimated for two general categories of administrative activity: planning and coordination, and supervision and review. The monitoring manager is responsible for determining which types of monitoring are needed or required in the area and implementing programs to support the necessary monitoring activities. Once a monitoring program is in place, the supervisor should review periodic data and QA reports, and conduct supervisory activities to ensure that the monitoring program is conducted within budget and schedule. It is estimated that 16 hours per monitor per year are needed for planning and coordination. Another 16 hours per monitor per year are allocated for supervision and review. These are somewhat artificial estimates since, in practice, these activities apply across the network.

3.9 REFERENCES

1. Noll, K. and T. Miller, *Air Monitoring Survey Design,* Ann Arbor Science Publishers, Inc. 1977.

2. *Results of the 1990 Survey on Ambient Air Quality Data Management and Reporting Systems.* U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Monitoring and Reports Branch. January 1991.

3. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, *Quality Assurance Handbook for Air Pollution Measurement Systems: Volume I Principles.* EPA-600/9-76-005. December 1984.

SECTION 4.0

CRITERIA POLLUTANT MONITORING

4.1 BACKGROUND

Criteria pollutants include sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), carbon monoxide (CO) and particulate matter with an aerodynamic diameter equal to or less than a nominal 10 micrometers (PM-10). Requirements for establishing uniform ambient air quality monitoring for the criteria pollutants came as a result of Section 319 of the Clean Air Act Amendments of 1977. EPA promulgated regulations in 1979 for establishing ambient monitoring networks for the criteria pollutants under 40 CFR Part 58.[1] Part 58 includes requirements for network design and siting, QA, monitoring methodologies, probe siting, data reporting, and determination of air quality indices. National ambient air quality standards (NAAQS) for each of the criteria pollutants are contained in 40 CFR Part 50.[2] Reference methods for measuring the concentrations of each of the criteria pollutants are included in the Appendices to Part 50.[3]

Requirements for maintaining NAAQS for the criteria pollutants are contained in 40 CFR Part 51.[4] In general, Part 51 requires areas which are not in attainment with the prescribed NAAQS (*i.e.*, nonattainment areas) to develop and implement control strategies for attaining the NAAQS within a specified time period. Such control strategies include the use of air quality models and/or ambient air quality data for demonstrating attainment of the NAAQS by the required date. More specifically, Part 51 requires that ambient air quality monitoring programs be established in nonattainment areas, in accordance with the provisions of Part 58 as a means of determining the NAAQS attainment/nonattainment status of the designated area.

For areas which are currently in attainment with the NAAQS, Part 51 includes provisions for ensuring prevention of significant deterioration (PSD) to the ambient air in the respective areas.[4] In some cases, certain major stationary sources and source modifications which are applying for construction permits in these attainment areas may be required to conduct preconstruction ambient monitoring for certain criteria or noncriteria pollutants. The required monitoring generally must adhere to the provisions of 40 CFR Part 58.

An acceptable State Implementation Plan (SIP) must include the establishment of an air quality surveillance system for monitoring ambient air concentrations for those pollutants for which standards have been established in Part 50, and for affected agencies, for ozone precursors, and surface and upper air meteorological parameters. Such a surveillance system is referred to as the State and Local Air Monitoring Stations (SLAMS) network and includes SLAMS, National Air Monitoring Stations (NAMS) and Photochemical Assessment Monitoring Stations (PAMS) sites.

The SLAMS and NAMS sites are established to measure concentrations of the criteria pollutants while the PAMS sites monitor for NO_2, O_3, ozone precursors (volatile organic compounds, other oxides of nitrogen, carbonyl compounds), and meteorological parameters. This section discusses the costs associated with criteria pollutant monitoring, and Section 7 covers monitoring costs for the PAMS sites.

Cost estimates are included for each of the criteria pollutants calculated for a single monitoring system. Amortization of capital costs is based on a 5-year period lifetime for a monitoring site. Where ranges of capital costs are provided, the corresponding annual costs are determined based on a reasonable estimate of the most likely methods and procedures to be used.

Travel costs for routine site service, maintenance and repairs, and audits are not explicitly estimated for criteria pollutant monitoring. Criteria pollutant monitoring is generally assumed to be conducted in non-remote areas within a reasonable distance (about 10 to 15 miles) from the base of operations for site operators and maintenance personnel. It is assumed that travel expenses are accounted for within general overhead expenses. General overhead is reflected in the multiplier applied to obtain the burdened labor rate. When remote sites are used, additional travel costs should be added.

4.2 COST ESTIMATES FOR LEAD MONITORING

Over the last decade, lead impacts from mobile sources have decreased rapidly due to the removal of lead additives from automotive fuel. As a result, the focus of lead monitoring has shifted from high traffic areas to point sources of lead such as primary and secondary smelters, and lead acid battery manufacturing and reclamation facilities.

Table 4-1 gives the costs associated with sampling and analysis for lead. The costs are based on daily sampling using a 48-hour sampling period. Capital expenditures (*i.e.*, one time costs) listed in the table as CPTL and annual operating/maintenance costs listed as O/M, as well as the professional level and amount of time needed to complete a given activity are provided. Table 4-2 gives the average (amortized) annual costs for capital expenditures and total costs for capital and operational measures.

A network design study for lead around point sources could include dispersion modeling to determine maximum impact areas from nearby point sources. Monitors may also have to be located to capture background concentrations from urbanized areas. Cost estimates for a network design study (including dispersion modeling) are based on approximately 375 hours divided between the mid and senior professional levels. The cost per site is obtained by dividing the cost of the study by five sites.

Site selection includes a field survey of candidate sites, and selection of final monitoring locations based the monitoring objectives and logistical constraints. Site selection costs are based on 24 hours per site at an average rate corresponding to a senior technician (TEC2).

Lead is usually sampled using a high-volume sampler, which is also used for sampling total suspended particulates (TSP). These are self contained, weatherproof samplers. A complete sampler including flow control and recording equipment can be obtained for about $2,000. Site preparation costs assume a new but reasonably accessible site. Costs include constructing a platform for the sampler and/or securing the sampler to the roof of a shelter. It is assumed that the site may need to be fenced and lighted to prevent vandalism. The estimate for site preparation includes labor and materials. The work may be done in-house or contracted out.

TABLE 4-1. COST ESTIMATES FOR LEAD DAILY SAMPLING (48-Hour Sampling Period)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Network Design				
Network design study*	CPTL	PRO2	40	1,680
Network design study*	CPTL	PRO4	35	2,310
Site selection	CPTL	TEC2	24	792
Site Installation				
Procurement	CPTL	PRO1	8	288
Land/lease	O/M			1,500
Site preparation	CPTL			3,000
Power drop	CPTL			350
High volume sampler (complete)	CPTL			2,000
Equipment installation	CPTL	TEC2	8	264
Sampling				
Filter media	O/M			400
Supplies	O/M			200
Utilities	O/M			600
Site service	O/M	TEC1	270	8,100
Maintenance				
Spare parts/supplies	O/M			200
Repairs	O/M	TEC2	8	264
Routine maintenance	O/M	TEC2	16	528
Analysis				
Laboratory services	O/M			1,000
Data Management				
Data acquisition/processing	O/M	PRO1	10	360
Data reporting	O/M	PRO2	8	336
Data validation	O/M	PRO2	12	504
Quality Assurance				
Audit/calibration kit	CPTL			125

(Continued)

TABLE 4-1. COST ESTIMATES FOR LEAD (48-Hour Sampling Period) (Continued)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
QA plan preparation	CPTL	PRO2	16	672
Audits	O/M	TEC2	16	528
Training	O/M	TEC2	8	264
Reporting	O/M	PRO2	8	336
Implementation/coordination	O/M	PRO2	16	672
Supervision				
Planning/coordination	O/M	PRO3	16	800
Supervision/review	O/M	PRO3	16	800
Total Capital (CPTL) Costs				11,481
Total Operation and Maintenance (O/M) Costs				17,392

* - Asterisk denotes dispersion modeling conducted for network design.

TABLE 4-2. LEAD COST SUMMARY DAILY SAMPLING (48-Hour Sampling)

Cost Type	Cost
Capital Costs	11,481
Annualized Operation and Maintenance Costs	17,392
Average Annualized Cost**	19,688

**Average annualized cost is obtained by dividing the capital cost by five (the number of years used for amortization), and then adding the annualized operation and maintenance costs. Average annualized cost = 11,481/5 + 17,392 = 19,688.

TABLE 4-3. LEAD COST SUMMARY (1/6 Day Sampling Schedule)

Cost Type	Cost
Capital Costs	9,771
Annualized Operation and Maintenance Costs	10,130
Average Annualized Cost**	12,084

**Average annualized cost is obtained by dividing the capital cost by five (the number of years used for amortization), and then adding the annualized operation and maintenance costs. Average annualized cost = 9,771/5 + 10,130 = 12,084.

Sampling for lead involves routine site visits to replace filter media, record flows, and maintain the sampler. A sampling schedule of 1 sample every 6 days has traditionally been used to characterize mobile source impacts. Due to the increased variability in atmospheric lead concentrations near point sources, every day sampling is recommended in these locations. The cost estimates provided in Table 4-1 reflect a daily sampling schedule. A summary of the captial, O/M, and annualized costs for a 1/6 day sampling schedule is given in Table 4-3. The daily sampling estimates assume a 48-hour sampling period. A noon-to-noon sampling period is assumed so that it is not necessary to use two samplers to obtain consecutive samples as it would be with a midnight-to-midnight period. The labor estimates for site service include travel time. Alternative sampling strategies can be used to help mitigate the increased cost of daily sampling. These include 48-hour sampling periods, flexibility in sample start and stop times, and composite filter analysis.

Sampling supplies include filters, folders, envelopes, flow recorder charts, and inks. Either quartz or glass fiber filters may be used for sampling. Filters cost approximately $2 each. Cost estimates assume 200 filters per site per year for 48-hour sampling, allowing for blanks and damaged filters. Power consumption is about 6000 kilowatt hours per year, assuming continuous operation.

Lead analysis is conducted on a filter extract by atomic absorption spectrophotometry (AAS). Analysis may be done in-house or contracted out. The cost estimate assumes that 8-day samples are composited for each analysis (four 48-hour samples). Approximately 50 analyses would be needed per sampler per year including QC samples. The per sample cost for contract analysis is about $20. This includes the cost of shipping the samples to and from the laboratory. In-house analysis requires purchasing the AAS instrument and associated equipment and supplies and providing laboratory space and a trained technician to conduct the analysis. The cost of AAS equipment ranges from $55,000 to $95,000 depending on the degree of automation desired. The per sample cost would depend on the sample volume. Shipping costs are assumed to be rolled into the cost per sample.

Routine maintenance involves cleaning and lubricating the sampler, inspecting gaskets and electrical connections, replacing the pump motor brushes, inspecting the pump bearings and housing, and recalibrating inlet flow rates. The average cost for spare parts and maintenance supplies is estimated at $200 per sampler per year. Quarterly routine maintenance is assumed for the cost estimates. An additional maintenance visit is allowed for remedial maintenance (repairs).

Data management activities and level of effort per sample are typical of those for intermittent sampling. Intermittent data acquisition and processing involves obtaining the laboratory data reports, formatting the data as necessary, and integrating them with the agency's data management system. The total cost may be somewhat higher than average intermittent data management costs based on a 1-in-6 day sampling interval due to the possibility of greater sampling and analysis frequency. For example, if cost estimates were based on data from approximately 200 samples per year (including blanks and QC samples) for 48-hour, every day sampling, instead of the 60 samples per year obtained with a 1-in-6 day sampling interval, then total data management costs would tend to run $720 for data acquisition/processing for 20 hours at the PRO1 level, $756 for data reporting for 18 hours at the PRO2 level, and $1,050 for data validation for 25 hours at the PRO2 level. For the assumptions used in Table 4-1, of 48-hour sampling interval and 4 samples composited for analysis, the data management costs are roughly comparable to those of 1/6 day sampling.

QA costs include preparation of the QA plan, coordination and supervision of the QA/QC program, flow audits, participation in an internal audit, reports, and training. QA costs are divided among the number of monitors in the network (assumed to be five). QA plan preparation is a one time (capital) cost. Coordination and supervision includes reviewing audits and field operations, and ensuring that procedures are followed and that necessary corrective measures are taken when necessary. Reports on QA activities, problems, and solutions should be prepared for management review once per quarter. Training is assumed to be an annual cost due to operator turnover. Flow audits must be conducted at least once per year on each sampler. Allowance is made for two flow audits per year for the cost estimate. Flow calibration involves using either a variable flow calibrator which uses a primary standard traceable to the National Institute of Science and Technology (NIST) or an orifice calibration kit. The cost for a variable flow calibrator kit which is used in the calculation shown is $625, and the cost for an orifice calibration kit, which is not used in Table 4-1, is $400. The cost of the flow calibration kit is divided among a network of five samplers and is shown in Table 4-1 as $125.

Management and supervision costs are estimated as for a typical monitoring program as discussed in Section 3.8.

4.3 COST ESTIMATES FOR PM-10 MONITORING

Both continuous and intermittent methods are available for ambient PM-10 monitoring. Intermittent methods are more common and include high volume samplers fitted with a size selective inlet (SSI), and dichotomous samplers. Of these, the SSI sampler is the most widely used for routine SLAMS and NAMS monitoring. The dichotomous sampler (Dichot) collects particulate in two size ranges: smaller than 10 microns and larger than 2.5 μm (coarse), and smaller than 2.5 μm (fine). The PM-10 concentration is the sum of the coarse and fine fractions. The filters are collected during site visits, and sent to a laboratory for weight determination.

Continuous PM-10 monitors include beta attenuation monitors and a continuous weighing, oscillating microbalance (OM). Both employ a size selective inlet. The beta attenuation monitor collects PM-10 on a filter tape. The deposit buildup on the tape is continuously recorded by measuring the attenuation of beta radiation through the tape. The tape is automatically advanced at preset intervals. The OM collects PM-10 on a small filter interfaced with an inertial mass transducer which allows near continuous weighing of the filter as the deposit accumulates. The filter is changed manually when the particulate loading rises beyond the tolerance limits of the device.

The cost for PM-10 monitoring, using each of these types of monitors, is estimated based on SLAMS/NAMS monitoring requirements. The dichotomous samplers and continuous PM-10 monitors are more often used in special circumstances. The dichotomous sampler is often used to collect data for receptor modeling applications. The continuous monitors are used in circumstances where there is large temporal variation in PM-10 concentrations, particularly in high concentration areas, or for PSI index reporting.

Network design and siting cost estimates are the same for each method based on SLAMS/NAMS monitoring requirements. A PM-10 network design study follows the network design methodology outlined in Section 3 of this guideline. Such a study may or may not include modeling. A reasonable estimate of costs for such a study, excluding modeling, is about 200 hours at the mid to senior professional level (PRO2 to PRO4). Using 75 hours at the PRO2 level and 125 hours of PRO4 time, such a study would cost $11,400. Assuming a network size of five stations, the cost per station can be estimated at $2,280. The inclusion of dispersion modelling would require approximately 175 additional hours (125 at the P2 level and 50 at the P4 level) for a total cost of about $19,950. Costs for site selection are based on the same assumptions used for site selection for lead monitoring.

4.3.1 Cost Estimates for Intermittent PM-10 Sampling

Cost estimates for intermittent PM-10 sampling are detailed in Table 4-4 and summarized in Table 4-5. Option 1 describes costs for sampling with an SSI sampler, and Option 2 describes the costs for a dichotomous sampler. The figures given in Table 4-4 are based on a 1 in 6 day sampling schedule. Table 4-5 summarizes costs for 1 in 6 (1/6), every other day (1/2), and every day (1/1 and 1/1a) sampling schedules for both methods. The 1/2 and 1/1 sampling schedules use two samplers at each site. Costs are also summarized for an every day sampling schedule using three samplers per site (1/1a). The capital costs for option 1/1a are higher; however, these are largely offset by lower operating costs since fewer site visits are required.

The cost increase due to a more frequent sampling schedule depends on the number of samples and the number of samplers. Some cost elements such as network design and siting, and the cost of a laboratory microbalance do not change with increased sampling frequency. Costs for such items as filter media and supplies increase directly with the number of samples. Capital equipment and installation costs increase directly with the number of samplers. Economies of scale are realized for laboratory analysis, data management and administrative costs. These factors were taken into account in projecting the costs for the more frequent sampling schedules.

The standard SSI sampler is designed to be operated outdoors without a shelter. Dichotomous samplers are commercially available in weatherproof configurations so that a shelter is not required. A complete PM-10 SSI sampler including high volume sampler, size selective inlet, flow control and recording equipment costs about $4,500. The dichotomous sampler costs about $8,000, complete. Assumptions used in estimating site preparation costs are the same as those used for lead sampling.

PM-10 sampling requires scheduled site visits to change the filter media and service the sampler. Sampling supplies include filter media, filter shipper holder envelopes (SSI) or petri slides (dichotomous), and flow recorder charts and inks. For 1-in-6 day sampling, about 75 filters should be allowed per SSI sampler per year. The SSI sampler uses 8 x 10 inch quartz fiber filters which cost about $2 each. The dichotomous sampler, which uses teflon filters costing about $3 each, requires twice the number of filters (150 filters) because of the two size

TABLE 4-4. COST ESTIMATES FOR INTERMITTENT PM-10 SAMPLING (1/6 Day Sampling Schedule)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Network Design						
Network design study	✓	✓	CPTL	PRO2	15	630
Network design study	✓	✓	CPTL	PRO4	25	1,650
Site selection	✓	✓	CPTL	TEC2	24	792
Site Installation						
Procurement	✓	✓	CPTL	PRO1	8	288
Land/lease	✓	✓	O/M			1,500
Site preparation	✓	✓	CPTL			3,000
Power drop	✓	✓	CPTL			350
SSI sampler (complete)	✓		CPTL			4,500
Dichotomous Sampler (complete)		✓	CPTL			8,000
Equipment installation	✓	✓	CPTL	TEC2	8	264
Sampling						
Filter media (PM-10)	✓		O/M			150
Filter Media (Dichotomous)		✓	O/M			450
Supplies	✓	✓	O/M			200
Utilities	✓	✓	O/M			100
Site service	✓	✓	O/M	TEC1	90	2,700
Maintenance						
Spare parts/supplies	✓	✓	O/M			200
Repairs	✓	✓	O/M	TEC2	8	264
Routine maintenance	✓	✓	O/M	TEC2	16	528
Analysis						
Microbalance	✓	✓	CPTL			1,500
Laboratory	✓	✓	O/M	TEC2	16	528
Data Management						
Data acquisition/processing (SSI)	✓		O/M	PRO1	8	288
Data acquisition/processing (Dichot)		✓	O/M	PRO1	12	432
Data reporting (SSI)	✓		O/M	PRO2	7	294
Data reporting (Dichot)		✓	O/M	PRO2	10	420

(Continued)

TABLE 4-4. COST ESTIMATES FOR INTERMITTENT PM-10 SAMPLING (1/6 Day Sampling Schedule) (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Data validation (SSI)	✓		O/M	PRO2	10	420
Data validation (Dichot)		✓	O/M	PRO2	15	630
Quality Assurance						
Audit/calibration kit (SSI)	✓		CPTL			125
Audit/calibration kit (Dichot)		✓	CPTL			200
QA plan preparation	✓	✓	CPTL	PRO2	16	672
Audits	✓	✓	O/M	TEC2	8	264
Training	✓	✓	O/M	TEC2	8	264
Reporting	✓	✓	O/M	PRO2	8	336
Implementation/coordination	✓	✓	O/M	PRO2	16	672
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	16	800
Supervision/review	✓	✓	O/M	PRO3	16	800
Total Capital (CPTL) Costs - Option 1						13,771
Total Operation and Maintenance (O/M) Costs - Option 1						10,308
Total Capital (CPTL) Costs - Option 2						17,346
Total Operation and Maintenance (O/M) Costs - Option 2						11,088

Option 1 - Sampling with an SSI sampler
Option 2 - Sampling with a dichotomous sampler

TABLE 4-5. INTERMITTENT PM-10 SAMPLING COST SUMMARY

Cost Type	Sampling Schedule			
	1/6	1/2	1/1	1/1(a)
SSI Sampler				
Capital	13,771	18,403	18,403	23,035
Annual O/M	10,308	14,441	21,730	20,430
Average Annual (5 yr)	13,062	18,122	25,411	25,037
Dichotomous Sampler				
Capital	17,346	25,478	25,478	33,610
Annual	11,088	15,821	25,130	23,830
Average Annual (5 yr)	14,557	20,917	30,226	30,552

fractions (coarse and fine). The dichotomous sampler uses comparatively small (37 mm diameter) circular filters. A variety of filter media are available for the dichotomous sampler; however, Teflon filters are most commonly used. Power consumption for both samplers is estimated at 1000 kilowatt hours per year based on running 24 hours in each 6-day period.

Routine maintenance of the SSI sampler is similar to that for the lead sampler. In addition to the maintenance requirements for the flow system, the SSI must be disassembled and cleaned. While the maintenance procedures vary, the spare parts and labor estimates for routine maintenance and repairs are the same for both the SSI and dichotomous samplers. These estimates are general figures that take into account variations in the need for maintenance and repairs among samplers within a network. Quarterly routine maintenance is assumed for the cost estimates for both methods. These visits include flow calibration. Allowance is made for one major or two minor repairs per year.

After being allowed to equilibrate in a desicator, filters collected by either the SSI or the dichotomous sampler are analyzed gravimetrically on a microbalance accurate to 0.1 mg. The cost of such a microbalance ranges from about $4,000 to $9,000. A reasonable estimate is $7,500. For the cost estimate, this cost is divided across a network containing five sites; however, a single microbalance is capable of handling filters from a network of up to 20 sites. The cost per filter analysis is reduced for larger networks. Gravimetric analysis involves filter conditioning and pre-weighing, filter weighing, and data reduction. The cost estimates are based on 75 filters per year for SSI sampling and 150 filters per year for dichotomous sampling. The analytical cost per filter is approximately the same for both methods. The labor required for data reduction is somewhat lower for the second filter from the dichotomous sampler since the flow rates and sampling conditions are the same as for the first filter; however, the dichotomous data also require the additional step of combining the weights from the coarse and fine fractions.

The costs of data acquisition and processing, validation, and reporting are typical of those for intermittent sampling data (see Section 3.6). Slightly higher data management costs are incurred for the dichotomous sampler due to the larger number of filters. QA and supervision activities and costs are similar to those for lead sampling except an allowance is made for one audit per year. The calibration kit for the dichotomous sampler consists of two mass flow meters. The cost of the kit is about $1,000. This cost is distributed among a network of five sites for the cost estimate.

4.3.2 Cost Estimates for Continuous PM-10 Sampling

Cost estimates for continuous PM-10 monitoring are detailed in Table 4-6 and summarized in Table 4-7. Option 1 describes costs for a beta attenuation monitor and Option 2 describes the costs for an OM monitor. Costs are estimated assuming that hourly data are collected and that the data are polled remotely via telephone lines.

The cost of a complete beta attenuation monitor is about $15,000. This includes an approved shipping container needed to transport the sampler in accordance with Department of Transportation regulations for shipping radioactive material. The OM sampler costs about $17,000. The OM sampler requires a temperature controlled shelter. Commercially available

TABLE 4-6. COST ESTIMATES FOR CONTINUOUS PM-10 SAMPLING

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Network Design						
Network design study	✓	✓	CPTL	PRO2	15	630
Network design study	✓	✓	CPTL	PRO4	25	1,650
Site selection	✓	✓	CPTL	TEC2	24	792
Station Installation						
Data logger	✓	✓	CPTL			1,600
Modem	✓	✓	CPTL			200
Beta attenuation monitor	✓		CPTL			15,000
TEOM monitor		✓	CPTL			17,000
Small shelter (temperature controlled)	✓	✓	CPTL			3,750
Land/lease	✓	✓	O/M			1,500
Power drop	✓	✓	CPTL			350
Equipment installation	✓	✓	CPTL	TEC2	16	528
Procurement	✓	✓	CPTL	PRO1	8	288
Site preparation	✓	✓	CPTL			3,000
Sampling						
Filter tape media (Beta)	✓		O/M			375
Filter media (TEOM)		✓	O/M			260
Routine site service (Beta)	✓		O/M	TEC2	12	396
Routine site service (TEOM)		✓	O/M	TEC2	26	858
Utilities	✓	✓	O/M			300
Maintenance						
Supplies (Beta)	✓		O/M			200
Supplies (TEOM)		✓	O/M			200
Spare parts (Beta)	✓		O/M			80
Spare parts (TEOM)		✓	O/M			75
Routine maintenance	✓	✓	O/M	TEC2	8	264
Repairs	✓	✓	O/M	TEC2	8	264
Data Management						
Data acquisition/processing	✓	✓	O/M	PRO1	26	936
Data reporting	✓	✓	O/M	PRO2	24	1,008

(Continued)

TABLE 4-6. COST ESTIMATES FOR CONTINUOUS PM-10 SAMPLING (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Data validation - operational	✓	✓	O/M	PRO1	18	648
Data validation - statistical	✓	✓	O/M	PRO2	16	672
Quality Assurance						
Calibration kit (Beta)	✓		CPTL			1,900
Calibration kit (TEOM)		✓	CPTL			1,000
Flow audits	✓	✓	O/M	TEC2	16	528
Implementation/coordination	✓	✓	O/M	PRO3	26	1,300
QA plan preparation	✓	✓	CPTL	PRO2	20	840
Reporting	✓	✓	O/M	PRO2	26	1,092
Training	✓	✓	O/M	TEC2	8	264
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	26	1,300
Supervision/review	✓	✓	O/M	PRO3	26	1,300
Total Capital (CPTL) Costs - Option 1						30,528
Total Annual Operation and Maintenance (O/M) Costs - Option 1						12,427
Total Capital (CPTL) Costs - Option 2						31,628
Total Annual Operation and Maintenance (O/M) Costs - Option 2						12,769

Option 1 - Beta attenuation monitor
Option 2 - Oscillating microbalance monitor

TABLE 4-7. CONTINUOUS PM-10 SAMPLING COST SUMMARY

Cost Type	Option 1	Option 2
Capital	30,528	31,628
Annual Operation and Maintenance	12,427	12,769
Average Annualized Cost	18,533	19,095

beta attenuation monitors do not require a weatherproof shelter, although a shelter is recommended for improved reliability. The cost estimates include a shelter for both methods. The cost for an 8' x 8', prewired, temperature controlled shelter is about $7,000. Small shelters can also be used that are designed to house only the sampler. The cost for such a shelter is about $3,750. The utility cost for heating and cooling the smaller shelter is also lower. The cost estimate in Table 4-6 is based on use of the smaller shelter. If more than one type of monitoring will be conducted at the site, the larger shelter would be used and the cost would be divided among the monitors using the shelter.

A datalogger configured with a modem is used to store and retrieve data from both types of continuous PM-10 monitors. Data are polled remotely over telephone lines. The cost of the off-site computer used for remote polling is not included in the cost estimates (see Section 3.6). A new version of the OM monitor that does not require an external data logger has recently become available, at the same cost. The cost estimates in Table 4-6 assume that a datalogger, including a data storage cartridge is used for both types of monitor.

Both types of monitors require minimal field service. The sample collection filter in the OM monitor must be changed when the filter becomes too heavily loaded. This is estimated at one filter change every 2 weeks at an average PM-10 concentration of from 25 to 50 $\mu g/m^3$. Twenty-six site visits per year are assumed for routine service of the OM monitor. The sample collection tape in the beta attenuation monitor should be changed about two times per year; however, the sample inlet should be cleaned about every 2 months. Six site visits per year are assumed for routine service of the beta attenuation monitor.

Routine maintenance for the beta attenuation monitor includes replacing gaskets and tubing. Periodic maintenance for the OM monitor includes replacing gaskets, tubing, and a protective filter. The cost estimate includes two routine maintenance visits per year. In addition, the estimates include a pump overhaul once per year for each type of monitor. Although both types of monitors generally need few repairs, the estimates allow technician time for minor repairs to the instruments, phone lines, and wiring at the site. Each sampler is shipped, when purchased, with sufficient spare parts and supplies for about 1 year's operation. The average annualized cost over the 5-year period takes this into account by subtracting 1 year's expense for spare parts and supplies.

Data management costs are typical of those for handling hourly averaged data (see Section 3.6). These include automated data acquisition and processing, data validation, and reporting. QA costs include the cost of preparing the QA plan, conducting audits, reviewing operations, implementing corrective actions, and providing training. The cost estimate allows for flow audits twice per year. Both types of monitors are audited using certified mass flow meters. The audit kit for the beta attenuation monitor costs about $1,900. The audit kit for the OM monitor costs about $1,000. Calibration of the OM monitor includes flow controller software calibration every six months and flow controller hardware, analog and mass transducer calibration at an interval of 1 to 2 years. These activities would be conducted during the semi-annual maintenance visits. No external calibration is required for the beta attenuation monitor.

Costs for program management and supervision are typical of those for a continuous monitoring system (see Section 3.8).

4.4 COST ESTIMATES FOR CONTINUOUS MONITORING FOR NITROGEN DIOXIDE, OZONE, SULFUR DIOXIDE, AND CARBON MONOXIDE

Although continuous and intermittent monitoring methods are available for the monitoring of gaseous criteria pollutants in ambient air, except for SO_2, the reference or equivalent methods for the other four gaseous criteria pollutants, NO_2, O_3, SO_2, and CO, are continuous methods. The reference method for SO_2 is an intermittent method; however, all SLAMS and NAMS sites use continuous methods for measuring SO_2. Therefore, the cost estimates presented here only address continuous monitoring methods.

A number of different principles of detection are used for measurement of the four pollutants and the reader is referred to the reference method descriptions in the Appendices of 40 CFR Part 50, the *Federal Register* announcements of equivalent method designations, or the equipment manufacturers literature for detailed descriptions of the methods. For purposes of simplifying the cost estimations, we have included a single analyzer cost for each of the four pollutants. Choice of the type of reference or equivalent analyzer is up to the user and the cost may vary from that listed in the table.

Table 4-8 gives a detailed breakdown of the cost estimates for NO_2, O_3, SO_2, and CO. All of the pollutant monitoring costs are similar for the continuous analyzers; therefore, they all appear on one table. There are some added complexities in the NO_2 analyzer because it measures NO_2 as the difference between NO and NO_x. Since the analyzer requires more time to calibrate than the other analyzers and provides concentration levels for NO, NO_2, and NO_x, adjustments for these differences have been considered and reflected in the cost estimates for NO_2 calibration, and data management. In addition, NAMS and SLAMS sites frequently have more than one continuous analyzer at the same site while the cost estimates included in the table assume one analyzer per site. In calculating costs for a multipollutant monitoring site, cost adjustments should be made to reflect multiple use of items such as the shelter, and the multigas calibrator, as well as to avoid duplicate costing for site selection, power drop, land/lease, and site preparation.

Network design and siting cost estimates for the four pollutants are assumed to be the same and follow the methodology presented in Section 3. For these pollutants it is assumed that the cost of a network design is about $11,400 prorated among five monitoring sites or $2,280 per station.

Site installation costs include the cost of equipment procurement, land lease, site preparation, power drop and equipment installation. In addition, the costs for an NO_2, O_3, SO_2, and CO analyzer and other major equipment expenditures are included under this category. The other major costs include, multipollutant gas calibrator, zero air supply, data logger, strip chart recorder, ambient air intake manifold, 8' x 12' prewired temperature controlled shelter, and shelter accessory equipment such as a constant voltage regulator, workbench, filing and wall cabinets, and an exterior gas bottle compartment.

TABLE 4-8. COST ESTIMATES FOR CONTINUOUS MONITORING OF NITROGEN DIOXIDE, OZONE, SULFUR DIOXIDE, AND CARBON MONOXIDE

Cost Element	Pollutant				Cost Type	Labor		Cost
	NO_2	O_3	SO_2	CO		Level	Hour	
Network Design								
Network design study	✓	✓	✓	✓	CPTL	PRO2	15	630
Network design study	✓	✓	✓	✓	CPTL	PRO4	25	1,650
Site selection	✓	✓	✓	✓	CPTL	TEC2	24	792
Site Installation								
$NO\text{-}NO_2\text{-}NO_x$ analyzer	✓				CPTL			9,300
Ozone analyzer		✓			CPTL			6,900
SO_2 analyzer			✓		CPTL			9,300
Carbon monoxide analyzer				✓	CPTL			9,100
Multigas calibrator	✓	✓	✓	✓	CPTL			3,600
Zero air supply	✓	✓	✓	✓	CPTL			3,000
Ambient air intake manifold assembly	✓	✓	✓	✓	CPTL			1,280
Data logger	✓	✓	✓	✓	CPTL			2,100
Strip chart recorder	✓	✓	✓	✓	CPTL			2,300
Power drop	✓	✓	✓	✓	CPTL			350
Land/lease	✓	✓	✓	✓	O/M			1,500
Procurement	✓	✓	✓	✓	CPTL	PRO1	8	288
Shelter (8x12 temperature controlled)	✓	✓	✓	✓	CPTL			8700
Optional shelter equipment/accessories	✓	✓	✓	✓	CPTL			4,000
Site preparation	✓	✓	✓	✓	CPTL			3,000
Equipment installation	✓	✓	✓	✓	CPTL	TEC2	16	528
Sampling and Analysis								
Supplies	✓	✓	✓	✓	O/M			400
Utilities	✓	✓	✓	✓	O/M			960
Routine site visits	✓	✓	✓	✓	O/M	TEC2	52	1,716
Maintenance								
Spare parts/supplies	✓	✓	✓	✓	O/M			500
Remedial repairs	✓	✓	✓	✓	O/M	TEC2	16	528
Routine maintenance	✓	✓	✓	✓	O/M	TEC2	20	660

(Continued)

TABLE 4-8. COST ESTIMATES FOR CONTINUOUS MONITORING OF NITROGEN DIOXIDE, OZONE SULFUR DIOXIDE, AND CARBON MONOXIDE (Continued)

Cost Element	Pollutant				Cost Type	Labor		Cost
	NO_2	O_3	SO_2	CO		Level	Hour	
Data Management								
Data acquisition/processing		✓	✓	✓	O/M	PRO1	26	936
Data acquisition/processing	✓				O/M	PRO1	30	1,080
Data reporting		✓	✓	✓	O/M	PRO2	24	1,008
Data reporting	✓				O/M	PRO2	28	1,176
Data validation		✓	✓	✓	O/M	PRO2	34	1,428
Data validation	✓				O/M	PRO2	40	1,680
Quality Assurance								
Portable ozone transfer calibrator		✓			CPTL			2,400
Multigas calibration/audit system	✓	✓	✓	✓	CPTL			7,200
Audits	✓	✓	✓	✓	O/M	PRO2	16	672
Routine calibrations	✓				O/M	TEC2	52	1,716
Routine calibrations		✓	✓	✓	O/M	TEC2	26	858
Coordination/implementation	✓	✓	✓	✓	O/M	PRO3	12	600
Training	✓	✓	✓	✓	O/M	PRO2	24	1,008
QA plan preparation	✓	✓	✓	✓	CPTL	PRO2	20	840
Supervision								
Planning/coordination	✓	✓	✓	✓	O/M	PRO3	32	1,600
Supervision/review	✓	✓	✓	✓	O/M	PRO3	32	1,600
Total Capital (CPTL) Costs - NO_2								49,558
Total Operation and Maintenance (O/M) Costs - NO_2								17,396
Total Capital (CPTL) Costs - O_3								49,558
Total Operation and Maintenance (O/M) Costs - O_3								15,974
Total Capital (CPTL) Costs - SO_2								49,558
Total Operation and Maintenance (O/M) Costs - SO_2								15,974
Total Capital (CPTL) Costs - CO								49,358
Total Operation and Maintenance (O/M) Costs - CO								15,974

Sampling and analysis normal operational costs include $400 for supplies such as chart paper, pens, log books, and miscellaneous items, $960 for utilities at $80 per month, and $1,716 for 26 2-hour site visits per year. Maintenance and repair costs of approximately $1,700 per year consist of corrective repairs, routine maintenance of the analyzers, including spare parts.

Data management costs allow for 26 hours per year for data acquisition and processing for O_3, SO_2, and CO analyzers with an additional 4 hours per year for NO_2. Data reporting entails 28 hours per year for NO_2 and 24 hours for the other three pollutants. Finally data validation is estimated at 40 hours per year for a PRO2 for NO_2 and 34 hours for the other pollutants.

QA costs encompass capital costs for a portable ozone transfer calibrator, a multigas calibration/audit system and 20 hours of a PRO2 time to prepare/update a QA project plan. Also included are operation and maintenance charges for the conduct of routine calibrations, audits (internal and external), training and overall coordination and implementation of a QA program. Supervision and management total 64 hours per year for planning, program review and upper level management supervision.

Table 4-9 gives a summary of the annual costs for continuous monitoring of nitrogen dioxide, ozone, sulfur dioxide, and carbon monoxide.

TABLE 4-9. SUMMARY OF COSTS FOR CONTINUOUS MONITORING OF NITROGEN DIOXIDE, OZONE, SULFUR DIOXIDE, AND CARBON MONOXIDE

	Nitrogen Dioxide	Ozone	Sulfur Dioxide	Carbon Monoxide
Capital	49,558	49,558	49,558	49,358
Annual Operation and Maintenance	17,396	15,974	15,974	15,974
Average Annualized Cost	27,308	25,886	25,886	25,846

The operation and maintenance (O/M) costs given in Table 4-8 are for a year-round (12 month) monitoring period. Many agencies, however, do not conduct ozone monitoring throughout the year. According to Appendix D of CFR Part 58 ozone monitoring schedules can be 4, 5, 7, 9, or 12 months depending on what state the monitoring is being conducted in. Table 4-10 gives a summary of the annual costs incurred for ozone monitoring on one of these other schedules. These costs were approximated by taking the O/M costs for the 12-month time period, and multiplying the O/M costs by the fraction of the year actually monitored. For example a 7-month monitoring period would have a multiplier of 7/12 (0.5833) or for a 4-month period 4/12 (0.33).

TABLE 4-10. SUMMARY OF COSTS FOR CONTINUOUS MONITORING OF OZONE FOR SELECTED MONITORING PERIODS

COSTS PER OZONE MONITORING SEASON				
	4 - Months	5 - Months	7 - Months	9 - Months
Capital	49,558	49,558	49,558	49,558
Operation and Maintenance Costs per Season	5,324	6,656	9,318	11,981
Average Annualized Cost	15,236	16,568	19,230	21,893

4.5 REFERENCES

1. "Ambient Air Quality Surveillance", *Federal Register* 44:27558-27604. May 10, 1979.

2. "National Primary and Secondary Ambient Air Quality Standards", *Code of Federal Regulations*, Title 40, Part 50, July 1, 1991.

3. "National Primary and Secondary Ambient Air Quality Standards, Reference Methods for the Determination of Criteria Pollutants", *Code of Federal Regulations*, Title 40, Part 50, Appendices A-G, July 1991.

4. "Requirements for Preparation, Adoption, and Submittal of Implementation Plans", *Code of Federal Regulations*, Title 40, Part 51, July 1, 1991.

SECTION 5.0

SELECTED AIR TOXICS MONITORING

5.1 BACKGROUND

This section deals with costs incurred in the collection and analysis of selected air toxic pollutants. Determination of toxic organic compounds in ambient air is a complex task, due to the wide variety of compounds of interest and the lack of standardized sampling and analysis procedures. In recent years, more and more attention has been focused on the standardization of monitoring and analysis techniques for air toxics. In 1988, the EPA revised the *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air.*[1] This document was originally produced in 1984 and it contains EPA recommended sampling and analysis procedures for selected air toxics. It is updated periodically to incorporate new methods. In 1987, the Urban Air Toxics Monitoring Program was initiated by EPA. The purpose of the program is to support State and local agency efforts to assess the nature and magnitude of the urban air toxics problem in their respective areas. The program consists of these different types of air samplers:

- Canister - for volatile organic compounds (VOC)
- Adsorbent tube cartridge - for formaldehyde and other carbonyl compounds
- Total suspended particulate filter - for metals

Other EPA documents dealing with air toxics include *Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air,* and *Screening Methods for the Development of Air Toxic Emission Factors.*[2,3] The cost estimates included in this chapter focus on the pollutants and methods described in these EPA documents.

This section is arranged so that complete costs are tabulated for each monitoring system. The majority of the monitoring systems described here were taken from the *Compendium of Methods for the Determination of Toxic Organic Compounds* and can be identified by their Compendium number, TO1-TO14.[1] However, the old *Cost of Ambient Air Monitoring for Criteria Pollutants and Selected Toxic Pollutants* (EPA-450/4-85-004) document was also used to furnish methods for this section and they are noted accordingly.[4] These sources should be consulted for a more detailed breakdown and description of the different monitoring systems.

Table 5-1 provides an easy cross-reference of subsections that deal with sampling and analytical costs for each of the selected air toxic pollutants. Individual pollutants are listed alphabetically in the left column of the table. Recommended monitoring systems for the selected air toxics are listed across the page. Each monitoring system is also listed by the collection media used for sampling. The number of the subsection covering costs for the recommended monitoring system is included in each column heading. Thus, each pollutant can be cross-referenced across the page to locate report subsections where sampling and analysis costs are found.

Certain assumptions were made in compiling the toxic pollutant cost estimates. In calculating laboratory analysis costs, it is assumed that there is an existing fully-equipped laboratory with all basic laboratory furniture, equipment and associated glassware. Specific analytical equipment costs are included in descriptions for the specific method. A second assumption involves the use of air sampling equipment and supplies. To the extent possible, prices are listed for complete sampling systems rather than individual components of the sampling system. The following assumptions were also made:

- A monitoring network consists of five monitoring sites
- CPTL costs are amortized over 5 years
- The sampling schedule is once every 6 days

The cost estimate tables summarize the start up costs incurred for the installation of one sampler and the purchase and set up of the appropriate analytical equipment. As stated previously, there are many alternatives for how a monitoring system can be set up and run. However, only the following two cost options have been given for each of the monitoring systems. These options differ in how the analytical portion of the monitoring system is handled; sampling activities remain the same regardless of the option chosen.

Option 1 - This option includes all sampling requirements and necessitates the purchase and installation of all the analytical equipment needed to analyze the samples. It also covers all expenses incurred conducting the analysis, such as operation and maintenance of analytical equipment, audits, calibrations, training, data management, and management and supervision.

Option 2 - This option includes all sampling requirements but necessitates the purchase of analytical services from a laboratory. The cost estimates are in the tables and are based on 61 samples per year. The agency collects the samples, sends the sample to the lab for analysis and receives a report on the results.

TABLE 5-1. CROSS REFERENCE TABLE FOR MONITORING SYSTEMS FOR SELECTED TOXIC AIR POLLUTANTS

Pollutant	Selected Compendium and Other Methods for the Determination of Air Toxics										
	Sorbent Tube (Section 5.2)				Liquid Impinger (Section 5.3)			Cryogenic Trapping (5.4)	Hi-vol Sampler (Section 5.5)		Canister (5.6)
	TO1	TO2	TO7	TO11	TO5	TO6	TO8	TO3	TO4	Filter	TO14
Acetaldehyde				●	●						
Acetone				●	●						
Acrolein				●	●						
Acrylonitrile		●									
Aldrin									●		
Allyl Chloride		●									
Arsenic										●	
Benzene	●	●						●			●
Benzaldehyde					●						
Benzyl Chloride											●
Beryllium										●	
Bromoform	●										
Bromobenzene	●										
Butyraldehyde				●							
Captan									●		
Cadmium										●	
Carbon tetrachloride	●	●									●

(continued)

TABLE 5-1. CROSS REFERENCE TABLE FOR MONITORING SYSTEMS FOR SELECTED TOXIC AIR POLLUTANTS (Continued)

Pollutant	Selected Compendium and Other Methods for the Determination of Air Toxics										
	Sorbent Tube (Section 5.2)				Liquid Impinger (Section 5.3)			Cryogenic Trapping (5.4)	Hi-vol Sampler (Section 5.5)		Canister (5.6)
	TO1	TO2	TO7	TO11	TO5	TO6	TO8	TO3	TO4	Filter	TO14
Chlordane									●		
Chlorobenzene	●							●			●
Chlorobiphenyls									●		
Chloroform	●	●						●			●
Chlorpyrifos									●		
Chlorothalonil									●		
Chromium										●	
Crotonaldehyde				●	●						
Cumene	●										
1,1-Dichloroethane											●
1,2-Dichloroethane	●	●						●			●
1,2-Dichloropropane	●										●
1,3-Dichloropropane	●										
4,4'-DDE									●		
4,4'-DDT									●		
Dichloromethane											●
Dimethylnitrosamine											

(continued)

TABLE 5-1. CROSS REFERENCE TABLE FOR MONITORING SYSTEMS FOR SELECTED TOXIC AIR POLLUTANTS (Continued)

Pollutant	Selected Compendium and Other Methods for the Determination of Air Toxics										
	Sorbent Tube (Section 5.2)				Liquid Impinger (Section 5.3)			Cryogenic Trapping (5.4)	Hi-vol Sampler (Section 5.5)		Canister (5.6)
	TO1	TO2	TO7	TO11	TO5	TO6	TO8	TO3	TO4	Filter	TO14
cis-1,2-Dichloroethylene											●
cis-1,3-Dichloropropene											●
trans-1,3-Dichloropropene											●
1,2-Dibromoethane											●
m-o-p-Dichlorobenzene											●
2,5-Dimethylbenzaldehyde				●							
Ethyl Benzene	●										●
Ethylene Dibromide	●										
Ethyl Chloride											●
Formaldehyde				●	●						
Freon 12											●
Freon 114											●
Freon 11											●
Freon 113											●
n-Heptane	●										
1-Heptene	●										
Hexanal					●						

(continued)

TABLE 5-1. CROSS REFERENCE TABLE FOR MONITORING SYSTEMS FOR SELECTED TOXIC AIR POLLUTANTS (Continued)

Pollutant	Selected Compendium and Other Methods for the Determination of Air Toxics										
	Sorbent Tube (Section 5.2)				Liquid Impinger (Section 5.3)			Cryogenic Trapping (5.4)	Hi-vol Sampler (Section 5.5)		Canister (5.6)
	TO1	TO2	TO7	TO11	TO5	TO6	TO8	TO3	TO4	Filter	TO14
Hexachlorobutadiene											●
Isobutyraldehyde					●						
Isovaleraldehyde				●							
Manganese										●	
Methylene Chloride											●
Methyl Chloroform								●			●
Methyl Ethyl Ketone					●						
Methyl Chloride		●									
Methyl Bromide											●
Nickel										●	
n-Nitrosodimethylamine			●								
o-m-p-Cresol							●				
o-m-p-Xylene	●										●
o-m-p-Tolualdehyde				●	●						
Pentanal					●						
Phenol							●				
Polychlorinated Biphenyls									●		

(continued)

TABLE 5-1. CROSS REFERENCE TABLE FOR MONITORING SYSTEMS FOR SELECTED TOXIC AIR POLLUTANTS (Continued)

Pollutant	Selected Compendium and Other Methods for the Determination of Air Toxics										
	Sorbent Tube (Section 5.2)				Liquid Impinger (Section 5.3)			Cryogenic Trapping (5.4)	Hi-vol Sampler (Section 5.5)		Canister (5.6)
	TO1	TO2	TO7	TO11	TO5	TO6	TO8	TO3	TO4	Filter	TO14
Phosgene						●					
Propanal					●						
Propionaldehyde				●							
Styrene											●
Toluene	●	●									●
1,1,1-Trichloroethane	●	●									
Tetrachloroethylene	●							●			●
Trichloroethylene								●			●
1,1,2-Trichloroethane											●
1,1,2,2-Tetrachloroethane											●
1,3,5-Trimethylbenzene											●
1,2,4-Trimethylbenzene											●
1,2,4-Trichlorobenzene											●
Valeraldehyde				●							
Vinyl Chloride		●									●
Vinylidene Chloride		●						●			●

5.2 COST ESTIMATES FOR SOLID ADSORBENT SAMPLING (METHODS TO1, TO2, TO7, and TO11)

5.2.1 Introduction

Solid adsorbents are frequently used for sampling gas phase organics. The primary advantage of this sampling approach is the large volume of air which can be sampled when compared to other techniques such as impingers or cryogenic sampling. Sampling and analytical costs are similar for solid adsorbent methods, TO1, TO2, and TO7. Cost data provided in this section may be used for all three adsorbents. However, Method TO11 uses a silica gel solid adsorbent cartridge that contains silica gel coated with 2,4-dinitrophenylhydrazine (DNPH) reagent. Aldehydes and ketones readily form a stable derivative with the DNPH reagent. Method TO11 is a modification of Method TO5 which uses a DNPH solution in a midget impinger for air sampling. The sampling component of Method TO11 is the same as for the other solid adsorbents but the analytical process is different. Method TO5 must be consulted to obtain a detailed breakdown of analytical cost for TO11 adsorbent used. The basic difference between Methods TO1, TO2, and TO7 is the cost of the particular solid. Method TO11 solid adsorbent costs are included in this cost breakdown, but the summary cost estimate is found in Section 5.3. There are generally three categories of solid adsorbents: organic polymeric adsorbents, inorganic adsorbents, and carbon adsorbents.

Methods TO1 and TO7 are examples of organic polymeric adsorbents. These methods do not collect water in the sampling process so large volumes of air can be collected. Another advantage of the organic polymeric adsorbents is the absence of "active sites" which can lead to irreversible adsorption of certain polar compounds. A major disadvantage for these adsorbents is their inability to capture highly volatile materials, like vinyl chloride, as well as certain polar materials like methanol or acetone.

Method TO2 uses a carbon adsorbent for its sampling requirement. These adsorbents are relatively nonpolar compared to the inorganic adsorbents, and thus water adsorption is less of a problem. Carbon based materials tend to exhibit much stronger adsorption properties than organic polymeric adsorbents. This allows for efficient collection of volatile materials such as vinyl chloride. However, the strong adsorption can be a problem in cases where recovery is desired by thermal desorption of less volatile materials such as benzene or toluene because of the high temperature (400°C) required.

This chapter does not contain any methods using inorganic adsorbents. However, inorganic adsorbents are more polar than the organic polymeric adsorbents, leading to better collection of polar material. Unfortunately, water is also collected leading to the rapid deactivation of the adsorbents. Consequently, these materials are seldom used for sampling trace organic compounds in air.

Table 5-2 illustrates the type of solid adsorbent used, analytical method employed, and compounds sampled by each method.

TABLE 5-2. SOLID ADSORBENTS

TO1	TO2	TO7	TO11
Solid adsorbent - Tenax®	Solid adsorbent - Carbon Molecular Sieve	Solid adsorbent - Thermosorb	Solid adsorbent - Silica gel
Analytical Method - GC/MS	Analytical Method - GC/MS	Analytical Method - GC/MS	Analytical Method - HPLC/UV
Pollutants - Benzene, Toluene, Ethyl Benzene, Xylene(s), Cumene, n-Heptane, 1-Heptene, Chloroform, Carbon Tetrachloride, 1,2-Dichloroethane, 1,1,1-Trichloroethane, Tetrachloroethylene, 1,2-Dichloropropane, 1,3-Dichloropropane, Chlorobenzene, Bromoform, Ethylene Dibromide, Bromobenzene.	Pollutants - Vinyl Chloride, Acrylonitrile, Vinylidene Chloride, Methylene Chloride, Allyl Chloride, Chloroform, 1,2-Dichloroethane, 1,1,1-Trichloroethane, Benzene, Carbon Tetrachloride, Toluene	Pollutants - N-Nitrosodimethylamine	Pollutants - Acetaldehyde, Acetone, Acrolein, Butyraldehyde/ Isobutyraldehyde Crotonaldehyde, 2,5-Dimethylbenzaldehyde Formaldehyde, Hexanaldehyde, Isovaleraldehyde, Propionaldehyde, o-m-p-Tolualdehyde, Valeraldehyde Benzaldehyde
This method is used to determine compounds that are nonpolar organics having boiling points in the range of approximately 80° - 200°C. However, not all compounds falling into this category can be determined. Conventional methods have relied on carbon adsorption approaches with subsequent solvent desorption. This is not sensitive enough to pick up adequate concentrations for these compounds so a thermal desorption process within the analytical system fulfills this need for enhanced sensitivity.	Compounds which can be determined by this method are nonpolar and nonreactive organics having boiling points in the range -15 to +120°C. However not all compounds meeting these criteria can be determined. This approach is capable of capturing highly volatile organics like vinyl chloride, which are not collected on Tenax®.	This method determines N-nitrosodimethylamine (NDMA) in ambient air. Nitrosamines, including NDMA, are suspected human carcinogens. These compounds may be present in ambient air as a result of emissions from tire manufacturing or from atmospheric reactions between secondary or tertiary amines and NO_x.	This method is primarily used for the sampling and analysis of formaldehyde. However, the separation conditions or chromatographic conditions can be adjusted to determine higher molecular weight carbonyls as well.

5.2.2 Cost Estimates for Solid Adsorbent Sampling and Analysis

Table 5-3 gives the detailed costs for operating a solid adsorbent sampling unit for one year and conducting sample analyses using a gas chromatograph/mass spectrometer (GC/MS). These costs are based on a sample collection schedule of one 24-hour sample every sixth day. Analytical operational costs are given for 61 samples, both for in-house analytical work and outside laboratory analysis.

Station installation costs include the costs associated with site procurement, site preparation, equipment purchase, and labor to install the site. The sampling system consists of a vacuum pump, 7-day skip timer with elapsed time indicator, fine metering valves, and quick connect fittings. This system is self-contained in an anodized aluminum shelter. The price shown in Table 5-3 is for a complete system, although the components can be purchased separately.

Sampling costs include supplies, sampling media, utilities, and labor for servicing the site. Sampling supplies include pens, chart paper, carrying cases for sampling tubes, and a chain of custody form. There are three types of solid adsorbent sampling media: Tenax®, carbon molecular sieve, and thermosorb. Sampling media consist of a glass or metal cartridge, with the solid adsorbent in the middle and glass wool plugs on the inlet and outlet of the adsorbent. Method TO11 uses silica gel spheres that have been coated with DNPH. These cartridges cost about $10 each and can be purchased ready for use. Utility prices are based on one sampler but could be higher if multiple samplers are used. Site service is conducted by a TEC1 and is based on travel time, calibration of equipment, and replacing cartridges. Site service has been estimated at 2 hours per site visit.

Maintenance and repair costs differ for options 1 and 2 since option 1 requires repair and maintenance on the sampling and laboratory equipment, while option 2 only requires service on the sampling equipment. Option 1 parts and supply costs include spare sampling and analytical parts, such as pumps, fittings, and laboratory glassware and equipment. Option 2 parts and supplies would include spare pump parts, fittings, etc. Repair and maintenance labor hours associated with option 1 sampling and analytical equipment are estimated at 8 and 10 hours, respectively, while option 2 labor hours for repair and maintenance are estimated at 4 and 5 hours. Remedial maintenance and repair is conducted by a TEC2 and includes quarterly recalibrations and pump maintenance.

Analytical costs include analytical equipment, supplies, and labor. There are two general ways to handle sample analysis. The first is to purchase the needed equipment and conduct the analysis in-house; the second is to hire an outside laboratory to do the analysis. If option one is chosen, then a GC/MS is purchased and set up. The GC/MS is assumed to be fully automated with a PC-based data system and software. Purchase price for the complete system is estimated at $115,000. After the sample is collected on the solid adsorbent cartridge, it is prepared for analysis by placing it in a heated chamber and purging with an inert gas which transfers the VOCs from the cartridge onto a cold trap and subsequently onto the front of the GC column.

Component identification is accomplished on the basis of GC retention time and mass spectral characteristics. Capital costs for analytical equipment purchase are divided between the five sites assumed in the network. Analytical supplies include such items as gas purifier cartridges, GC gases including helium, and nitrogen, cryogen (liquid nitrogen or argon), pressure regulators and valves, gas tight syringes, reagents standards and miscellaneous material like pens, paper, and printer cartridges. It would take a PRO2 or equivalent an estimated 40 hours of labor to set up, calibrate, and otherwise prepare the analytical equipment for use. Method TO11 analytical costs for Options 1 and 2 which are based on HPLC/UV analysis are given in Section 5.3. Method TO7 would not require the use of a desorption unit and assumes the need for a TEC2 with support from a PRO2 to set up and optimize the analytical equipment. Once the equipment has been optimized, it is estimated that at least one hour is required for analysis of each adsorbent sample cartridge.

If Option 2 is used, laboratory analysis is performed by a contractor laboratory. The cost estimates listed in Table 5-3 assume 61 samples at $350 per sample plus an additional $3,150 to perform replicate analysis on 15 percent of the samples.

Data management and reporting costs include data acquisition, processing, reporting, and validation for one site for one year. These cost estimates assume that an automated data management system is in place and will handle data from five sites. Routine data reports include quarterly computer generated data summaries. The hours per site for the data management and reporting category under Option 1 include: 16 hours for data acquisition/data processing, 8 hours for data reporting, and 8 hours for data validation (operational and statistical).

QA and QC includes both capital and operation and maintenance costs. CPTL costs are included for the preparation of the QA plan and for calibration equipment. The effort required for QA plan preparation is divided between the five sites in the network. Annual QA/QC costs include coordination, implementation and oversight of the QA program, preparation of periodic reports on data quality, audits and flow calibrations for the sampling and analytical equipment. QA activities should be conducted by mid- to senior-level professionals. Training covers sampling site operators, lab analysts, and personnel involved with data management and quality assurance. QA/QC costs for Option 2 are less because of the absence of the laboratory work.

Supervision costs include planning, coordination, supervision and review. This is usually done by a senior level professional who must oversee the budget, employee scheduling conflicts, and other duties associated with the operation and maintenance of a monitoring network.

Table 5-4 gives a summary of the capital costs, operation and maintenance costs, and annualized costs based on a five year amortization rate. The only difference in the cost estimates for Methods TO1, TO2, and TO7 is the price of the solid adsorbent material.

TABLE 5-3. SOLID ADSORBENT SAMPLING COSTS

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hour	
Network Design						
Network design study	✓	✓	CPTL	PRO2	15	630
Network design study	✓	✓	CPTL	PRO4	25	1,650
Site selection	✓	✓	CPTL	TEC2	24	792
Station Installation						
Procurement	✓	✓	CPTL	PRO1	8	288
Land/lease	✓	✓	O/M			1,500
Site preparation	✓	✓	CPTL			3,000
Power hookup	✓	✓	CPTL			350
Solid adsorbent sampler	✓	✓	CPTL			2,830
Equipment installation	✓	✓	CPTL	TEC2	8	264
Sampling						
Supplies	✓	✓	O/M			100
TENAX cartridges (70 at $30)	✓	✓	O/M			2,100
Carbon molecular sieve	✓	✓	O/M			244
Thermosorb	✓	✓	O/M			915
Silica gel/DNPH cartridge (70 at $10)	✓	✓	O/M			700
Utilities	✓	✓	O/M			100
Site service	✓	✓	O/M	TEC1	122	3,660
Maintenance						
Spare parts	✓		O/M			400
Spare parts		✓	O/M			200
Remedial calibrations	✓		O/M	TEC2	12	396
Remedial calibrations		✓	O/M	TEC2	6	198

(continued)

TABLE 5-3. SOLID ADSORBENT SAMPLING COSTS (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hour	
Routine repairs	✓		O/M	TEC2	6	198
Routine repairs		✓	O/M	TEC2	4	132
Remedial maintenance	✓		O/M	TEC2	6	198
Remedial maintenance		✓	O/M	TEC2	4	132
Analytical						
Contract lab analysis ($350/sample for TO1, TO2, TO7) ($170/sample for TO11)		✓	O/M			24,500 11,900
Equipment (GC/MS)	✓		CPTL			23,000
Thermal desorption/cryogenic trap unit	✓		CPTL			2,510
Extra GC columns	✓		O/M			200
Standards and reagents	✓		O/M			200
Sample analysis	✓		O/M	PRO2	138	5,796
Equipment Setup	✓		CPTL	PRO2	8	336
Data Management						
Data acquisition/processing	✓		O/M	PRO1	16	576
Data acquisition/processing		✓	O/M	PRO1	8	288
Data reporting	✓	✓	O/M	PRO2	14	588
Data validation	✓	✓	O/M	PRO2	20	840
Quality Assurance						
Calibration standards	✓		O/M			300
Audits	✓		O/M	PRO2	16	672
Audits		✓	O/M	PRO2	8	336
Calibrations	✓		O/M	TEC2	24	792
Calibrations		✓	O/M	TEC2	8	264

(continued)

TABLE 5-3. SOLID ADSORBENT SAMPLING COSTS (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hour	
Training	✓		O/M	PRO2	40	1,680
				TEC2	20	660
Training		✓	O/M	PRO2	8	336
				TEC2	8	264
Reporting	✓	✓	O/M	PRO2	30	1,260
QA plan preparation	✓		CPTL	PRO2	10	420
QA plan preparation		✓	CPTL	PRO2	8	336
Implementation/coordination	✓		O/M	PRO2	25	1,050
Implementation/coordination		✓	O/M	PRO2	15	630
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	8	400
Supervision/review	✓	✓	O/M	PRO3	8	400
Total Capital (CPTL) Costs - Option 1						36,070
Total Operation and Maintenance (O/M) Costs - Option 1 (Excluding Sampling Media)						21,966
Total Capital (CPTL) Costs - Option 2						10,140
Total Operation and Maintenance (O/M) Costs - Option 2 (Excluding Sampling Media & Analysis)						11,628

Option 1 - Sampling and analysis conducted by agency
Option 2 - Sampling conducted by agency, analysis conducted by a contractor

TABLE 5-4. SOLID ADSORBENT COST SUMMARY

Cost Type	Cost							
	Method TO1		Method TO2		Method TO7		Method TO11	
	Opt1	Opt2	Opt1	Opt2	Opt1	Opt2	Opt1	Opt2
Capital Costs	36,070	10,140	36,070	10,140	36,070	10,140	16,620	10,140
Annualized Operation and Maintenance Costs	24,066 (a)	38,228	22,210 (b)	36,372	22,881 (c)	37,043	19,282 (d)	24,228
Average Annualized Cost	31,280	40,256	29,424	38,400	30,095	39,071	22,606	26,256

(a) Includes TENAX cartridges as sampling media

(b) Includes Carbon Molecular Sieve as sampling media

(c) Includes Thermosorb as sampling media

(d) Includes silica gel/DNPH cartridges as sampling media (and substitutes Table 5-6 analytical costs for Method TO5)

5.3 COST ESTIMATES FOR LIQUID IMPINGER SAMPLING (METHODS TO5, TO6, and TO8)

5.3.1 Introduction

Three methods (TO5 for carbonyl compounds, TO6 for phosgene, and TO8 for phenol and cresols), each using a liquid impinger sampling technique as the method for trapping the air pollutants, are discussed in this subsection. The liquid impinger sampling system is similar to that described for organic sampling on solid adsorbents. In this case, the pollutants are captured in a liquid solution using an impinger or "bubbler" collection system. The procedure involves passing the air pollutant gas stream through an organic solvent or other suitable liquid to capture the air pollutant compounds by absorbing them into the solvent. This technique is relatively simple and may be useful in high pollutant concentration monitoring situations. Large volumes of air, however, cannot be sampled due to solvent evaporation during the sampling process; therefore, impinger sampling methods are not generally used for trace organic analysis. To optimize the collection efficiency, the impinger should be designed so that contact between the air and solvent is maximized. In addition, the system should be cooled so as to reduce solvent loss during sampling and increase sample collection efficiency. The analytical technique for determining the concentration of the pollutants for each of the methods is high performance liquid chromatography (HPLC) with an ultraviolet absorbance detector at a specified wavelength.

Table 5-5 contains general descriptions for impinger methods TO5, TO6, and TO8. These methods are similar in most respects except for the type of reagent used in the impinger sampling train. Method TO5 uses a solution of DNPH and isooctane, Method TO6 a solution containing aniline and toluene, and Method TO8 a sodium hydroxide (NaOH) solution.

TABLE 5-5. LIQUID IMPINGER SAMPLING METHODS

Method TO5	Method TO6	Method TO8
Absorbing Solution - 2,4-dinitrophenylhydrazine(DNPH) and isooctane	**Absorbing solution -** Aniline and toluene	**Absorbing solution -** Sodium hydroxide
Analytical Method - HPLC/UV	**Analytical Method -** HPLC/UV	**Analytical Method -** HPLC/UV
Pollutants Sampled - Formaldehyde, Acetaldehyde, Acrolein, Propanol, Acetone, Crotonaldehyde, Isobutyraldehyde, Methyl Ethyl Ketone, Benzaldehyde, Pentanol, o-Tolualdehyde, m-Tolualdehyde, p-Tolualdehyde, Hexanol	**Pollutants Sampled -** Phosgene	**Pollutants Sampled -** Phenol, Methylphenols (cresols)
Background - Conventional methods for aldehydes and ketones used colorimetric techniques that detected only one or two compounds, or the sum of numerous compounds. This method can specifically determine a wide variety of aldehydes and ketones at typical ambient concentrations.	**Background -** The old method for phosgene detection could not detect below 10 ppbv and had many interferences. Method TO6 can detect to 0.1 ppbv and has less interferences.	**Background -** Conventional methods for phenols used colorimetric or GC techniques with large detection limits. Method TO8 reduces these limits by using an HPLC.

5.3.2 Cost Estimates for Liquid Impinger Sampling Methods

Table 5-6 includes a detailed breakdown of the capital and operational and maintenance costs for a monitoring system using a liquid or midget impinger sampling train and an HPLC/UV analytical measurement system. Table 5-7 summarizes these costs. The basic assumptions of Section 5.1 that applied for solid adsorbent sampling and analysis also apply for liquid impinger sampling. In addition, the same network design costs given in Table 5-3 also apply here.

Station installation costs include site procurement and preparation, power installation, sampling equipment procurement and installation, and labor. These costs are considered to be capital costs because they occur once and are amortized over the lifetime of the monitoring site. Station installation costs were based on the assumption that the site is easily accessible, near existing power source, and relatively secure, meaning additional security fences or lights are not required. An example of a site meeting these assumptions would be the rooftop of an apartment building or the yard of a municipal building. Therefore, site preparation materials would include weather resistant electrical cords, miscellaneous hardware, and materials to build a platform for the sampling unit to rest on. For this cost estimate, the midget impinger sampling train is purchased as a complete unit. The unit includes a sample pump capable of drawing air at 100-1000 ml/minute, rotameter, vacuum gauge, elapsed timer, dry gas meter, pressure gauge for precision volume corrections, a self contained shelter, and other assorted features. The cost also includes a midget impinger glassware set, 8 clamps, and a stainless steel glassware tray with insulated liner. A TEC2 or equivalent would be required to install and calibrate the equipment. In colder climates thermostatically controlled heat tape would be necessary to prevent the impinger solution from freezing. This cost is not included here.

Sampling operational costs include supplies, impinger reagents, utilities, and labor for servicing the site. Site servicing is conducted by a TEC1 and includes travel time, loading the impingers, checking out the sampling train, checking the initial and final flow, and conducting a periodic flow calibration. Utility costs are estimated at the same values as the solid adsorbent sampling costs.

Maintenance costs include spare parts, corrective action, and servicing equipment not covered by routine site service. Spare parts for a liquid impinger would be a pump rebuilding kit, cleaning materials, and any extra tubing or hardware. An extra glassware set was added for an additional $243. Remedial maintenance is performed by a TEC2 and includes pump servicing and flow meter cleaning or servicing. Quarterly recalibration of the flow measurement devices is also assumed.

There are two general ways to handle sample analysis. The first is to purchase the needed equipment and conduct the analysis in-house. The second is to hire an outside laboratory to conduct the analysis. For option 1, the analytical costs include equipment, supplies, and labor. Methods TO5, TO6, and TO8 all utilize the HPLC/UV for sample analysis. For this cost estimate the unit is equipped with a data handling system. Cost for this system is about $21,000. This cost, along with the costs for the auxiliary equipment and analytical balance, were distributed among five sites so the costs shown for these items are only one fifth of the actual price. Other capital costs include a nitrogen evaporator with heating block, analytical balance, and installation costs. Method TO8 does not require a nitrogen evaporator for sample concentration. Analytical operation and maintenance costs include supplies, labor for sample analysis, and, if option 2 is chosen, costs for an outside laboratory to perform the analysis. In Option 2, the cost per sample for Method TO5 is $170, Method TO6 is $180, and Method TO8 is $150. The contract laboratory analysis cost of $170 is used in Table 5-6. Option 1 would require a PRO2 or equivalent to perform the sample analysis.

Data management and reporting costs include data acquisition, processing, reporting, and validation. These costs are the same as the solid adsorbent monitoring costs.

QA and QC costs include capital costs for QA plan preparation and calibration standards, labor costs for QA reporting, internal and external audits, calibrations, training, QA implementation, and QA coordination. The QA project plan cost is divided among the number of sites in the network.

Overall supervision and management costs are those normally associated with the overall planning, coordination, tracking, and review of a monitoring program. The cost estimates for these activities are the same as those identified in earlier discussions.

TABLE 5-6. LIQUID IMPINGER SAMPLING COSTS

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Network Design	✓	✓	CPTL			3,072
Station Installation						
Procurement	✓	✓	CPTL	PRO1	8	288
Land/lease	✓	✓	O/M			1,500
Site preparation	✓	✓	CPTL			3,000
Power hookup	✓	✓	CPTL			350
Liquid impinger sampler	✓	✓	CPTL			3,690
Equipment installation	✓	✓	CPTL	TEC2	8	264
Sampling						
Supplies	✓	✓	O/M			100
Reagents	✓	✓	O/M			300
Utilities	✓	✓	O/M			100
Impinger preparation	✓	✓	O/M	PRO2	61	2,562
Site service	✓	✓	O/M	TEC1	122	3,660
Maintenance						
Spare parts	✓		O/M			400
Spare parts		✓	O/M			200
Remedial calibrations	✓		O/M	TEC2	12	396
Remedial calibrations		✓	O/M	TEC2	6	198
Routine repairs	✓		O/M	TEC2	6	198
Routine repairs		✓	O/M	TEC2	4	132
Remedial maintenance	✓		O/M	TEC2	6	198
Remedial maintenance		✓	O/M	TEC2	4	132

(continued)

TABLE 5-6. LIQUID IMPINGER SAMPLING COSTS (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Analytical						
Contract laboratory analysis (70 samples/yr at $170/sample)		✓	O/M			11,900
Equipment - HPLC/UV	✓		CPTL			4,200
Equipment (auxiliary)	✓		CPTL			400
Analytical balance	✓		CPTL			200
Supplies	✓		O/M			250
Sample analysis	✓		O/M	PRO2	61	2,562
Equipment Setup	✓		CPTL	PRO2	40	1,680
Data Management						
Data acquisition/processing	✓		O/M	PRO1	16	576
Data acquisition/processing		✓	O/M	PRO1	8	288
Data reporting	✓	✓	O/M	PRO2	14	588
Data validation	✓	✓	O/M	PRO2	20	840
Quality Assurance						
Calibration standards	✓		O/M			300
Audits	✓		O/M	PRO2	16	672
Audits		✓	O/M	PRO2	8	336
Calibrations	✓		O/M	TEC2	24	792
Calibrations		✓	O/M	TEC2	8	264
Training	✓		O/M	PRO2	40	1,680
				TEC2	20	660
Training		✓	O/M	PRO2	8	336
				TEC2	8	264
Reporting	✓	✓	O/M	PRO2	30	1,260
QA plan preparation	✓		CPTL	PRO2	10	420

(continued)

TABLE 5-6. LIQUID IMPINGER SAMPLING COSTS (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
QA plan preparation		✓	CPTL	PRO2	8	336
Implementation/coordination	✓		O/M	PRO2	25	1,050
Implementation/coordination		✓	O/M	PRO2	15	630
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	8	400
Supervision/review	✓	✓	O/M	PRO3	8	400
Total Capital (CPTL) Costs - Option 1						17,564
Total Operation and Maintenance (O/M) Cost - Option 1						21,444
Total Capital (CPTL) Costs - Option 2						11,000
Total Operation and Maintenance (O/M) Cost - Option 2						26,390

Option 1 - Sampling and analysis conducted by agency
Option 2 - Sampling conducted by agency, analysis conducted by a contractor

TABLE 5-7. LIQUID IMPINGER COST SUMMARY

Cost Type	Cost					
	Method TO5		Method TO6		Method TO8	
	Option 1	Option 2	Option 1	Option 2	Option 1	Option 2
Capital Costs	17,564	11,000	17,564	11,000	17,564	11,000
Annualized Operation and Maintenance Costs	21,444	26,390 (a)	21,444	25,690 (b)	21,444	24,990 (c)
Average Annualized Cost	24,957	28,590	24,957	27,890	24,957	27,190

(a) Analysis performed on 70 samples at $170/sample
(b) Analysis performed on 70 samples at $180/sample
(c) Analysis performed on 70 samples at $150/sample

5.4 COST ESTIMATES FOR CRYOGENIC TRAPPING (METHOD TO3)

5.4.1 Introduction

The collection of atmospheric volatile organics by condensation in a cryogenic trap is an attractive alternative to adsorption or impinger collection. The trap used in Method TO3 is stainless steel tubing packed with glass beads. This technique has the following advantages.

- A wide range of organic materials can be collected
- Contamination problems with adsorbents and impinger solutions are reduced
- The sample is immediately available for analysis without further handling
- Consistent recoveries are generally obtained

Unlike the previously described sampling methods for toxic organic compounds, Method TO3 uses an on-site GC with an FID which combines the sampling and analysis at the sampling sites; therefore, Option 2 for contracted analytical services is not included. Method TO3 can detect highly volatile compounds having boiling points in the range of -10° to 200°C. Because these species are present in the atmosphere at ppb levels or below, preconcentration is needed to acquire sufficient material for identification and quantitation.

The following compounds are detected by Method TO3:

Vinylidene chloride	Chloroform	1,2-Dichloroethane
Methylchloroform	Benzene	Trichloroethylene
Tetrachloroethylene	Chlorobenzene	

5.4.2 Cost Estimates for Cryogenic Trapping

Table 5-8 provides a breakdown of the capital, operation, and maintenance costs incurred in the installation and operation of a cryogenic trap sample concentrator and gas chromatograph/flame ionization detector (GC/FID) or electron capture detector (GC/EC) system. Network design costs are equivalent to that of the solid adsorbent and liquid impinger sampling methods. Table 5-9 summarizes these costs.

Site installation costs are higher for this method than those for other organic monitoring sites because of the installation of the more complex GC system. A sample of ambient air is drawn through a collection trap submerged in either liquid nitrogen or argon. Once the sample is collected, a carrier gas is used to sweep the contents of the trap onto the head of a cooled GC. A temperature-controlled shelter must be provided to house the equipment. The cost for a wired, 8 by 10-foot shelter with air conditioning and base board heat is given. Site preparation costs are also going to be higher both for labor and materials. Furthermore, security will probably be needed around the shelter. A 30-foot square of 6 to 8 foot high chain linked fence will cost approximately $1,200 to $1,800 installed. Other costs include utility hookup, phone line installation, and any benches, chairs, shelving, or lighting needed for the shelter. The sampling and analytical system consists of a cryogenic trap connected to a GC/FID or EC detector. This system is automated so a sample is automatically drawn and analyzed. It also is equipped with a data computerized acquisition system. The installation of a phone line will allow the site operator to upload and download information offsite. A PRO2 or senior TEC2 would be needed to install and operate this system.

Sampling and analysis costs include supplies, cryogen at about $50/day for 100 days and carrier gases, utility and phone costs, spare GC column, and site operation and service. Supplies for this method would be extra computer disks, printer paper, pens, and other assorted items. Gases required for this method include helium, hydrogen, air, liquid argon or liquid oxygen, and liquid nitrogen. Utility costs will be higher because of maintaining a temperature controlled environment and conducting analysis operations on site. A monthly fee will be charged for telephone service. Site service would be performed by a PRO2, and tasks performed on-site include instrument calibration and checkouts, sampling, and analysis. Travel time to and from the site is also included in the labor estimate.

Maintenance costs cover operation and maintenance activities that are not part of routine field service and spare parts. A PRO2 would conduct any maintenance while on site. These activities would include quarterly calibrations, replacement of any malfunctioning equipment, or fixing any system leaks.

Data management and reporting costs are basically the same as for other methods. However, data validation, both operational and statistical, would be higher because having the analytical equipment in the field exposes the results to more variability because of weather and site conditions. Therefore, more time is needed to evaluate other information to determine data validity.

QA and QC costs include capital and operational costs. Capital costs include QA plan preparation. calibration standards, audits, routine calibrations, reporting, training, and implementation nd coordination. Calibrations costs are estimated based on weekly calibration and audits on a quarterly basis. Reports on data quality and QA/QC conditions would be generated quarterly.

Supervision costs are higher for this method because of the additional complexity of the system and the extra time needed to review data and management requirements.

TABLE 5-8. CRYOGENIC TRAP METHOD TO3 SAMPLING COSTS

Cost Element	Options	Cost Type	Labor		Cost
			Level	Hours	
Network Design	✓	CPTL			3,072
Station Installation					
Procurement	✓	CPTL	PRO1	8	288
Land/lease	✓	O/M			1,500
Site preparation	✓	CPTL			3,000
Power hookup	✓	CPTL			350
Telephone hookup	✓	CPTL			50
Shelter	✓	CPTL			7,670
Shelter equipment	✓	CPTL			500
Security fencing	✓	CPTL			1,600
GC/FID or ECD with Cryogenic trap	✓	CPTL			35,000
Equipment installation	✓	CPTL	PRO2	40	1,680
Sampling and Analysis					
Supplies	✓	O/M			400
Cryogen, Supply gases	✓	O/M			5,800
Telephone service	✓	O/M			300
Utilities	✓	O/M			1,000
Site operation service	✓	O/M	PRO2	400	16,800
Maintenance					
Spare parts/supplies	✓	O/M			1,000
Remedial calibrations	✓	O/M	PRO2	12	504
Routine repairs	✓	O/M	PRO2	20	840
Remedial maintenance	✓	O/M	PRO2	25	1,050
Data Management					
Data acquisition/processing	✓	O/M	PRO1	16	576

(continued)

TABLE 5-8. CRYOGENIC TRAP METHOD TO3 SAMPLING COSTS (Continued)

Cost Element	Options	Cost Type	Labor		Cost
			Level	Hours	
Data reporting	✓	O/M	PRO2	8	336
Data validation operational	✓	O/M	PRO2	14	588
Data validation statistical	✓	O/M	PRO2	20	840
Quality Assurance					
Calibration standards	✓	O/M			1,000
Audits (in house)	✓	O/M	PRO2	16	672
Calibrations	✓	O/M	TEC2	61	2,013
Training	✓	O/M	PRO2	40	1,680
Training	✓	O/M	PRO2	20	660
Reporting	✓	O/M	PRO2	30	1,260
QA plan preparation	✓	CPTL	PRO2	40	1,680
Implementation/coordination	✓	O/M	PRO2	25	1,050
Supervision					
Planning/coordination	✓	O/M	PRO3	16	800
Supervision/review	✓	O/M	PRO3	16	800
Total Capital (CPTL) Costs					54,890
Total Operation and Maintenance Costs					41,469

TABLE 5-9. CRYOGENIC TRAP (METHOD TO3) COST SUMMARY

Cost Type	Cost
Capital Costs	54,890
Annualized Operation and Maintenance Costs	41,469
Average Annualized Cost	52,447

5.5 COST ESTIMATES FOR HI-VOL AND HI-VOL (PUF) SAMPLING

5.5.1 Introduction

This section provides cost summaries for two monitoring systems using hi-vol samples. The first system uses a hi-vol sampler for the detection of metals such as arsenic, beryllium, cadmium, chromium, manganese, and nickel. This sampler can also be used for TSP sampling. The second method (TO4) uses a modified hi-vol sampler with a polyurethane foam (PUF) backup absorbent cartridge to sample for a variety of organochlorine pesticides and polychlorinated biphenyls (PCBs). Table 5-10 illustrates the three types of metals analyses available. The table gives the metals detected, cost of equipment if purchased outright, and the contract cost per sample. Analysis methods include X-ray fluorescence (XRF), neutron activation analysis (NAA), and inductively coupled argon plasma optical emission spectrum (ICAP-OES).

TABLE 5-10. METALS ANALYSIS COSTS

	Methods		
	XRF	NAA	ICAP-OES
Metals detected	Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, Sr, Sn, Pb	Na, Mg, Al, Sc, Ti, V, Cr, Mn, Fe, Co, As, Se, Cd, Sb, I, La, Ce, Th	Be, Cd, Ba, Cu, Fe, Mg, Mo, Ni, Pb, V, Zn
Cost of equipment purchase	$33,000 - $50,000	Requires a nuclear reactor.	$185,000-$225,000
Contract cost per sample	$45	$300	$13 per element

5.5.2 Cost Estimates for Hi-Vol Metals Sampling

Table 5-11 gives a detailed cost breakdown for determining metals. Network design costs for metals sampling is the same as that given in Section 4.2 for lead, 1/6 day sampling and Section 4.3.1 for intermittent PM-10 sampling. The cost estimate is based on 75 hours at the mid-professional level (PRO2) and 125 hours of senior professional (PRO4) labor. The cost per site is obtained by dividing the cost of the study by five sites. Site selection includes a survey of candidate sites, and selection of final monitoring locations based on monitoring objectives and logistical constraints.

Station installation costs assume a reasonably accessible site near existing power. Metals are sampled using a hi-volume sampler which is self-contained in a weatherproof aluminum shelter. A complete sampler including flow control and recording equipment can be obtained for $2,000. Other costs include constructing a platform for the sampler and/or securing the unit to the roof of an existing shelter or building. These costs are included within the site preparation costs.

Sampling for metals involves routine site visits to replace filter media, record flows, and maintain the sampler. A sampling schedule of one 24-hour sample every 6 days is used for this cost estimate. Sampling supplies include folders and envelopes, flow recorder charts, and inks. Filter media are quartz filters and come in boxes of 100. Utilities would be approximately $100 a year. Site service would take about 1½ hours per sample and would be performed by a TEC1.

Maintenance involves cleaning and lubricating the sampler, inspecting gaskets and electrical connections, replacing the pump motor brushes and inspection of the pump bearings and housing, and recalibrating inlet flow rates. The average cost for spare parts and maintenance supplies is estimated at $250 per sampler per year. An additional maintenance visit is allowed for remedial maintenance (repairs).

Analytical costs for metals collected by hi-vol sampling are variable. Inductively coupled argon plasma optical emission spectrometry (ICAP-OES) is the analytical system used for the cost estimate. Unfortunately, this system is very expensive and must, in most cases, be used for other types of analyses as well to justify the expenditure. A suitable ICAP-OES including a data management system, output device, and exhaust system will cost around $200,000, and auxiliary equipment such as regulators, extractors, etc. will cost another $6,000. Equipment installation is time consuming and expensive. Other costs include analytical reagents and sample processing time. The Option 1 analytical (ICAP/OES, analytical reagents, equipment setup) and QA plan preparation costs were apportioned among five sites so that the costs shown in Table 5-11 are only one-fifth of the actual costs for these activities. Table 5-12 summarizes these costs. Table 5-10 shows three methods, including ICAP, for analyzing metals, what metals they are used for, the cost of equipment if reasonably available, and the price per sample for an outside laboratory to do the analysis.

Data management and reporting activities and level of effort per sample are typical of those for other toxic organic monitoring systems. Costs include data acquisition, processing, reporting, and validation.

QA and QC costs include QA plan preparation, coordination and implementation of the QA program, flow audits, reports, training, calibration standards, and calibration kit. Flow audit costs are based on two audits per year on each sampler. A PRO2 is assumed for conducting the audit, and a TEC2 is assumed for flow calibrations. Calibration standards for ICAP-OES are variable depending on the target species to be analyzed. For the cost estimate only one standard was priced. Depending on the final system used, this cost could be much higher. Reports on QA activities were based on one management review report per quarter. Training costs are also included.

Estimated costs for supervision and management are given for a typical monitoring program as discussed in Section 5.2.

TABLE 5-11. HI-VOL METALS SAMPLING COSTS

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Network Design	✓	✓	CPTL			3,072
Site Installation						
Procurement	✓	✓	CPTL	PRO1	8	288
Land/lease	✓	✓	O/M			1,500
Site preparation	✓	✓	CPTL			3,000
Power hookup	✓	✓	CPTL			350
Hi-vol sample system	✓	✓	CPTL			2,000
Filter holders (2)	✓	✓	CPTL			120
Equipment installation	✓	✓	CPTL	TEC2	8	264
Sampling						
Supplies	✓	✓	O/M			100
Quartz filters (100)	✓	✓	O/M			225
Utilities	✓	✓	O/M			100
Site service	✓	✓	O/M	TEC1	90	2,700
Maintenance						
Spare parts	✓		O/M			200
Spare parts		✓	O/M			150
Remedial calibrations	✓		O/M	TEC2	12	396
Remedial calibrations		✓	O/M	TEC2	6	198
Routine repairs	✓		O/M	TEC2	6	198
Routine repairs		✓	O/M	TEC2	4	132
Remedial maintenance	✓		O/M	TEC2	6	198
Remedial maintenance		✓	O/M	TEC2	4	132
Analytical						
Contract laboratory analysis		✓	O/M			10,010
Equipment - ICAP/OES	✓		CPTL			40,000
Equipment (auxiliary)	✓		CPTL			1,200
Analytical reagents	✓		O/M			1,000
Processing	✓		O/M	PRO2	70	2,940
Equipment Setup	✓		CPTL	PRO2	40	1,680

(continued)

TABLE 5-11. HI-VOL METALS SAMPLING COSTS (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Data Management						
Data acquisition/processing	✓		O/M	PRO1	16	576
Data acquisition/processing		✓	O/M	PRO1	8	288
Data reporting	✓	✓	O/M	PRO2	8	336
Data validation	✓	✓	O/M	PRO2	8	336
Quality Assurance						
Calibration standards & kit	✓		O/M			780
Audits	✓		O/M	PRO2	8	336
Audits		✓	O/M	PRO2	4	168
Calibrations	✓		O/M	TEC2	16	528
Calibrations		✓	O/M	TEC2	8	264
Training	✓		O/M	PRO2	40	1,680
				TEC2	20	660
Training		✓	O/M	PRO2	8	336
				TEC2	8	264
Reporting	✓	✓	O/M	PRO2	30	1,260
QA plan preparation	✓		CPTL	PRO2	16	672
QA plan preparation		✓	CPTL	PRO2	2	66
Implementation/coordination	✓		O/M	PRO2	16	672
Implementation/coordination		✓	O/M	PRO2	8	336
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	16	800
Supervision/review	✓	✓	O/M	PRO3	16	800
Total Capital (CPTL) Costs - Option 1						52,646
Total Operation and Maintenance Costs - Option 1						18,321
Total Capital (CPTL) Costs - Option 2						9,160
Total Operation and Maintenance Costs - Option 2						20,435

Option 1 - Sampling and analysis conducted by agency
Option 2 - Sampling conducted by agency, analysis conducted by a contractor

TABLE 5-12. HI-VOL METALS COST SUMMARY

Cost Type	Cost			
	Option #1	Option #2		
		XRF	NAA	ICAP-OES
Capital Costs	52,646	9,160	9,160	9,160
Annualized Operation and Maintenance Costs	18,321	13,575 (a)	31,425 (b)	20,435 (c)
Average Annualized Cost	28,850	15,407	33,257	22,267

(a) Analysis performed on 70 samples at $45/sample

(b) Analysis performed on 70 samples at $300/sample

(c) Analysis performed on 70 samples at $143/sample

5.5.3 Cost Estimates for Polychlorinated Biphenyls (PCBs) and Organochlorine Pesticides using Hi-Vol (PUF) Sampling (TO4)

Table 5-13 gives detailed cost estimates for PCB and organochlorine pesticides. Network design costs may be more extensive than for metals sampling. The identification and location of sources and determination of pollutant distributions and concentrations can be expected to take more time and resources than for metals. For these reasons, the cost of network design for hi-vol (PUF) sampling is equivalent to the other toxic organic sampling methods.

Station installation costs are the same as for metals sampling. However, the cost of the hi-vol sampler is different. This method requires the use of a modified hi-vol sampler with a polyurethane foam (PUF) plug behind a quartz filter to trap the analytes. This absorbent plug is then analyzed for specific analytes using a GC with an electron capture detector (ECD). A hi-vol (PUF) sampler consists of a vacuum pump capable of drawing samples at 200-280ℓ/minute, dual sampling module, flow venturi, elapsed time indicator, seven day skip timer, and an anodized aluminum shelter.

Sampling costs are basically the same as for metals. Site service is performed by a TEC1 responsible for changing filters, checking equipment, and conducting flow checks. The cost of PUF plugs are $2.75 apiece for the 2" plug and the cost for quartz filters are the same as those for metals sampling.

Maintenance and repair costs are also the same as those for metals sampling (see Section 5.6.2).

Analytical costs include GC/ECD, solvents, standards, and labor. A GC/ECD would cost about $26,500 and includes a computerized data acquisition system. Auxiliary equipment would include regulators, extra GC column, etc. The cost estimate for solvents and standards is for one standard size cylinder. Depending on laboratory operation, number of samples, and type of method used, this cost will most probably be much higher. Sample analysis can be broken down into two parts: sample preparation and sample analysis. Sample processing can be conducted by a TEC2 and involves extracting the analytes from the sample. This needs to be done within one week of collection. A PRO2 would conduct the sample analysis and the analytical equipment installation. The Option 1 analytical (GC/ECD, auxiliary equipment, analytical reagents, equipment setup) and QA plan preparation costs were divided among five sites so that the costs given in Table 5-13 are only one-fifth of the actual costs for these activities. Laboratory analysis on a contract basis would cost approximately $150 per sample. The sampling schedule of one 24-hour sample every 6 days would yield 61 samples per year at a yearly cost of $9,150. Another $1,350 is required for duplicate/replicate sample analyses.

Data management and reporting costs including data acquisition would be the same as for metals. QA and QC costs include capital and operational expenditures. Capital costs are for a calibration kit and QA plan preparation. Operational costs include audits, calibrations, training, reporting, and implementation and coordination. These costs are the same as for metals analysis.

Supervision and management costs are the same as those for high-volume sampling for metals.

TABLE 5-13. COSTS ESTIMATES FOR HI-VOL (PUF) SAMPLING (TO4)

Cost Element	Options		Cost Type	Professional		Cost
	Opt1	Opt2		Level	Hours	
Network Design	✓	✓	CPTL			3,072
Site Installation						
Procurement	✓	✓	CPTL	PRO1	8	288
Land/lease	✓	✓	O/M			1,500
Site preparation	✓	✓	CPTL			3,000
Power hookup	✓	✓	CPTL			350
Hi-vol (PUF) sample system	✓	✓	CPTL			2,130
Filter holders (2)	✓	✓	CPTL			120
Equipment installation	✓	✓	CPTL	TEC2	8	264
Sampling						
Supplies	✓	✓	O/M			100
Quartz filter (100)	✓	✓	O/M			225
2" PUF Plug (100)	✓	✓	O/M			170
Utilities	✓	✓	O/M			100
Site service	✓	✓	O/M	TEC1	90	2,700
Maintenance						
Spare parts	✓		O/M			200
Spare parts		✓	O/M			150
Remedial calibrations	✓		O/M	TEC2	12	396
Remedial calibrations		✓	O/M	TEC2	6	198
Routine repairs	✓		O/M	TEC2	6	198
Routine repairs		✓	O/M	TEC2	4	132
Remedial maintenance	✓		O/M	TEC2	6	198
Remedial maintenance		✓	O/M	TEC2	4	132
Analytical						
Contract laboratory analysis (70 samples)		✓	O/M			10,500
Equipment - GC/ECD	✓		CPTL			5,300
Equipment (auxiliary)	✓		CPTL			200
Sample preparation	✓		O/M	TEC2	104	3,432
Analytical reagents	✓		O/M			300
Analysis	✓		O/M	PRO2	115	4,830
Equipment Setup	✓		CPTL	PRO2	8	336

(continued)

TABLE 5-13. COSTS ESTIMATES FOR HI-VOL (PUF) SAMPLING (TO4) (Continued)

Cost Element	Options		Cost Type	Professional		Cost
	Opt1	Opt2		Level	Hours	
Data Management						
Data acquisition/processing	✓		O/M	PRO1	16	576
Data acquisition/processing		✓	O/M	PRO1	8	288
Data reporting	✓	✓	O/M	PRO2	8	336
Data validation	✓	✓	O/M	PRO2	8	336
Quality Assurance						
Calibration standards & kit	✓		O/M			780
Audits	✓		O/M	PRO2	8	336
Audits		✓	O/M	PRO2	4	168
Calibrations	✓		O/M	TEC2	16	528
Calibrations		✓	O/M	TEC2	8	264
Training	✓		O/M	PRO2	40	1,680
				TEC2	20	660
Training		✓	O/M	PRO2	8	336
				TEC2	8	264
Reporting	✓	✓	O/M	PRO2	20	840
QA plan preparation	✓		CPTL	PRO2	8	336
QA plan preparation		✓	CPTL	PRO2	2	66
Implementation/coordination	✓		O/M	PRO2	16	672
Implementation/coordination		✓	O/M	PRO2	8	336
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	16	800
Supervision/review	✓	✓	O/M	PRO3	16	800
Total Capital (CPTL) Costs - Option 1						15,396
Total Operation and Maintenance (O/M) Costs - Option 1						22,693
Total Capital (CPTL) Costs - Option 2						9,290
Total Operation and Maintenance (O/M) Costs - Option 2						20,675

Option 1 - Sampling and analysis conducted by agency
Option 2 - Sampling conducted by agency, analysis conducted by a contractor

TABLE 5-14. HI-VOL (PUF) COST SUMMARY

Cost Type	Cost	
	Option #1	Option #2
Capital Costs	15,396	9,290
Annualized Operation and Maintenance Costs	22,693	20,675
Average Annualized Cost	25,772	22,533

5.6 SUMMA® CANISTER VOC SAMPLING (Method TO14)

5.6.1 Introduction

Method TO14 describes a procedure for collecting ambient air VOCs in canisters. The use of canisters provides convenient integration of ambient air samples over a specific time period, remote sampling and central analysis, ease of storing and shipping samples, unattended sample collection, analysis of samples from multiple sites with one analytical system, and collection of sufficient sample volume to allow assessment of measurement precision and/or analysis of samples by several analytical systems. In addition to VOCs, some semi-volatile organic compounds (SVOCs) can also be collected using SUMMA® canisters. SVOCs are organic compounds that are too volatile to be collected by filtration air sampling but not volatile enough for thermal desorption from solid adsorbents. Generally, these compounds have saturation pressures at 25°C between 10^{-1} and 10^{-7} mm Hg. VOCs are generally classified as those organics having saturated vapor pressures greater than 10^{-1} mm Hg.

SUMMA® canister sampling using Method TO14 can be used to test for the following compounds: Freon 12, Methyl chloride, Freon 114, Vinyl chloride, Methyl bromide, Ethyl chloride, Freon 11, Vinylidene chloride, Dichloromethane, Freon 113, 1,1-Dichloroethane, cis-1,2-Dichloroethylene, Chloroform , 1,2-Dichloroethane, Methyl chloroform, Benzene, Carbon tetrachloride, 1,2-Dichloropropane, Trichloroethylene, cis-1,3-Dichloropropene, trans-1,3-Dichloropropene, 1,1,2-Trichloroethane, Toluene, 1,2-Dibromoethane, Tetrachloroethylene, Chlorobenzene, Ethylbenzene, m-Xylene, p-Xylene, Styrene, 1,1,2,2-Tetrachloroethane, o-Xylene, 1,3,5-Trimethylbenzene, 1,2,4-Trimethylbenzene, m-Dichlorobenzene, Benzyl chloride, o-Dichlorobenzene, p-Dichlorobenzene, 1,2,4-Trichlorobenzene, Hexachlorobutadiene

Method TO14 is used by the Air Toxics Program and the Non-methane Organic Compound Program to sample for VOCs. These programs specify specific sampling apparatus in order to comply with the program. Costs collected for this method are for a single event canister monitoring site.

5.6.2 Cost Estimate for SUMMA® Canister VOC Sampling and Analysis

Details of the costs associated with VOC measurements are provided in Table 5-15. Station installation costs include labor, site preparation, power hookup, site leasing, and equipment purchases. This cost estimate assumes a readily accessible site near an existing power supply. A power drop under this scenario would be about $300. Site preparation would be performed by a TEC2. Materials needed for this activity would include items to build a platform for the sampler and any hardware to attach the sampler. The VOC sampler is a self-contained single event system. It consists of a 0-30 cc/min controller with electronic display, teflon diaphragm vacuum pump, electronic 1-24 hour programmer/timer, elapsed time meter, and a portable weather cabinet with thermostat control and collapsible legs. Equipment installation costs are based on 12 hours of TEC2s time.

Sampling incorporates both capital and operational costs. Capital costs cover the purchase of five SUMMA® canisters and two shipping containers. Canister costs are based on a single purchase price of about $560 each and a shipping container at $179 each. Operation and maintenance costs include supplies, utilities, and site service. Site service is conducted by a TEC1 based on 1 hour per site to change canisters, examine equipment, and check flow rates.

Maintenance costs include supplies, remedial calibrations, routine repairs, and any other corrective action. These include field and laboratory activities. Routine calibrations are usually performed on a quarterly basis and are estimated at 3 hours per quarter. Four hours have been allocated for any emergency or remedial maintenance and for routine repairs.

Analysis of SUMMA® canister samples can either be done by a contract laboratory or done in-house after the purchase of needed equipment. If the samples are sent out, the cost is about $350 per sample or $24,500 dollars for 70 samples per year including blanks. The cost includes cleaning of the canister to required certification, shipping of the canisters, and a data report of the findings. In order to conduct the analysis in house a high resolution gas chromatograph coupled to a mass spectrometer or multi-detector system is needed. Prices will vary depending on the specific detection system chosen. For this example a system priced at $115,000 is used. The GC/MS or multidetector in this cost estimate is equipped with a data acquisition and report preparation system. A canister cleaning system is included and can be purchased for $15,000. Supplemental equipment costs include GC columns, regulators, and other miscellaneous items. Equipment setup is estimated at about 40 hours by a PRO2. Sample processing takes roughly 1 hour per sample. The canister cleaning system can hold up to 16 canisters at one time and takes 3 hours to complete the cleaning cycle. However, it is assumed that actual labor time is one hour.

Data management and reporting costs are slightly higher than for the other toxic organic monitoring systems because of the larger number of pollutants measured.

QA and QC measures include calibration standards, development of a QA plan, training, audits, calibrations, reporting on QA activities, and implementation and coordination of QA procedures. Duplicate and replicate sample costs should be added to the total price for the 70 samples. Audits, training, reporting, and QA plan preparation are calculated for a PRO2 and TEC2. TEC2 rates are used for estimating routine calibrations.

Supervision and management cost estimates are the same as for the other toxic organic monitoring systems. A summary of the VOC monitoring costs is given in Table 5-16.

TABLE 5-15. SUMMA CANISTER (Method TO14) COSTS

Cost Element	Options		Cost Type	Professional		Cost
	Opt1	Opt2		Level	Hours	
Network Design	✓	✓	CPTL			3,072
Site Installation						
Procurement	✓	✓	CPTL	PRO1	8	288
Land/lease	✓	✓	O/M			1,500
Site preparation	✓	✓	CPTL			3,000
Power hookup	✓	✓	CPTL			350
VOC canister sampler	✓	✓	CPTL			6,940
Equipment installation	✓	✓	CPTL	TEC2	12	396
Sampling						
Supplies	✓	✓	O/M			100
SUMMA® canisters (8 at $535)	✓	✓	CPTL			4,280
Shipping containers (6 at $180)		✓	CPTL			1,080
Utilities	✓	✓	O/M			100
Site service	✓	✓	O/M	TEC1	61	1,830
Maintenance						
Spare parts/supplies	✓		O/M			500
Spare parts/supplies		✓	O/M			200
Remedial repairs	✓		O/M	TEC2	8	264
Remedial repairs		✓	O/M	TEC2	4	132
Routine maintenance	✓		O/M	TEC2	20	660
Routine maintenance		✓	O/M	TEC2	10	330
Analytical						
Contract laboratory analysis		✓	O/M			24,500
Equipment (GC/MS)	✓		CPTL			23,000
Canister cleaning system	✓		CPTL			3,000
Supplemental equipment	✓		CPTL			300
Supplies	✓		O/M			100
Operation of GC/MS	✓		O/M	PRO2	80	3,360
				TEC2	100	3,300
Canister cleaning	✓		O/M	PRO2	20	840
				TEC2	61	2,013
Equipment Setup	✓		CPTL	PRO2	40	1,680

(continued)

TABLE 5-15. SUMMA CANISTER (Method TO14) COSTS (Continued)

Cost Element	Options		Cost Type	Professional		Cost
	Opt1	Opt2		Level	Hours	
Data Management						
Data acquisition/processing	✓		O/M	PRO1	24	864
Data acquisition/processing		✓	O/M	PRO1	16	576
Data reporting	✓	✓	O/M	PRO2	12	504
Data validation	✓	✓	O/M	PRO2	12	504
Quality Assurance						
Canister certification system	✓		CPTL	-		233
Calibration standards	✓		O/M			200
Audits	✓		O/M	PRO2	16	672
Audits		✓	O/M	PRO2	8	336
Calibrations	✓		O/M	TEC2	12	396
Calibrations		✓	O/M	TEC2	6	198
Training	✓		O/M	PRO2	40	1,680
				TEC2	20	660
Training		✓	O/M	PRO2	8	336
				TEC2	8	264
QA plan preparation	✓		CPTL	PRO2	10	420
QA plan preparation		✓	CPTL	PRO2	8	336
Supervision						
Implementation/coordination	✓		O/M	PRO2	16	672
Implementation/coordination		✓	O/M	PRO2	8	336
Planning/coordination	✓	✓	O/M	PRO3	8	400
Supervision/review	✓	✓	O/M	PRO3	8	400
Total Capital (CPTL) Costs - Option 1						46,959
Total Operation and Maintenance (O/M) Costs - Option 1						21,519
Total Capital (CPTL) Costs - Option 2						19,742
Total Operation and Maintenance (O/M) Costs - Option 2						32,546

Option 1 - Sampling and analysis conducted by agency
Option 2 - Sampling conducted by agency, analysis conducted by a contractor

TABLE 5-16. SUMMA® CANISTER COST SUMMARY FOR VOCs

Cost Type	Cost	
	Option #1	Option #2
Capital Costs	46,959	19,742
Annualized Operation and Maintenance Costs	21,519	32,546
Average Annualized Cost	30,911	36,494

5.7 REFERENCES

1. U.S. Environmental Protection Agency, *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, EPA-600/4-89-017. Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 27711. June 1988.

2. U.S. Environmental Protection Agency, *Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air*, EPA-600/4-83-027. Environmental Monitoring Systems Laboratory, Research Triangle Park, NC, 27711. June 1983.

3. Radian Corporation, *Screening Methods for the Development of Air Toxic Emission Factors*, EPA-450/4-91-021. U.S. Environmental Protection Agency, Technical Support Division, Research Triangle Park, NC, 27711. September 1991.

4. PEI Associates, Inc., *Cost of Ambient Air Monitoring for Criteria Pollutants and Selected Toxic Pollutants*, EPA-450/4-85-004, U.S. Environmental Protection Agency, Office of Air and Radiation, Research Triangle Park, NC, 27711. May 1985.

SECTION 6.0

METEOROLOGICAL MEASUREMENTS

6.1 BACKGROUND

Meteorological parameters are measured as an integral part of PSD monitoring programs as well as by the National Weather Service and by independent research studies. Recent changes to the 40 CFR Part 58 air quality surveillance regulations added provisions for surface meteorological monitoring at each PAMS site and upper air meteorological monitoring for each PAMS area.[1]

In this cost analysis, two levels of site sophistication are presented: (1) a site that is configured to meet basic PSD and PAMS monitoring requirements, and (2) an advanced system that includes equipment to measure additional parameters for a more detailed atmospheric characterization which could also be incorporated into a part of the PSD or PAMS monitoring program. The advanced system includes cost estimates to conduct upper air meteorological monitoring.

6.2 COST ESTIMATES FOR A BASIC METEOROLOGICAL SYSTEM

The following parameters must be measured in a meteorological monitoring program that meets the basic requirements of the PSD monitoring guidelines: wind speed (horizontal, hourly), wind direction (horizontal, hourly), hourly ambient temperature, hourly precipitation, hourly dewpoint, barometric pressure and solar radiation.[2] The parameters listed in EPA's guidance document, *Technical Assistance Document for Sampling and Analysis of Ozone Precursors*,[3] include all of the preceding except hourly precipitation, and dewpoint.[3] In addition, hourly average mixing heights may be necessary for air quality impact analysis and model input and evaluation. These mixing height measurements can be derived by extrapolating the twice-daily radar acoustic sounding measurements routinely collected by the NWS. The cost of an upper air system for the PAMS program is included in Section 6.3.

Requirements for additional instrumentation and data will depend upon the topography of the area; the effects of pollutant emissions on ambient air quality, soils, vegetation, and visibility; and the input requirements of the dispersion modeling techniques used in the air quality analysis. The basic system assumes that these other complexities are minimal and does not consider the special requirements that such an area would entail. Cost estimates for the proposed basic meteorological system described in this section are presented in Table 6-1.

Station installation costs include site preparation, equipment, shelter, and labor to install the equipment. The basic meteorological system includes a wind direction/wind speed measuring system, a temperature probe, a dewpoint sensor, a pyranometer for solar radiation, a tipping bucket sensor that records precipitation, and a barometric pressure sensor. The data acquisition system includes a computer that can be polled remotely by a telephone or satellite link. A strip chart recorder is used as a backup. Because a wide variety of meteorological sensors, translators,

TABLE 6-1. COST ESTIMATES FOR BASIC METEOROLOGICAL MEASUREMENT SYSTEM

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Network Design				
Network design & site selection	CPTL	PRO2	150	6,300
		PRO3	50	2,500
Site Installation				
Site lease	O/M			1,500
Utilities hookup	CPTL			350
10-m tower	CPTL			1,000
6-ft boom	CPTL			600
Guy kit	CPTL			400
Shelter	CPTL			8,700
Security fence	CPTL			600
Site preparation (clearing, setup & wiring)	CPTL	Contractor		3,000
Wind direction/speed system	CPTL			845
Crossarm	CPTL			275
Air temperature probe	CPTL			200
Dew point sensor	CPTL			600
Solar radiation shield	CPTL			200
Pyranometer	CPTL			1,000
Mast adapter	CPTL			300
8" tipping bucket	CPTL			1,450
Wind screen	CPTL			460
Barometric pressure sensor	CPTL			1,100
Wind direction calibrator	CPTL			1,900
Wind speed calibrator	CPTL			1,500
Temperature calibrator	CPTL			650
Precipitation calibrator	CPTL			300

(Continued)

TABLE 6-1. COST ESTIMATES FOR BASIC METEOROLOGICAL MEASUREMENT SYSTEM (Continued)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Humidity & dew point calibrator	CPTL			1,000
Solar radiation calibrator	CPTL			1,000
Pressure calibrator	CPTL			1,400
Data logger	CPTL			2,000
Ram pack	CPTL			450
Data cassette recorder	CPTL			900
Strip chart recorder (backup)	CPTL			1,600
Niemann enclosure	CPTL			1,000
Computer hardware and software	CPTL			5,000
Additional power supply for instruments	CPTL			1,000
Accessories	CPTL			700
Procurement	CPTL	PRO1	60	2,160
Equipment installation	CPTL	TEC2	40	1,320
		PRO2	24	1,008
Acceptance testing	CPTL	TEC2	16	528
		PRO2	6	252
		Contractor	6	300
Sampling				
Utilities	O/M			1,800
Routine field service supplies	O/M			500
Routine field service checks	O/M	TEC1	208	6,240
		TEC2	60	1,980
		PRO2	16	672
Travel expenses	O/M			1,254
Maintenance				
Remedial field service - corrective action	O/M	TEC1	16	480
		TEC2	16	528
		TEC2	8	340
Remedial field service - spare parts	O/M			1,500

(Continued)

TABLE 6-1. COST ESTIMATES FOR BASIC METEOROLOGICAL MEASUREMENT SYSTEM (Continued)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Data Management				
Data acquisition, processing and reporting	O/M	TEC2	144	4,752
Data validation	O/M	PRO2	24	1,008
Quality Assurance				
Implementation/coordination	O/M	PRO2	24	1,008
QA plan preparation	CPTL	PRO2	20	840
Calibrations	O/M	TEC2	24	792
QA/QC reporting & review	O/M	PRO2	24	1,008
Audit	O/M	TEC1	16	480
		TEC2	16	528
		PRO2	16	672
Supervision				
Planning/coordination	O/M	PRO3	24	1,200
Supervision/review	O/M	PRO3	24	1,200
Total Capital (CPTL) Costs				56,688
Total Operation and Maintenance (O/M) Costs				29,442

A summary of the costs for the basic meteorological measurement systems are shown in Table 6-2.

TABLE 6-2. TOTAL COSTS FOR THE BASIC METEOROLOGICAL SYSTEM

Cost Type	Cost
Capital Costs	56,688
Annualized Operation and Maintenance Costs	29,442
Average Annualized Cost	40,779

data loggers, and other system components are available, the meteorological monitoring equipment performance and accuracy specifications contained in EPA's PSD monitoring guideline are used as a guideline for this cost analysis.

All sensors should be mounted on a 10-meter tower. Installation costs for the tower are included in site preparation costs. Associated booms, cross arms, and cable assemblies will be needed to mount the sensors and to connect them to the data acquisition system. Costs for miscellaneous cables, connectors, locks, mounting bolts pads, etc are included in the cost for accessories. Labor costs for bench-testing and calibrating the instruments before they are installed in the field are included. Contractor assistance is assumed for sensors that might require elaborate preset-up testing and periodic retesting such as the use of a wind tunnel.

Sampling costs include routine operations and field service. These are labor, travel, supplies, and utilities. Costs for routine site visits include 52 weekly visits per year plus an additional 24 visits per year for other activities such as data acquisition and QA. This assumes a 60 mile round trip for the site operator for PSD sites. Technician time on-site includes travel time and time required for the necessary weekly and monthly routine service and operational checks. Quarterly field checks are also conducted by a junior professional. Annual supply costs for routine site service include costs such as chart paper, pens, and cleaning supplies. Costs for utilities include a monthly telephone service charge.

Maintenance and repair costs include spare parts, and corrective action repairs and remedial equipment service that is not part of routine field service. Data management and reporting costs are for continuous data acquisition, processing, validation and reporting. Routine data reports consist of monthly, computer generated data summaries including graphics. The cost of developing software and procedures for data management is not included in the cost estimates; however, the purchase of appropriate software is included as part of the PC hardware and software items listed under the installation category.

QA procedures at the site as recommended in the EPA document, *Quality Assurance Handbook for Air Pollution Measurements, Volume IV-Meteorological Measurements*, specifies a minimum of two yearly audits.[4] In addition to the required audits, costs for routine quarterly calibrations, QA checks on data logging and reporting procedures and preparation of a QA project plan are also included.

6.3 COST ESTIMATES FOR AN ADVANCED METEOROLOGICAL SYSTEM

The advanced meteorological system may be obtained by building upon the basic system described in Section 6.2. For the advanced system discussed in this section, it is assumed that complex terrain and associated wind-flow regimes are predominant and the equipment selected has been chosen to provide extra accuracy, sensitivity, and dependability. The following parameters are included: wind speed (horizontal and vertical, hourly), wind direction (three dimensional, hourly), hourly ambient temperature profile at two different heights on the 30-meter tower, coincidental temperature and humidity, hourly precipitation, hourly dewpoint, barometric pressure, solar radiation, and hourly average mixing heights. The Part 58 PAMS regulations specify that at least one upper air meteorological measurement station be established to obtain improved mixing height estimations.[1] For cost estimations we assumed here that a doppler radar system (at $125,000) would be used to determine upper air wind speed and wind direction. In addition, the cost of a radio acoustic sounding system ($15,000) was added for temperature determinations. Finally a price of $10,000 was included for a computer, processing software, and communication equipment which allows for transfer of the data to the agency main database. The advanced and the basic system both have the following equipment: guy kit, 6-foot boom, shelter, security fence, crossarm, dew point sensor, wind screen, barometric pressure sensor, wind direction calibrator, wind speed calibrator, solar radiation calibrator, pressure calibrator, data logger, ram pack, data cassette recorder, stripchart recorder, and a nieman enclosure. New equipment included in the advanced system are net radiometer, doppler radar system, and the radar acoustic sounding system. Enhanced equipment at the advanced site include a 30-meter tower versus a 10-meter tower at the basic station, 2 temperature probes for vertical temperature profiles, multiple radiation shields, 12" tipping bucket, and enhanced computer and software package. Detailed cost estimates for the entire advanced meteorological system described in this section are presented in Table 6-3, and a summary is given in Table 6-4.

Station installation costs include site preparation, equipment and shelter, and labor. Because a wide variety of meteorological sensors, translators, data loggers, and other system components are available, the requirements of the PSD specifications for equipment performance and accuracy were used as a guideline for this cost analysis. All assemblies should be mounted on a 30-meter tower for improved accuracy. Installation costs for the tower are included in site preparation costs. A safety climb system and a work platform are included for safer and more convenient tower maintenance. Associated booms, cross arms and cable assemblies are be needed to mount the sensors and to connect them to the data acquisition system. Costs for miscellaneous cables, connectors, locks, mounting bolts pads, etc. are included in costs for accessories. Labor costs for bench-testing and calibrating the instruments before they are installed in the field are also included. Contractor assistance is assumed for sensors that might require an elaborate set-up such as a wind tunnel.

Sampling costs include routine operations and field service. These are labor, travel, supplies, and utilities. Costs for routine site visits include 52 weekly visits per year plus an additional 36 visits per year for other activities such as data acquisition and QA. This assumes a 60-mile round trip for the site operator. A senior technician (TEC 2) is required due to the use of more sophisticated equipment. Technician time on-site includes travel time and time required for the necessary weekly, monthly, service and operational checks. Quarterly field checks are also conducted by a junior professional. Annual supply costs for routine site service include costs such as computer supplies, chart paper, pens, and cleaning supplies. Costs for utilities include a monthly telephone service charge.

Maintenance costs include corrective action, spare parts and routine equipment service that is not part of routine field service. Data management and reporting costs are for continuous data acquisition, processing, validation and reporting. Routine data reports consist of monthly, computer generated data summaries including graphics. The cost of developing software and procedures for data management is not included in the cost estimates.

TABLE 6-3. COST ESTIMATES FOR ADVANCED METEOROLOGICAL MEASUREMENT SYSTEM

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Network Design				
Network design & site selection	CPTL	PRO2	200	8,400
		PRO3	100	5,000
Site Installation				
Site lease	O/M			1,500
Utilities hookup	CPTL			350
30-m tower	CPTL			5,500
Guy kit	CPTL			400
6-ft boom	CPTL			600
Work platform	CPTL			400
Safety climb system	CPTL			850
Shelter	CPTL			9,000
Security fence	CPTL			600
Site preparation (clearing, wiring & setup)	CPTL	Contractor		4,600
Micro response wind vane	CPTL			900
Crossarm	CPTL			275
Propeller anemometer	CPTL			450
U-V-W mast adapter	CPTL			725
Temperature profile (2 temp. probes)	CPTL			400
Dew point sensor	CPTL			600
Humidity/temp. probe	CPTL			900
Solar radiation shield (4)	CPTL			800
Net radiometer	CPTL			1,300
Free standing mast	CPTL			110
12 " tipping bucket	CPTL			1,800
Wind screen	CPTL			460
Barometric pressure sensor	CPTL			1,100

(Continued)

TABLE 6-3. COST ESTIMATES FOR ADVANCED METEOROLOGICAL MEASUREMENT SYSTEM (Continued)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Doppler radar system	CPTL			125,000
Radar acoustic sounding system	CPTL			15,000
Additional computer hardware & software	CPTL			10,000
Wind direction calibrator	CPTL			1,900
Wind speed calibrator	CPTL			1,500
Temperature calibrator	CPTL			650
Humidity & dew point calibrator	CPTL			1,000
Solar radiation calibrator (duplicate equipment)	CPTL			1,300
Precipitation calibrator	CPTL			300
Pressure calibrator	CPTL			1,400
Data logger	CPTL			2,000
Ram pack	CPTL			450
Data cassette recorder	CPTL			900
Strip chart recorder (backup)	CPTL			1,600
Niemann enclosure	CPTL			1,000
Additional power supply for instruments	CPTL			900
Accessories	CPTL			1,000
Equipment procurement	CPTL	PRO1	100	4,200
Equipment installation	CPTL	TEC2	48	1,584
		PRO2	32	1,344
Acceptance testing	CPTL	TEC2	20	660
		PRO2	8	336
		Contractor	8	300
Sampling				
Utilities	O/M			1,980
Routine field service supplies	O/M			700
Routine field service checks	O/M	TEC2	312	10,296

(Continued)

TABLE 6-3. COST ESTIMATES FOR ADVANCED METEOROLOGICAL MEASUREMENT SYSTEM (Continued)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
	O/M	PRO2	24	1,008
Travel expenses	O/M			1,452
Maintenance				
Remedial field service - corrective action	O/M	TEC2	40	1,320
		PRO2	16	672
Remedial field service - spare parts	O/M			2,000
Data Management				
Data acquisition, processing and reporting	O/M	TEC2	192	6,336
Data validation	O/M	PRO2	36	1,512
Quality Assurance				
Implementation/coordination	O/M	PRO2	32	1,344
QA plan preparation	CPTL	PRO2	28	1,176
Calibrations	O/M	TEC2	32	1,056
QA/QC reporting & review	O/M	PRO2	32	1,344
Audits	O/M	TEC2	24	792
		PRO2	24	1,008
Supervision				
Planning/coordination	O/M	PRO3	32	1,600
Supervision/review	O/M	PRO3	32	1,600
Total Capital (CPTL) Costs				221,020
Total Operation and Maintenance (O/M) Costs				37,520

TABLE 6-4. TOTAL COSTS FOR THE ADVANCED METEOROLOGICAL SYSTEM

Cost Type	Cost
Capital	221,020
Annual Operation and Maintenance	37,520
Average Annualized Cost	81,724

QA procedures at the site as recommended by the EPA document, *Quality Assurance Handbook for Pollution Measurements, Volume IV-Meteorological Measurements*,[4] consist of a minimum of two yearly audits. In addition to the required audits, costs for routine quarterly calibrations and QA checks on data logging and reporting procedures are also included. Supervision and management for the overall measurement program include 64 hours for a PRO 3.

6.4 REFERENCES

1. U.S. Environmental Protection Agency, *Federal Register*, Volume 58, No. 28, Appendix D, Section 4.6, February 12, 1993.

2. *Ambient Air Monitoring Guideline for Prevention of Significant Deterioration* (PSD), EPA-450/4-87-007, U.S. Environmental Protection Agency, Research Triangle Park, NC, 27711. May 1987.

3. *Technical Assistance Document for Sampling and Analysis of Ozone Precursors*, EPA-600/8-91-215, U.S. Environmental Protection Agency, Research Triangle Park, NC, 27711. October 1991.

4. *Quality Assurance Handbook for Air Pollution Measurements, Volume IV-Meteorological Measurements*, Revised EPA-600/4-90-003, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. August 1989.

SECTION 7.0

PHOTOCHEMICAL ASSESSMENT MONITORING

7.1 BACKGROUND

Unlike the SLAMS and NAMS network design criteria which are pollutant specific, PAMS network design criteria are specific to site location.[1] At each PAMS, concurrent measurements of O_3, NO_x, speciated VOCs, carbonyl compounds, and meteorological parameters are conducted. Consequently, design criteria for the PAMS network are based on selection of an array of site locations for O_3 precursor source areas and predominant wind directions associated with high O_3 events. Specific monitoring objectives associated with each PAMS location are related to the following five principal uses of the PAMS data: (1) NAAQS attainment and control strategy development, (2) SIP control strategy evaluation, (3) emissions tracking, (4) air quality trends including VOC, NO_x, O_3, and limited toxic air pollutant trends, and (5) exposure assessment. A maximum of five PAMS sites are required in O_3 nonattainment areas listed as serious, severe, or extreme. The actual number of sites depends on the population of the Metropolitan Statistical Area/Consolidated Metropolitan Statistical Area (MSA/CMSA) or nonattainment area, whichever is larger. Specific monitoring objectives associated with each site result in four distinct site types.

Type (1) sites are established to characterize upwind background and transported O_3 and its precursor concentrations entering the area and will identify those areas which are subjected to overwhelming transport. The type (1) sites are located in the predominant morning upwind direction from the local area of maximum precursor emissions during the O_3 season.

Type (2) sites are established to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions are expected to impact and are suited for the monitoring of urban area toxic pollutants. Type (2) sites are located immediately downwind of the area of maximum precursor emissions and are typically placed near the downwind (morning) boundary of the central business district to ensure that neighborhood scale measurements are obtained.

Type (3) sites are intended to monitor maximum O_3 concentrations occurring downwind (afternoon) from the area of maximum precursor emissions. Type (3) sites should be located so that urban scale measurements are obtained.

Type (4) sites are established to characterize the extreme downwind transported O_3 and its precursor concentrations exiting the area and will identify those areas which are potentially contributing to overwhelming transport in other areas. Type (4) sites are located in the predominant afternoon downwind direction, as determined for site type (3). Further information on the four site types and PAMS monitoring requirements is contained in 40 CFR Part 58.[1]

7.2 COST ESTIMATES FOR PAMS MONITORING

7.2.1 Network Design

PAMS network design costs are based on a five station network for an isolated MSA. Of the five stations two are Type (2) sites and the other three include a Type (1), Type (3) and Type (4) site. In designing the network it is further assumed that existing stations would be evaluated and at least two would be selected as PAMS sites. The other three are assumed to be new sites requiring an analysis of the meteorological data, topographic and climatological and topographic features of the area, as well as ozone precursor emission sources. Further resources are required to prepare a formal PAMS network design for submission to EPA. Finally, efforts are also needed to conduct actual field trips to several potential sites to ensure that the specific probe siting criteria specified in the Part 58 PAMS regulations are satisfied. To conduct these activities it is estimated that a total 75 hours of a PRO2 and 125 hours of a PRO4 would be required. This total effort is prorated equally among the five sites recognizing that one or two of the sites will be existing sites and special data analysis and site evaluation visits at these sites may not be required.

The cost for the PAMS network design is reflected in the Table 7-1 summary costs for ozone and therefore not duplicated in the other tables presented in this section. A more complicated multi-State or Regional network could readily double or triple the level of effort because of the additional technical and administrative personnel involved, the increase in the size of the network, and the additional resources required to prepare, review, and agree on a combined PAMS network.

7.2.2 Cost Estimates for Sampling O_3

Cost estimates for O_3 sampling for 12 months are summarized in Table 7-1. Details of all relevant capital and operating costs for monitoring O_3 are located in Table 4-8 of Section 4.

The capital cost estimates for O_3 monitoring include a PAMS network design (assuming a network of five stations, each monitoring for O_3, NO_2, VOC, carbonyl, and meteorological parameters), site installation costs, a shelter to house all PAMS monitoring equipment such as an O_3 analyzer, a gas phase titration system, an O_3 generator, a data logger and a strip chart recorder. The capital costs may vary slightly from the costs presented in the table depending on the equipment vendors and the model of equipment chosen.

The operation and maintenance costs include routine maintenance, repairs, and necessary recalibrations following maintenance to the equipment. It is assumed that routine maintenance will be conducted during the usual site visits. Data management (including data acquisition, processing, reporting, and data validation), QA/QC, and management and supervision are also considered here as operation and maintenance costs.

TABLE 7-1. SUMMARY OF TOTAL COSTS FOR O_3 SAMPLING (12-Month Sampling Period)

Cost Type	Cost
Capital Costs	49,558
Annual Operation and Maintenance Costs	15,974
Average Annualized Costs (5 years)	25,886

7.2.3 Cost Estimates for Sampling Nitrogen Oxides (NO_x)

Cost estimates for monitoring NO_x (including NO, NO_2, and NO_x) are summarized in Table 7-2. Details of all relevant capital and operating and maintenance costs for monitoring nitrogen oxides is given in Table 4-8 of Section 4.

Capital and operation and maintenance costs for monitoring nitrogen oxides include items similar to those for O_3. They exclude network design costs, however, since such expenditures were included in the cost estimates for O_3 monitoring. In addition, sampling is only required for 3 months so O/M costs are based on that 3-month sampling period.

TABLE 7-2. SUMMARY OF TOTAL COSTS FOR NO_x SAMPLING (3-Month Sampling Period)

Cost Type	Cost
Capital Costs	46,486
Annual Operation and Maintenance Costs	4,349
Average Annualized Costs (5 years)	13,646

7.2.4 Cost Estimates for VOC Monitoring

7.2.4.1 *Background*

VOC O_3 precursors usually refer to nonmethane organic compounds in the C_2 through C_{12} carbon number range. The number of VOC O_3 precursors typically measured by EPA's guidance document for O_3 precursor monitoring, *Technical Assistance Document for Sampling and Analysis of Ozone Precursors*,[2] is approximately 55. In this guidance document, EPA describes two methods for collecting and analyzing VOC O_3 precursor ambient air samples. The first method is a manual method that consists of collecting integrated air samples in a SUMMA® passivated stainless steel canister with subsequent laboratory gas chromatographic analysis. The second method is an on-site automated method where sampling, analysis, and data integration and laboratory data reports are generated automatically. In EPA's 40 CFR Part 58 monitoring regulations, three minimum PAMS VOC sampling frequencies (A, B, and C) are specified depending upon the type of site.[3] Sites on an (A) sampling frequency collect eight 3-hour samples every third day and one 24-hour sample every sixth day during the monitoring period (typically June, July, and August). Sites with a (B) sampling frequency collect eight 3-hour samples every day during the monitoring period and one 24-hour sample every sixth day all year. Sites with a (C) sampling frequency collect eight 3-hour samples on the peak O_3 days plus each previous day, eight 3-hour samples every sixth day, and one 24-hour sample every sixth day during the monitoring period. Meeting these (C) requirements would require predicting high O_3 concentration time periods or sampling more frequently.

For all affected MSA/CMSA populations, site types (1), (3), and (4) may use sampling frequencies (A) or (C). For MSAs having populations less than 500,000, site type (2) may also use frequency (A) or (C); however, for areas having populations greater than 500,000, type (2) sites must use sampling frequency (B). To satisfy these sampling frequencies, an agency may choose to use a continuous analyzer.

7.2.4.2 *Cost Estimates for VOC Canister Sampling and Analysis*

Cost estimates for PAMS VOC monitoring vary significantly depending on variables such as the use of continuous analyzers or canisters, the canister sampling frequency, and the alternative selected to conduct the laboratory analysis. In deciding on the laboratory analysis options, an agency may for example, elect to conduct the analyses within the agency, obtain analytical services from a private laboratory, or arrange for an interagency agreement with another agency that has the necessary equipment and experience to perform VOC analyses. Although numerous combinations of options are possible, three detailed examples are presented here. The examples include the use of VOC canister sampling at frequency (A) with two options for analysis and the use of continuous VOC analyzers. The first example (option 1) gives monitoring costs for an agency that uses in-house personnel to collect canister samples and to conduct the laboratory analysis. The second example (option 2) provides costs for an agency that runs the canister sampling program in-house, but contracts out for VOC analysis of the canisters. The third example shows the cost breakdown for an agency that operates its type (2) site every day for VOCs using a continuous analyzer. Operating a site on an every day schedule using canisters for eight 3-hour samples per day may be impractical because (1) the number of canisters required per site would be in the range of 100 to 200, and (2) about eight samples per day is the approximate maximum number that a central laboratory can analyze in a 10-hour work shift. In this case, an on-site continuous GC analyzer seems more appropriate; therefore, this option was selected as a practical example.

Cost estimates for the first two examples are shown in Table 7-3 as option 1 (VOC sampling and analysis within the agency) and option 2 (agency sampling with contractor laboratory analysis). In keeping with the division given in Section 3, breakdowns for the monitoring costs were considered for eight major categories of activities: network design and siting, station installation, sampling, maintenance and repair, analysis, data management and reporting, QA/QC, and management and supervision. For purposes of the first two examples, it is assumed that the monitoring period is 3 months. Based on an (A) sampling frequency, a total of 264 VOC samples are scheduled for collection during the three month monitoring period.

TABLE 7-3. CANISTER VOC SAMPLING AND ANALYSIS COSTS PER SITE SAMPLING FREQUENCY (A) AND 3-MONTH MONITORING PERIOD

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hour	
Network Design						
Site Installation						
Procurement	✓	✓	CPTL	PRO2	16	672
Automated multi-event canister sampling system	✓	✓	CPTL			15,000
Equipment installation	✓	✓	CPTL	TEC2	12	396
Sampling						
Canisters (40/site)	✓	✓	CPTL			17,000
Travel expenses	✓	✓	O/M			250
Routine site visits	✓	✓	O/M	TEC1	64	1,920
Maintenance						
Spare parts/supplies	✓		O/M			2,000
Spare parts/supplies		✓	O/M			1,000
Remedial repairs	✓		O/M	TEC2	32	1,056
Remedial repairs		✓	O/M	TEC2	16	528
Routine maintenance	✓		O/M	TEC2	40	1,320
Routine maintenance		✓	O/M	TEC2	20	660
Data Management						
Data acquisition/processing	✓		O/M	PRO1	20	720
Data acquisition/processing		✓	O/M	PRO1	15	540
Data reporting	✓		O/M	PRO2	8	336
Data reporting		✓	O/M	PRO2	8	336
Data validation	✓		O/M	PRO1	12	432
Data validation		✓	O/M	PRO1	12	432
Data analysis and trends	✓		O/M	PRO2	85	3,570
Data analysis and trends		✓	O/M	PRO2	85	3,570
Laboratory analysis						
Automated gas chromatograph (FID)(In LAB) 1/3 sites	✓		CPTL			27,000

(Continued)

TABLE 7-3. CANISTER VOC SAMPLING AND ANALYSIS COSTS PER SITE SAMPLING FREQUENCY (A) AND 3-MONTH MONITORING PERIOD (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hour	
Initial GC installation and checkout	✓		CPTL	TEC2	160	5,280
				PRO2	80	3,360
Annual GC checkout	✓		O/M	TEC2	50	1,650
				PRO2	25	1,050
Operation of GC and canister cleaning (includes 10% replicate analysis)	✓		O/M	TEC2	290	9,570
				PRO2	100	4,200
GC cylinder gases	✓		O/M			900
Calibration standards	✓		O/M			600
Gas cleaning system	✓		CPTL			5,000
Contractor lab analysis (290 samples at $325/sample)		✓	O/M			94,250
Quality Assurance						
Canister certification system	✓		CPTL			1,165
Calibration standards	✓		O/M			1,000
Audits	✓		O/M	PRO2	16	672
Audits		✓	O/M	PRO2	8	336
Routine calibrations	✓		O/M	TEC2	12	396
Routine calibrations		✓	O/M	TEC2	6	198
Training	✓		O/M	PRO2	40	1,680
Training		✓	O/M	PRO2	8	336
Implementation/coordination	✓	✓	O/M	PRO3	4	200
QA plan preparation	✓	✓	CPTL	PRO2	8	336
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	32	1,600
Supervision/review	✓	✓	O/M	PRO3	32	1,600
Total Capital (CPTL) Costs - Option 1						75,209
Total Annual Operation and Maintenance (O/M) Costs - Option 1						36,722
Total Capital (CPTL) Costs - Option 2						33,404
Total Annual Operation and Maintenance (O/M) Costs - Option 2						107,756

Option 1 - Sampling and analysis conducted by control agency
Option 2 - Sampling conducted by control agency, analysis conducted by contractor

This amounts to 248 samples [eight 3-hour samples every third day for a 3-month (92 day) monitoring period plus 16 samples for the one 24-hour sample every sixth day for the monitoring period]. Using the EPA VOC monitoring method contained in reference 2 with one automated GC analytical system, an average total of six VOC samples can be analyzed in an 8-hour work shift, including a zero and one point calibration span. In a 10-hour shift, eight canister samples can be processed. This is desirable since it corresponds to the daily number of samples for a site on an (A) sampling frequency and for a laboratory on a 5-day work schedule. Based on these assumptions, the option 1 agency laboratory cost estimates given in Table 7-3 were calculated based on using one GC system for every three sites on an (A) sampling frequency.

Cost estimates for network design are not listed in Table 7-3, since the PAMS site is a multi-parameter site, and the network design costs are included as part of the O_3 cost estimates. Similarly, some of the normal site or station installation costs such as site procurement, land/lease, site preparation, and power hookup are not included in this cost estimate of the manual VOC sampling option. The installation costs apply to both options since sampling will be conducted internally. Installation costs for both options include the capital cost for a $15,000 dollar automated multi-event canister sampling system at each site. Labor costs for VOC sampling equipment procurement and internal labor expenses for equipment installation at the site are also included under the category of installation.

Under the costs for sampling, option 1 and 2 costs include the purchase of approximately 40 6-liter canisters per site at a volume discount price of $425 per canister. Single canister prices are in the range of $500 to $560 dollars. Forty canisters per site allows approximately 3 to 4 days time for shipment to and from the laboratory and a 2-3 day turnaround time for analysis and canister cleaning. A few more samplers per site would be required if longer time periods for shipping, cleaning, and analysis were found to be necessary. In addition to canister costs, the sampling costs include labor and travel expenses (assuming a 30-mile round trip) for 31 site visits.

Maintenance and repair costs differ for options 1 and 2 since option 1 requires repair and maintenance on the sampling and laboratory equipment, while option 2 only requires service on the sampling equipment. Option 1 parts and supply costs are based on expenditures for such items as spare valves, fittings, chromatography columns, and pumps while option 2 is restricted to sampling equipment. Repair and maintenance labor costs associated with option 1 sampling and analytical equipment are estimated at 72 hours. Option 2 costs are estimated at 36 hours for repair and maintenance for sampling equipment only. Because the automated GC systems are new and complex, it may be prudent to invest in available extended service warranties. These may be offered at a cost of about $1,500 dollars for 3 years.

Analytical costs for options 1 and 2 are based on using EPA's recommended technique for measuring VOC which is gas chromatography with flame ionization detection (GC/FID). In this technique, an air sample is taken from ambient air samples collected in stainless steel canisters and transferred to the GC/FID system. The sample is first passed into a primary sample concentration system, followed by desorption and collection on a secondary cold trap, called a cryo-focusing trap. This second trap serves to enhance the convergence of the sample prior to injection on the analytical column, thereby improving pollutant resolution. The concentrated, focused sample is then desorbed onto the analytical column(s) for separation, and qualitative and quantitative analysis. For the continuous analyzer this entire cycle is fully automated.

Laboratory cost estimates for canister analysis are based on the use of a continuous analyzer equipped with a VOC autosampler using a multi-port valve for automatic switching of multiple canisters to the GC/FID system. Costs for continuous VOC analyzers including a data integrator, personal computer (PC), and appropriated software range from $50,000 to $125,000. A cost of $81,000 prorated among three sites was used for option 1 of Table 7-3. Other costs for option 1 include one time up front costs associated with the installation, checkout, and optimization of the GC system (12 weeks of TEC2 and 6 weeks of PRO2 labor apportioned among three sites). Another option 1 major capital cost item prorated among three sites is the canister cleaning system ($15,000/3 sites). The laboratory analysis activities also include prorated costs for GC cylinder support gases and liquid cryogen ($50/day for 95 days). The 95 days includes a 12-week checkout period and the 3-month monitoring period. Also tabulated are site prorated labor operating costs for a TEC2 (290 hours) and a PRO2 (100 hours) to operate the GC during the monitoring period. The 290 hours per site are based on the assumption that it will take about 870 hours (eight samples per day, 1 hour per sample) to analyze the total of 870 canister samples collected from the three sites during the monitoring period (290 per site for three sites which is 264 samples plus an additional 26 per site for replicate analyses).

In option 2, laboratory analyses are performed by a contractor laboratory. The cost estimates listed in Table 7-3 assume a charge of $325 per canister for analysis. For the 3-month sampling period a total of 264 canister samples are collected. At $325 dollars per canister, this amounts to a total of about $85,800 in analytical costs. Replicate analysis costs are not included in these costs. Including 10 percent replicates adds another $8,450 to the analysis costs for a total of $94,250.

Data management and reporting (as described in Section 3.6) includes those costs associated with data acquisition, processing, validation and reporting the data from each site to the agency's data bank. Because the number of compounds measured per sample can be as large as 50 to 55, the resources allotted for data management activities are greater than those suggested in Section 3.6. The hours per site for the data management and reporting category under option 1 were apportioned as follows: 20 hours for data acquisition/data processing, 8 hours for data reporting, and 12 hours for data validation (operational and statistical). In addition, this category includes an EPA suggested allotment of 0.2 work year (416 hours per year) per site (every day sampling) for data analysis and air quality trends. For sampling frequency (A) this amounts to about 85 hours per site. Option 2 cost estimates are similar except that the hours for data acquisition/data processing were reduced to 15 hours per site.

QA/QC costs for option 1 include capital costs for a canister certification system (prorated among 3 sites), and the prorated cost to prepare a QA project plan. Operation and maintenance costs under this category are identified for calibration gases (prorated), audits, routine calibrations, and training. Apportioned supervisory hours at the PRO3 level are also included. Costs for option 2 are less because of the absence of the laboratory work. Management and supervision costs have been increased to reflect the newness and complexity of the VOC program.

A summary of the capital costs and annual operation and maintenance costs is presented in Table 7-4. The annualized cost for option 2 is about 2.2 times larger than option 1. This difference may be due to the need for a larger burden rate for the laboratory analysis portion of option 1 to reflect the true overhead rate and costs associated with operating a laboratory. The burden rate used in all of the cost estimates was 2.5 times the average labor rate. In addition, the laboratory analysis costs of option 1 do not include any confirmation analyses (such as GC/MS) that is usually recommended for 10 to 15 percent of the samples.

TABLE 7-4. SUMMARY OF VOC CANISTER SAMPLING AND ANALYSES COSTS FOR SITES WITH SAMPLING FREQUENCY (A) AND 3-MONTH MONITORING PERIOD

Cost Type	Option 1	Option 2
Capital Costs	75,209	33,404
Annual Operation and Maintenance Costs	36,722	107,756
Average Annualized Costs (5 years)	51,764	114,437

Option 1 - Canister sampling and analysis conducted by control agency personnel
Option 2 - Canister sampling conducted by agency personnel, analysis conducted by contractor

7.2.4.3 *Cost Estimates for VOC Monitoring Using On-Site Continuous Analyzers*

Cost estimates for VOC monitoring for a year-round monitoring period are given in Table 7-5. This example illustrates the monitoring requirement cost estimates for a PAMS VOC type (2) site operating with a year-round (B) sampling frequency. The (B) sampling frequency requires the collection of eight 3-hour samples every day during the monitoring period and one 24-hour sample every sixth day all year. For this example the monitoring period is 3 months. As noted in Section 7.2.3.1, however, VOC canister sampling every day at a rate of eight 3-hour samples per day followed by laboratory GC analysis is not very practical and would be more effectively conducted using an on-site continuous VOC monitor. Cost estimates therefore are given based on the use of a continuous VOC monitor everyday for 3 months plus one 24-hour canister sample every sixth day all year.

For the same reasons noted previously, network design costs are not included here but in the costs for O_3 monitoring. Site installation costs for on-site continuous VOC monitoring are greater because of the additional time required to install the automated GC. Costs for sampling and analysis include $81,000 for a fully automated GC with FID, PC and appropriate software. The actual price for an automated system may range from $50,000 to $125,000 depending upon the options chosen. Other sampling and analysis costs include time for instrument installation, checkout, and optimization of parameters. Although it may take as long as 2 to 4 months to set up and optimize the GC, we elected to use the lower limit based on the assumption that the

TABLE 7-5. CONTINUOUS VOC SAMPLING COSTS SAMPLE FREQUENCY (B) 12-MONTH MONITORING PERIOD (3-Month Continuous, 12-Month 1/6 Day Canister Sampling)

Cost Element	Cost Type	Labor		Cost
		Level	Hour	
Network Design				
Site Installation				
Equipment procurement	CPTL	PRO2	40	1,680
Automated multi-event canister sampling system	CPTL			15,000
Equipment installation	CPTL	TEC2	24	792
		PRO2	16	672
Sampling and Analysis				
On-site automated GC with FID	CPTL			81,000
GC installation and checkout	O/M	TEC2	330	10,890
		PRO2	160	6,720
On-site operation	O/M	TEC2	1,650	54,450
		PRO2	250	10,500
Canisters (12/site)	CPTL			5,100
GC support gases	O/M			1,800
Liquid cryogen	O/M			17,500
Maintenance				
Spare parts/supplies	O/M			2,500
Remedial repairs	O/M	TEC2	100	3,300
Routine maintenance	O/M	TEC2	125	4,125
Data Management				
Data acquisition/processing	O/M	PRO1	80	2,880
Data reporting	O/M	PRO2	32	1,344
Data validation	O/M	PRO1	48	1,728
Data analysis and trends	O/M	PRO2	416	17,472
Quality Assurance				
Calibration standards	O/M			1,500
Audits	O/M	PRO2	56	2,352
Routine calibrations	O/M	TEC2	350	11,550
Training	O/M	TEC2	40	1,320
		PRO2	24	1,008
Implementation/coordination	O/M	PRO3	16	800
QA plan preparation	CPTL	PRO2	24	1,008
Supervision				
Planning/coordination	O/M	PRO3	64	3,200
Supervision/review	O/M	PRO3	64	3,200
Total Capital (CPTL) Costs				105,252
Total Operation and Maintenance (O/M) Costs				160,139

agency would have gained experience at other sites or a central lab using a similar system. Additional sampling and analysis costs include cryogen at $50 per day and support gases.

Maintenance and repair costs include an estimated $2,500 for spare parts and supplies such as columns, GC replacement parts, regulators, and pumps. Costs for remedial repairs and maintenance are estimated as $3,300 and $4,125 respectively, including 100 hours of a TEC2 for repairs and 125 hours for routine maintenance.

Data management costs are similar to those estimated for VOC canister sampling and laboratory analysis but increased by a factor of four to cover operating costs for the entire year. Cost estimates for data analysis and trends, however are based on EPA's estimate of 0.2 work year per site.

QA and QC costs include the customary items of audits, calibrations, training, and QA project plan preparation. An additional 40 hours are allotted for participation in external audits. In addition, the hours allotted for calibrations have been increased to allow about 1 hour per day for calibrations.

Supervision and management costs are based on 64 hours of a PRO3 for planning and coordination, and another 64 hours for supervision and review.

A summary of the capital costs and annual operation and maintenance costs for continuous VOC monitoring for a 12-month period is given in Table 7-6.

TABLE 7-6. SUMMARY COSTS FOR CONTINUOUS VOC MONITORING FOR 12-MONTH PERIOD

Costs Type	Cost
Capital Costs	105,252
Annual Operation and Maintenance Costs	160,139
Average Annualized Costs	181,189

7.2.5 Cost Estimates for Formaldehyde and Other Carbonyl Compound Monitoring

The PAMS methodology for measuring formaldehyde and other carbonyl compounds in ambient air is described in EPA's, *Technical Assistance Document for Sampling and Analysis of Ozone Precursors.*[2] The method is basically EPA's Method 11 from the *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air.*[4] The method is based on the reaction of organic carbonyl compounds (aldehydes and ketones) with 2,4-dinitrophenylhydrazine (DNPH) in the presence of an acid to form stable derivatives which are analyzed using high pressure liquid chromatography (HPLC) with an ultraviolet (UV) absorption detector operated at 360 nm. In the method protocol, ambient air is passed through a prepacked silica gel cartridge impregnated with acidified DNPH; after sampling, the cartridges are capped and shipped to the laboratory for analysis. Three aldehyde sampling frequencies (D, E, or F) are specified in the 40 CFR Part 58 PAMS regulations depending on the population of the MSA/CMSA.[3] Sampling frequency (D) requires eight 3-hour samples every third day during the monitoring period, and one additional 24-hour sample every sixth day during the 3-month monitoring period; (E) specifies eight 3-hour samples every day during the monitoring period, plus one additional 24-hour sample every sixth day during the entire year; and (F) requires eight 3-hour samples on peak O_3 days plus each previous day, and eight 3-hour samples every sixth day during the monitoring period. Meeting these (F) requirements would require predicting high O_3 concentration time periods or sampling more frequently.

A detailed breakdown of the cost estimates for a site operating with a (D) sampling frequency for a 3-month monitoring period is given in Table 7-7. The table shows costs for two options. The first option is for an agency that uses in-house personnel to collect the samples and conduct the laboratory analysis, and the second option is for an agency that collects the samples, but contracts out for laboratory analysis.

Network design costs have been given previously and are not duplicated here. Station installation costs reflect the labor costs associated with the procurement and installation of the carbonyl cartridge sampler. The price of the sampler ($2,830) is also listed. The detailed sampling costs include miscellaneous supplies, about $300, commercially available sampling cartridges, and labor hours for routine site visits. The 31 labor hours given for site visits are based on the assumption of 31 site visits at one hour per site. Travel expenses were not included since they were allotted in the VOC cost estimate. Maintenance and repair cost estimates reflect the normal ranges generally allocated for these activities.

Analytical services for option 1 include $28,000 for an HPLC/UV system for measuring carbonyl compounds, and auxiliary laboratory equipment such as extraction glassware, liquid syringes, special pipets, and miscellaneous fittings. The HPLC/UV system includes an autosampler which automatically transfers sample tubes to the analyzer. In addition, hours are allotted for equipment set up, and sample analysis. The hours allocated for sample analysis assumed a total of 290 samples per site (eight samples per day for 31 days plus 16 samples for the one 24-hour sample every sixth day for the 3-month monitoring period, plus 26 replicate analyses and an analyses rate of 40 samples per 8-hour work day). This amounts to about 58 hours of a TEC2's time plus an additional 20 hours for a PRO2. The carbonyl compounds assumed to be measured at this analyses rate are formaldehyde, acetaldehyde, and acetone. In most air samples these three compounds constitute essentially all of the carbonyl compounds detected. For option 2 the only cost estimate provided is the cost for analyzing 290 samples. The cost was based on a volume discount price of $125 per cartridge. The contract analysis price ranges from about $150 per sample to $375 per sample, while the volume discount price ranges from about $100 to $300. For option 2, a discount price of $125 per sample analysis is used which brings the total analysis price for the 290 samples to $36,250.

Data management and reporting costs for both options include the customary activities for this category but are less than the hours allotted for VOC monitoring because the number of pollutants measured are smaller. The hours given for QA/QC, and supervision and management are in the normal range.

A summary of the capital costs and annual operation and maintenance costs for formaldehyde and other carbonyl costs for sampling frequency (D) is given in Table 7-8.

Cost estimates for a site operating with an (E) sampling frequency for a 3-month monitoring period is given in Table 7-9. The table shows costs for the same two options presented in Table 7-7. All capital costs remain the same as given in Table 7-7. All operation and maintenance costs, except training costs, have been modified to reflect carbonyl sampling frequency E. In option 1, the hours allocated for sample analyses are based on a total of 877 samples per site (eight samples per day for 92 days, sixty-one, 24-hour samples every sixth day for the entire year, 80 replicate analyses samples, and an analyses rate of 40 samples per 8-hour work day. For option 2, the only cost estimate provided is the cost for analyzing 877 samples. A volume discount analyses price of $125 per sample is used which results in a total analysis price of $109,625. Data management and reporting costs for both options are similar to sampling frequency D but adjusted to reflect the increased frequency of sampling. The same adjustment was made for QA/QC, and supervision and management.

A summary of the capital costs and annual operation and maintenance costs for sampling frequency (E) is provided in Table 7-10.

7.2.6 Cost Estimate for a Surface Meteorological Monitoring Station

Table 7-11 shows the detailed costs for a PAMS surface meteorological monitoring station operating for a 3-month monitoring period. The cost estimates are essentially the same as those given in Table 6-1 of Section 6 except that they were adjusted to reflect a 3-month monitoring period compared to the 12-month cost estimates given in Section 6. In addition, other modifications were made to include an apportionment of the calibration systems (wind speed and wind direction calibrator, temperature and pressure calibrator, humidity and dew point calibrator, and solar radiation calibrator) among five PAMS sites. Also, a number of items from Table 6-1 such as site installation activities were not included here because they were already included in Table 7-1 and Table 4-8. In addition, the 8" tipping bucket and the wind screen were excluded from Table 7-11 because they were not listed among the measurement parameters in EPA's technical assistance document.[2] Table 7-12 gives a summary of the capital and operation and maintenance costs for a PAMS surface meteorological monitoring station.

7.2.7 Monitoring Costs for Upper Air Meteorology

A breakdown of the costs for an upper air meteorological monitoring station operating for a 3-month period is presented in Table 7-13. The principal monitoring equipment include a doppler radar system to measure wind speed and direction up to approximately 4,000 meters.

TABLE 7-7. CARBONYL MONITORING COSTS FOR SAMPLING FREQUENCY (D) 3-MONTH MONITORING PERIOD

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Network Design						
Station Installation						
Equipment procurement	✓	✓	CPTL	PRO2	16	672
Cartridge sampler	✓	✓	CPTL			2,830
Equipment installation	✓	✓	CPTL	TEC2	8	264
Sampling						
Supplies	✓	✓	O/M			110
Carbonyl sample cartridges ($10 each)	✓	✓	O/M			3,000
Routine site visits	✓	✓	O/M	TEC2	31	1,023
Maintenance						
Spare parts/supplies	✓	✓	O/M			280
Remedial calibrations	✓	✓	O/M	TEC2	15	495
Routine repairs	✓	✓	O/M	TEC2	10	330
Remedial maintenance	✓	✓	O/M	TEC2	10	330
Analytical						
Contract laboratory analyses (290 samples at $125 per sample		✓	O/M			36,250
Equipment - HPLC/UV with autosampler	✓		CPTL			28,000
Equipment (auxiliary)	✓		CPTL			2,000
Supplies/reagents	✓		O/M			250
Sample analysis	✓		O/M	TEC2	58	1,914
				PRO2	20	840
Equipment setup	✓		CPTL	PRO2	40	1,680
Data Management						
Data acquisition/processing	✓	✓	O/M	PRO1	18	648
Data reporting	✓	✓	O/M	PRO2	10	420
Data validation	✓	✓	O/M	PRO2	14	588

(Continued)

TABLE 7-7. CARBONYL MONITORING COSTS FOR SAMPLING FREQUENCY (D) 3-MONTH MONITORING PERIOD (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Quality Assurance						
Calibration standards	✓	✓	O/M	N/A		300
Calibrations (site & lab)	✓		O/M	TEC2	10	330
Calibrations (site)		✓	O/M	TEC2	5	165
Audits	✓		O/M	TEC2	18	594
Audits		✓	O/M	TEC2	10	330
Training	✓		O/M	PRO2	40	1,680
Training		✓	O/M	TEC2	8	264
Implementation/coordination	✓	✓	O/M	PRO3	4	200
QA plan preparation	✓	✓	CPTL	PRO2	8	336
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	34	1,700
Supervision/review	✓	✓	O/M	PRO3	34	1,700
Total Capital (CPTL) Costs - Option 1						35,782
Total Annual Operation and Maintenance (O/M) Costs - Option 1						16,732
Total Capital (CPTL) Costs - Option 2						4,102
Total Annual Operation and Maintenance (O/M) Costs - Option 2						48,133

Option 1 - Sampling and analysis conducted by control agency
Option 2 - Sampling conducted by control agency, analysis by contract laboratory

TABLE 7-8. SUMMARY COSTS FOR FORMALDEHYDE AND OTHER CARBONYL COMPOUNDS SAMPLING FREQUENCY (D) AND 3-MONTH MONITORING PERIOD

Cost Type	Option 1	Option 2
Capital Costs	35,782	4,102
Annual Operation and Maintenance Costs	16,732	48,133
Average Annualized Costs (5 years)	23,888	48,953

TABLE 7-9. CARBONYL MONITORING COSTS FOR SAMPLING FREQUENCY (E) 3-MONTH MONITORING PERIOD

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Network Design						
Station Installation						
Procurement	✓	✓	CPTL	PRO2	16	672
Cartridge sampler	✓	✓	CPTL			2,830
Equipment installation	✓	✓	CPTL	TEC2	8	264
Sampling						
Supplies	✓	✓	O/M			320
Carbonyl sample cartridges (900) ($10 each)	✓	✓	O/M			9,000
Routine site visits	✓	✓	O/M	TEC2	140	4,620
Maintenance						
Spare parts/supplies	✓	✓	O/M			800
Remedial calibrations	✓	✓	O/M	TEC2	36	1,188
Routine repairs	✓	✓	O/M	TEC2	24	792
Remedial maintenance	✓	✓	O/M	TEC2	24	792
Analytical						
Contract laboratory analyses (877 samples at $125 per sample		✓	O/M			109,625
Equipment - HPLC/UV with autosampler	✓		CPTL			28,000
Equipment (auxiliary)	✓		CPTL			2,000
Supplies/reagents	✓		O/M			800
Sample analysis	✓		O/M	TEC2	175	5,775
				PRO2	60	2,520
Equipment setup	✓		CPTL	PRO2	40	1,680
Data Management						
Data acquisition/processing	✓	✓	O/M	PRO1	32	1,152
Data reporting	✓	✓	O/M	PRO2	16	672
Data validation	✓	✓	O/M	PRO2	24	1,008

(Continued)

TABLE 7-9. CARBONYL MONITORING COSTS FOR SAMPLING FREQUENCY (E) 3-MONTH MONITORING PERIOD (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Quality Assurance						
Calibration standards	✓	✓	O/M	N/A		900
Calibrations (site & lab)	✓		O/M	TEC2	24	792
Calibrations (site)		✓	O/M	TEC2	12	396
Audits	✓		O/M	TEC2	32	1,056
Audits		✓	O/M	TEC2	16	528
Training	✓		O/M	PRO2	40	1,680
Training		✓	O/M	TEC2	8	264
Implementation/coordination	✓	✓	O/M	PRO3	4	200
QA plan preparation	✓	✓	CPTL	PRO2	8	336
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	64	3,200
Supervision/review	✓	✓	O/M	PRO3	64	3,200
Total Capital (CPTL) Costs - Option 1						35,782
Total Annual Operation and Maintenance (O/M) Costs - Option 1						40,467
Total Capital (CPTL) Costs - Option 2						4,102
Total Annual Operation and Maintenance (O/M) Costs - Option 2						138,657

Option 1 - Sampling and analysis conducted by control agency
Option 2 - Sampling conducted by control agency, analysis by contract laboratory

TABLE 7-10. SUMMARY COSTS FOR FORMALDEHYDE AND OTHER CARBONYL COMPOUNDS SAMPLING FREQUENCY (E) AND 3-MONTH MONITORING PERIOD

Cost Type	Option 1	Option 2
Capital Costs	35,782	4,102
Annual Operation and Maintenance Costs	40,467	138,657
Average Annualized Costs (5 years)	47,623	139,477

TABLE 7-11. COSTS FOR A SURFACE METEOROLOGICAL MONITORING STATION OPERATING FOR A 3-MONTH PERIOD

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Network Design				
Site Installation				
10-m tower	CPTL			1,000
6-ft boom	CPTL			600
Guy kit	CPTL			400
Wind direction/speed system	CPTL			845
Crossarm	CPTL			275
Air temperature probe	CPTL			200
Dew point sensor	CPTL			600
Solar radiation shield	CPTL			200
Pyranometer	CPTL			1,000
Mast adapter	CPTL			300
Barometric pressure sensor	CPTL			1,100
Wind direction calibrator	CPTL			380
Wind speed calibrator	CPTL			500
Temperature calibrator	CPTL			130
Precipitation calibrator	CPTL			60
Humidity & dew point calibrator	CPTL			200
Solar radiation calibrator	CPTL			200
Pressure calibrator	CPTL			280
Data logger	CPTL			2,000
Ram pack	CPTL			450
Data cassette recorder	CPTL			900
Strip chart recorder (backup)	CPTL			1,600
Niemann enclosure	CPTL			1,000
Computer hardware and software	CPTL			5,000
Additional power supply for instruments	CPTL			1,000
Accessories	CPTL			700
Equipment procurement	CPTL	PRO1	60	2,160
Equipment installation	CPTL	TEC2	40	1,320
	CPTL	PRO2	24	1,008
Acceptance testing	CPTL	TEC2	16	528
	CPTL	PRO2	6	252
	CPTL	Contractor	6	300
Subtotal for CPTL site installation				26,488

(Continued)

TABLE 7-11. COSTS FOR A SURFACE METEOROLOGICAL MONITORING STATION OPERATING FOR A 3-MONTH PERIOD (Continued)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Sampling				
Routine field service supplies	O/M			500
Routine field service checks	O/M	TEC1	52	1,560
	O/M	TEC2	15	495
	O/M	PRO2	4	168
Travel expenses	O/M			313
Maintenance				
Remedial field service - corrective action	O/M	TEC1	4	120
	O/M	TEC2	4	132
	O/M	PRO2	4	168
Remedial field service - spare parts	O/M			1,500
Data Management				
Data acquisition, processing and reporting	O/M	TEC2	36	1,188
Data validation	O/M	PRO2	6	252
Quality Assurance				
Implementation/coordination	O/M	PRO2	4	168
QA plan preparation	CPTL	PRO2	20	840
Calibrations	O/M	TEC2	6	198
QA/QC reporting & review	O/M	PRO2	6	252
Audit	O/M	TEC1	4	120
	O/M	TEC2	4	132
	O/M	PRO2	4	168
Supervision				
Planning/coordination	O/M	PRO3	6	300
Supervision/review	O/M	PRO3	6	300
Total Capital (CPTL) Costs				27,328
Total Operation and Maintenance (O/M) Costs				8,034

A summary of the costs for the surface meteorological measurement station is shown in Table 7-12.

TABLE 7-12. SUMMARY COSTS FOR A SURFACE METEOROLOGICAL MONITORING STATION OPERATING FOR 3 MONTHS

Cost Type	Cost
Capital Costs	27,328
Annualized Operation and Maintenance Costs	8,034
Average Annualized Cost	13,500

The cost for this system is about $130,000. Also included is a radio acoustic sounding system (RASS) for the measurement of temperature up to about 2.0 kilometers. This will allow for the calculation of mixing heights. The price of this unit is about $20,000. Approximately $10,000 is also necessary for a PC, data processing software, and a communication package. Other costs listed cover site installation (equipment procurement and equipment installation and set up), maintenance, data management, quality assurance and supervision. The costs for these activities are very similar to those given in the table for the surface meteorological station (Table 7-11). Table 7-14 gives a summary of the capital and annual operation and maintenance costs for the upper air station

TABLE 7-13. COSTS FOR AN UPPER AIR METEOROLOGICAL MONITORING STATION OPERATING FOR A 3-MONTH PERIOD

Cost Element	Cost Type	Labor		Cost
		Level	Hour	
Network Design				
Site Installation				
Procurement	CPTL	PRO2	16	672
Equipment installation	CPTL	TEC2	16	528
		PRO1	16	576
Sampling				
Doppler radar system	CPTL			130,000
Shelter (assume system uses PAMS shelter)				
Radar accoustic sounding system	CPTL			20,000
PC, processing software, and communications package	CPTL			10,000
Routine field service supplies	O/M			500
Routine field service checks	O/M	TEC2	12	396
		PRO2	6	252
Maintenance				
Remedial field service - corrective action	O/M	TEC2	4	132
Remedial field service - spare parts	O/M			500
Data Management				
Data acquisition, processing and reporting	O/M	TEC2	36	1,188
Data validation	O/M	PRO2	6	252
Quality Assurance				
Implementation/coordination	O/M	PRO2	4	168
QA plan preparation	CPTL	PRO2	20	840
Calibrations	O/M	TEC2	6	198
QA/QC reporting & review	O/M	PRO2	6	252
Audit	O/M	TEC2	4	132
	O/M	PRO2	4	168
Supervision				
Planning/coordination	O/M	PRO3	4	200
Supervision/review	O/M	PRO3	4	200
Total Capital (CPTL) Costs				162,616
Total Operation and Maintenance (O/M) Costs				4,538

TABLE 7-14. SUMMARY OF COSTS FOR AN UPPER AIR METEOROLOGICAL STATION OPERATING FOR A 3-MONTH PERIOD

Cost Type	Cost
Capital	162,616
Annual Operation and Maintenance Costs	4,538
Average Annualized Costs	37,061

7.3 REFERENCES

1. U.S. Environmental Protection Agency, *Federal Register*, Vol. 58, No. 28, Appendix D, Section 4.2, February 12, 1993.

2. *Technical Document for Sampling and Analysis of Ozone Precursors*, EPA-600/8-91-215, U.S. Environmental Protection Agency, Research Triangle Park, NC. October 1991.

3. U.S. Environmental Protection Agency, *Federal Register*, Vol. 58, No. 28, Appendix D, Section 4.4, February 12, 1993.

4. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, EPA-600/4-89-017. U.S. Environmental Protection Agency, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 27711. June 1988.

SECTION 8.0

VISIBILITY MONITORING

8.1 BACKGROUND

Section 169 of the Clean Air Act requires EPA to promulgate regulations to ensure progress towards the goal of preventing future and remedying existing visibility impairment in Class I Federal areas, when such impairment is caused by anthropogenic air pollution. EPA promulgated regulations in 40 CFR Part 51 that require States to develop programs designed to achieve this goal and establish procedures for visibility impact analyses for new source review. These regulations also direct States to include a strategy for evaluating visibility in Class I Federal areas in the implementation plan. This strategy must take into account current and anticipated visibility monitoring research, the availability of appropriate monitoring techniques, applicable EPA guidance, and existing visibility data. EPA has promulgated visibility monitoring strategies for States that have failed to do so on their own in a timely fashion.

Visibility impairment can be defined as the extent to which the ability of an observer to clearly see an object or vista is limited by the scattering and absorption of light caused by particles and gases in the atmosphere. The relationship between air pollution and human visual perception is complex. There is no single measurement that adequately characterizes visibility impairment and provides an indication of its causes. Therefore, a visibility monitoring system typically consists of measurements of multiple parameters.

Visibility related measurements can be generally divided into three groups: optical, aerosol, and scene. Optical measurements register the ability of the atmosphere to change or obstruct light passing through it. Aerosol measurements identify and quantify the particulate and gaseous constituents of the atmosphere that are related to visibility impairment. Scenic indices characterize the appearance of the view through the atmosphere. Models are used to establish relationships among measurements in different groups.

There are many methods that have been used to measure visibility related parameters. Over time, the state-of-the-art has evolved and some methods have taken precedence over others due to increased data quality. The current state-of-the-art in visibility monitoring is represented by the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. This is a cooperative visibility monitoring effort between the EPA and several federal land management agencies. It is designed to address the data needs of the Section 169 visibility protection program. The monitoring objectives are to establish background visibility levels in order to assess the impacts of new sources; to determine the sources and their contributions to visibility impairment; to assess progress toward the national visibility goal; and to promote the development of visibility monitoring technology.

The IMPROVE network provides optical, aerosol, and scene measurements. Long path transmissometers are used for optical measurements. Aerosol measurements are obtained by the IMPROVE sampler, which collects four simultaneous filter samples. Scene characteristics are recorded by color photography. At sites where there is no transmissometer, color slides may be analyzed by scanning densitometry to give a rough quantification of visual range. Temperature and relative humidity are also measured at IMPROVE sites.

The cost estimates provided in this document are based on the IMPROVE sampling protocol. Costs are also provided for a nephelometer designed to provide particle light scattering data at ambient conditions. Nephelometers have been used in many visibility monitoring studies to provide an optical measurement of visibility impairment. The nephelometer samples the atmosphere at a single point while the transmissometer measures light extinction over a sight path. In addition, costs are provided for the use of a dichotomous sampler in place of the IMPROVE sampler. Table 8-1 summarizes the visibility measurements addressed in this document.

8.2 NETWORK DESIGN

Network design and site selection costs for a visibility monitoring program reflect the complexity of the relationships being investigated, the concurrent needs of multiple monitoring systems, and the logistical constraints imposed by remote monitoring locations. It can be difficult to find a representative site with a suitable vista for transmissometer and/or photographic measurements. The potential influences of sources adversely affecting visibility must be carefully considered. Predicting the impacts of sources on a regional scale may require sophisticated source and receptor oriented modeling. Understanding the influence of local sources is especially important if point based measurements, such as those made by a nepelometer, are used. This may require a micro-inventory of the area near candidate sites.

Due to limited resources, there is a need to select sites that are representative of the area where the site is located and that are comparable with other visibility protected areas. Four criteria were established for selecting sites among the 156 visibility protected Class I Federal areas: anticipated changes in visibility in the area, existing visibility problems, scenic value and sensitivity, and the representativeness of the data to other visibility protected areas.

Network design for visibility monitoring is an ongoing process that reflects continuing changes in monitoring techniques, scientific understanding of visibility related issues, and resources available for visibility monitoring. For Class I Federal areas, the initial network design phase involving evaluation of monitoring needs versus available monitoring techniques and resources has been completed.

A somewhat more limited network design effort is required for establishing a visibility monitoring station or network of stations in an area in order to obtain background information needed to assess potential impacts on visibility from new sources. A study should be conducted to determine background monitoring locations of a suitable scale. These may focus on areas of particular visibility interest, especially scenic vistas. Between 300 to 400 hours at the mid- to senior professional level (PRO2 to PRO4) is a generally reasonable estimate of the effort required to undertake such a study. This would be followed by additional effort required for site selection.

TABLE 8-1. VISIBILITY MONITORING PROGRAM

Instrument	Parameter(s)	Frequency
IMPROVE Sampler Module A - Fine (<2.5μm) Teflon	· Mass (gravimetric), · Optical Absorption (integrating plate), · Sodium through Lead (Particle Induced X-Ray Emission - PIXE, or X-Ray Fluorescence - XRF)	Two samples per week - Weekly filter change
IMPROVE Sampler Module B - Fine Nylon	· Nitrate (Ion Chromatography)	Two samples per week - Weekly filter change
IMPROVE Sampler Module C - Fine Quartz	· Organic and Elemental Carbon (combustion analyzer)	Two samples per week - Weekly filter change
IMPROVE Sampler Module D - PM-10 Teflon	· Mass (gravimetric)	Two samples per week - Weekly filter change
IMPROVE Sampler - Impregnated Quartz Filter (Back-up to PM-10 Teflon)	· Sulfur Dioxide (Ion Chromatography)	Two samples per week - Weekly filter change
Transmissometer	· Extinction coefficient	Continuous - Data uploaded via satellite (DCP), telephone, or data cartridge. Strip chart backup.
Automated 35mm Camera system	· View monitoring · Extinction coefficient (slide contrast measurements)	Three photographs daily
Temperature/Humidity Sensor	· Ambient temperature and relative humidity	Continuous - Data uploaded via satellite (DCP), telephone, or data cartridge. Strip chart backup.
Dichotomous Sampler	· Fine mass and PM-10 mass	Two samples per week - Weekly filter change
Integrating Nephelometer	· Extinction coefficient	Continuous - Data uploaded via satellite (DCP), telephone, or data cartridge. Strip chart backup.

Due to the difficulties in site selection, at least 100 hours of effort at the senior technical (TEC2) and midprofessional level (PRO2 to PRO3) should be allowed for selection and proper documentation of each monitoring site. This includes consideration of up to three candidate sites. Resources required for travel to the site locations should be added. These may be significant given the remoteness of typical visibility monitoring locations.

Cost estimates for network design and site selection should be added to the total cost for the individual monitoring systems that are determined to be necessary for a particular monitoring program.

8.3 COST ESTIMATES FOR AEROSOL SAMPLING

Aerosol sampling is necessary to characterize the atmospheric constituents contributing to visibility degradation and to provide data for source apportionment. The IMPROVE sampler collects simultaneous filter samples in four sample collection modules. Separate pump and control modules control flow through the filter modules. Each filter module is capable of exposing up to four samples at prescribed intervals over a period of up to 14 days; however, the IMPROVE protocol calls for exposing two sample sets per week. Table 8-1 describes the filter media, particle size cutpoint, and analytical data for each module.

Cost estimates for aerosol sampling are detailed in Table 8-2 and summarized in Table 8-3. Detailed costs given in Table 8-2 assume that the full four modules of the IMPROVE sampler are used. In specific situations, the IMPROVE sampler modules may be used independently. Capital and annual operation and maintenance costs are also given (see Table 8-3) for alternative configurations using the IMPROVE sampler modules or a dichotomous sampler.

The IMPROVE sampler can be installed on a wooden or aluminum platform or housed in a shelter. The cost estimates provided assume that a wooden platform is used. Site preparation, land/lease, and power drop costs are given separately. However, in many cases, the aerosol sampler will be collocated with other visibility monitoring equipment, such as a transmissometer, nephelometer, or camera system. Site preparation costs are given for each method, since some sites may contain a single system. It is important that site preparation costs are not double counted when determining total station costs. An AC power drop is necessary for the aerosol sampler. The system requires 25 amps power at 120 volts. Power consumption is about 4,000 kilowatt hours per year.

Sampling costs include filter media and supplies, labor, and travel. The sampler is serviced weekly. The cost of filter media is based on use of 120 sets of 5 filters per year (see Table 8-1). Analysis costs are provided for elements (sodium through lead), ions (nitrate, sulfate), and carbon (elemental and organic) for 120 filters per year. Other costs include shipping and replacement parts. These costs are included in an overall figure for filter media and supplies. Travel costs are estimated based on a 50 mile round trip. This figure should be adjusted as necessary. Costs for travel time and expense are broken out separately from the labor required to service the sampler. If multiple visibility parameters are measured at the same site, the travel expense should be counted only once.

TABLE 8-2. AEROSOL SAMPLING COSTS
(Full Four Modules of IMPROVE)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Station Installation				
IMPROVE Sampler (4 modules, controller, and pump house)	CPTL			10,000
Installation and delivery (IMPROVE Sampler)	CPTL			4,000
Land/lease	O/M			1,500
Power drop	CPTL			350
Procurement	CPTL	PRO1	16	576
Site preparation	CPTL			3,000
Sampling				
Filter media and supplies	O/M			2,100
Routine weekly site service	O/M	TEC2	52	1,716
Travel expense	O/M			702
Travel time	O/M	TEC2	52	1,716
Utilities	O/M			400
Maintenance				
Remedial calibrations	O/M	TEC2	8	264
Routine maintenance	O/M	TEC2	16	528
Repairs	O/M	TEC2	20	660
Spare parts	O/M			500
Analysis				
Elemental analysis	O/M	PRO2	100	4,200
Carbon analysis	O/M	PRO2	85	3,570
Ions (Nitrate, Sulfate)	O/M	PRO2	50	2,100
Data Management				
Data acquisition/processing	O/M	PRO2	48	2,016
Data reporting	O/M	PRO2	64	2,688

(Continued)

TABLE 8-2. AEROSOL SAMPLING COSTS (Continued)

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Data validation level 1	O/M	PRO1	48	1,728
Data validation level 2	O/M	PRO2	32	1,344
Quality Assurance				
Audits (contract)	O/M			600
Calibration kit certification	O/M			200
Calibration kit	CPTL			200
Implementation/coordination	O/M	PRO2	48	2,016
Planning	O/M	PRO2	48	2,016
Reporting	O/M	PRO2	32	1,344
Routine calibration	O/M	TEC2	16	528
Training	O/M	TEC2	8	264
Supervision				
Planning/coordination	O/M	PRO3	26	1,300
Supervision/review	O/M	PRO3	26	1,300
Total Capital (CPTL) Costs				18,126
Total Operation and Maintenance (O/M) Costs				37,300

TABLE 8-3. AEROSOL SAMPLING COST SUMMARY BREAKDOWN

	Sampler Type	Capital	Annual O/M	Average Annualized
IMPROVE	Full Sampler	18,126	37,300	40,925
IMPROVE	Full less PM-10	14,260	34,140	36,992
IMPROVE	Double Module (Teflon and Nylon)	8,980	23,039	24,835
IMPROVE	Double Module (Teflon and Quartz)	8,980	25,079	26,875
IMPROVE	PM-10 Only (Includes elements)	7,870	15,100	16,674
IMPROVE	Fine Only (Includes elements)	6,780	15,100	16,456
	Dichotomous Sampler	8,375	28,700	30,375

Maintenance costs include routine maintenance, repairs, and necessary recalibrations following adjustments to the equipment. A budget of $500 per year is allowed for replacement parts. No separate travel allowance is estimated for maintenance. It is assumed that routine maintenance will be conducted during the usual site visits. Travel time is allowed for in the estimates for emergency repairs.

Data management costs include obtaining the data from the laboratories and preparing it in a suitable format in a centralized database. About 50 filters per month will be handled for each site. Costs are included for data validation and preparation of quarterly data reports. Routine data management is handled by a junior to mid-level professional and overseen by a senior professional.

QA and QC include both capital and operation and maintenance costs. Capital costs are for preparation of the QA plan and for field calibration equipment. The effort required for QA plan preparation is divided over the number of sites in the network. The cost estimates provided here assume an arbitrary network size of five sites. Annual QA/QC costs include coordination, implementation and oversight of the QA program, preparation of periodic (e.g. quarterly) reports on data quality, and training. QA activities should be conducted by mid- to senior level professionals. Training includes both site operator training and training of personnel involved with data management and QA. Training is considered to be an annual cost because of personnel turnover and updates in operating procedures.

8.4 COST ESTIMATES FOR TRANSMISSOMETER MONITORING

The transmissometer measures light extinction over a site path. The transmissometer consists of a transmitter and receiver, a photometer, and electronic components. It measures the loss of visible light (green - 550 nm) received from a source of known intensity over a known path length. Cost estimates for monitoring light extinction using a transmissometer are detailed in Table 8-4 and summarized in Table 8-5.

Station installation costs include site preparation, equipment and shelters, and labor. Separate transmitter and receiver stations are required, each with its own shelter and power supply. The receiver includes a data acquisition computer that can be polled remotely by telephone or satellite link. A strip chart recorder is used as a backup. Sites located in remote areas may require solar power and a satellite link to transmit continuous data. Costs are summarized for a site where AC power and telephone services are available (Option 1), and a site where solar power and a satellite link are required. Cellular telephone service is increasingly available in remote areas (Option 2).

Sampling costs include routine operations and field service. These are labor, travel, supplies, and electric power (if available). Costs for routine site visits include 52 weekly visits per year, assuming a 50 mile round trip for the site operator. A senior technician (TEC2) is required because of the sophisticated nature of the equipment. Technician travel time and time on-site are given separately to allow cost adjustments to be made for more or less remote sites.

Technician time on-site includes the time required for the necessary weekly and monthly service and operational checks. Annual supply costs for routine site service include costs such as transmissometer lamps, chart paper, pens, and cleaning supplies. Electric power costs are estimated for a power consumption of about 11,000 kilowatt hours per year (about 10 amps drawn continuously). In remote locations, solar power may be used instead of electric power. Costs for a solar-powered system are provided separately. The transmissometer can be operated in a cycled mode which would consume less power. Cost estimates are for continuous operation.

Maintenance costs include corrective actions, spare parts and routine equipment service that is not part of routine field service. Standard operating procedures[1] call for an annual equipment exchange so that the transmissometer system can be thoroughly checked and calibrated in the laboratory.

Data management and reporting costs are for continuous data acquisition, processing, validation and reporting. This includes the transmissometer extinction data and concurrent temperature and humidity data necessary for data interpretation. Data management costs are applicable to data collected at one site over a year. Routine data reports consist of a monthly, computer-generated data summary including graphics. The cost of developing software and procedures for data management is not included in the cost estimates.

TABLE 8-4. TRANSMISSOMETER COSTS

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Station Installation						
Field Tripod	✓	✓	CPTL			800
Installation	✓	✓	CPTL	TEC2	80	2,640
Satellite platform		✓	CPTL			6,500
Adjustable mounting base (receiver)	✓	✓	CPTL			1,700
Mounting pier (receiver)	✓	✓	CPTL			900
Power supply (receiver)	✓	✓	CPTL			300
AC power drop (receiver)	✓		CPTL			350
Solar power system (receiver)		✓	CPTL			4,600
Receiver unit	✓	✓	CPTL			9,700
Shelter (receiver)	✓	✓	CPTL			1,900
Strip chart recorder	✓	✓	CPTL			1,600
Telescopes (receiver and transmitter)	✓	✓	CPTL			1,800
Temperature/humidity sensor (receiver station)	✓	✓	CPTL			1,000
Mounting base (transmitter)	✓	✓	CPTL			1,700
Mounting pier (transmitter)	✓	✓	CPTL			900
AC power drop (transmitter)	✓		CPTL			350
Solar power system (transmitter)		✓	CPTL			4,600
Shelter (transmitter)	✓	✓	CPTL			1,900
Transmitter	✓	✓	CPTL			5,500
Land lease	✓	✓	O/M			1,500
Telephone service	✓		O/M			1,200
Procurement	✓	✓	CPTL	PRO1	60	2,160
Site preparation	✓	✓	CPTL			3,000
Sampling						
Routine field service supplies	✓	✓	O/M			500
Routine field service travel expense	✓	✓	O/M			702
Routine field service weekly checks	✓	✓	O/M	TEC2	104	3,432

(Continued)

TABLE 8-4. TRANSMISSOMETER COSTS (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Routine field service weekly checks - travel time	✓	✓	O/M	TEC2	52	1,716
Utilities	✓		O/M			1,100
Maintenance						
Remedial field service - corrective action	✓	✓	O/M	TEC2	30	990
Remedial field service - spare parts	✓	✓	O/M			500
Routine field service - annual equipment exchange	✓	✓	O/M	TEC2	24	792
Data Management						
Data acquisition/processing	✓	✓	O/M	PRO1	52	1,872
Data reporting	✓	✓	O/M	PRO2	24	1,008
Level 1 Data validation - operational	✓	✓	O/M	PRO1	12	432
Level 2 Data validation - statistical	✓	✓	O/M	PRO2	12	504
Quality Assurance						
Implementation/coordination	✓	✓	O/M	PRO2	26	1,092
Calibration disk	✓	✓	CPTL			125
Neutral density filter and holder	✓	✓	CPTL			300
QA plan preparation	✓	✓	CPTL	PRO2	20	840
QA/QC reporting	✓	✓	O/M	PRO2	26	1,092
QA/QC Review (field logs/reports)	✓	✓	O/M	PRO2	26	1,092
Training	✓	✓	O/M	TEC2	8	264
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	26	1,300
Supervision/review	✓	✓	O/M	PRO3	26	1,300
Total Capital (CPTL) Costs - Option 1						39,465
Total Operation and Maintenance (O/M) - Option 1						22,388
Total Capital (CPTL) Costs - Option 2						54,465
Total Operation and Maintenance (O/M) - Option 2						20,088

Option 1 - AC power and telephone services available
Option 2 - Cellular telephone service

TABLE 8-5. TRANSMISSOMETER COST SUMMARY

Cost Type	Option 1	Option 2
Capital	39,465	54,465
Annual Operation and Maintenance	22,388	20,088
Average Annualized Cost	30,281	30,981

8.5 COST ESTIMATES FOR AUTOMATED CAMERA SYSTEMS

The automated camera system is used to document conditions affecting the visual scene such as ground cover, cloud cover, visible haze, and meteorological conditions. These data can be used to help interpret extinction measurements obtained by instrumental methods such as the transmissometer or nephelometer. Color slides are usually taken three times daily. In addition, target/sky contrast measurements on color slides can be used to derive the light extinction coefficient. A dark target such as a forested mountainside is preferred. When other methods are not available to, a camera may be used alone to document visibility conditions and obtain estimates of light extinction.

The automated camera system consists of a 35mm camera with autowinder and databack and a 135mm lens. A programmable timer is used to expose the film at specified intervals. The camera is mounted inside a weatherproof enclosure. The system is battery operated. Installation costs include the cost of the camera system, site preparation, land lease, and procurement. Site preparation involves providing access and clearing vegetation so that an unobstructed view is presented. A back-up camera system should be maintained for a network of five sites in order to minimize downtime.

Operation costs include weekly checks, film changes, and travel time and expense. Travel costs are based on a 50 mile round trip. The costs of film and shipping are included in the analysis cost. The analysis includes film processing, slide coding, densitometry, data reduction, reporting, and archival. If contrast data are not required, densitometry can be omitted from the analysis; however, this option does not result in significant cost savings. The difference is about $600 per year. Most of the analysis cost is in the slide coding, data reduction and reporting. Slide coding involves having a trained technician examine the slide and assign codes describing meteorological and scene conditions.

Data management costs presented refer to integrating the photographic data into a central database for the visibility monitoring program. Most data reduction and reporting costs are included in the figure for overall analytical costs. QA costs presented are for initial QA plan preparation, periodic data quality reports, and training. Data quality reports should include a descriptive analysis of any operational or analytical problems. QA costs for the slide coding and densitometry are also included in the overall analytical figure. Costs are broken down in Table 8-6 and summarized in Table 8-7.

TABLE 8-6. COST ESTIMATES FOR PHOTOGRAPHIC MEASUREMENTS

Cost Element	Cost Type	Labor		Cost
		Level	Hours	
Station Installation				
Camera system (complete)	CPTL			2,800
Equipment installation	CPTL	TEC2	12	396
Land/lease	O/M			1,500
Procurement	CPTL	PRO1	8	288
Site preparation	CPTL			1,500
Sampling				
Routine site service	O/M	TEC1	26	780
Travel expense	O/M			702
Travel time	O/M	TEC1	52	1,560
Maintenance				
Routine maintenance and repairs	O/M	TEC2	8	264
Spare parts	O/M			100
Analysis				
Processing and coding only	O/M			5,400
Processing coding, and densitometric analysis	O/M			6,000
Data Management				
Data processing	O/M	PRO1	16	576
Quality Assurance/Quality Control				
Implementation/coordination	O/M	PRO2	8	336
QA plan	O/M	PRO2	8	336
Reporting	O/M	PRO2	16	672
Training	O/M	PRO2	8	336
Supervision				
Planning/coordination	O/M	PRO3	8	400
Supervision/review	O/M	PRO3	16	800
Total Capital (CPTL) Costs				4,984
Total Operation and Maintenance (O/M) Costs*				14,362

* Total based on processing coding, and densitometric analysis

TABLE 8-7. PHOTOGRAPHIC MEASUREMENTS COST SUMMARY

Cost Type	Option 1
Capital	4,984
Annual Operation and Maintenance	14,362
Average Annualized Cost	15,359

8.6 COST ESTIMATES FOR NEPHELOMETRY

The nephelometer measures scattered light extinction by pulling a sample volume of air into an optical chamber with a light source of known intensity and a detector. The nephelometer provides a measurement of light extinction that is representative of the atmosphere at the point of sampling. The accuracy of this measurement depends on the uniformity of the atmosphere over the sight path. The costs presented in this document are based on a nephelometer designed to operate at ambient conditions. That is, the sample temperature is not changed by introducing the sample into the optical chamber. This is important since relative humidity can have a profound effect on the measured scattering coefficient. A heated inlet can be added to measure the dry atmospheric scattering coefficient. A heated inlet adds about $1,300 to the cost of the system.

Costs in this document are based on a nephelometer that can be operated outdoors during all weather conditions. This nephelometer can also be powered by solar energy when AC line power is not available. Some models of nephelometers, however, do require AC line power and a temperature controlled shelter to protect the instrument's optics and electronics. A telephone connection is used to provide control inputs and upload data from the system. Cellular telephone service is available in many areas where line service may not be. When no telephone service is available, a satellite linkup may be used. The cost of the equipment required for the satellite link is about $6,500. A detailed cost breakdown is provided in Table 8-8. Costs are summarized in Table 8-9. Option 1 gives costs for a site where AC power is available. A shelter is also used at the Option 1 site. The Option 2 configuration requires solar power, but does not require a shelter.

The sampler is serviced weekly and a span check is performed using a reference gas. Maintenance costs depend on whether the nephelometer is run continuously or in a cycled mode. More lamp replacements are required for continuous operation. Typically, a nephelometer would be run continuously where rapid changes in the scattering coefficient might be expected, such as in urban areas. In remote areas, the nephelometer would normally be run in a cycled mode. Cost estimates are based on continuous operation. Data management and QA are based on handling hourly averaged data.

TABLE 8-8. COST ESTIMATES FOR NEPHELOMETRY

Cost Element	Options		Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Station Installation						
Data logger and control system	✓	✓	CPTL			6,700
Modem	✓	✓	CPTL			600
Nephelometer	✓	✓	CPTL			12,000
Shelter (temperature controlled)	✓		CPTL			7,000
Equipment installation	✓	✓	CPTL	TEC2	16	528
Land/lease	✓	✓	O/M			1,500
AC power drop	✓		CPTL			350
Power supply	✓	✓	CPTL			400
Solar power system		✓	CPTL			4,500
Procurement	✓	✓	CPTL	PRO1	8	288
Site preparation	✓	✓	CPTL			2,000
Telephone line	✓	✓	O/M			1,200
Sampling						
Routine weekly site service	✓	✓	O/M	TEC2	26	858
Travel expense	✓	✓	O/M			702
Travel time	✓	✓	O/M	TEC2	52	1,716
Utilities	✓		O/M			320
Maintenance						
Remedial calibrations	✓	✓	O/M	TEC2	4	132
Repairs	✓	✓	O/M	TEC2	20	660
Spare parts and supplies	✓	✓	O/M			500
Data Management						
Data acquisition/processing	✓	✓	O/M	PRO1	52	1,872
Data reporting	✓	✓	O/M	PRO2	32	1,344
Data validation level 1	✓	✓	O/M	PRO1	24	864
Data validation level 2	✓	✓	O/M	PRO2	24	1,008
Quality Assurance						

(Continued)

TABLE 8-8. COST ESTIMATES FOR NEPHELOMETRY (Continued)

Cost Element	Options		Type	Labor		Cost
	Opt1	Opt2		Level	Hours	
Audits	✓	✓	O/M	PRO2	4	168
Span calibration system	✓	✓	CPTL			1,000
Implementation/coordination	✓	✓	O/M	PRO2	12	504
QA/QC data review	✓	✓	O/M	PRO2	26	1,092
QA plan preparation	✓	✓	CPTL	PRO2	20	840
Reporting	✓	✓	O/M	PRO2	26	1,092
Calibration gas	✓	✓	O/M			300
Training	✓	✓	O/M	PRO2	8	336
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	26	1,300
Supervision/review	✓	✓	O/M	PRO3	26	1,300
Total Capital (CPTL) Costs - Option 1						31,706
Total Operation and Maintenance (O/M) - Option 1						18,768
Total Capital (CPTL) Costs - Option 2						28,856
Total Operation and Maintenance (O/M) - Option 2						18,448

TABLE 8-9. NEPHELOMETER COST SUMMARY

Cost Type	Option 1	Option 2
Capital	31,706	28,856
Annual Operation and Maintenance	18,768	18,448
Average Annualized Cost	25,109	24,219

8.7 COST ESTIMATES FOR AN INTEGRATED VISIBILITY MONITORING STATION

Costs for an integrated visibility monitoring station where more than one monitoring system is in place will be less than the sum of the costs for the individual monitoring systems. Duplicate costs include site preparation, and power drop (capital), and travel expense, travel time, and land/lease (operation and maintenance). Table 8-10 represents the costs for a monitoring system consisting of the full IMPROVE sampler (Aerosol), transmissometer (Optical), and automated camera system (Scene) located in a remote area, but where AC line power and telephone service are available. Network design costs reflect a mix of technical and mid- to senior level professional labor hours totalling 400 hours at $50 per hour. Site selection costs are estimated at 100 hours per site at an average rate of $45 per hour for senior technical to mid-level professional labor. Total network design and siting costs are divided by an arbitrary network size of five sites.

TABLE 8-10. INTEGRATED VISIBILITY MONITORING SYSTEM COST SUMMARY

Cost Type	Design/ Siting	Duplicate Costs	Aerosol	Optical	Scene	Total
Capital	8,500	3,350	14,776	37,615	3,484	67,725
Operation/Maintenance	N/A	3,918	34,882	18,470	10,600	67,870
Average Annual Cost	1,700	4,588	37,837	25,993	11,297	81,415

8.8 REFERENCE

1. Air Resource Specialists, LPV-2 *Transmissometer Standard Operating Procedures Manual*, prepared for the National Park Service Visibility Monitoring and Data Analysis Program. May 1988.

SECTION 9.0

SATURATION MONITORING

Saturation monitoring is an air monitoring approach directed at obtaining finely detailed spatial and temporal resolution of air pollutant impacts in an area. This is accomplished through a study design employing a large number of relatively inexpensive, portable battery operated samplers. Such samplers are normally mounted to existing utility poles and require very little effort for site preparation and installation. Saturation monitoring studies are typically conducted over relatively short intervals during the part of the year in which maximum impacts are expected to occur. A successful saturation study provides data that can complete information unavailable through traditional monitoring and modeling approaches.

Saturation study designs are tailored to the area under consideration and the specific monitoring objectives involved. For example, a saturation study might focus on identifying high concentration areas, or on establishing the spatial distribution of pollutant concentrations. Samplers could be clustered in areas thought to be most heavily impacted or spread over an area in order to identify high impact areas. Saturation data can be used to resolve spatial concentration gradients and identify distinct impact areas associated with different source types. In addition, saturation data can provide missing background and area/mobile source baseline concentrations. Dispersion model performance can be evaluated using data obtained from saturation studies. Saturation studies may be particularly valuable in complex terrain situations where existing monitoring data are likely to lack the required spatial resolution, and modeling results are subject to the greatest uncertainties.

Portable samplers are currently available that have been evaluated for PM-10 and CO monitoring. The current samplers are capable of running continuously for 24 hours and can be programmed to start and stop at preset times over a 7-day period. The PM-10 version collects particulate on a filter at a constant flow rate of about 5 liters per minute. A single stage impactor is used to separate the fine from the course particulate. The PM-10 samplers have also been run with the size selective inlet removed, and the filters analyzed for lead and other metals. The CO version fills up to two Tedlar® bags on a preset schedule. The flow rate is adjusted to fill each bag over the proper interval. The sample is later analyzed using an infra-red gas filter correlation analyzer.

Designing a saturation monitoring network requires many of the same considerations necessary for designing any other monitoring network. Historical meteorological and monitoring data must be analyzed, emissions information and topographic influences need to be considered, and any previous modeling studies should be reviewed. Additional information, such as citizen complaints, should also be considered when available. Saturation study costs depend on the number of samplers, and the length and complexity of the study. The study interval must be long enough to allow collection of sufficient valid samples to ensure the statistical integrity of the data. The sampling schedule should be addressed in terms of the monitoring objectives and logistical constraints. Whatever sampling period is chosen, it is important to devise a scheme for sample changes to ensure that samples are collected over comparable intervals at different locations. The saturation study design can also incorporate multiple or dynamic sampling periods, if appropriate. Sampling can be triggered by meteorological conditions. Logistical considerations, including regulatory deadlines, manpower, and resources, will play a significant role in study design.

Currently available portable samplers exhibit detection limits and operating ranges comparable to reference methods. A limited number of intercomparison studies have been conducted to validate portable sampling methods. If possible, the study design should include a set of samples from a portable sampler collocated with a reference or equivalent sampler (operated on the same schedule) so that an assessment of the relative accuracy of the data can be obtained. In addition, a duplicate set of measurements should be obtained from collocated portable samplers so that operational precision can be assessed. A QA project plan should be prepared and adhered to as with any monitoring program.

9.1 SATURATION MONITORING COSTS

This section provides cost estimates for PM-10 (Option I) and CO (Option 2) saturation monitoring studies. Costs for a study collecting 30 valid samples using 20 samplers are provided. Operation costs are inflated by about 15 percent to allow for incomplete data capture. Thus, in effect, the cost estimates represent a 35 sample study. Capital equipment is depreciated completely over five years. It is assumed that the samplers purchased will be used in one study per year.

The PM-10 sampler units cost $1,300 each. The additional equipment required for CO sampling adds $188 per sampler, including two sample collection chambers, and the necessary valves and fittings. Individual Tedlar® bags cost $15.50 each. The Tedlar® bags should last for a 30-day study, but would be replaced for the next study. Tedlar® bag costs for each study are estimated based on consumption of 4 bags plus 1 spare per sampler.

A glass fiber filter is used when sampling CO. The filter should be changed each day. PM-10 samples are usually collected on quartz fiber or a low pressure drop Teflon® filter. Quartz filters cost about $1 each and Teflon® filters cost from $2 to $4 each. Cost estimates are based on filters at $2 each. Supplies required for PM-10 sampling include hexane, Apiezon® grease, dropper and wash bottles for cleaning and regreasing the impactors, and plastic bags for storing filter holders. Costs for shipping PM-10 samples to the laboratory are based on overnight service. Samples are shipped every 5 days or 100 samples.

For CO studies, a CO analyzer will be needed on-site because the samples degrade rapidly. A capital equipment cost estimate is provided for the CO analyzer. The operating cost for the study is estimated at about 1/12 of the annual operating cost. This includes the cost of a gas cylinder used for daily span checks. The 40 samples collected each day can be analyzed in an 8-hour period, allowing time for QC, data recording, and preparing the bags for the next day's samples. The PM-10 samples are weighed at a remote lab. The cost is estimated on a per sample basis including data recording and reporting.

Data management costs include data processing, validation, analysis, and reporting. Data processing costs include the effort required to obtain and properly format either the PM-10 or CO data and supporting meteorological data for analysis. The data analysis costs include examination of spatial and temporal variation with respect to daily meteorological conditions. QA costs include preparation of the QA plan, audits, review, reporting, and training. It is assumed that the QA plan will be adapted from existing material. Flow audits are conducted at the beginning, middle, and end of the study. Costs for a flow audit device are based on use of a portable electronic bubble flow meter. Training costs for the provider include preparation or adaptation of training materials for the study. Time is allowed for training site operators. Laboratory technicians (including the operator of the CO analyzer) are assumed to have had prior training. Supervision costs include planning study details and supervising daily operations.

Detailed breakdowns of saturation monitoring costs for PM-10 (Option I) and CO (Option 2) are given in Table 9-1. These costs are summarized in Table 9-2.

TABLE 9-1. SATURATION MONITORING COSTS

Cost Element	Option		Cost Type	Labor		Cost
	OPT1	OPT2		Level	Hours	
Network Design						
Network design study	✓	✓	CPTL	PRO3	100	5,000
Site selection	✓	✓	CPTL	PRO2	48	2,016
Installation						
Portable PM-10 samplers (20)	✓	✓	CPTL			26,000
CO sampler add-on (20)		✓	CPTL			3,760
Installation hardware	✓	✓	CPTL			800
Installation labor	✓	✓	O/M	TEC2	16	528
Procurement	✓	✓	O/M	PRO1	24	864
Sampling						
Filter media (PM-10)	✓		O/M			1,380
Filters (for CO)		✓	O/M			690
Tedlar bags 4 per sampler plus 1 spare		✓	O/M			1,550
Shipping	✓		O/M			100
Routine site service	✓	✓	O/M	TEC1	210	6,300
Travel expense for routine site service	✓	✓	O/M			4,725
Maintenance						
Spare parts	✓	✓	O/M			250
Supplies	✓		O/M			100
Repairs	✓	✓	O/M	TEC2	20	660
Analysis						
PM-10 gravimetric analyses (700 filters)	✓		O/M			5,520
CO analyzer		✓	CPTL			10,000
CO analyzer operating expenses		✓	O/M			200
CO analysis		✓	O/M	TEC2	280	9,240
Data Management						
Data processing	✓	✓	O/M	PRO2	12	504

(Continued)

TABLE 9-1. SATURATION MONITORING COSTS (Continued)

Cost Element	Option		Cost Type	Labor		Cost
	OPT1	OPT2		Level	Hours	
Data analysis	✓	✓	O/M	PRO3	40	2,000
Data reporting	✓	✓	O/M	PRO3	24	1,200
Data validation - level 1	✓	✓	O/M	PRO2	16	672
Data validation - level 2	✓	✓	O/M	PRO3	8	400
Quality Assurance/Quality Control						
Bubble flow calibrator	✓	✓	CPTL			1,200
Flow audits	✓	✓	O/M	TEC2	24	792
Review	✓	✓	O/M	PRO2	24	1,008
Implementation/coordination	✓	✓	O/M	PRO2	4	168
QA plan	✓	✓	CPTL	PRO2	40	1,680
Reporting	✓	✓	O/M	PRO2	16	672
Training (provider)	✓	✓	O/M	PRO2	24	1,008
Training (receiver)	✓	✓	O/M	TEC1	8	240
Supervision						
Planning/coordination	✓	✓	O/M	PRO3	40	2,000
Supervision/review	✓	✓	O/M	PRO3	48	2,400
Total Capital (CPTL) Costs - Option 1						36,696
Total Operation and Maintenance (O/M) Costs - Option 1						33,491
Total Capital (CPTL) Costs - Option 2						50,456
Total Operation and Maintenance (O/M) Costs - Option 2						38,071

Option 1 - Saturation monitoring costs for PM-10
Option 2 - Saturation monitoring costs for CO

TABLE 9-2. SUMMARY OF SATURATION MONITORING COSTS

Cost type	Option 1 (PM-10)	Option 2 (CO)
Capital	36,696	50,456
Operation and Maintenance (30 day study)	33,491	38,071
Average Annual Cost (5 yrs)	40,830	48,162

SECTION 10.0

COSTS FOR AN EXAMPLE NETWORK

This section presents an example application of the cost estimates in the preceding sections to an hypothetical network. The network configuration was chosen to be representative of a large (population greater than 2,000,000), isolated MSA where PAMS monitoring will be required. The example includes costs for operation and maintenance of the existing criteria pollutant monitoring network and implementation of PAMS monitoring over a 5-year period. The existing network includes a basic meteorological station (see Section 6.2). The example also includes reconfiguration of the lead monitoring network from mobile source oriented monitoring to point source monitoring. Two new lead monitoring stations are established during the period using samplers relocated from existing sites. The example illustrates economies realized from location of multiple parameters at a single site, use of existing sites for new PAMS sites, and relocation of existing equipment to new sites.

For simplicity and consistency we have used cost estimates in this example that have been presented in earlier sections. For example, we have used the 48-hour sampling period for lead sampling even though the vast majority of current lead sites use a 1/6 day sampling schedule. In a number of instances the use of earlier cost estimates will result in an overestimate of actual costs. For instance, at a site with collocated PM-10 and lead samplers there will be a savings in travel time for routine field site visits. Also, sites that have numerous instruments collocated would see savings by sharing data loggers, computers, as well as travel time for instrument servicing. In addition, site installation savings may be realized when moving an existing site or installing multiple instrument at a new site. To include all these details here would make the example overly complex, obscure the basic derivation of costs, and would not be as generally applicable.

Estimates of capital and operating and maintenance costs are given for the existing network (year 0) and for the following 5-year period. The existing network contains 14 sites. Five PAMS sites and two lead sites are added during the 5-year period. Three of the PAMS sites are established at existing monitoring locations, so that the network contains a total of 17 sites at the end of the period. The site/parameter configuration of the network is shown in Table 10-1. The table also describes planned changes to the network over the 5-year period.

Figure 10-1 shows capital and operating and maintenance costs accumulating over the 5-year period. Table 10-2 gives detailed costs for the existing network (year 0) and for years 1 through 5. Capital and operating and maintenance costs are given for each site and parameter. The costs are obtained from the appropriate pollutant/meteorological station tables presented in earlier sections of this report. The table includes comments describing changes to the network and economies due to multiple parameters at a single site, relocation of existing equipment to new sites, and use of existing sites for new PAMS sites.

TABLE 10-1. HYPOTHETICAL NETWORK CONFIGURATION

Site	Parameter	Comments
0001	**PM-10**	No changes over 5-year period.
0002	**PM-10** **Lead** **SO_2** **NO_2**	PM-10 and lead monitors are collocated. No changes over 5-year period.
0003	**Lead** **CO**	No changes over 5-year period.
0004	**SO_2** **O_3**	No changes over 5-year period.
0005	**PM-10** **O_3**	O_3 monitor, shelter, and peripheral equipment moved to site 0015 year 5.
0006	**Lead** **SO_2** **NO_2**	NO_2 monitor moved to site 0012 year 2.
0007	**Lead** **CO**	Lead sampler moved to site 0016 year 2.
0008	**Lead** **CO**	Lead sampler moved to site 0017 year 3.
0009	**CO** **NO_2**	NO_2 monitor moved to site 0011 year 1.
0010	**O_3**	Equipment moved to site 0012 year 2. Monitoring discontinued after year 1.
0011	**PM-10** **CO** O_3 NO_2 VOC (B) Carbonyls (A) Surface Met.	PAMS site type 2 located at existing neighborhood scale site. New O_3 monitor. NO_2 monitor relocated from site 0009.

(continued)

TABLE 10-1. HYPOTHETICAL NETWORK CONFIGURATION (Continued)

Site	Parameter	Comments
0012	O_3 NO_2 VOC (B) Carbonyls (A) Surface Met.	PAMS site type 2 established year 2. New site established year 2. O_3 monitor, shelter, and peripheral equipment relocated from site 0010. NO_2 relocated from site 0006.
0013	**SO_2** **O_3** NO_2 VOC (A) Surface Met. Upper Met.	PAMS site type 3 located at existing downwind site. Established year 3. New NO_2 monitor. Upper air meteorology is established year 2.
0014	**SO_2** **O_3** NO_2 VOC (A) Surface Met.	PAMS site type 1 located at existing upwind site. Established year 4. New NO_2 monitor.
0015	O_3 NO_2 VOC (A) **Surface Met.**	PAMS site type 4 established year 5. O_3 monitor, shelter and peripheral equipment relocated from site 0005. Surface meteorology is part of the existing network and operates year round.
0016	Lead	New point source oriented lead site.
0017	Lead	New point source oriented lead site.

Note: **Bold** parameters are part of existing network.

FIGURE 10-1. NETWORK COST SUMMARY

Operation and maintenance costs for the existing network total $451,632 per year. This figure more than doubles to $1,020,376 per year at the end of 5-years. The increase is due to implementation of the PAMS network. No allowance is made for inflation, or for possible reduction in costs due to technological improvements in methods for non-criteria pollutants (especially VOCs). Capital costs total $839,999 over the 5-year period. The largest single year capital expenditure comes in year 2 when the second PAMS station and the upper air meteorological station are installed.

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5

Site	Monitor	Year	Type	Cost	Comments
1	PM-10	0	O/M	$10,308	Includes lease
2	PM-10	0	O/M	$19,116	Collocated. Less lease for 2nd sampler.
2	Lead	0	O/M	$31,784	Collocated. Less lease
2	SO_2	0	O/M	$14,474	Less lease
2	NO_2	0	O/M	$15,896	Less lease
3	Lead	0	O/M	$17,392	Includes lease
3	CO	0	O/M	$14,474	Less lease
4	SO_2	0	O/M	$15,974	Includes lease
4	O_3	0	O/M	$14,474	Less lease
5	PM-10	0	O/M	$10,308	Includes lease
5	O_3	0	O/M	$14,474	Less lease
6	Lead	0	O/M	$17,392	Includes lease
6	SO_2	0	O/M	$14,474	Less lease
6	NO_2	0	O/M	$15,896	Less lease
7	Lead	0	O/M	$15,892	Less lease
7	CO	0	O/M	$15,974	Includes lease
8	Lead	0	O/M	$15,892	Less lease
8	CO	0	O/M	$15,974	Includes lease
9	CO	0	O/M	$15,974	Includes lease
9	NO_2	0	O/M	$15,896	Relocate to site #11 first year
10	O_3	0	O/M	$14,474	Less lease
11	PM-10	0	O/M	$10,308	Includes lease
11	CO	0	O/M	$14,474	Less lease
13	SO_2	0	O/M	$15,974	Includes lease
13	O_3	0	O/M	$14,474	Less lease
14	SO_2	0	O/M	$15,974	Includes lease
14	O_3	0	O/M	$14,474	Less lease
15	Met	0	O/M	$29,442	Basic meteorological station (year round operation)
Total Operation and Maintenance Costs (O/M) - Year 0				**$451,632**	

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
1	PM-10	1	O/M	$10,308	Includes lease
2	PM-10	1	O/M	$19,116	Collocated. Less lease for 2nd sampler.
2	Lead	1	O/M	$31,784	Collocated. Less lease
2	SO_2	1	O/M	$14,474	Less lease
2	NO_2	1	O/M	$15,896	Less lease
3	Lead	1	O/M	$17,392	Includes lease
3	CO	1	O/M	$14,474	Less lease
4	SO_2	1	O/M	$15,974	Includes lease
4	O_3	1	O/M	$14,474	Less lease
5	PM-10	1	O/M	$10,308	Includes lease
5	O_3	1	O/M	$14,474	Less lease
6	Lead	1	O/M	$17,392	Includes lease
6	SO_2	1	O/M	$14,474	Less lease
6	NO_2	1	O/M	$15,896	Relocate to site #12 after year 1
7	Lead	1	O/M	$15,892	Relocate to #16 after year 1
7	CO	1	O/M	$15,974	Includes lease
8	Lead	1	O/M	$15,892	Less lease
8	CO	1	O/M	$15,974	Includes lease
9	CO	1	O/M	$15,974	Includes lease
10	O_3	1	O/M	$14,474	Relocate monitor and shelter to site #12 after year 1
11	PM-10	1	O/M	$10,308	Includes lease
11	CO	1	O/M	$14,474	Less lease
11	O_3	1	CPTL	$7,716	New monitor added (includes procurement 288, monitor 6900, and installation 528). Assume peripheral equipment in place for existing CO monitor.
11	O_3	1	O/M	$14,474	Less lease

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
11	NO_2	1	CPTL	$1,028	Cost to relocate monitor from site #9. Installation + $500 for site modifications. Assumes peripheral equipment for ozone analyzer is used for NO_2.
11	NO_2	1	O/M	$15,896	Less lease
11	VOC	1	CPTL	$105,252	PAMS continuous VOC. Sampling schedule B.
11	VOC	1	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
11	Carbonyls	1	CPTL	$35,782	Carbonyls sampling frequency D. Option 1.
11	Carbonyls	1	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
11	Met	1	CPTL	$27,328	PAMS surface meteorological station
11	Met	1	O/M	$8,034	3 months operation
13	SO_2	1	O/M	$15,974	Includes lease
13	O_3	1	O/M	$14,474	Less lease
14	SO_2	1	O/M	$15,974	Includes lease
14	O_3	1	O/M	$14,474	Less lease
15	Met	1	O/M	$29,442	Basic meteorological station (year round operation)
Total Capital (CPTL) Costs - Year 1				**$177,106**	
Total Operation and Maintenance Costs (O/M) - Year 1				**$651,011**	
1	PM-10	2	O/M	$10,308	Includes lease
2	PM-10	2	O/M	$19,116	Collocated. Less lease for 2nd sampler.
2	Lead	2	O/M	$31,784	Collocated. Less lease
2	SO_2	2	O/M	$14,474	Less lease
2	NO_2	2	O/M	$15,896	Less lease
3	Lead	2	O/M	$17,392	Includes lease
3	CO	2	O/M	$14,474	Less lease
4	SO_2	2	O/M	$15,974	Includes lease
4	O_3	2	O/M	$14,474	Less lease

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
5	PM-10	2	O/M	$10,308	Includes lease
5	O_3	2	O/M	$14,474	Less lease
6	Lead	2	O/M	$17,392	Includes lease
6	SO_2	2	O/M	$14,474	Less lease
7	CO	2	O/M	$15,974	Includes lease
8	Lead	2	O/M	$13,892	Relocate to #17 after year 2
8	CO	2	O/M	$15,974	Includes lease
9	CO	2	O/M	$15,974	Includes lease
11	PM-10	2	O/M	$10,308	Includes lease
11	CO	2	O/M	$14,474	Less lease
11	O_3	2	O/M	$14,474	Less lease
11	NO_2	2	O/M	$15,896	Less lease
11	VOC	2	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
11	Carbonyls	2	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
11	Met	2	O/M	$8,034	3 months operation
12	O_3	2	CPTL	$3,878	Cost to establish new site and relocate monitor, shelter, and peripheral equipment from site #10. Site preparation (3000) + Power drop (350) + Installation (528).
12	O_3	2	O/M	$15,974	Includes lease
12	NO_2	2	CPTL	$1,028	Cost to relocate monitor from site #6. Installation + $500 for site modifications. Assumes peripheral equipment for ozone analyzer is used for NO_2.
12	NO_2	2	O/M	$15,896	Less lease
12	VOC	2	CPTL	$105,252	PAMS continuous VOC. Sampling schedule B.
12	VOC	2	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
12	Carbonyls	2	CPTL	$35,782	Carbonyls sampling frequency D. Option 1.

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
12	Carbonyls	2	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
12	Met	2	CPTL	$27,328	PAMS surface met
12	Met	2	O/M	$8,034	3 months operation
13	SO_2	2	O/M	$15,974	Includes lease
13	O_3	2	O/M	$14,474	Less lease
13	Met	2	CPTL	$162,616	Upper air meteorological station
13	Met	2	O/M	$4,538	3 month operation
14	SO_2	2	O/M	$15,974	Includes lease
14	O_3	2	O/M	$14,474	Less lease
15	Met	2	O/M	$29,442	Basic meteorological station (year round operation)
16	Lead	2	CPTL	$6,250	Cost to relocate from site #7 and establish new site. Site preparation (3000)+Power (350) + Installation (264) + a portion of network design and siting.
16	Lead	2	O/M	$17,392	Includes lease
Total Capital (CPTL) Costs - Year 2				$342,134	
Total Operation and Maintenance (O/M) Costs - Year 2				$841,454	
1	PM-10	3	O/M	$10,308	Includes lease
2	PM-10	3	O/M	$19,116	Collocated. Less lease for 2nd sampler.
2	Lead	3	O/M	$31,784	Collocated. Less lease
2	SO_2	3	O/M	$14,474	Less lease
2	NO_2	3	O/M	$15,896	Less lease
3	Lead	3	O/M	$17,392	Includes lease
3	CO	3	O/M	$14,474	Less lease
4	SO_2	3	O/M	$15,974	Includes lease
4	O_3	3	O/M	$14,474	Less lease
5	PM-10	3	O/M	$10,308	Includes lease
5	O_3	3	O/M	$14,474	Less lease
6	Lead	3	O/M	$17,392	Includes lease
6	SO_2	3	O/M	$14,474	Less lease

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
7	CO	3	O/M	$15,974	Includes lease
8	CO	3	O/M	$15,974	Includes lease
9	CO	3	O/M	$15,974	Includes lease
11	PM-10	3	O/M	$10,308	Includes lease
11	CO	3	O/M	$14,474	Less lease
11	O_3	3	O/M	$14,474	Less lease
11	NO_2	3	O/M	$15,896	Less lease
11	VOC	3	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
11	Carbonyls	3	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
11	Met	3	O/M	$8,034	3 months operation
12	O_3	3	O/M	$15,974	Includes lease
12	NO_2	3	O/M	$15,896	Less lease
12	VOC	3	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
12	Carbonyls	3	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
12	Met	3	O/M	$8,034	3 months operation
13	SO_2	3	O/M	$15,974	Includes lease
13	O_3	3	O/M	$14,474	Less lease
13	NO_2	3	CPTL	$10,116	Analyzer (9300) + Procurement (288) + Installation (528) - assumes that peripheral equipment is in place due to ozone and SO_2 analyzers in place
13	NO_2	3	O/M	$15,896	Less lease
13	VOC	3	CPTL	$75,209	PAMS VOC sampling schedule A (canisters). Option 1 - in-house analysis.
13	VOC	3	O/M	$36,722	PAMS VOC sampling schedule A (canisters). Option 1 - in-house analysis.
13	Met	3	CPTL	$27,328	PAMS surface meteorological station
13	Met	3	O/M	$8,034	3 months operation

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
13	Met	3	O/M	$4,538	Upper air meteorological station (3 month operation)
14	SO_2	3	O/M	$15,974	Includes lease
14	O_3	3	O/M	$14,474	Less lease
15	Met	3	O/M	$29,442	Basic meteorological station (year round operation)
16	Lead	3	O/M	$17,392	Includes lease
17	Lead	3	CPTL	$6,250	Cost to relocate from site #8 and establish new site. Site preparation (3000) + Power (350) + Installation (264) + a Portion of network design and siting.
17	Lead	3	O/M	$17,392	Includes lease
Total Capital (CPTL) Costs - Year 3				**$118,903**	
Total Operation and Maintenance (O/M) Costs - Year 3				**$905,606**	
1	PM-10	4	O/M	$10,308	Includes lease
2	PM-10	4	O/M	$19,116	Collocated. Less lease for 2nd sampler.
2	Lead	4	O/M	$31,784	Collocated. Less lease
2	SO_2	4	O/M	$14,474	Less lease
2	NO_2	4	O/M	$15,896	Less lease
3	Lead	4	O/M	$17,392	Includes lease
3	CO	4	O/M	$14,474	Less lease
4	SO_2	4	O/M	$15,974	Includes lease
4	O_3	4	O/M	$14,474	Less lease
5	PM-10	4	O/M	$10,308	Includes lease
5	O_3	4	O/M	$14,474	Relocate after year 4 to site #15. Also move shelter.
6	Lead	4	O/M	$17,392	Includes lease
6	SO_2	4	O/M	$14,474	Less lease
7	CO	4	O/M	$15,974	Includes lease
8	CO	4	O/M	$15,974	Includes lease
9	CO	4	O/M	$15,974	Includes lease
11	PM-10	4	O/M	$10,308	Includes lease

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
11	CO	4	O/M	$14,474	Less lease
11	O_3	4	O/M	$14,474	Less lease
11	NO_2	4	O/M	$15,896	Less lease
11	VOC	4	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
11	Carbonyls	4	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
11	Met	4	O/M	$8,034	3 months operation
12	O_3	4	O/M	$15,974	Includes lease
12	NO_2	4	O/M	$15,896	Less lease
12	VOC	4	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
12	Carbonyls	4	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
12	Met	4	O/M	$8,034	3 months operation
13	SO_2	4	O/M	$15,974	Includes lease
13	O_3	4	O/M	$14,474	Less lease
13	NO_2	4	O/M	$15,896	Less lease
13	VOC	4	O/M	$36,722	PAMS sampling schedule A (canisters). Option 1 - in-house analysis.
13	Met	4	O/M	$8,034	3 months operation
13	Met	4	O/M	$4,538	3 months operation
14	SO_2	4	O/M	$15,974	Includes lease
14	O_3	4	O/M	$14,474	Less lease
14	NO_2	4	CPTL	$10,116	Assumes that peripheral equipment is in place due to ozone and SO_2 analyzers at site. Analyzer (9300) + Procurement (288) + Installation (528).
14	NO_2	4	O/M	$15,896	Less lease
14	VOC	4	CPTL	$75,209	PAMS sampling schedule A (canisters). Option 1 - in-house analysis.
14	VOC	4	O/M	$36,722	PAMS sampling schedule A (canisters). Option 1 - in-house analysis.

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
14	Met	4	CPTL	$27,328	PAMS surface met
14	Met	4	O/M	$8,034	3 months operation
15	Met	4	O/M	$29,442	Basic meteorological station (year round operation)
16	Lead	4	O/M	$17,392	Includes lease
17	Lead	4	O/M	$17,392	Includes lease
Total Capital (CPTL) Costs - Year 4				$112,653	
Total Operation and Maintenance (O/M) Costs - Year 4				$966,258	
1	PM-10	5	O/M	$10,308	Includes lease
2	PM-10	5	O/M	$19,116	Collocated. Less lease for 2nd sampler.
2	Lead	5	O/M	$31,784	Collocated. Less lease
2	SO_2	5	O/M	$14,474	Less lease
2	NO_2	5	O/M	$15,896	Less lease
3	Lead	5	O/M	$17,392	Includes lease
3	CO	5	O/M	$14,474	Less lease
4	SO_2	5	O/M	$15,974	Includes lease
4	O_3	5	O/M	$14,474	Less lease
5	PM-10	5	O/M	$10,308	Includes lease
6	Lead	5	O/M	$17,392	Includes lease
6	SO_2	5	O/M	$14,474	Less lease
7	CO	5	O/M	$15,974	Includes lease
8	CO	5	O/M	$15,974	Includes lease
9	CO	5	O/M	$15,974	Includes lease
11	PM-10	5	O/M	$10,308	Includes lease
11	CO	5	O/M	$14,474	Less lease
11	O_3	5	O/M	$14,474	Less lease
11	NO_2	5	O/M	$15,896	Less lease
11	VOC	5	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
11	Carbonyls	5	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
11	Met	5	O/M	$8,034	3 months operation

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
12	O_3	5	O/M	$15,974	Includes Lease
12	NO_2	5	O/M	$15,896	Less lease
12	VOC	5	O/M	$160,139	PAMS continuous VOC. Sampling schedule B.
12	Carbonyls	5	O/M	$16,732	Carbonyls sampling frequency D. Option 1.
12	Met	5	O/M	$8,034	3 months operation
13	SO_2	5	O/M	$15,974	Includes lease
13	O_3	5	O/M	$14,474	Less lease
13	NO_2	5	O/M	$15,896	Less lease
13	VOC	5	O/M	$36,722	PAMS sampling schedule A (canisters). Option 1 - in-house analysis.
13	Met	5	O/M	$8,034	3 months operation
13	Met	5	O/M	$4,538	3 months operation
14	SO_2	5	O/M	$15,974	Includes lease
14	O_3	5	O/M	$14,474	Less lease
14	NO_2	5	O/M	$15,896	Less lease
14	VOC	5	O/M	$36,722	PAMS sampling schedule A (canisters). Option 1 - in-house analysis.
14	Met	5	O/M	$8,034	3 months operation
15	O_3	5	CPTL	$3,878	Cost to establish new site and relocate monitor, shelter, and peripheral equipment from site #5. Site preparation (3000) + Power drop (350) + Installation (528).
15	O_3	5	O/M	$15,974	Includes Lease
15	NO_2	5	CPTL	$10,116	Assumes that peripheral equipment is in place due to ozone and SO_2 analyzers in place. Analyzer (9300) + procurement (288) + installation (264).
15	NO_2	5	O/M	$15,896	Less lease
15	VOC	5	CPTL	$75,209	PAMS sampling schedule A (canisters). Option 1 - in-house analysis.

(continued)

TABLE 10-2. NETWORK COST DETAILS--YEAR 0 - 5 (Continued)

Site	Monitor	Year	Type	Cost	Comments
15	VOC	5	O/M	$36,722	PAMS sampling schedule A (canisters). Option 1 - in-house analysis.
15	Met	5	O/M	$29,442	Basic meteorological station (year round operation)
16	Lead	5	O/M	$17,392	Includes lease
17	Lead	5	O/M	$17,392	Includes lease
Total Capital (CPTL) Costs - Year 5				**$89,203**	
Total Operation and Maintenance (O/M) Costs - Year 5				**$1,020,376**	
Total Network Capital (CPTL) Costs				**$839,999**	
Total Operation and Maintenance (O/M) Costs				**$4,836,337**	

TABLE 10-3. SUMMARY OF NETWORK COSTS

	Network Year					
Costs	**0**	**1**	**2**	**3**	**4**	**5**
CPTL	0	$177,106	$342,134	$118,903	$112,653	$89,203
O/M	$451,632	$651,011	$841,454	$905,606	$966,258	$1,020,376
Annualized	$451,632	$686,432	$909,881	$929,387	$988,789	$1,038,217

ATTACHMENT A

SAMPLING COST TABLE

TABLE __. ______________ SAMPLING COSTS

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hour	
Network Design						
Station Installation						
Sampling						
Maintenance						

(continued)

TABLE __. ____________ SAMPLING COSTS (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hour	
Analytical						
Data Management and Reporting						
Quality Assurance and Quality Control						

(continued)

TABLE __. ____________ SAMPLING COSTS (Continued)

Cost Element	Options		Cost Type	Labor		Cost
	Opt1	Opt2		Level	Hour	
Supervision						
Total Capital (CPTL) Costs - Option 1						
Total Operation and Maintenance (O/M) Costs - Option 1 (Excluding Sampling Media)						
Total Capital (CPTL) Costs - Option 2						
Total Operation and Maintenance (O/M) Costs - Option 2 (Excluding Sampling Media & Analysis						

Option 1
Option 2

TABLE __. ________COST SUMMARY

Cost Type	Cost	
	Option #1	Option #2
Capital Costs		
Annualized Operation and Maintenance Costs		
Average Annualized Cost		

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-454/R-93-042	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Guidance for Estimating Ambient Air Monitoring Costs for Criteria Pollutants and Selected Toxic Pollutants		5. REPORT DATE October 1993
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15. SUPPLEMENTARY NOTES
EPA Work Assignment Manager: Edward Hanks

16. ABSTRACT

This document provides cost estimates for monitoring, collecting and analyzing criteria pollutants in ambient air, toxic air pollutants, for enhanced ozone, saturation sampling for PM-10, and carbon monoxide (CO) using portable samplers. The document also describes the design and implementation of a model to be used in developing and presenting costs associated with different measurement methodologies. The capital and operating costs were developed based on 1992/1993 manufacturers' equipment costs and upon labor categories and rates as provided by a cross section of private and Governmental agencies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Ambient Air Monitoring Criteria Pollutant Monitoring Selected Air Toxics Monitoring Photochemical Assessment Monitoring		

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