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THE OBJECTIVE OF THIS CMP IS TO: VERIFY AND EVALUATE POTENTIAL AIR QUALITY HEALTH HAZARDS, TO VERIFY PROGRESS THAT HAS BEEN MADE TO DATE IN REMOVING CONTAMINANTS RESULTING FROM PREVIOUS ACTIVITIES, TO PROVIDE BASELINE DATA FOR THE EVALUATION OF PROGRESS THAT WILL BE MADE IN FUTURE REMEDIAL ACTIVITIES, TO DEVELOP REAL-TIME GUIDELINES, STANDARD PROCEDURES AND DATA COLLECTION METHODS, AS APPROPRIATE, TO INDICATE IMPACTS OF ONGOING REMEDIAL ACTIONS, AND TO VALIDATE AND DOCUMENT DATABASE RELIABILITY.

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COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

AIR QUALITY DATA ASSESSMENT REPORT FOR FY90

FINAL REPORT

SEPTEMBER 1991

Version 3.1
Volume I

~~19960620 010~~

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TABLE OF CONTENTS

PAGE

VOLUME I

TABLE OF CONTENTS (continued)

VOLUME II

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

VOLUME III

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

VOLUME IV

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

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ACRONYMS AND ABBREVIATIONS

111TCE	1,1,1-Trichloroethane
112TCE	1,1,2-Trichloroethane
ADI	Acceptable Daily Intake
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-s-trianine
BCHPD	Bicycloheptadiene
C_6H_6	Benzene
CCl_4	Carbon Tetrachloride
CH_2Cl_2	Methylene Chloride
$CHCl_3$	Chloroform
Chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methano-1H-indene
ClC_6H_5	Chlorobenzene
CMP FY90	Comprehensive Monitoring Program Fiscal Year 1990
CO	Carbon Monoxide
CRL	Certified Reporting Limit
DBCP	Dibromochloropropane
DCLE11	1,1-Dichloroethane
DCLE12	1,2-Dichloroethane
DCPD	Dicyclopentadiene
DDD	Dichlorodiphenyldichloroethane
DMB12	Dimethylbenzene
DMDS	Dimethyl Disulfide
EPA	Environmental Protection Agency
ETC_6H_5	Ethylbenzene
GC/MS	Gas Chromatography/Mass Spectrometry
GC/ECD	Gas Chromatography/Electron Capture Detection
ICAP	Inductively Coupled Argon Plasma
Malathion	0,0-dimethyl-s-(1,2-dicarboxyethyl) phosphorodithioate
MEC_6H_5	Toluene
MIBK	Methyl Isobutyl Ketone
MST	Mountain Standard Time
NAAQS	National Ambient Air Quality Standards
NATICH	National Air Toxics Information Clearinghouse
NIOSH	National Institute of Occupational Safety and Health
NNDMEA	N-Nitrosodimethylamine
NO_x	Nitrogen Oxides
O_3	Ozone

OCP	Organochlorine Pesticides
Parathion	Parathion ($C_{10}H_{14}NO_5PS$)
PMRMA	Program Manager Rocky Mountain Arsenal
PM-10	Respirable Particulates less than 10 microns
PPDDE	Dichlorodiphenylethane
PPDDT	Dichlorodiphenyltrichloroethane
SO_2	Sulfur Dioxide
Supona	2-chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate
SVOC	Semi-Volatile Organic Compounds
T12DCE	Trans-1,2-Dichloroethene
TCLEE	Tetrachloroethene
TLV	threshold limit value
tpy	tons per year
TRCLE	Trichloroethene
TSP	Total Suspended Particulates
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USAEHA	U.S. Army Environmental Hygiene Agency
VOC	Volatile Organic Compounds
XYLENE	Xylene

EXECUTIVE SUMMARY

The purpose of the Air Monitoring Element of the Comprehensive Monitoring Program (CMP) at the Rocky Mountain Arsenal (RMA) is to continue the ongoing collection of baseline data that was established under the Remedial Investigation Program. The program is used to determine ambient air quality levels at RMA in support of remedial actions and as a guide to evaluate progress. The CMP has several related key objectives: (1) to verify and evaluate potential air quality health hazards; (2) to verify progress that has been made to date in removing air contaminants resulting from previous activities; (3) to provide baseline data for the evaluation of progress that will be made in future remedial activities; (4) to develop real-time guidelines, standard procedures and data collection methods, as appropriate, to indicate impacts of ongoing remedial actions; and (5) to validate and document database reliability.

The CMP comprises a network of fixed and portable monitoring stations that collect air samples and measure the following analytes:

Total suspended particulates (TSP)
Respirable particulates less than 10 microns (PM-10)
Volatile organic compounds (VOC)
Semi-volatile organic compounds (SVOC)
ICP Metals (cadmium, chromium, copper, lead and zinc)
Mercury
Arsenic
Asbestos
Organochlorine pesticides (OCP)
Carbon monoxide
Nitrogen oxides
Ozone
Sulfur dioxide

The CMP consists of three modes of operation: (1) year-round and routine seasonal baseline monitoring of PM-10, VOC, SVOC, total suspended particulates (TSP), organochlorine pesticides (OCP), asbestos, specified metals, and gaseous pollutants; (2) "high event" monitoring during specified meteorological conditions to measure peak concentrations of VOC, SVOC, arsenic and metals; and (3) remedial monitoring coordination and direct support, as may be appropriate, to standardize and supplement air monitoring procedures for on-site remedial and construction activities.

This report focuses on results of the CMP for FY90 and includes analyses and comparisons to data for preceding monitoring programs at RMA and for other programs which ran concurrently. The CMP FY90 data, in conjunction with CMP FY88 and FY89 data, Basin F Remedial Monitoring Program data, and Basin F post-remedial IRA-F Monitoring Program data provide a strong and comprehensive database for evaluating remedial progress resulting from the Basin F cleanup program. These combined data and an assessment of remedial progress are provided as a special feature of this report.

Analyses of these data were used to characterize potential sources for air contaminants which were observed, including both RMA and metropolitan Denver influences. On-site meteorological data and ambient visibility observations were also used to describe those conditions associated with the average and the extreme events. Dispersion modeling was used to evaluate potential sources.

The following discussion summarizes the results of the analyses for each group of air quality parameters.

Total Suspended Particulates

TSP levels at RMA can be attributed to two principal sources: (1) the influx of particulates from metropolitan Denver, and (2) remedial activity sources which helped to produce wind-blown dust, particularly during very dry episodes. The TSP data clearly reflect the impact of Basin F remedial activities, with dramatic decreases in TSP levels around Basin F after the conclusion of remedial activities. During the height of these activities, the TSP levels which could be attributed to remediation activities decreased significantly with distance from the basin. This feature was observed both in the FY88 and FY89 data. During FY90, other construction activities at RMA, such as in the vicinity of the Lower Derby Lake spillway, produced noticeable TSP impacts; again these were highly localized and decreased rapidly from the source. In addition, there were several episodes during which impacts from metropolitan Denver completely overwhelmed impacts from potential on-site sources. At the eastern and northern boundaries of RMA, the TSP levels were well below those of metropolitan Denver, and were more representative of rural conditions.

Respirable Particulates (PM-10)

Respirable particulates are generated at RMA by dry windy conditions, but to a much lesser extent than for TSP. There were no violations of the annual or 24-hour PM-10 standards at RMA during FY90. The high PM-10 levels at RMA could be related to relatively high PM-10 levels in metropolitan Denver. Remediation activities played a minor role in increasing PM-10 levels during local remediation and construction activities. Impacts also decreased rapidly with distance from the potential source.

Metals

Ambient concentrations of metals across RMA were generally proportional to levels of TSP. Maximum concentrations were sampled on high wind speed days and also when there were high TSP and PM-10 levels, which in turn were attributed to sources off the Arsenal. During remediation activities, Basin F appeared to be a source of mercury, chromium, copper and zinc, and these concentrations decreased rapidly with distance from Basin F. Following closure of the basin, the metals levels were reduced to those typical of baseline conditions.

Asbestos

Asbestos was not detected at RMA during FY90. There were no detections of asbestos during FY88, and only two days with detections during FY89; results confirm that there is no evident source of ambient asbestos fibers on RMA.

Volatile Organic Compounds

During the Basin F remediation, on-site activities appeared to be a source of several volatile organic compounds, including bicycloheptadiene, dimethyl disulfide, benzene, toluene, and ethylbenzene. Some of these emissions could have resulted from the emissions from heavy equipment which was used during remediation. Chloroform was identified near both Basin F and the South Plants. Levels of VOCs which were attributed to RMA sources during the Basin F remediation period decreased rapidly with distance from those sources, and levels at RMA boundaries were similar to or less than those within the urban environment of metropolitan Denver. During FY89 and FY90 many of the VOCs attributed to Basin F decreased significantly. During FY90, many of the VOCs measured at RMA monitoring sites were attributed to close-by off-Arsenal sources as identified in this report.

Semi-Volatile Organic Compounds

Basin F appeared to be a source of several semi-volatile organic compounds, including aldrin, dieldrin, and endrin during the Basin F remediation period. The highest levels were detected in the immediate vicinity of Basin F during these remediation efforts. Results from a location downwind from the basin at the northeast perimeter of Basin F showed the highest levels of SVOCs, but at the RMA boundaries, these levels were reduced to roughly background levels. During the FY89 and FY90 post-remediation periods, SVOC concentrations were reduced significantly in the vicinity of Basin F and all SVOC concentrations measured at other RMA (CMP) monitoring sites were close to background levels.

Organochlorine Pesticides

These compounds were at or near the detection limit at the RMA boundary sites. Highest levels were sampled during the Basin F remediation effort, and nearest to Basin F itself. Following the completion of the remedial activities, these levels were reduced to near background levels in the vicinity of Basin F as well.

Criteria Pollutants

Ambient concentrations of the criteria pollutants, including sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone were monitored continuously at RMA during FY90. Generally, the air quality at the RMA monitoring location was cleaner than that at other sites in the Denver area. The RMA data showed no violations of any short-term or long-term standards for these pollutants. Episodes with relatively high concentrations at RMA were related to potential nearby sources under certain meteorological conditions. Several of these have been specifically related to typical Denver "brown cloud" conditions and have been identified in this report.

1.0 INTRODUCTION

The purpose of the Air Monitoring Element of the Comprehensive Monitoring Program (CMP) at the Rocky Mountain Arsenal (RMA) is to continue the ongoing collection of baseline data that was established under the Remedial Investigation Program. The program is used to determine ambient air quality levels at RMA in support of remedial actions and as a guide to evaluate progress. The CMP has several related key objectives: (1) to verify and evaluate potential air quality health hazards; (2) to verify progress that has been made to date in removing air contaminants resulting from previous activities; (3) to provide baseline data for the evaluation of progress that will be made in future remedial activities; (4) to develop real-time guidelines, standard procedures and data collection methods, as appropriate, to indicate impacts of ongoing remedial actions; and (5) to validate and document database reliability.

This is the third CMP annual report. During the CMP FY88 monitoring year, an intensive remediation effort was undertaken at Basin F and air monitoring data pertinent to those cleanup operations were incorporated into this initial report. Remediation activities continued through 1988 and were terminated on May 4, 1989. Consequently, the CMP FY89 monitoring period encompassed both Basin F remediation and post-remediation periods. The FY89 annual report, which included combined CMP FY88 and FY89 data, Basin F Remedial Monitoring Program Data and Basin F Post-Remedial IRA-F Monitoring Data, provided a comprehensive database for evaluating remedial progress resulting from the Basin F cleanup program. The present report for FY90 again incorporates both CMP and IRA-F data, and provides a continuation of post-remedial assessment for the Basin F cleanup. In addition, as in the previous reports, the database provides results of monitoring at 12 fixed RMA interior and perimeter site locations, and at approximately 24 "high event" mobile monitoring sites covering areas and/or activities of special concern across the arsenal.

Results of data summaries of total suspended particulates (TSP), respirable particulates less than 10 microns (PM-10), volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), asbestos, metals, mercury and organochlorine pesticides (OCP) for CMP F[illegible]) and the Interim Response Action F (IRA-F) Monitoring Program are provided in appropriate sections of the report; all sequential data are provided in appendices.

The CMP comprises a network of fixed and portable monitoring stations that collect air samples and measure the following analytes:

Total suspended particulates (TSP)
Respirable particulates less than 10 microns (PM-10)
Volatile organic compounds (VOC)
Semi-volatile organic compounds (SVOC)
ICP Metals (cadmium, chromium, copper, lead and zinc)
Mercury
Arsenic
Asbestos
Organochlorine Pesticides (OCP) - formerly referred to as OTSP
Carbon monoxide
Nitrogen dioxide
Ozone
Sulfur dioxide

The CMP consists of three modes of operation: (1) year-round and routine seasonal baseline monitoring of PM-10, VOC, SVOC, TSP, OCP, asbestos, specified metals, and gaseous pollutants; (2) "high event" monitoring during specified meteorological conditions to measure peak concentrations of VOC, SVOC, arsenic and metals; and (3) remedial monitoring coordination and direct support, as may be appropriate, to standardize and supplement air monitoring procedures for on-site remedial and construction activities. In addition, the program provides for upgrading and maintaining the existing meteorological network at RMA. Finally, the program provides for evaluation of the collected baseline and site-specific data so that it can be used in planning remedial actions and in assessing remedial progress.

The CMP is envisioned as a long-term air monitoring program that will run concurrently with remedial activities and will provide an ongoing database of remedial progress until the completion of the program. Year One of the CMP (CMP FY88) was initiated on October 1, 1987, and was completed on September 30, 1988. The Air Quality Data Assessment Report, dated February 1990 (R.L. Stollar and Associates, CMP, Contract Number DAAA15-87-0095) (CMP FY88 Report) summarizes data monitoring results that were collected during the first year of operation. Results of the first option year of the CMP are provided in the Air Quality Data Assessment Report for 1989 (R.L. Stollar and Associates, June 1990) (CMP FY89 Report). The present report contains results of RMA air quality and meteorological data collection programs for the second option year of the CMP (CMP FY90), and encompasses the period from October 1, 1989, to September 30,

1990. The parameters are essentially the same as those collected in the first and second years of monitoring.

As previously discussed, the CMP FY90 assessment has been augmented with data from the Basin F Interim Remedial Action Air Monitoring Program, and also the follow-on IRA-F Monitoring Program that is presently in operation. Application of these data strongly supplement the CMP database and enable a more comprehensive evaluation of Basin F post-remedial cleanup activities on ambient air quality. These data also form a basis for the evaluation of remedial progress by the comparison of potential toxic airborne compounds both during and after the Basin F cleanup activities. Comparisons are also made with air quality data collected during FY90 in the Denver metropolitan area. Through the use of an extensive air quality database, meteorological data and dispersion modeling evaluations, the CMP identifies potential air pollutant and air contaminant sources, both off-post and on-post, that impact RMA monitoring sites.

The initial period of CMP FY88 activity was confined to program planning, equipment procurement and installation, development of monitoring and analytical procedures, and certification of laboratory methods. Monitoring was initiated for total suspended particulates (TSP), respirable particulates (PM-10), asbestos, arsenic and ICAP metals in March 1988. Monitoring of volatile organic compounds (VOC), semi-volatile organic compounds (SVOC) and organics in TSP samples (OTSP), which required certification, review, and approval by the United States Army Toxic and Hazardous Materials Agency (USATHAMA), started in June and July 1988. The USATHAMA data certification, review and approval procedures were adopted and supervised by the Program Manager at Rocky Mountain Arsenal (PMRMA) during FY89. Later references to PMRMA certification also include USATHAMA certification. As a result of the startup time, the FY88 program did not contain a full four-season data evaluation. Both the CMP FY89 and FY90 programs contained a full year's database. Also, the combined 31-month CMP FY88, FY89, and FY90 data covering the Basin F pre-remedial, remedial, and post-remedial periods are clearly suitable for the evaluation of Basin F cleanup progress with respect to air quality.

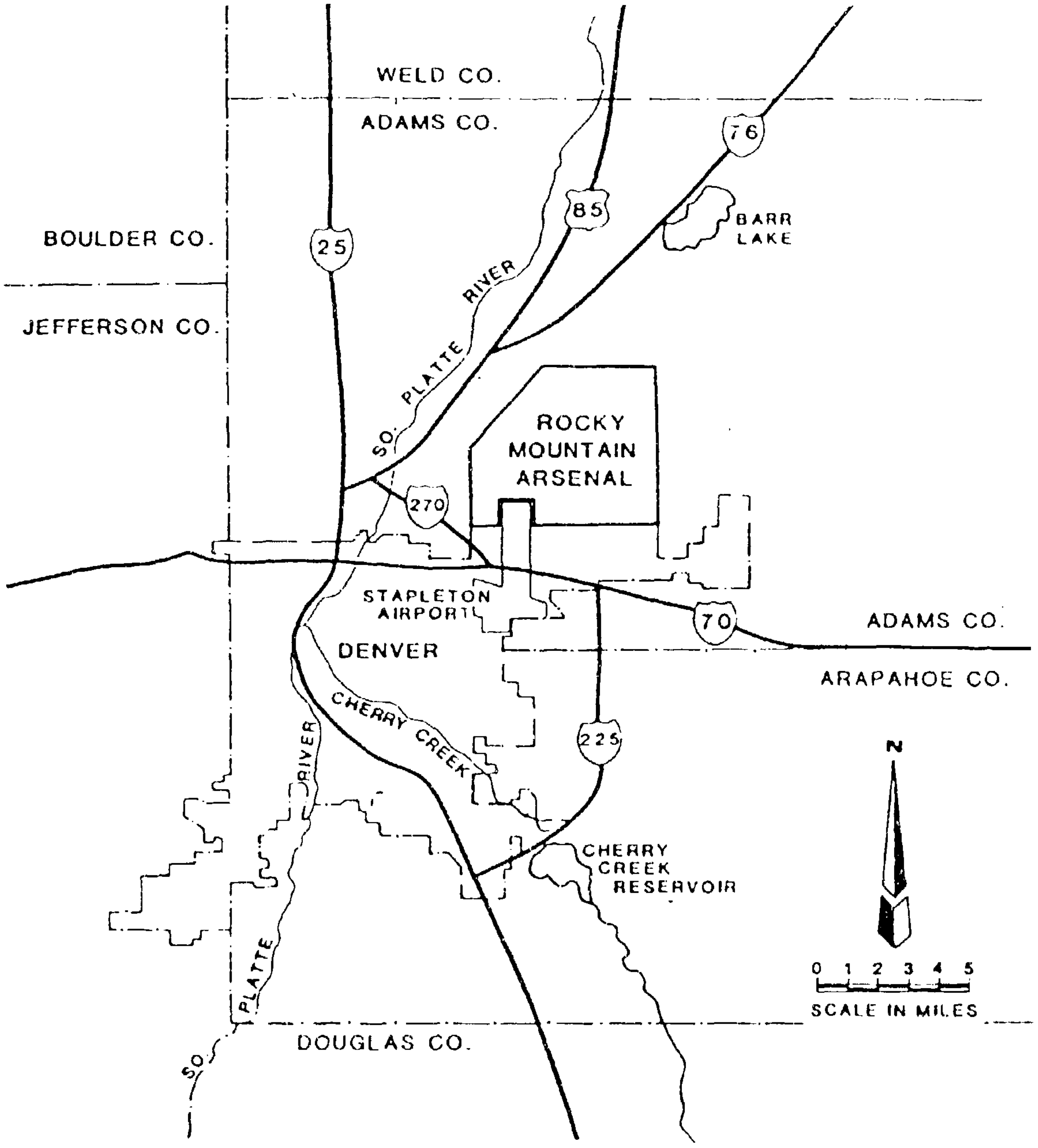
Various background and reference materials relating to the CMP are available (see Section 10.0), including the Final Technical Plan for Air Quality submitted by R. L. Stollar & Associates, Inc. (Stollar, 1990) and the CMP FY88 and FY89 Air Quality Data Assessment Reports (Stollar, 1990). It is appropriate to review and summarize in some detail several of the CMP's major considerations and elements. These include: (1) the nature and background of RMA air quality concerns; (2) regional air quality and meteorological characteristics; (3) RMA air quality and meteorological characteristics; and (4) a description of the CMP sampling and analyses programs. As these elements were reviewed in some detail in the CMP FY88 Report, they will be further discussed here only to the extent that they have changed after the first year's operations.

1.1 SITE BACKGROUND INFORMATION

RMA occupies over 17,000 acres (27 sq mi) northeast of Denver, Colorado in western Adams County (Figure 1.1-1). It was established in 1942, and was used to manufacture chemical and incendiary munitions, and to demilitarize chemical munitions. Additionally, industrial chemicals were manufactured at RMA from 1947 to 1982. A number of manufacturing, storage and transportation facilities were built and used throughout the years to support RMA activities. These identifiable RMA features were naturally perceived as potential contaminant sources, and their names along with the names of local geographic features are frequently used in discussing specific RMA areas (see Figure 1.1-2). The history of RMA operations from the initiation of manufacturing in 1942 to the cessation of activities was discussed in detail in the CMP FY88 Report.

1.2 POTENTIAL CONTAMINANT SOURCES

Potential sources of airborne contaminants within RMA boundaries were identified and air quality and meteorological monitoring stations were located near them, as shown in Figure 1.2-1. Previous air monitoring studies and remedial investigations conducted at RMA indicated that major sources of potential airborne emissions existed from the South Plants area, through Sections 36 and 26, to Basin F. Because production and demilitarization activities have ceased, there are no longer discrete or point sources of emissions at RMA. Rather, the sources shown in Figure 1.2-1 are large area or potential fugitive sources whose emissions are a function of atmospheric conditions, surface cover, and the contaminants' physical state. These sources, under typical conditions, do not appear to pose a major problem; however, remediating these sources may create temporary problems with air quality. These conditions are and continue to be monitored under the CMP. An example of this is the Basin F Interim Action Remedial Cleanup Program. Although the liquid from Basin F has been removed and it no longer represents an uncontrolled source of several potential contaminants, air monitoring has continued in the vicinity of Basin F, both under the CMP and the Basin F follow-on IRA-F Monitoring Program. The location of the initial Basin F source has been maintained in the various figures shown in this report in order to better depict possible continuing impacts and remedial progress as a result of the cleanup activities.



Source: RMA, 1983, ESE, 1987

Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

FIGURE 1.1-1

Rocky Mountain Arsenal
Location Map

CMP AR FY90 Drafted: 4/29/88

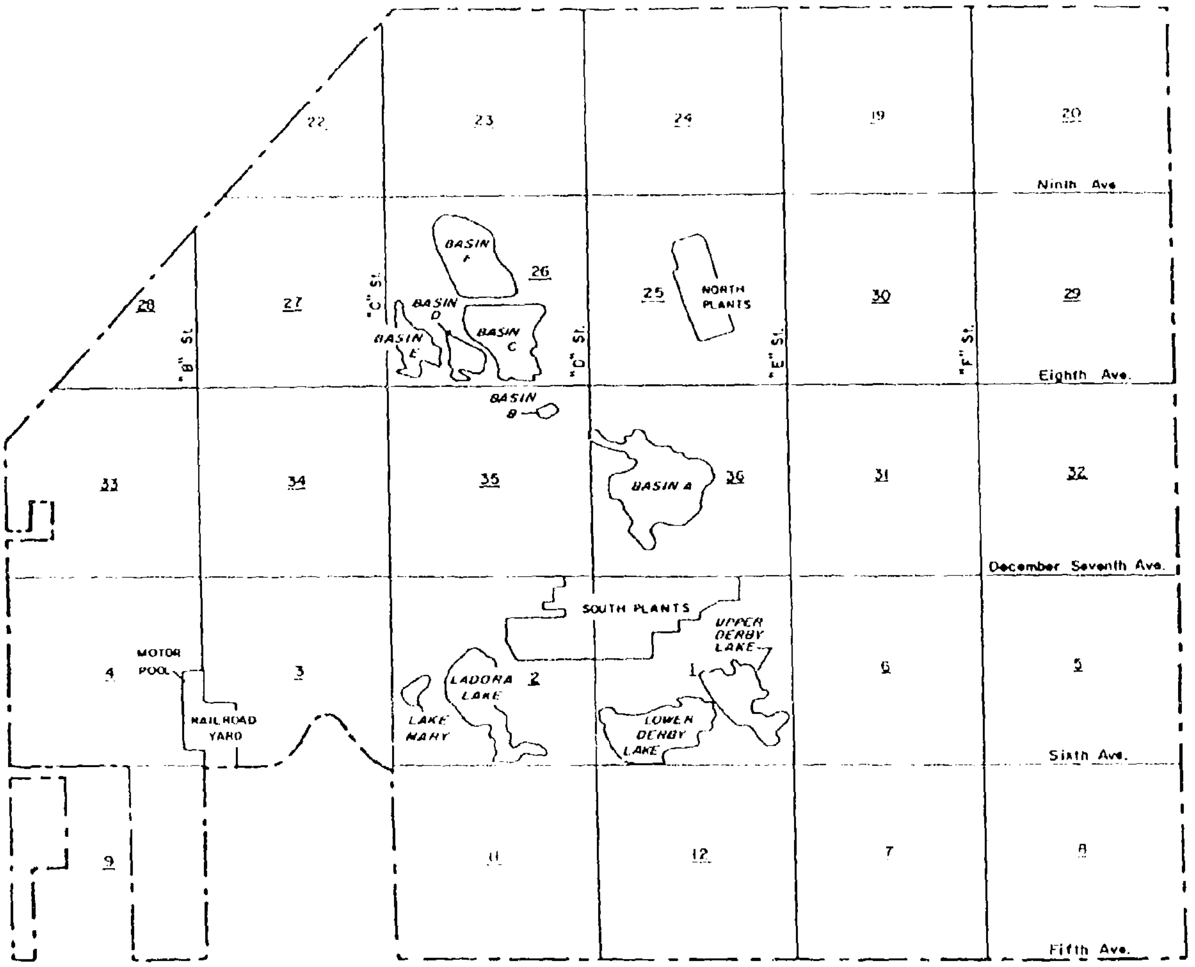


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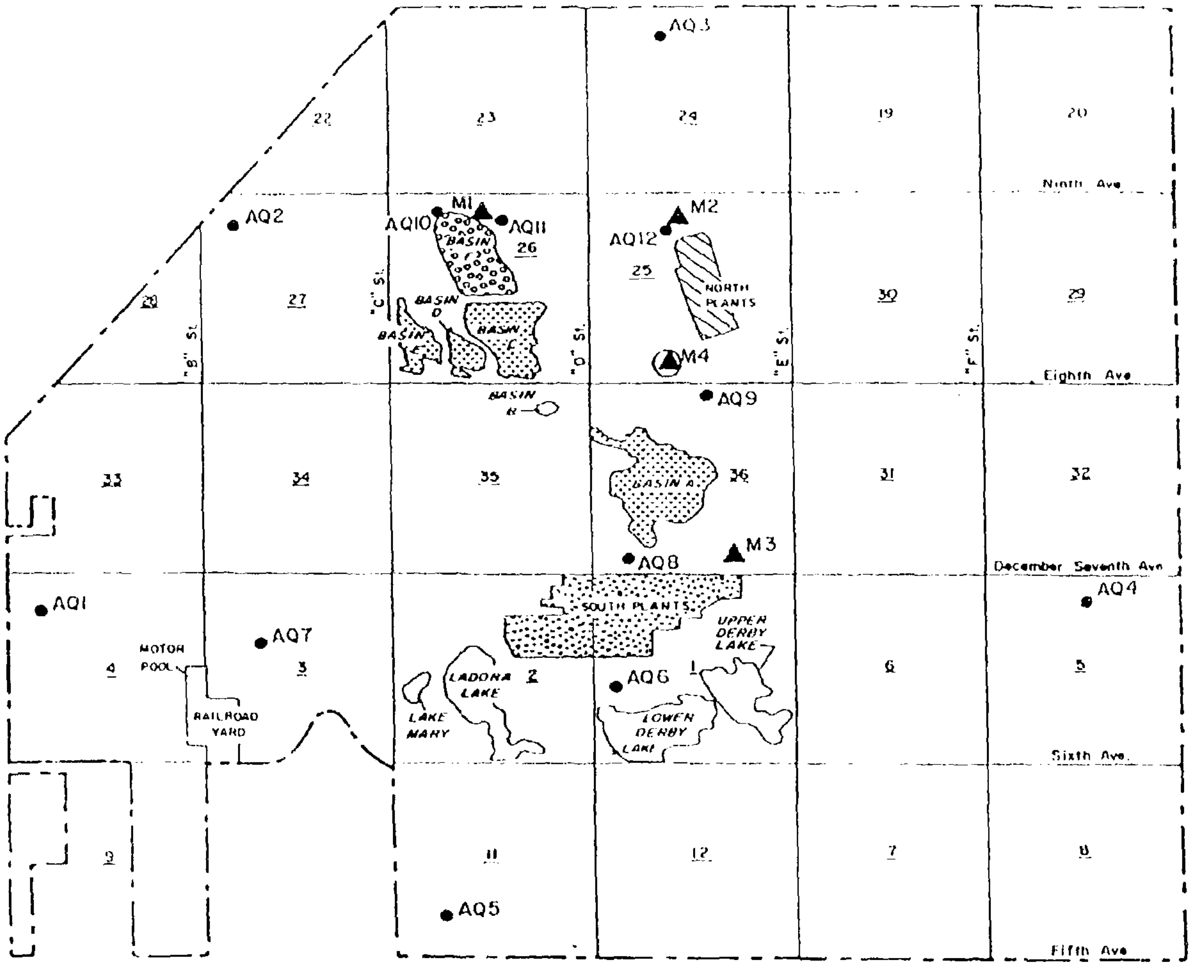
Figure 1.1-2

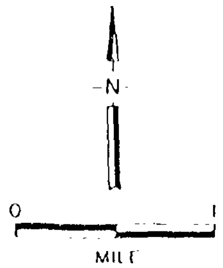
Rocky Mountain Arsenal
Reference Map

CMP AR FY90



Legend

Potential Sources	Monitoring Response
☐	TSP/PM-10
▨	TSP/PM-10, Asbestos, Volatile Organics, Semi-Volatile Organics
▧	TSP/PM-10, Asbestos
▨	TSP/PM-10, Metals, Arsenic, Mercury, Semi-Volatile Organics
▨	TSP/PM-10, Metals, Arsenic, Mercury, Semi-Volatile Organics, Volatile Organics (during FY88)
●	Air Quality Monitoring Station
▲	Meteorological Monitoring Station
◬	Continuous Gaseous and Meteorological Monitoring Station, FY 89,FY90



Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc
Ebasco Services, Inc.

Figure 1.2-1

CMP Air Quality and Meteorological Monitoring Stations

CMP AR FY90

Based upon historical records of disposal activities and chemical spills, the following general RMA areas have been suspected as potential sources of fugitive airborne emissions during the CMP FY88, FY89, and FY90 monitoring periods:

- South Plants manufacturing complex - Volatile and semi-volatile organic compounds (VOCs and SVOCs) and asbestos;
- Basin A - Semi-volatile organic compounds, metals and particulates; and
- Basin F - Volatile and semi-volatile organic compounds, metals and particulates.

There are other minor sources suspected of contributing to airborne levels of the contaminants listed above. The following sections describe both major and minor potential contamination sources.

1.2.1 SOUTH PLANTS MANUFACTURING COMPLEX

The South Plants area was used by Colorado Fuel and Iron, Julius Hyman and Company, Shell and the U.S. Army from the early 1940s to the early 1980s to produce chemicals, including pesticides, herbicides, insecticides and chemical warfare agents. Although production has ceased at the South Plants facilities, contaminants have been observed there in soil and ground water, and under certain conditions, airborne organic contaminant odors are noticeable. There are, however, no open waste basins in the South Plants area. The bottom sediments of the lakes near South Plants are known to contain chemical contaminants, but are not presently suspected of being a significant source of airborne emissions.

In addition to being a potential source of volatile and semi-volatile organic emissions, the South Plants area may also be a source of asbestos containing material. The South Plants facilities were constructed when the use of asbestos insulation was common practice. With the deterioration of the buildings in the South Plants area, it is possible that airborne levels of asbestos fibers could be released from them during future demolition activities.

1.2.2 BASIN A

Basin A is located in Section 36 and is the original disposal area for all waste from the South Plants activities. When the North Plants complex came on-line, wastes from that operation were also disposed of in Basin A. The approximate maximum areal extent of Basin A is shown in Figure 1.2-1.

Waste discharge to Basin A was discontinued when construction of Basin F was completed in the mid-1950s. Currently the basin is relatively dry, with some ponding in the wetter months of the year, particularly after heavy rains that occur mainly in the summer. During the winter the basin becomes extremely dry and dusty. Strong winds that prevail in the spring can create dust clouds from Basin A because it lacks a vegetative cover.

Organics, including pesticides and Army agent wastes, were deposited in Basin A since 1943. Inorganic metals as well as inorganic non-metals are also present. A sample of blowing dust was obtained from the southern part of Basin A during a wind storm in September 1977 (Witt, 1978). The chemical analysis of this sample detected a number of contaminants, including aldrin, dieldrin, endrin, isodrin, chlorophenylmethyl sulfide, chlorophenylmethyl sulfoxide, chlorophenylmethyl sulfone, dithiane, copper, arsenic and mercury. As an interim response action, dust suppressants were applied in the past (e.g., 1983, 1988), and were applied at Basin A during 1988 to control the windborne transport of particulates from this area.

1.2.3 BASIN F

Basin F was a 93-acre, asphalt-lined basin in Section 26 with a holding capacity of 245,090,000 gallons. The basin was constructed in late 1956 to hold all industrial wastes and wastewaters generated at RMA. A 12-in layer of soil was placed over the 3/8-in thick asphalt liner to protect it from erosion and degradation from sunlight.

1.2.3.1 Background of Previous Studies

The Basin F wastes and local air quality conditions have been characterized by numerous studies (U.S. Army Corps of Engineers Waterways Experiment Station, WES, 1982; National Space Technology Laboratory, 1980; USAEHA, 1981; Hanson, 1981; USAEHA, 1982). The results of these studies were used to develop a target list for analysis, and the results are included where appropriate for comparison to CMP results. A more detailed discussion of the results of previous Basin F studies is also provided in the CMP FY89 Report.

In 1988 an interim response action was initiated to remove liquids from Basin F and to place solid wastes into a waste pile. During that effort, the air quality was sampled both near the perimeter of Basin F and at more remote sites of RMA. The details of the Basin F air sampling program are provided in Section 3.3. The CMP air program also collected air samples near Basin F during that activity as part of its high event sampling effort. Results of both the Basin F air sampling program and the concurrent CMP are presented in Section 4 for comparison and analysis with the CMP FY90 results.

1.2.3.2 Impacts of Basin F Remediation on CMP

As noted in the previous section, the Basin F Interim Action Remedial Cleanup Program had significant implications for the CMP. One CMP objective is to evaluate remedial progress at RMA. The Basin F Interim Remediation Program began in 1988, (nearly concurrent with the start of the CMP FY88 Program) and was completed by late spring 1989. The Basin F Program involved the movement of liquid and other materials, and mixing and drying of potentially contaminated sediments. These activities impacted the immediate vicinity of Basin F as well as various CMP air monitors across RMA, depending upon distance from Basin F sources and upon meteorological conditions. Consequently, a knowledge of these activities and of specific Basin F air monitoring data results was essential to interpret CMP monitoring results. In this report as in the two previous CMP reports, the CMP data are supplemented with data from the Basin F Interim Response Action Air Monitoring Program and the IRA-F follow-on monitoring program. A particular objective of the FY90 report is to assess the effectiveness of the cleanup program with respect to air quality, and to determine if remedial impacts are still being experienced. Summaries of data and assessment of remedial and post-remedial monitoring results are discussed in various sections of this report.

1.2.4 OTHER POTENTIAL CONTAMINANT SOURCE AREAS

In addition to the South Plants area and Basins A and F, there are several other areas within RMA that could contribute to airborne contaminants. Within Section 36 there is historical evidence of pesticide pits, munitions testing areas, burn sites, settling ponds and trenches. These areas are dry and may be a source of semi-volatile organic compounds, metals and other particulates. Between Section 36 and Basin F are Sections 26 and 35, in which Basins B, C, D and E are located. These basins are currently dry, although at one time liquids from Basin A flowed into them. Therefore, the suspected contaminants in Basins B, C, D and E would be similar to those found in Basin A. No odors have been noted from these basins; however, particulates could become airborne during high wind events.

In addition, Sections 1 through 6, 11, 12, 19, 20, 23, 24, 25, 27, 29, 30, 31, 32, and 35 of RMA contain some or all of the following: munitions impact areas, burn sites, disposal pits, spill areas and trenches. Contaminants from these source areas may include volatile organics, pesticides, herbicides and heavy metals. No odors have been noted from any of these sources.

1.2.5 FINDINGS OF THE AIR REMEDIAL INVESTIGATION PROGRAM

As noted in this introduction, the CMP is a continuation of the ongoing collection of air quality baseline data initiated under the Air Remedial Investigation Program. The results of this monitoring program, conducted from June 1986 to June 1987, are contained in the Task 18 Air Remedial Investigation Report and are summarized in the following paragraphs (ESE, 1988).

> Suspended particulate matter at RMA appears to originate from both on-post and off-post sources. Because total suspended particulates and PM-10 concentrations are generally higher at RMA boundaries and lower at the interior of the site, off-post sources such as nearby vehicular traffic appear to be a significant source of particulates on RMA itself. Dried basins and other open RMA areas that are susceptible to wind erosion are a suspected source of airborne particulates on RMA. Measured TSP and PM-10 levels are well within federal and state guidelines.
>
> Since facility operations, except for the physical plant's steam generation, which is a minor source, have ceased and no longer emit combustion-related pollutants such as nitrogen oxides, carbon monoxide, sulfur dioxide and ozone into the air, current RMA operations are not a major source of these pollutants. The combustion-related pollutants probably originate from off-post sources such as vehicular traffic. In the Denver metropolitan area, air quality standards are routinely exceeded for carbon monoxide and ozone. Nitrogen oxides and sulfur dioxide standards have not been violated in the recent past in the Denver area.
>
> The sources of toxic airborne contamination at RMA appear to be from known fugitive sources emitting dust and vapors, such as basins and surface impoundments. A detailed emissions inventory will be required to accurately assess the nearby emissions of air toxics. In general, Basin F appears to have emitted the majority of VOCs and SVOCs, and Basin A has been a potential source for airborne metals contamination. The types and

concentration of contaminants found in the Air Remedial Investigation Program are consistent with the results of past investigations.

The results of the Air Remedial Investigation Program reflect an assessment of air quality potential contamination levels at RMA prior to general remediation activities and have been used for comparison purposes in the CMP FY88 and FY89 Reports. These data will again be used as appropriate in subsequent CMP assessment evaluations.

1.2.6 RESULTS OF THE CMP FY88 AND FY89 ASSESSMENTS

As noted the CMP is a continuing program in which annual monitoring results are reported and evaluated with respect to RMA air quality baseline conditions and remedial programs. Results of the CMP FY88 and FY89 Data Assessment Reports are summarized below:

a. TSP levels at RMA were attributed to two principal sources: (1) the influx of industrial emissions from metropolitan Denver, and (2) remedial activity sources producing wind-blown dust, usually during high wind episodes. Because there was increased remedial activity at RMA during the FY88 and FY89 monitoring periods, there was a noticeable increase in total suspended particulates levels at sites adjacent to or directly downwind from construction work. Exceedances of the 24-hour and annual ambient air quality standards were measured; these occurred primarily during strong and gusty wind periods. However, the Arsenal-generated sources were localized and impacts fell off rapidly with distance from the source. At RMA boundaries, total suspended particulates levels were below those of metropolitan Denver. During the FY89 post-remedial monitoring period, TSP concentrations downwind from Basin F decreased significantly.

b. Strong gusty winds were conducive to higher PM-10 values at RMA, similar to TSP. There were no violations of the PM-10 standards during FY88 and one violation of the 24-hour standard during FY89 that was related to very high PM-10 levels across the entire Denver metropolitan area on this particular day. Also, as in the case of TSP, there were two principal sources of PM-10 impacting the Arsenal and its surroundings: (1) the influx of PM-10 emissions from metropolitan Denver, and (2) remediation activity sources at RMA, especially during high wind event episodes. Unlike the TSP assessment, the data do not indicate a significant, or in fact, any, average increase in PM-10 levels during the remedial activity. This may have been the result of the lack of PM-10 monitoring stations immediately adjacent to remedial activities; however, it appears that the PM-10 remediation-generated emissions were localized and fell off significantly with distance from the activity.

c. Ambient concentrations of metals across RMA were generally proportional to levels of TSP. Maximum concentrations, especially during the FY89 winter monitoring period, occurred on days when there were high TSP and PM-10 levels which were directly attributed to sources off the Arsenal.

During remediation activities, Basin F appeared to be a source of mercury, chromium, copper and zinc, with concentrations decreasing rapidly with distance from Basin F. During the FY89 post-remedial period (following closure of Basin F), metals levels surrounding the Basin were reduced to typical baseline concentrations.

d. Asbestos was monitored but not detected at RMA throughout the FY88 program. Low levels of asbestos were detected on 2 days during FY89 when there were high levels of TSP measured. Results suggest that there was no evident source of ambient asbestos fibers on RMA.

e. During the FY88 monitoring period, Basin F appeared to be a source of volatile organic compounds. These included bicycloheptadiene, methylene chloride, benzene, ethylbenzene, dimethyl disulfide and toluene. Several of these compounds were directly related to the intensive remedial activities and probably resulted from emissions from heavy equipment and vehicles used in connection with these activities. Organic compounds that were unique to the Basin F area decreased rapidly with distance from this source and were measured at low levels at RMA boundaries. In general, compounds measured at RMA boundaries did not appear to present toxic risks significantly different from the urban environment of metropolitan Denver. Chloroform was identified in the South Plants on several occasions. Other compounds measured at RMA appeared to be distributed fr industrial sources outside the Arsenal. During the FY89 post-remedial monitoring period, VOC levels surrounding Basin F decreased significantly.

f. Basin F appeared to be a potential source of several semi-volatile organic compounds measured under the CMP and Basin F monitoring programs, including aldrin, endrin and dieldrin. The highest levels were clustered around the Basin F working compound. SVOCs at all other RMA monitoring stations decreased rapidly with distance from Basin F, and reached negligible and/or regional baseline levels at RMA boundaries. During the FY89 post-remedial monitoring period, SVOC levels surrounding Basin F decreased significantly.

g. Organics in total suspended particulates or measurements of organochlorine pesticides were low to undetectable at RMA boundary sites during both FY88 and FY89. This confirmed SVOC measurements from the CMP and Basin F programs that indicated rapid decrease in pesticide concentrations with distance from the Basin F potential source area. Following completion of remedial activities, these levels were reduced to near background concentrations in the vicinity of Basin F.

2.0 REGIONAL AND LOCAL AIR QUALITY AND METEOROLOGICAL CHARACTERISTICS

2.1 AIR QUALITY

The Denver metropolitan area, which includes RMA, has experienced chronic air quality problems in recent years. During stagnant and/or air inversion conditions, ozone and carbon monoxide concentrations sometimes create extremely poor air quality. This problem has generally been associated with motor vehicles, although air pollution also comes from a wide variety of industrial sources located in the Denver area. Major sources include power plants, oil refineries and transfer stations, chemical plants, cement plants and various agricultural operations. In addition to these sources, substantial emissions occur as a result of wood burning. The majority of background air quality information for criteria pollutants contained in this section is provided by the Colorado Department of Health (CDH, 1984; 1985; 1986, 1987, 1988, 1989, 1990).

A more detailed discussion and update (from the CMP FY88 and FY89 Reports) is provided in the following sections on the status of criteria pollutants (i.e., those airborne contaminants for which the U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) in the Denver metropolitan area and in the RMA vicinity). Table 2.1-1 shows applicable standards. Data collected in the Denver metropolitan area, concurrent with CMP FY90, have been obtained and are considered in the assessment sections of this report.

2.1.1 PARTICULATES

Particulate matter in the atmosphere is a major contributing factor to health and visibility-related problems in both urban and rural areas. In Denver this is commonly known as the "Brown Cloud," or more appropriately the "Denver Haze," because frequently it is not brown, nor is it actually a cloud. The sources of particulates are many: blown dust and sand from roadways, fields and construction, and coal dust, fly ash, and carbon black from various combustion sources, including automobile exhaust. Two additional particulates sources that could have a major impact on haze problems are diesel automobiles and woodburning stoves. These sources emit potentially significant amounts of elemental and organic carbon particles that play a major role in haze phenomena and health effects. Particulates that range in size from less than 0.1 micrometers (μm) to 50 μm are called total suspended particulates (TSP). Particles larger than that range tend to settle out of the

Table 2.1-1 Colorado and National Ambient Air Quality Standards

Pollutant	Averaging Time	Concentration
Carbon Monoxide (CO)		
Primary	1-Hour*	35 ppm (40 mg/m^3)
Primary	8-Hour*	9 ppm (10 mg/m^3)
Ozone (O_3)		
Primary	1-Hour**	0.12 ppm (235 μg/m^3)
Nitrogen Dioxide (NO_2)		
Primary	Annual Arithmetic Mean	0.053 ppm (100 μg/m^3)
Secondary	Annual Arithmetic Mean	0.053 ppm (100 μg/m^3)
Sulfur Dioxide (SO_2)		
Primary	Annual Arithmetic Mean	0.03 ppm (80 μg/m^3)
Primary	24-Hour*	0.14 ppm (365 μg/m^3)
Secondary	3-Hour*	0.5 ppm (1300 μg/m^3)
Particulates (TSP)		
Primary	Annual Geometric Mean	75 μg/m^3
Secondary	Annual Geometric Mean	60 μg/m^3
Primary	24-Hour*	260 μg/m^3
Secondary	24-Hour*	150 μg/m^3
Particulates (PM-10)		
Primary	Annual Arithmetic Mean	50 μg/m^3
Primary	24-Hour	150 μg/m^3
Lead (Pb)		
Primary	Month/Quarter ***	1.5 μg/m^3

Source:	Colorado Department of Health, 1989.
*	Not to be exceeded more than once per year.
**	Statistically estimated number of days with exceedances averaged over a three year period, is not to be more than 1.0 per year.
***	The federal standard is averaged over a 3-month (calendar quarter) period; the Colorado standard is averaged over a 1-month period.
ppm	Parts of pollutant per million parts of air.
μg/m^3	Micrograms of pollutant per cubic meter of air at 760 mm Hg and 25°C.
mg/m^3	Milligrams per cubic meter.
Primary	Primary standard intended to protect public health.
Secondary	Secondary standard intended to protect public welfare.

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air. Particulate matter 10 μm in diameter and smaller is considered inhalable and is commonly called PM-10.

Primary standards define air quality levels that the EPA judges are necessary to protect the public against adverse human health effects. National secondary standards define air quality levels that the EPA judges are necessary to protect the public welfare, including factors such as vegetation, animals, and visibility, from any known or anticipated adverse effects of a pollutant (40 CFR, Part 50, 1985). EPA and the Colorado Department of Health recently revised the particulate standards (July 1987) to account for the deeper inhalability of smaller particles. The new standards, rather than applying to TSP, apply to particles less than 10 μm in diameter (PM-10). The primary standard for PM-10 is an annual arithmetic average of 50 micrograms per cubic meter of air (μg/m^3) and the 24-hour standard is 150 μg/m^3 (to be exceeded no more than once per year).

The State of Colorado, however, retained the TSP standard and is continuing monitoring until a determination is made about the need to continue the TSP standard. The primary federal standards for TSP, independent of particle size or chemical composition, are as follows: the long-term standard is an annual geometric mean not to exceed 75 μg/m^3, the short-term standard is a 24-hour average of 260 μg/m^3 not to be exceeded more than once per year. The current 24-hour secondary TSP standard is 150 μg/m^3 not to be exceeded more than once per year. EPA is also considering a total particulate secondary standard designed to protect visibility by designating an annual mean TSP standard in the range of 70 to 90 μg/m^3.

During 1989, the maximum 24-hour TSP level in downtown Denver at the CAMP location was 386 μg/m^3 and the maximum annual geometric mean was 118 μg/m^3. Partial results for the Denver area for 1990 are discussed in this report concurrent with CMP FY90 TSP and PM-10 data. It is noted that the maximum 24-hour downtown Denver TSP level reached 363 μg/m^3 during February of 1990.

Historical data from 1974 to 1984 for Denver in the vicinity of RMA show an average TSP value of 97 μg/m^3. Studies conducted by the Army in 1969 at the RMA boundary show a maximum value of 274 μg/m^3 and geometric means ranging from 24 to 72 μg/m^3 (USAEHA, 1969).

TSP monitoring as part of the Air Remedial Investigation Program was conducted at 12 fixed sampling stations within RMA from June 1986 to June 1987 (Hunter/ESE, 1988). The stations are essentially identical to those employed in the CMP FY90 program and are shown in Figure 1.2-1.

The data collected at all sites were in compliance with both the primary and secondary NAAQS, except for one 24-hour sample near South Plants. This sample was 151 $\mu g/m^3$, compared to the 24-hour secondary standard of 150 $\mu g/m^3$. The highest annual average TSP level was 55 $\mu g/m^3$ at the west boundary, while the lowest was 34 $\mu g/m^3$ at the interior of the Arsenal. During the CMP FY88 period, TSP levels were comparable to the RI Program results, with the exception of monitoring sites adjacent to Basin F remediation and dirt moving efforts. These sites, on occasion, reached 24-hour maximum levels of 500 $\mu g/m^3$ to 600 $\mu g/m^3$. Several higher 24-hour maximum values were also measured under the Basin F Remedial Monitoring Program. As noted in previous reports, these high levels decreased rapidly with distance from the ground disturbances. Also, higher TSP levels in the vicinity of Basin F continued until ground cover and general landscaping activities were concluded in May, 1989, and then decreased significantly. This trend continued through the CMP FY90 period. TSP results are discussed in Section 4.2.

During 1989, the highest metropolitan Denver PM-10 levels were reported in downtown Denver (14th Street station); the maximum 24-hour PM-10 value was 154 $\mu g/m^3$ and the maximum annual average was 42 $\mu g/m^3$. PM-10 results for Denver through September 1990 indicate a 24-hour maximum PM-10 level of 118 $\mu g/m^3$ during January with several downtown readings in excess of 100 $\mu g/m^3$. It is noted that high 24-hour TSP levels also occurred during these periods, both in metropolitan Denver and at RMA, and were most likely attributed to especially intense inversion conditions on these monitoring days. Specific events are discussed in this report.

PM-10 was monitored during the 1986-1987 Air Remedial Investigation Program at three air quality sampling stations, two at the RMA boundaries, and one at the Arsenal's interior. PM-10 levels were highest at the boundary stations and lowest at the interior of RMA. The arithmetic mean values ranged from 18 $\mu g/m^3$ at the interior (near Basin A) to 36 $\mu g/m^3$ at the northwest boundary. Individual 24-hour values ranged from 5 to 94 $\mu g/m^3$, with lower levels at the RMA interior and higher levels at its boundary. During the CMP FY89 period, the maximum 24-hour PM-10 level was 168 $\mu g/m^3$ measured at AQ1 at the RMA western boundary. Again, this was attributed to impacts from Denver "brown cloud" conditions and was documented in the CMP FY89 report. The maximum arithmetic mean was 33 $\mu g/m^3$ also measured at AQ1. PM-10 results for CMP FY90 were lower than FY89 results and are discussed in Section 4.3.

2.1.2 METALS

Airborne metals that exist primarily as particulate matter may be inhaled and can cause adverse health effects. One of these metals is lead, which exists in the atmosphere and is produced predominantly by vehicles that burn leaded gasoline. Lead is the only metal which is a criteria pollutant according to EPA. The current federal standard for lead is a 3-month (calendar quarter) average concentration not to exceed 1.5 $\mu g/m^3$. The Colorado standard is 1.5 $\mu g/m^3$ averaged over a 1-month data period. Lead values have decreased steadily in the Denver metropolitan area over the past decade. Maximum quarterly levels have decreased from in excess of 1.5 $\mu g/m^3$ in the 1970's to less than 0.08 $\mu g/m^3$ in 1989.

Historical data in the vicinity of RMA for lead indicate concentrations of 0.5 to 1.0 $\mu g/m^3$, but a significant decline has again been realized in the last 10 years with the introduction of lead-free gasoline. The Army monitored lead concentrations at the boundary of RMA and at its interior in 1980. The average concentrations ranged from 0.13 to 0.26 $\mu g/m^3$ (Hanson, 1981). Lead and other metals were monitored during the 1986-1987 Air Remedial Investigation Program. Samples were taken on "high event" (high wind) days at approximately 10 locations. Lead values were generally less than 0.1 $\mu g/m^3$ and were consistent with typical urban values. Other metals (mercury, arsenic, cadmium, chromium, copper and zinc) were also detected at typical urban metals concentrations, with cadmium and copper slightly elevated near the basins. Zinc levels were typical of urban environmental levels, except for 1 day when concentrations were in excess of 10 $\mu g/m^3$. The Air Remedial Investigation Report states that the zinc levels measured for this day may be suspect, as low levels were detected at all other events. During the CMP FY88 period, metals values were consistent with previous RMA investigations with the exception of somewhat higher levels of copper, chromium, mercury, and zinc in the immediate vicinity of Basin F cleanup work. However, these levels also dropped significantly at the conclusion of remedial activities during FY89 and continued to decrease during FY90. Results will be discussed further in Section 4.4.

2.1.3 SULFUR DIOXIDE

Sulfur dioxide is considered one of the major pollution problems on a worldwide basis. It is emitted mainly from stationary sources that burn fossil fuels. There are two existing primary NAAQS for sulfur dioxide. The first is an annual arithmetic average of 0.03 parts per million (ppm). The second is a 24-hour average standard where concentrations are not to exceed 0.14 ppm more than once per year. The current secondary NAAQS for sulfur dioxide is a 3-hour average concentration of 0.5 ppm not to be exceeded more than once per year. In Denver, the second-highest 3-hour maximum value in 1989 was 0.08 ppm; the second-highest 24-hour maximum was 0.04 ppm; the overall average was 0.008 ppm. From May through September 1989, the maximum values observed at RMA were 0.02 ppm and 0.004 ppm for the 3-hour and 24-hour averages.

Background data from the Army's 1969 air monitoring show a maximum value of 0.10 ppm of sulfur dioxide, which was measured on the western boundary when the wind was blowing in a northeasterly direction (USAEHA, 1969). Because most sulfur dioxide values were less than detection limits at all stations, the Army reported geometric means of 0 $\mu g/m^3$ at each of the nine stations. Currently there are no significant sources of sulfur dioxide within RMA. However, in order to establish RMA background levels, sulfur dioxide monitoring was initiated in 1989 under the CMP. Results and comparisons with ambient standards and metropolitan Denver data for FY90 are discussed in Section 5 of this report.

2.1.4 NITROGEN OXIDES

Nitrogen in the air combines with oxygen during high temperature combustion processes to produce oxides of nitrogen. Most of the nitrogen oxides emitted are nitric oxide. Nitrogen dioxide is formed generally from the oxidation of the more commonly emitted nitric oxide. Nitrogen dioxide is the predecessor of gaseous nitric acid and nitric aerosols. The relationship between nitrogen oxides and the resultant ambient nitrogen dioxide, nitric acid, and nitrate aerosol concentrations is neither direct nor constant. About 48 percent of nitrogen oxides emissions in the Denver area comes from large combustion sources such as power plants; 37 percent comes from motor vehicles; 11 percent comes from space heating; and 4 percent comes from aircraft (Hunter/ESE, 1987). The current standard for nitrogen dioxide is an annual arithmetic mean value not to exceed 0.053 ppm (100 $\mu g/m^3$). A short-term standard does not exist for nitrogen oxides.

There have been no violations of the nitrogen dioxide standard in Colorado in recent years. Data from 1969 Army monitoring stations showed a maximum value of 0.075 ppm at the southern RMA boundary (USAEHA, 1969). During 1989 the maximum annual average was 0.103 ppm at downtown Denver. In the vicinity of the Arsenal at 78th Street and Steele, the annual average was 0.025 ppm. Nitrogen dioxide monitoring was initiated at RMA under the CMP during 1989; results and comparisons with metropolitan Denver data for FY90 are provided in this report.

2.1.5 OZONE

Problems with Denver's air quality can generally be blamed on ozone and carbon monoxide. Ozone is not emitted directly from a source, as are other pollutants, but forms as a secondary pollutant. Precursors of ozone are certain reactive hydrocarbons and nitrogen oxides which chemically react in sunlight to form ozone. The reactive hydrocarbons are emitted from automobile exhaust, gasoline and oil storage and transfer; from industrial use of paint solvents, degreasing agents, cleaning fluids, and ink solvents; from incompletely burned coal or wood; and from many other sources. Vegetation also emits reactive hydrocarbons; for example, pine trees release terpenes.

Although ozone production is a year-round phenomenon, the highest ozone levels generally occur during the summer season. Strong sunlight and stagnant meteorological conditions can cause reactive pollutants to remain in an area for several days. Ozone produced under these conditions can be transported many miles outside the urban environment.

In 1979 the ozone standard was changed to a statistical form that accounts for missing data in estimating total yearly violations. The 3-year average of these yearly estimates is the expected number of violations. The standard is attained ". . . when the expected number of days per calendar year with a maximum hourly average concentration above 0.12 ppm is equal to or less than one" (CDH, 1983). North Denver has been classified as a non-attainment area for ozone because it has in the past experienced violations of this standard. The maximum 1-hour ozone level reported at 78th Street and Steele in 1989 was 0.10 ppm; the second maximum 1-hour value was also 0.10 ppm. The highest 1-hour concentration recorded at RMA for 1989 was also 0.10 ppm. Ozone monitoring was initiated at RMA under the CMP during 1989; results and comparison with metropolitan Denver data for FY90 are provided in this report.

2.1.6 CARBON MONOXIDE

Urban atmospheres contain about 100 times as much carbon monoxide as any other pollutant. Urban carbon monoxide is produced primarily by motor vehicles. In Denver, it is estimated that 90 percent of the carbon monoxide emissions in 1982 were from vehicular sources. The remainder originated from other combustion sources such as heating, incineration and power generation (Hunter/ESE, 1987).

Because motor vehicle emissions are the major source of carbon monoxide, daily concentration peaks coincide with morning and evening rush hours. The worst carbon monoxide problems are found where large numbers of slow moving cars congregate, such as in large parking lots or during traffic jams. Carbon monoxide can accumulate temporarily to harmful levels, especially in calm autumn and winter weather when automobile emissions and fuel combustion for space heating reach their peak. Carbon monoxide problems are worse in winter because: (1) cold weather makes motor vehicles run less efficiently; (2) more combustion for space heating is required; and (3) on winter evenings a strong inversion layer develops near the ground during rush hour which traps pollutants.

A relatively new source of carbon monoxide has been introduced into urbanized areas in Colorado in recent years. The large-scale use of wood for home heating in airtight stoves contributes up to 10 percent of the total urban carbon monoxide concentrations (CDH, 1984; 1985).

There are two current standards for carbon monoxide, which are 9 ppm averaged over a period of 8 hours, and 35 ppm average over a 1-hour period. These levels are not to be exceeded more than once per year.

North Denver is classified as non-attainment for carbon monoxide because the NAAQS for this pollutant have been routinely exceeded. The monitored data for carbon monoxide in the Denver area in 1988 were well above the 8-hour average concentration standard: maximum 8-hour values reached 18.7 ppm in the downtown area; the 1-hour maximum value was 50.5 ppm. During 1989, however, there appeared to be a noticeable decrease in CO levels across the metropolitan Denver area. The highest 8-hour concentration was 11.5 ppm in downtown Denver (14th and Albion) and the maximum 1-hour concentration was 27.3 ppm, also at the same site. This trend of decreasing CO concentrations in Denver has been evident for several years (CDH, 1987, 1988, 1989). The maximum 8-hour level measured at the Welby site (78th and Steele) in 1989 was 7.5 ppm, while the maximum 1-hour level was 11.8 ppm (both of these values were below NAAQS). Carbon monoxide was monitored under the CMP during 1990; results and comparisons with Denver metropolitan data are provided in Section 5 of this report.

2.2 METEOROLOGY AND AIR QUALITY DISPERSION

The RMA area is generally classified as having a mid-latitude and semiarid climate, with hot summers, cold winters, and relatively light rainfall. Tables 2.2-1 through 2.2-4 provide a summary of meteorological and climatological data in the RMA vicinity. Data were collected during FY90

Table 2.2-1 Summary of Temperature Data in the RMA Vicinity

	Temperatures							Mean Number of Days			
	Normal[1]			Extreme[2]				Max.		Min.	
Month	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	90°F & above	32°F & below	32°F & below	0°F & below
				49^3		49^3		23^3	23^3	23^3	23^3
January	43.1	15.9	29.5	73	1982	-25	1963	0	7	30	4
February	46.9	20.2	33.6	76	1963	-30	1936	0	4	26	2
March	51.2	24.7	38.0	84	1971	-11	1943	0	3	25	1
April	61.0	33.7	47.4	85	1960	-2	1975	0	-	12	-
May	70.7	43.6	57.2	96	1942	22	1954	-	0	2	0
June	81.6	52.4	67.0	104	1936	30	1951	6	0	0	0
July	88.0	58.7	73.3	104	1939	43	1972	15	0	0	0
August	85.8	57.0	71.4	101	1938	41	1964	9	0	0	0
September	77.5	47.7	62.6	97	1960	20	1971	2	0	1	0
October	66.8	36.9	51.9	88	1947	3	1969	0	-	8	-
November	52.4	25.1	38.7	79	1941	-8	1950	0	2	24	-
December	46.1	18.9	32.6	75	1980	-21	1983	0	5	29	3
Annual	64.3	36.2	50.3	104	July 1939	-30	Feb. 1936	33	22	158	9

Source: Hunter/ESE, Air Remedial Investigation, Final Report, Version 3.1, August, 1988.

1 Normal - based on record for the 1951-1980 period.

2 Extreme - length of record may be for other than complete or consecutive data years. Date is the most recent in cases of multiple occurrences.

3 Length of record, years, based on January data.

Table 2.2-2 Summary of Precipitation and Humidity Data in the RMA Vicinity

Month	Precipitation (inches)											Relative Humidity %			
	Water Equivalent							Snow, Ice pellets				0.5 hr	11 hr	17 hr	23 hr
	Normal[1]	Max.[2] Monthly	Year	Min. Monthly	Year	Max. in 24 hrs	Year	Max. Monthly	Year	Max. in 24 hrs	Year	(local time)			
		49[3]		49[3]		49[3]		49[3]		49[3]		23[3]	23[3]	23[3]	23[3]
January	0.51	1.44	1948	0.01	1952	1.02	1962	23.7	1948	12.4	1962	63	46	49	63
February	0.69	1.66	1960	0.01	1970	1.01	1953	18.3	1960	9.5	1953	66	43	42	64
March	1.21	4.56	1983	0.13	1945	2.79	1983	30.5	1983	18.0	1983	67	42	41	64
April	1.81	4.17	1942	0.03	1963	3.25	1967	28.3	1935	17.3	1957	67	37	34	58
May	2.47	7.31	1957	0.06	1974	3.55	1973	13.6	1950	10.7	1950	70	40	38	61
June	1.58	4.69	1967	0.09	1960	3.16	1970	0.3	1951	0.3	1951	70	37	35	59
July	1.93	5.41	1965	0.17	1939	2.42	19[illegible]	0.0		0.0		68	35	34	56
August	1.53	5.85	1979	0.06	1960	3.43	1951	0.0		0.0		69	37	35	58
September	1.23	4.67	1961	T[4]	1944	2.44	1936	21.3	1936	19.4	1936	68	37	34	59
October	0.98	4.17	1969	0.05	1962	1.71	1947	31.2	1969	12.4	1969	64	36	35	58
November	0.82	2.97	1946	0.01	1949	1.29	1975	39.1	1946	15.9	1983	68	44	49	65
December	0.55	2.84	1973	0.03	1977	2.00	1982	30.8	1973	23.6	1982	64	45	51	63
Annual	15.31	7.31	May 1957	T[4]	Sept 1944	3.55	May 1973	39.1	Nov 1946	23.6	Dec 1982	67	40	40	60

Source: Hunter/ESE, Air Remedial Investigation, Final Report, Version 3.1, August, 1988.

[1] Normal - based on record for the 1951-1980 period.

[2] Maximum - length of record may be for other than complete or consecutive data years. Date is the most recent in cases of multiple occurrences.

[3] Length of record, years, through the last year recorded unless otherwise noted, based on January data.

[4] T = Trace; blank entries denote missing or unreported data.

Note: Normal cooling degree data published in the 1982 Annual were for the 1951-1980 period.

Table 2.2-3 Summary of Wind and Pressure Data in the RMA Vicinity

Month	Wind					Average Station Pressure mb
		Thru 1968	Fastest mile[1]			
	Mean Speed (mph)[2]	Prevailing Direction	Speed (mph)	Direction[3]	Year	Elevation 5,332 ft msl
	35[4]	15[4]	31[4]	31[4]		11[4]
January	8.8	S	53	N	1976	833.9
February	9.1	S	49	NW	1953	834.2
March	9.9	S	53	NW	1952	831.1
April	10.2	S	56	NW	1960	833.2
May	9.4	S	54	SE	1978	833.9
June	9.0	S	47	S	1956	836.2
July	8.4	S	56	SW	1965	838.9
August	8.1	S	42	N	1978	838.9
September	8.1	S	47	NW	1955	838.6
October	8.0	S	45	NW	1958	837.7
November	8.5	S	48	W	1962	835.5
December	8.8	S	51	NE	1953	834.5
Annual	8.8	S	56	SW	July 1965	835.6

Source: Hunter/ESE, Air Remedial Investigation, Final Report, Version 3.1, August, 1988.

[1] Fastest Mile Wind - speed is fastest observed in 1-minute value when direction is in tens of degrees. Fastest mile winds are through August 1981.

[2] Means and extremes above are from existing and comparable exposures. Area extremes have been exceeded at other sites in the locality as follows: wind - fastest mile = 65 W in May 1933.

[3] Wind Direction - numerals indicate tens of degrees clockwise from true north. 00 indicates calm.

[4] Length of record, years, through the current year unless otherwise noted, based on January data.

Table 2.2-4 Summary of Meteorological Data in the RMA Vicinity

			Mean Number of Days						
	Percent of Possible	Mean sky Cover, Tenths, Sunrise to	Sunrise to Sunset			Precipitation 0.01 inch	Snow, Ice Pellets 1.0 inch		Heavy Fog, Visibility 1/4 Mile
Month	Sunshine	Sunset	Clear	Partly Cloudy	Cloudy	or More	or More	Thunderstorms	or Less
	34*	35*	49*	49*	49*	49*	49*	43*	43*
January	72	5.6	10	9	12	6	2	0	1
February	71	5.9	8	8	12	6	2	-	2
March	70	6.1	8	10	13	9	4	-	1
April	68	6.0	7	11	12	9	3	1	1
May	64	6.3	6	12	13	11	-**	6	1
June	71	5.0	10	12	8	9	0	10	-
July	72	4.9	9	16	6	9	0	11	-
August	72	4.9	10	14	7	9	0	8	1
September	75	4.3	13	10	7	6	-	3	1
October	73	4.5	13	10	8	5	1	1	1
November	65	5.4	10	10	10	5	2	-	1
December	67	5.4	11	9	11	5	2	0	1
Annual	70	5.4	115	131	119	88	18	41	10

Source: Hunter/ESE, Air Remedial Investigation, Final Report, Version 3.1, August, 1988.

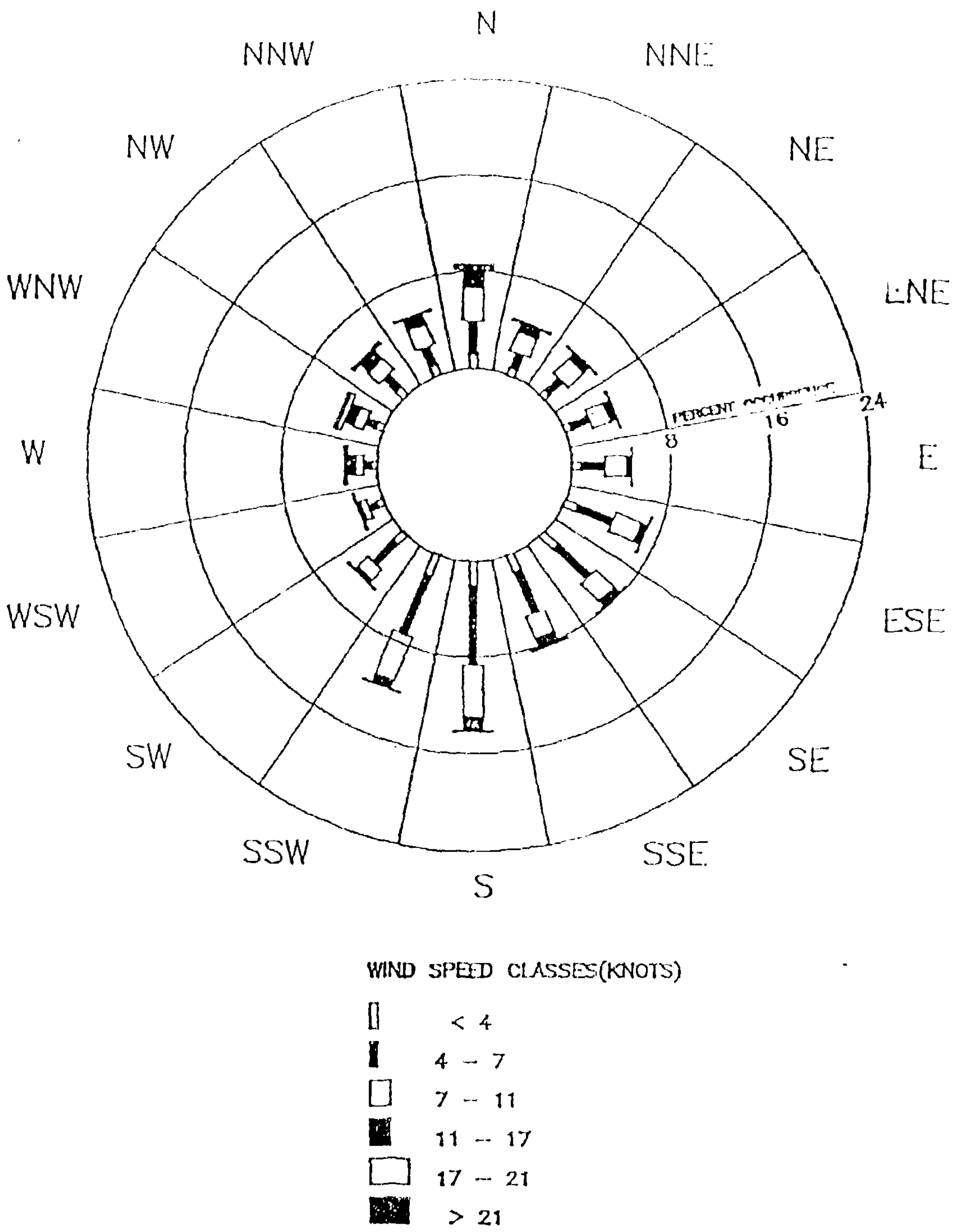
* Length of record, years, based on January data.
** Less than 0.5 inch.

both at RMA and at Stapleton International Airport (Stapleton Airport) adjacent to RMA. Because of the close proximity and relatively uniform topography between Stapleton Airport and RMA, the airport's long-term climatological and meteorological conditions are expected to be most representative of RMA long-term conditions and are employed in the following discussion. (However, it is noted that RMA local data collected at four towers were used extensively in the present CMP FY90 Report).

Mean maximum temperatures for the Denver area range from 43 degrees Fahrenheit (°F) in January to 88° F in July. The mean minimum temperatures are 16° F in January and 59° F in July. Precipitation in the general region ranges from 12 to 16 in per year, with approximately 80 percent falling between April and September. Snow and sleet usually occur from September to May, with the heaviest snowfall in March and possible trace accumulations as late as June. Thunderstorms occur frequently in the region and generally bring brief rain showers, gusty wind and frequent thunder and lightning. Occasionally they are accompanied by heavy showers, severe gusty winds, and hail. There are approximately 93 days per year with a cloud cover of 30 percent or less.

Wind directional frequencies reflect the drainage of the South Platte River Valley, which slopes gradually from south to north. Typically, surface winds in the area flow downslope (south to north) during the night and upslope (north to south) during the daytime, resulting in a north-south bimodal distribution, as illustrated in the wind rose for the RMA vicinity (Figure 2.2-1). Since the RMA area is on higher sloping terrain to the east of the South Platte River Valley, there is also a moderate easterly flow drainage component. Winds from all directions at moderate speeds will occur under varying synoptic conditions. The windy months are March and April, with gusts as high as 56 mph, generally from the north through the northwest. These windy months come immediately after the driest months of November through February, and therefore have the highest potential for dust storms.

Pollutant dispersion is the result of varying meteorological influences. Early morning inversions over the Denver metropolitan area are common and they occasionally persist throughout the day. This prevents mixing of the atmospheric boundary layer and causes accumulation of pollutants. During nearly 60 percent of the year, Denver experiences stable atmospheric conditions that favor air pollution events. Most of these stable conditions are observed during the winter.



Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.

Figure 2.2-1

Stapleton Airport Wind Direction Rose, 1982-1986

CMP AR FY90

Another factor that contributes to high air pollution in Denver is the daily back-and-forth motion of air along the Front Range. As noted, the metropolitan area is in the South Platte River basin, with decreasing elevation towards the north through northeast. Cold, heavy air drains downslope at night and during the early morning hours. As the atmosphere warms during the afternoon, the flow reverses sharply, and much of the air that traversed the city earlier as clean air re-enters Denver as polluted air going upslope.

Because Denver is at a high altitude, the atmosphere is thin, allowing more ultraviolet radiation to interact with airborne contaminants. Chemical reactions initiated by photochemical processes increase Denver's smog problem, particularly the ozone portion of smog. A more detailed evaluation relating meteorological conditions at RMA to the dispersion of atmospheric pollutants and potential contaminants will be discussed in subsequent sections of this report.

3.0 PROGRAM STRATEGY AND METHODOLOGY

3.1 GENERAL BACKGROUND

The procedures for air sample collection and analysis are described in detail in the CMP Final Technical Plan (Stollar, 1990). The methods for meteorological data collection are also contained in the Technical Plan. This section provides a brief overview of the sampling and analysis program with emphasis on field activities accomplished during the CMP FY90 Program. The Technical Plan incorporates a number of factors, such as the experience and results of the Air Remedial Investigation Program (Hunter/ESE, 1988), and anticipated long-term monitoring requirements to assess potential air contaminant levels during and after RMA remedial cleanup activities. The plan also provides a flexible vehicle for upgrading CMP monitoring techniques as experience is gained with site-specific requirements and as remedial programs continue. For example, during CMP FY89, modifications were incorporated into the Technical Plan which included: (1) the upgrading of the RMA meteorological network and maintenance of this system (of four towers) under the CMP, and (2) the continuous monitoring of gaseous criteria pollutants (sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone).

During CMP FY90, PM-10 monitoring was also increased from four sites to five sites because of more emphasis placed on this parameter by federal and state regulatory agencies. In FY90, OCP monitoring was reduced from every 6th day to every 12th day, and asbestos monitoring was reduced to monthly sampling. These changes were based on review and analysis of the data collected during the two previous years of the program. In a revision to the Technical Plan in June 1990 (Stollar, 1990), additional TSP and PM-10 portable stations and additional wind-activated "high event" episodes were incorporated into the program; several of these changes will be initiated in the FY91 program. Finally, in FY91, all IRA-F air quality monitoring sites (see Section 3.4) will be incorporated into the CMP.

An overview of the sampling and analysis program, which is the basis of the data collection results reflected in this report, is provided in this section. It is anticipated that the analyses of these data and experience with the FY88 through FY90 programs will form the basis of any further modifications to the CMP Technical Plan.

During the CMP FY90 program, the following parameters were sampled:

1. Air Quality
    - Total suspended particulates (TSP)
    - Respirable particulates (PM-10)
    - Asbestos
    - Volatile organic compounds (VOC)
    - Semi-volatile organic compounds (SVOC)
    - Organochlorine pesticides (OCP)
    - Metals
    - Arsenic (As)
    - Mercury (Hg)
    - Sulfur dioxide (SO_2)
    - Carbon monoxide (CO)
    - Ozone (O_3)
    - Nitrogen dioxide (NO_2)
    - Nitric oxide (NO)
    - Nitrogen oxides (NO_x)
    - Visibility characterizations (see Section 6.0)

2. Meteorology
    - Wind speed and direction
    - Standard deviation of wind direction (sigma theta)
    - Temperature
    - Barometric pressure
    - Precipitation
    - Humidity
    - Solar radiation

3.2 CMP AIR QUALITY MONITORING PROGRAM

Sample location and equipment, sampling frequency and method, and justification for selecting sample locations and parameters monitored are presented in this section. Specific sample handling procedures are discussed in a separate document, "Field Procedures Manual for the Comprehensive Monitoring Program" (Stollar, 1988). Procedures to develop the database were in accordance with

PMRMA requirements for sample collection, sample preservation, sample shipment, sample analysis, and chain-of-custody.

3.2.1 SITING CRITERIA

Air samples were collected from permanent and mobile air quality stations on RMA. Figure 3.2-1 shows the locations of the permanent stations on the perimeter of RMA, near Basins A and F, the South Plants area, the North Plants complex, and the rail classification yard. Portable air quality stations were also used; their locations were determined from high event conditions and remedial monitoring activities, as described in Sections 3.2.2.2 and 3.2.3.2. All stations were documented or surveyed as described in Table 3.2-1.

Locations of air quality stations were based on the following criteria:

- Proximity to a suspected contaminant source or RMA boundaries;
- Predominant wind speed and direction;
- Topographical features and obstructions; and
- Continuity with previous monitoring programs to maintain data integrity.

These criteria are discussed in detail below.

3.2.1.1 Proximity to Sources or Boundaries

All air quality stations were located either near a potential contaminant source or along the RMA boundary. Samplers were located near suspected contaminant sources and were positioned to collect airborne contamination originating from the source areas. Samplers located at the perimeter of RMA were established to monitor airborne contaminants crossing the RMA boundaries. These locations focused on on-site sources; however off-site sources also contributed to samples taken at these locations.

3.2.1.2 Wind Speed/Direction

Predominant wind speeds and directions were considered in choosing the locations of air quality stations. Figure 2.2-1, cited previously, indicates that during a recent 5-year period (1982 to 1986), the prevailing winds were from the south and south-southwest (representing downslope nighttime

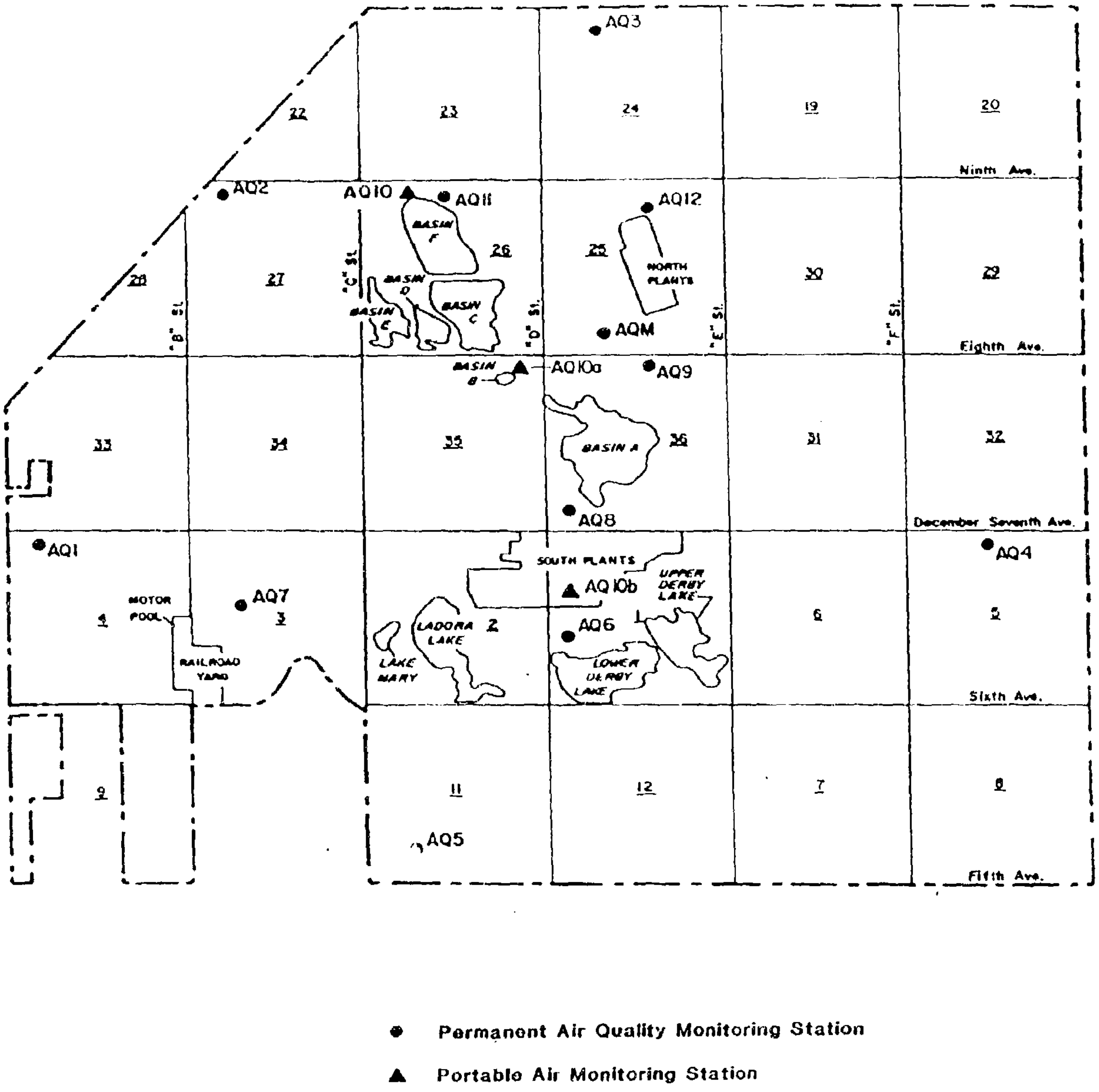


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Figure 3.2-1

CMP Air Quality Monitoring Stations at Rocky Mountain Arsenal

CMP AR FY90

Table 3.2-1 Sampling Locations

Location	Site ID	Start Date	End Date	Northing Easting Coordinates		Elevation	COC ID
Locations of SVOC High Event Sample Sites Other Than Permanent CMP Sites (FY90)							
Inject. Wells	South	01/12/90	01/13/90	196100.00	2183700.00	5155.0	CAQ23002
Inject. Wells	North	01/12/90	01/13/90	196200.00	2183000.00	5150.0	CAQ23001
Basin F	Mobile SE	07/19/90	07/20/90	188600.00	2181800.00	5210.0	AQ26006
Basin F	FC2	07/19/90	07/20/90	189877.06	2181324.36	5204.4	AQ2602036
Basin F	FC2	07/19/90	07/20/90	189877.06	2181324.36	5204.4	AQ2602034
Basin F	FC2	07/19/90	07/20/90	189877.06	2181324.36	5204.4	AQ2602035
Basin F	FC3	07/19/90	07/20/90	187997.29	2180259.12	5209.8	AQ2603020
Basin F	FC5	07/19/90	07/20/90	191232.76	2180501.15	5187.9	AQ2305019
Basin F	FC2	08/02/90	08/03/90	189877.06	2181324.36	5204.4	AQ2602041
Basin F	FC3	08/02/90	08/03/90	187997.29	2180259.12	5209.8	AQ2603024
Basin F	FC4	08/02/90	08/03/90	189688.41	2179373.28	5193.4	AQ2604016
Basin F	FC5	08/02/90	08/03/90	191232.76	2180501.15	5187.9	AQ2305023
Basin F	FC2FB	08/02/90	08/03/90	189877.06	2181324.36	5204.4	AQ2602042
Basin F	FC2COL	08/02/90	08/03/90	189877.06	2181324.36	5204.4	AQ2602043
South Plants	Mobile 1	08/08/90	08/09/90	180400.00	2185100.00	5265.0	AQ01066
South Plants	Mobile 2	08/08/90	08/09/90	180500.00	2184600.00	5265.0	AQ01067
South Plants	Mobile 3	08/08/90	08/09/90	179800.00	2184500.00	5270.0	AQ01068
South Plants	Mobile 4	08/08/90	08/09/90	179900.00	2184900.00	5270.0	AQ01069
South Plants	Mobile 1FB	08/08/90	08/09/90	180400.00	2185100.00	5265.0	AQ01070
Basin A	Mobile West	08/28/90	08/29/90	183200.00	2183700.00	5245.0	AQ36014
Basin A	Mobile East	08/28/90	08/29/90	182300.00	2187100.00	5245.0	AQ36015
Basin A	Mobile East	08/28/90	08/29/90	182300.00	2187100.00	5245.0	AQ36016
Basin A Neck	Mobile North	08/29/90	08/30/90	186900.00	2182200.00	5220.0	AQ26010
Basin A Neck	Mobile West	08/29/90	08/30/90	185800.00	2180700.00	5200.0	AQ35011
Basin A Neck	Mobile South	08/29/90	08/30/90	184700.00	2182100.00	5230.0	AQ35010
South Plants	Mobile East	09/12/90	09/13/90	178900.00	2183900.00	5260.0	AQ01072
South Plants	Mobile West	09/12/90	09/13/90	179200.00	2183500.00	5270.0	AQ02011

Table 3.2-1 Sampling Locations (continued)

Location	Site ID	Start Date	End Date	Northing Easting Coordinates		Elevation	COC ID
Locations of VOC High Event Samples Sites Other Than Permanent CMP Sites (FY90)							
Inject. Wells	South	01/12/90	01/13/90	196100.00	2183700.00	5155.0	CAQ23004
Inject. Wells	North	01/12/90	01/13/90	196200.00	2183700.00	5150.0	CAQ23003
Inject. Wells	North Col.	01/12/90	01/13/90	196200.00	2183700.00	5150.0	CAQ23005
South Plants	Mobile 1	06/27/90	06/28/90	180400.00	2185100.00	5265.0	CAQ01058
South Plants	Mobile 2	06/27/90	06/28/90	180500.00	2184600.00	5265.0	CAQ01059
South Plants	Mobile 3	06/27/90	06/28/90	179800.00	2184500.00	5270.0	CAQ01060
South Plants	Mobile 4	06/27/90	06/28/90	179900.00	2184900.00	5270.0	CAQ01061
South Plants	Mobile 1	06/28/90	06/29/90	180400.00	2185100.00	5265.0	CAQ01062
South Plants	Mobile 2	06/28/90	06/29/90	180500.00	2184600.00	5265.0	CAQ01063
South Plants	Mobile 3	06/28/90	06/29/90	179800.00	2184500.00	5270.0	CAQ01064
South Plants	Mobile 4	06/28/90	06/29/90	179900.00	2184900.00	5270.0	CAQ01065
Basin F	Mobile SE	07/19/90	07/20/90	188600.00	2181800.00	5210.0	AQ26005
Basin F	FC2	07/19/90	07/20/90	189877.06	2181324.36	5204.4	AQ2602033
Basin F	FC3	07/19/90	07/20/90	187997.29	2180259.12	5209.8	AQ2603019
Basin F	FC5	07/19/90	07/20/90	191232.76	2180501.15	5187.9	AQ2305018
Basin A Neck	AQN	07/27/90	07/28/90	186900.00	2182200.00	5220.0	CAQ26009
Basin A Neck	AQS	07/27/90	07/28/90	184700.00	2182100.00	5230.0	CAQ35009
Basin A Neck	AQW	07/27/90	07/28/90	185800.00	2180700.00	5200.0	CAQ35008
Basin F	FC2	08/02/90	08/03/90	189877.06	2181324.36	5204.4	AQ2602040
Basin F	FC3	08/02/90	08/03/90	187997.29	2180259.12	5209.8	AQ2603023
Basin F	FC4	08/02/90	08/03/90	189688.41	2179373.28	5193.4	AQ2604015
Basin F	FC5	08/02/90	08/03/90	191232.76	2180501.15	5187.9	AQ2305022
Basin A	Mobile West	08/09/90	08/10/90	183200.00	2183700.00	5245.0	AQ36013
Basin A	Mobile East	08/09/90	08/10/90	182300.00	2187100.00	5245.0	AQ36012

Table 3.2-1 Sampling Locations (continued)

Location	Site ID	Start Date	End Date	Northing Easting Coordinates		Elevation	COC ID
South Plants	Mobile West	09/12/90	09/13/90	179200.00	2183500.00	5270.0	AQ02010
South Plants	Mobile East	09/12/90	09/13/90	178900.00	2183900.00	5260.0	AQ01071
Locations of Mercury/Metals High Event Sample Sites Other than CMP Sites (FY90)							
Basin A	Basin A	11/08/89	11/09/89	182200.00	2186900.00	5250.0	AQ36003
Basin A	Basin FB	11/08/89	11/09/89	182200.00	2186900.00	5250.0	AQ36004
Basin A	Section 31	11/08/89	11/09/89	183000.00	2189000.00	5242.0	AQ31006
Basin F	FC2	12/05/89	12/06/89	189877.06	2181324.36	5204.4	AQ2602027
Basin F	FC2 FB	12/05/89	12/06/89	189877.06	2181324.36	5204.4	AQ2602028
Basin F	FC3	12/05/89	12/06/89	187997.29	2180259.12	5209.8	AQ2603017
Basin F	FC4	12/05/89	12/06/89	189688.41	2179373.28	5193.4	AQ2604011
Basin F	FC5	12/05/89	12/06/89	191232.76	2180501.15	5187.9	AQ2305014
Basin F	FC2	01/07/90	01/08/90	189877.06	2181324.36	5204.4	AQ2602032
Basin F	FC4	01/07/90	01/08/90	189688.41	2179373.28	5193.4	AQ2604014
Basin F	FC5	01/07/90	01/08/90	191232.76	2180501.15	5187.9	AQ2305017
Basin F	Mobile	01/07/90	01/08/90	188600.00	2181800.00	5210.0	AQ26003
Basin F	Mobile Backup	01/07/90	01/08/90	188600.00	2181800.00	5210.0	AQ26004
Basin A	Mobile West	01/08/90	01/09/90	183300.00	2183600.00	5240.0	AQ35006
Basin A	Mobile W FB	01/08/90	01/09/90	183300.00	2183600.00	5240.0	AQ35007
Basin A	Mobile East	01/08/90	01/09/90	182300.00	2187100.00	5235.0	AQ36007
Basin A	Mobile E Back	01/08/90	01/09/90	182300.00	2187100.00	5235.0	AQ36009
South Plants	Mobile West	01/10/90	01/11/90	180000.00	2183600.00	5270.0	AQ02002
South Plants	Mobile East	01/10/90	01/11/90	180000.00	2186200.00	5265.0	AQ01051
South Plants	Mobile E Back	01/10/90	01/11/90	180000.00	2186200.00	5265.0	AQ01052
South Plants	Mobile West	05/11/90	01/12/90	180000.00	2183600.00	5270.0	AQ02004
South Plants	Mobile East	05/11/90	01/12/90	180000.00	2186200.00	5265.0	AQ01054

Table 3.2-1 Sampling Locations (continued)

Location	Site ID	Start Date	End Date	Northing Easting Coordinates		Elevation	COC ID
South Plants	Mobile West	05/15/90	05/16/90	180000.00	2183600.00	5270.0	AQ02006
South Plants	Mobile W FB	05/15/90	05/16/90	180000.00	2186200.00	5265.0	AQ02007
South Plants	Mobile East	05/15/90	05/16/90	180000.00	2186200.00	5265.0	AQ01056
Basin A	SE Mobile	06/12/90	06/13/90	181500.00	2186700.00	5250.0	CAQ36011
Basin F	FC2	07/26/90	07/27/90	189877.06	2181324.36	5204.4	AQ2602038
Basin F	FC2 COL	07/26/90	07/27/90	189877.06	2181324.36	5204.4	AQ2602039
Basin F	FC3	07/26/90	07/27/90	187997.29	2180259.12	5209.8	AQ2603022
Basin F	FC5	07/26/90	07/27/90	191232.76	2180501.15	5187.9	AQ2305021
Basin F	Mobile SE	07/26/90	07/27/90	188600.00	2181800.00	5210.0	AQ26008
South Plants	Mobile West	09/20/90	09/20/90	179200.00	2183500.00	5270.0	AQ02012
South Plants	Mobile East	09/20/90	09/20/90	178900.00	2183900.00	5260.0	AQ01073
Basin F	FC2	09/26/90	09/26/90	189877.06	2181324.36	5204.4	AQ2602044
Basin F	FC3	09/26/90	09/26/90	187997.29	2180259.12	5209.8	AQ2603025
Basin F	FC4	09/26/90	09/26/90	189688.41	2179373.28	5193.4	AQ2604017
Basin F	FC5	09/26/90	09/26/90	191232.76	2180501.15	5187.9	AQ2305024
Basin F	FC5 FB	09/26/90	09/26/90	191232.76	2180501.15	5187.9	AQ2305025
Surveyed Locations for Permanent CMP Sites Used During High Event and/or Routine Sampling (FY90)*							
	AQ1			179894.09	2168044.46	5172.90	
	AQ2			190950.25	2173808.13	5131.03	
	AQ3			195895.65	2185671.67	5141.14	
	AQ4			180536.12	2196630.92	5299.22	
	AQ5			170517.42	2178593.75	5266.50	
	AQ6			177674.96	2183761.74	5259.90	
	AQ7			178246.45	2174165.98	5196.10	
	AQ8			180741.57	2184793.38	5263.93	
	AQ9			185767.70	2185937.88	5271.20	

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* All permanent stations were operational from 10/1/89 to 9/30/90.

Table 3.2-1 Sampling Locations (continued)

Location	Site ID	Start Date	End Date	Northing Easting Coordinates		Elevation	COC ID
	AQ10	10/01/89	04/19/90	190814.11	2180111.40	5190.80 *	
	AQ10a	04/20/90	09/04/90	185800.00	2183550.00	5240.00 *	
	AQ10b	09/05/90	09/30/90	178950.00	2183850.00	5265.00 *	
	AQ11			190596.94	2181735.99	5192.00	
	AQ12			190620.16	2186724.88	5186.02	
	MET1			190632.43	2181737.97	5192.43	
	MET2			190523.61	2186253.84	5193.76	
	MET3			180733.49	2187492.58	5263.19	
	MET4			185997.34	2184581.95	5278.70	
	AQ SITE			186089.28	2184630.75	5278.54	

* AQ10 is considered a mobile sampling site for the CMP. This site has been relocated twice during FY90 to allow more efficient sampling. The most recent locations are not surveyed, but estimated.

** All elevations for the Mobile Sites are estimates using a 7½ minute Quadrant USGS Topographical Map.

drainage). The next most frequent wind direction was from the north (representing typical daytime upslope heating effects). The strongest wind speeds were most frequently observed from the west, resulting from downslope wind off the foothills. These wind conditions have been substantiated by CMP FY88 through FY90 meteorological monitoring. While typical wind data are represented on the wind rose, highly variable conditions can occur on any given day.

3.2.1.3 Topographical Features and Obstructions

All air quality locations were in accordance with siting criteria given in EPA's document "Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD) for TSP Sampling" (EPA, 1987). Because all permanent stations maintained TSP high-volume air samplers, the following guidelines were followed:

- Stations were at least 20 meters from trees;
- Stations were placed away from buildings or other obstacles, such that the distance between an obstacle and sampler was equal to at least twice the height that the obstacle protruded above the sampler;
- At stations where there were multiple or collocated samplers, at least 2 meters separated the samplers;
- The stations were, to the extent possible, at least 25 meters from roadways;
- The sample inlet was approximately 2 meters above the ground;
- To assess sampling precision, collocated TSP, PM-10 and SVOC samplers were placed at one site (Station AQ5); and
- All the stations were placed at representative terrain locations.

3.2.1.4 Continuity With Previous Monitoring Programs

The CMP continues a data collection program initiated under the Remedial Investigation. Twelve permanent sample locations were maintained under this program. Sampling results were reported in the Air Remedial Investigation Final Report (Hunter/ESE, 1988). In order to maintain the integrity of these data for comparison and assessment purposes, an attempt was made to employ these initially selected sites to the fullest extent possible; consequently, only minor adjustments (primarily related to AC power availability) were made to the earlier fixed monitor program locations. CMP FY90 monitoring sites were essentially at the same locations as CMP FY88 and FY89 sites.

3.2.2 THE CMP AIR QUALITY MONITORING NETWORK LOCATIONS

3.2.2.1 Permanent Stations Locations

Figure 3.2-1 shows the locations of 11 permanent air quality stations, one mobile station and one collocated fixed station (at AQ5). TSP was monitored at all stations, PM-10 at five stations, and asbestos at four stations, as described below. Volatile and semi-volatile organic compounds and metals were monitored with both fixed and mobile samplers that were positioned to collect high event levels of contaminants. All permanent stations (including the collocated station) were supplied with line electricity. Depending upon meteorological conditions, the selected sampling locations for organics and metals were established at portable stations according to worst-case conditions or were placed at the permanent stations. The rationale for locating each permanent and portable station is described in the Technical Plan and also in the CMP FY88 Assessment Report. There are no changes to these descriptions.

In addition to the parameters indicated, the fixed sites were also employed to measure high event samples for metals, VOCs and SVOCs, as appropriate, depending upon meteorological conditions and potential sources investigated (e.g., Basin F, Basin A and South Plants). Specific sites used are identified in Table 3.2-1 and in the high event monitoring sections discussed later in this report.

3.2.2.2 Portable Air Quality Monitoring Stations

Volatile and semi-volatile organic compounds were sampled at the permanent air quality monitoring stations and at portable stations on high event days. Mercury was sampled only at portable sites and only on high-event days. The portable stations were employed near potential contaminant sources in areas including Basin F, the South Plants, the Hydrazine Plant, Basin A, and Basin A Neck. For example, a high event day may have had winds from the west. Using portable stations, samples were collected downwind directly east of the potential contaminant source; upwind stations were also sampled at these times for comparison to downwind samples. On several occasions, four or more mobile stations were placed surrounding the potential source.

The FY90 program also called for one portable station to monitor TSP (AQ10). This station was to be placed at areas of special interest, such as locations that were influenced by remedial activity. During the CMP FY89 program, AQ10 operated at the northern perimeter of Basin F (in the direction of the prevailing wind flow off the basin) from October 1, 1989, to April 19, 1990.

AQ10 was located in the northeast corner of Section 35 (downwind from Basin A Neck construction activities) from April 20 to September 4, 1990, and was moved on September 5, 1990, to the northwest quarter of Section 1 (downwind from South Plants subdrain operations) where it remained through FY90. A revision to the Technical Plan (June 1990) provided for an additional portable TSP monitor and two portable PM-10 monitors to be incorporated into the program in FY91 (thus allowing for both upwind and downwind coverage).

The portable stations provided flexibility to react to changing events as remedial activities proceeded at RMA. All activities at portable stations were documented to indicate location, parameters measured, date, time in operation, and frequency of use. When a portable station was employed, EPA guidelines for positioning air quality monitoring stations were followed where appropriate (EPA, 1987). Portable propane generators were available as the power supply for the portable monitoring stations when line power was not used for AC-power samplers.

3.2.3 AIR QUALITY MONITORING STRATEGIES

3.2.3.1 Baseline Assessment

Several monitoring strategies were developed to establish a broad baseline of air quality conditions in the RMA vicinity. The first program element was the collection of baseline data for TSP, PM-10, metals, arsenic, mercury, VOC, SVOC, OCP and asbestos for routine sampling periods as described in the Technical Plan. This program is a continuation of monitoring guidelines initiated under the Remedial Investigation program in 1986-1987 and later maintained under the CMP. Table 3.2-2 lists the parameters and strategies for the FY90 air monitoring program.

TSP, PM-10, metals and arsenic were collected every 6th day during FY90 following a standardized schedule that is generally applied on a national basis. The schedule is shown in Figure 3.2-2. OCP were collected every 12th day. Asbestos was collected every other scheduled sampling day through January 1990, and once per month thereafter. VOC and SVOC were sampled once per season in order to establish general background (in addition to high event monitoring described in the following section and the extensive IRA-F VOC and SVOC monitoring program described in Section 3.4). Detailed monitoring methods are provided in Section 3.2.4, as well as in Appendix A of the Field Procedures Manual (Stollar, 1988). Laboratory analytical procedures are described in Section 3.5.

Table 3.2-2 Parameters and Strategies for RMA Air Monitoring Program

Parameter	Type of Sampling	Frequency	Season	Sample Locations	No. of Samples Per Year	No. of Blanks Per Year	No. of Collocated Samples Per Year[a]
TSP	Baseline	Every 6th day	All	AQ1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12 and one portable station	732		61
PM-10	Baseline	Every 6th day	All	AQ1, 2, 3, 5, 9, 10[f]	309		61
Asbestos	Baseline	Every 12th day[g]	All	AQ1, 6, 8, 12	124	62[b]	
VOC	Baseline	Once per season	Fall, winter, spring	AQ1, 3, 4, 5	12	3	3
SVOC	Baseline	Once per season	Fall, winter, spring	AQ1, 3, 4, 5	12	10[c]	3
Metals	Baseline	Every 6th day	All	AQ3, 5	122	61	61
Arsenic	Baseline	Every 6th day	All	AQ3, 5	122	61	12[d]
OCP (formerly OTSP)	Baseline	Every 12th day	All	AQ1, 3, 5	92	24	12
VOC	High event	6 high event days	Late spring, summer,	AQ1, 3, 4, 5, and four mobile monitoring locations	48	6	6
SVOC	High event	6 high event days	Late spring, summer, early fall	AQ1, 3, 4, 5, or other fixed and mobile stations as appropriate	24	13[c]	6
Metals	High event	12 high event days (approx. once/month)	All	AQ1, 3, 4, 5 and four mobile monitoring locations per sampling event	96	12	12
Arsenic	High event	12 high event days (approx. once/month)	All	AQ1, 3, 4, 5 and four mobile monitoring locations per sampling event	96	12	12
Mercury	High Event	12 high event days (approx. once/month)	All	AQ1, 3, 4, 5 and four mobile monitoring locations per sampling event	96	12	24
Air Quality[e]	Baseline	Continuous	All	MET4	8760 hourly averages		

Source: R.L. Stollar & Associates, Inc., Draft Final Technical Plan for Air Quality, 1988.

[a] TSP, PM-10, SVOC, OTSP collocated samples were collected at AQ5. Collocated samples for other parameters were located with respect to suspected containment source proximity and logistical suitability.

[b] Two blanks per sample day.

[c] Includes collection efficiency spike samples with collocated background samples plus associated blank (1 ea.)

[d] Approximately one-tenth of sample events will incorporate collocated sampling.

[e] Includes monitoring of ozone, carbon monoxide, sulfur dioxide, nitric oxide, nitrogen dioxide, and nitrogen oxides.

[f] Additional site on September 5, 1990.

[g] Sampled every 12th day through January, 1990; once per month thereafter.

FY90 AIR SAMPLING SCHEDULE
DAY OF THE MONTH

MONTHS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
OCTOBER	■						■						■						■						■						■
NOVEMBER						■						■						■						■						■	
DECEMBER						■						■						■						■						■	
JANUARY					■						■						■						■						■		
FEBRUARY				■						■						■						■						■			
MARCH						■						■						■						■						■	
APRIL					■						■						■						■						■		
MAY					■						■						■						■						■		
JUNE				■						■						■						■						■			
JULY				■						■						■						■						■			
AUGUST			■						■						■						■						■				
SEPTEMBER		■						■						■						■						■					

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Prepared for :

U.S. Army Program Manager for
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Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 3.2-2

National Ambient Air Quality
Sampling Schedule for 1990

Source : CDH, 1984

CMP AR FY90

3.2.3.2 Worst-case Assessment

The second element was high event monitoring. High event monitoring was conducted in the vicinity of the site boundaries and suspected contaminant source areas under the Remedial Investigation Program and was continued under the CMP. Because of the low background levels initially encountered in these areas under normal weather conditions, sampling for organic compounds and metals was directed toward high event days or worst-case situations. Various strategies were developed to optimize the high event collection program; Table 3.2-3 lists the sampling strategies for high event air quality monitoring as established in the Technical Plan.

Table 3.2-3 Sampling Strategies for High Event Air Quality Monitoring

	High Event Conditions[1]		
Atmospheric Parameter	VOC/SVOC	Alternate[2] SVOC	Metals
Wind Speed	< 5 mph	> 10 mph	> 10 mph
Temperature	> 75° F	> 75° F	N/A
Relative Humidity	< 50%	N/A	N/A
Precipitation	None	None	None
Soil Moisture	Dry	Dry	Dry
Snow Cover	None	None	None

[1] These are approximate values for defining favorable monitoring conditions. When all or most conditions are met for a particular contaminant, samples should be collected.

[2] Two or three samples will be collected under this scenario.

During the CMP FY88 and FY89 programs, high event monitoring was principally conducted in the vicinity of Basin F in order to assess potential worst-case conditions while remediation activity occurred in these areas and to assess remedial progress after cleanup was completed. High event monitoring was also conducted at the Arsenal boundaries, South Plants, Basin A, and the Hydrazine Plant. This approach continued in FY90; however, emphasis was placed on new areas of construction or remedial effort, including the Basin A Neck and South Plants subdrain operations.

3.2.3.3 Remedial Assessment

A third element in the CMP includes strategies for remedial actions monitoring support. Parameters to be monitored include those described for the general ambient monitoring programs, plus special contaminants associated with unique remediation concerns.

During the CMP FY88, cleanup activity was initiated at Basin F in late February 1988 and was concluded in May 1989 (during FY89). Actual site monitoring was conducted by the remediation subcontractor. The CMP staff, however, coordinated with the Remedial Monitoring Team to ensure standardization of methods and to provide objective assessment of data. At the conclusion of the Basin F Remediation Monitoring Program, air monitoring was continued under a special follow-on monitoring effort (IRA-F) which continued through FY90. Again, the CMP and IRA-F efforts were closely coordinated to ensure consistency, to provide comprehensive and effective monitoring, and to avoid redundancy. Because of close coordination between the various monitoring activities, these programs strongly complemented each other and provided a composite database from which to assess RMA baseline conditions and remedial progress. Monitoring results of the three programs broken down into remedial and post-remedial phases are provided in Section 4 of this report.

During FY90, CMP monitoring was conducted at Basin A Neck to supplement MKE monitoring in the vicinity of this operation. Monitoring was also initiated at the South Plants subdrainage area to complement remedial efforts undertaken by Harding Lawson Associates.

As stated in Section 1.2.3.4, remedial activities have a significant impact on CMP monitoring results, making it essential to evaluate all CMP data in relation to the remedial program. For example, differences between the 1986-1987 Remedial Investigation Program results when no major remedial activity was in progress, when Basin F cleanup activity was in full progress, and when Basin F cleanup activity was concluded are quite evident and provide a very meaningful assessment of remedial progress.

3.2.3.4 Criteria for Gaseous Pollutant Assessment

A fourth element in the CMP is the continuous monitoring of gaseous pollutants including carbon monoxide, sulfur dioxide, ozone and nitrogen dioxide. This program is required to establish a baseline of gaseous pollutants to support possible future RMA activities and to assess the status of non-attainment pollutants and/or those of special concern in the Denver metropolitan area. Active monitoring began on May 6, 1989, and continued through FY90. Consequently, the FY89 results consisted of a partial year of monitoring, while the FY90 results reported in Section 5 provide the first full annual period of monitoring.

3.2.4 AIR QUALITY MONITORING METHODS

Sampling methods for TSP, PM-10 and asbestos were standard reference methods used by the EPA or the National Institute of Occupational Safety and Health (NIOSH, 1984). Certifications for these methods were not necessary. Analytical methods for volatile organics, semi-volatile organics, metals, arsenic and mercury were reviewed and certified by PMRMA. Details of sampler design and operation as well as reference methods are provided in the Technical Plan (Stollar, 1990).

The Analytical Procedures Manual contains the certification procedures. The Field Procedures Manual, Appendix A, contains specific operation, calibration and maintenance procedures for the TSP and PM-10 samplers. The following sections briefly describe the procedures followed for sample collection. All sampling times are 24 hours with the exception of some VOC and SVOC high events.

3.2.4.1 Total Suspended Particulates (TSP)

Sample collection and analytical procedures for TSP followed the EPA reference method as described in "Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere" (CFR Title 40, Appendix B, 1985). As presented in the Analytical Methods Manual, the detection range for this method is 2 to 750 micrograms per standardized cubic meter of air (μg/std m^3).

The high-volume (Hi-Vol) samplers were General Metal Works Model GMWL-2000H. Air flow was controlled with electronic mass flow controllers. The target flow rate was 40 standard cubic feet per minute (scfm). An installed pressure transducer/recorder or manometer indicated the air flow to provide a permanent record of the flow rate for each sample. A 6-day timer (Model GMW-70) was built into the samplers to start and stop the samplers at the required times. Calibrations were conducted quarterly, or more often as required.

3.2.4.2 Particulate Matter Less than 10 Microns (PM-10)

Sample collection and analytical procedures followed standard procedures similar to TSP monitoring, except that a Whatman, QM-A, quartz filter was used instead of a glass fiber filter (CFR Title 40, Appendix J, 1987). A General Metal Works size-selective Accu-Vol IP-10 Sampler with Model 1200 Inlet was employed. Particles of 10 μm or less in size pass through the impaction chamber and are collected on the filter. The target flow rate was 40 cubic feet per minute (cfm).

Calibration for PM-10 samplers followed the manufacturer's written protocols; seasonal average temperature and pressure data were used to establish actual (volumetric) flow control set points per manufacturer's calibration recommendations. The PM-10 samplers and associated manufacturer's operation manuals are both included in EPA Reference/Equivalency designation.

3.2.4.3 Asbestos

Sample collection and analytical procedures followed the NIOSH Method 7400, revised March 1, 1987, presented in Appendix B of the Procedures Manual (NIOSH, 1987). Sample volume, microscope count field area, and background airborne particulates define the usable range of the method. The minimum total fiber count in 100 microscope fields considered adequate for reliable quantification is 10 fibers.

3.2.4.4 Volatile Organic Compounds

The collection and analytical methods for VOCs were certified by PMRMA and incorporated modified methodological guidelines given in EPA Method TO-1, "Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air" (USEPA, 1984). The TO-1 method involves the use of a sorbent to trap organic compounds that have a wide range of volatility. Method TO-1 employs Tenax GC adsorbent (poly 2,6-diphenyl phenylene oxide) to trap organic species having a boiling point range of 80 degrees Celsius (°C) to 200°C. All collected samples include three sorbent sections in two tubes, which consist of a primary Tenax tube, and a Tenax section followed by a charcoal section in the second tube. The target flow rate was initially 300 standard cubic centimeters per minute (sccm), and was subsequently reduced to 150 sccm.

3.2.4.5 Semi-volatile Organic Compounds

The collection and analytical methods for SVOCs were certified by PMRMA. The semi-volatile contaminants were measured by methodology based on the guidelines outlined in EPA's Method TO-4 from the Compendium of Methods referenced above. This method was used for semi-volatiles such as chlordane, PPDDT and PPDDE, along with other pesticides such as aldrin, dieldrin, endrin and isodrin. Method TO-4 involves trapping semi-volatiles on a quartz fiber filter followed by a polyurethane foam (PUF) cartridge. The target flow rate was 200 standard liters per minute (slpm). The standard Method TO-4 calls for PUF as the adsorbent media. However, the procedure also indicates that other adsorbents may be suitable for nonstandard method application. The filter and PUF media are soxhlet extracted using methylene chloride. The extract is split with the OCP analysis, if required, and condensed to one milliliter and a small aliquot (1 to 2 microliters) is analyzed by gas chromatography/mass spectrometry.

3.2.4.6 ICP Metals and Arsenic

Collection and analytical methods for metals and arsenic were certified by PMRMA. The collection methodology for metals followed the EPA method for lead determination, "Reference Method for the Determination of Lead in Suspended Particulate Matter Collected from Ambient Air" (CFR Title 40, Appendix G, 1978, 1979). The analytical methodology for determining arsenic followed EPA Method 206.2, while determinations for the remaining metals were adapted from NIOSH Method 7300 (NIOSH, 1984) for elements in air using inductively coupled argon plasma (ICAP) emission spectrometry. These methods are contained in Appendix B of the CMP Procedures Manual (Stollar, 1988). Samples were collected in a standard Hi-Vol sampling apparatus used for TSP sampling. Analyses were performed on a portion of the TSP filters after the gravimetric analyses were completed. Methods followed EPA or NIOSH procedures but were certified via the PMRMA quality assurance program.

It should be noted that the EPA is in a period of transition from a TSP-based particulate standard to a PM-10 based standard. However, as of December 1990, lead and other metals were still to be determined from TSP samples. Telephone conversations with EPA staff at the Office of Air Quality Planning and Standards indicate that the agency policy may change, requiring lead and metals sampling to be performed on PM-10 samples instead of TSP samples. Transition by the EPA from TSP to PM-10 for lead sampling will be brought to the attention of PMRMA. Any revisions to the method used in the CMP will be based upon PMRMA's preference.

3.2.4.7 Organochlorine Pesticides (OCP)

The methodology for OCP (formerly OTSP) was adapted from EPA Method TO-4 (Analytical Methods Manual) and Method 608, "EPA Test Method for Organochlorine Pesticides and PCBs" (USEPA, 1984). The filter and PUF section is soxhlet extracted with methylene chloride. The extract is split with the SVOC analysis, if required, and the solvent exchanged to hexane. The extract is then concentrated using a KD apparatus, and a GC/ECD is used to determine aldrin, dieldrin, endrin, isodrin, PPDDT, PPDDE, and chlordane weights. The filters used for this method are pre-extracted in a soxhlet apparatus before use. Filter blanks are analyzed to monitor background contamination.

OCP samples were collected using General Metal Works PS-1 samplers, identical to those sampling devices used in SVOC sample collection. In this method, ambient air is drawn through a quartz fiber filter followed by a PUF sorbent section. The target aeration flow rate was 200 standard liters per minute (slpm).

3.2.4.8 Mercury

Mercury sampling was not performed during CMP FY88, but began during FY89 on October 26, 1988. Hydrar tubes manufactured by SKC, Inc. were used for sampling mercury and the analysis was performed according to the Rathje and Marcero method (AIHA, 1976). The hydrar tubes contained 500 mg of hopcalite, a treated charcoal. and were digested using acid. The digestate was analyzed by cold vapor atomic absorption spectroscopy (CVAAS).

3.3 THE BASIN F REMEDIATION AIR MONITORING PROGRAM

Ambient air quality monitoring was carried out by the contractor performing the Basin F Interim Remediation Action from March 1988 to May 1989. The main purpose of this monitoring was to characterize atmospheric concentrations in the perimeter zone around Basin F, to provide data to characterize potential impacts off-site, and to determine impacts from nontarget compounds. Since the data collected are an important ingredient of the Basin F post-remedial assessment provided in this report, a brief discussion of the remediation monitoring program follows. Target compounds virtually identical to the CMP target list were monitored, including VOCs, SVOCs, total suspended particulates, metals, mercury, and ammonia. Sample collection was targeted for a 24-hour period.

To provide a conservative estimate of off-site migration, and to generate data that were likely to provide a source characterization, the sampling methodology called for specific monitoring schedules at specific sites. The locations of these sites and their designator codes are shown in Figure 3.3-1. Sites BF1, BF2, BF3, and BF4 are at the perimeter of the Exclusion Zone, and Sites BF5, BF6, and BF7 are the off-site (beyond the Exclusion Zone) locations.

The sampling methodology included a deliberate selection of days of highest impact of potential air quality emissions for analysis, based on existing or predicted meteorological conditions. The perimeter zone air quality was sampled up to 6 days per week, including all times during which there was remedial activity in the Basin.

At least 1 day per week with predicted high impacts, based both on meteorology and on operations, was selected for sampling at the off-site locations. For those days, both off-site and perimeter samples were sent to the laboratory for analysis. After a week's collection, the project team reviewed the meteorological conditions that were associated with each sample, and selected the 2 perimeter site days with the highest potential impact for subsequent laboratory analysis.

All sampler inlets with the exception of those at BF4 were placed at breathing zone height, which for this program, was interpreted to be approximately 2 meters above the immediately adjacent ground level. At BF4, sampler inlets were approximately 4.5 meters above the adjacent ground. Samplers were placed so that local obstacles would not impede air flow. The EPA prevention of significant deterioration (PSD) probe siting guidelines for avoidance of flow obstructions were followed in locating the samplers. Collocated, or duplicate, samples were collected from Site BF2. A discussion of air quality monitoring methods (similar to the CMP) is provided in Section 3.2.4.

Sampling procedures including media and instrumentation were virtually identical to those used under the CMP. The laboratory's analytical procedures were conducted in accord with appropriate EPA techniques at an EPA-approved CLP Laboratory. Although the laboratory and its techniques were not certified by USATHAMA or PMRMA, the laboratory's techniques were very similar. VOCs were analyzed in accord with EPA method TO-1, by Gas Chromatography/Mass Spectrometry (GC/MS); SVOCs were analyzed by method TO-4, which is also a GC/MS technique; organochlorine pesticides were analyzed by gas chromatography/electron capture detection (GC/ECD), which is similar to the method used for analyzing OCPs in the CMP program; particulates were determined gravimetrically; metals were determined by use of inductively coupled argon plasma (ICAP) techniques and by graphite furnace atomic adsorption spectrometry (for

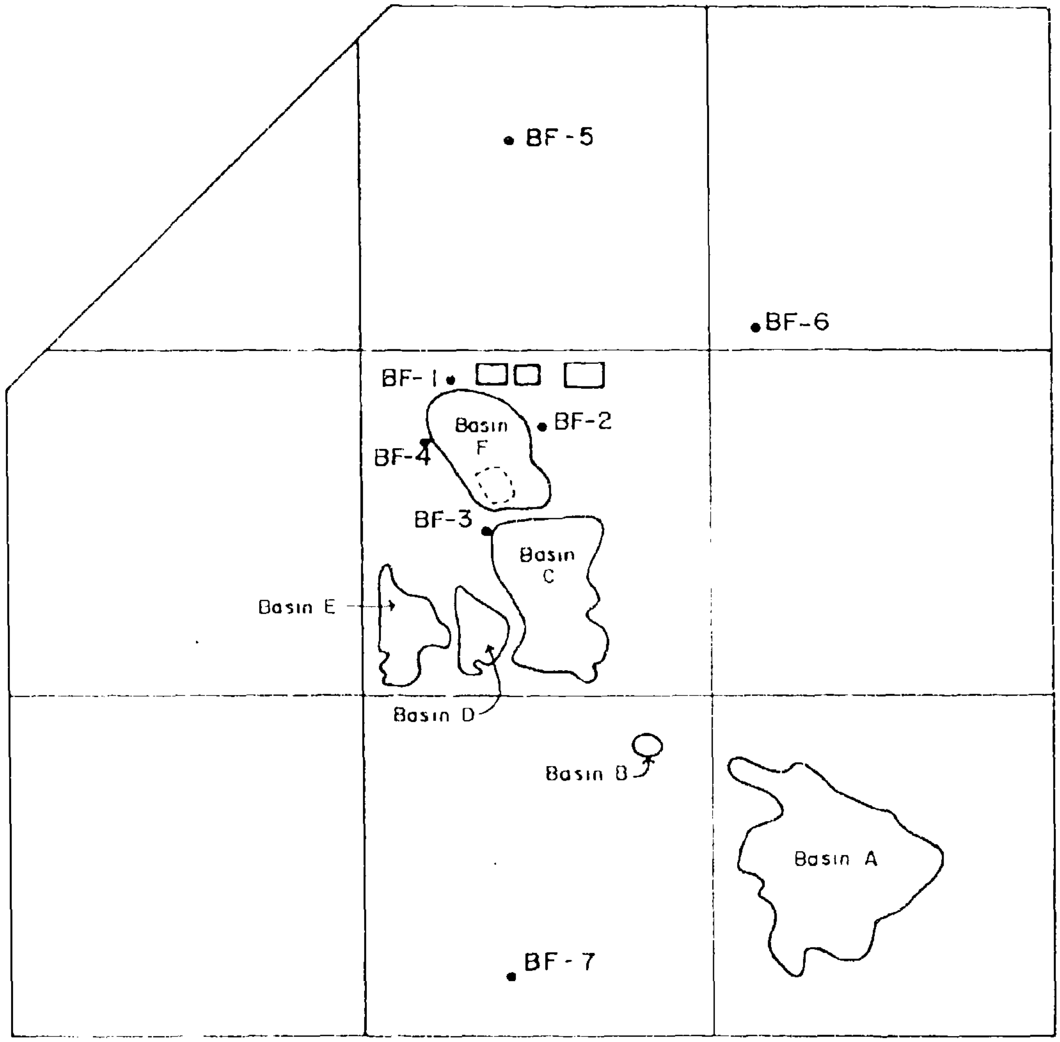

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FIGURE 3.3-1
Location of Basin F Air Quality Monitoring Stations at Rocky Mountain Arsenal

Rocky Mountain Arsenal

Prepared by Ebasco Services Incorporated arsenic). A separate report summarizing the Basin F Air Program is available (Ebasco Constructors et al, 1989).

3.4 THE IRA-F AIR QUALITY MONITORING PROGRAM

The IRA-F Air Quality Program was initiated during May 1989 as a follow-up sampling program for air quality near the Basin F site. The program was continued through FY90 and will be incorporated into the CMP during FY91. The objective was to continue sampling for important atmospheric emissions and to characterize the impacts of Basin F remediation. Sampling focused on both VOCs, SVOCs and OCPs near the Basin and near the storage pond for Basin F liquids.

3.4.1 SAMPLING LOCATIONS

Sampling locations for the IRA-F program are shown on Figure 3.4-1. Samplers were established on or near the Basin F "perimeter" site (or exclusion zone) locations which were used during the Basin F sampling program. The identical sites for BF1 and BF2 were used, and the sites were renamed FC1 and FC2, respectively under IRA-F. At site BF3, the monitoring platform was relocated to the east of BF3 on the berm of Basin C during May 1989. Subsequently, the site was renamed FC3. At site BF4, the monitoring platform was moved approximately 30 meters east of the old site, the sampling height was changed to 2 m above the ground, and the site was renamed FC4. A new site was established during the early part of the program at FC5, just north of the storage pond (Pond A). During May and June 1989, samples were also collected at three separate, more distant sites. These included RIFS1, about 1 mile to the west-northwest of Basin F, BF5, about 1 mile north of Basin F, and BF7, about 1.7 mile south of Basin F.

3.4.2 SAMPLING STRATEGY

Samples were collected on a 6-day frequency, in accord with the EPA national schedule for particulates, as shown on Table 3.4-1. Since organic compounds (VOCs and SVOCs) were a primary concern at Basin F and were potentially emitted from the capped Basin and from the waste pile, tank, and pond vents, the sampling for VOCs and SVOCs was conducted on a 6-day basis. Particulates, metals and mercury, were of less concern under this scenario and were sampled every 12 days. Because the data were also collected in accord with the CMP schedule they provided suitable data for extrapolating from the CMP data base. Samples were collected for a 24-hour period. The VOC, SVOC and mercury sampling began at noon on the day prior to the "sample

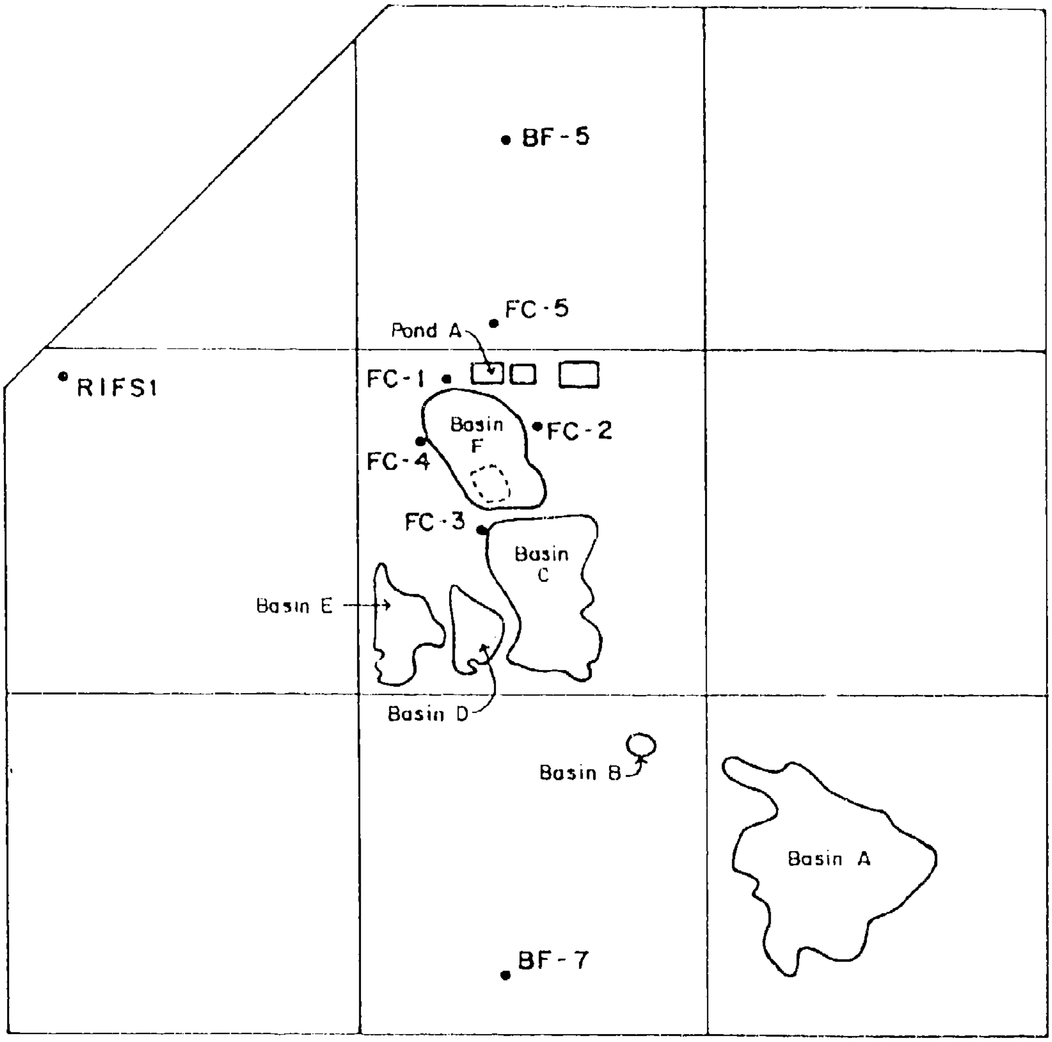

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FIGURE 3.4-1
Location of IRA-F Air Quality Monitoring Stations at Rocky Mountain Arsenal

Rocky Mountain Arsenal
Prepared by Ebasco Services Incorporated

Table 3.4-1 Location and Monitoring Parameters at IRA-F Sites

Site	Location from Basin F	Current Monitoring Equipment	Frequency[2]
FC1	N Perimeter	VOC, SVOC, TSP, PM-10[1], Metals	Every 6th day Every 12th day
FC2	ENE Perimeter	VOC, SVOC, TSP, Metals	Every 6th day Every 12th day
FC3	S Perimeter	VOC, SVOC, TSP, PM-10[1], Metals	Every 6th day Every 12th day
FC4	W Perimeter	VOC, SVOC, TSP, Metals	Every 6th day Every 12th day
FC5	N of Pond A	VOC, SVOC, TSP, Metals	Every 6th day Every 12th day
BF5	N 1 mile	VOC, SVOC, TSP, Metals	Every 6th day (through June 89) Every 12th day (through June 89)
BF7	S 1½ miles	VOC, SVOC, TSP, Metals	Every 6th day (through June 89) Every 12th day (through June 89)
RIFS1	WNW 1 mile	VOC, SVOC TSP, Metals	Every 6th day (through June 89) Every 12th day (through June 89)

1 Sampling began in June 1989.
2 Sampling began May 10, 1989, and continued on indicated frequency.

date." TSP, PM-10, and metals were sampled from midnight to midnight of the sampling date. VOC, SVOC, TSP, metals, arsenic, and mercury were sampled at all sites. A PM-10 sampling effort began in June 1989 at sites FC1 and FC3. Analytical, data processing, and quality assurance activities were identical for both the IRA-F and the CMP programs.

3.4.3 CAP AND VENT MONITORING

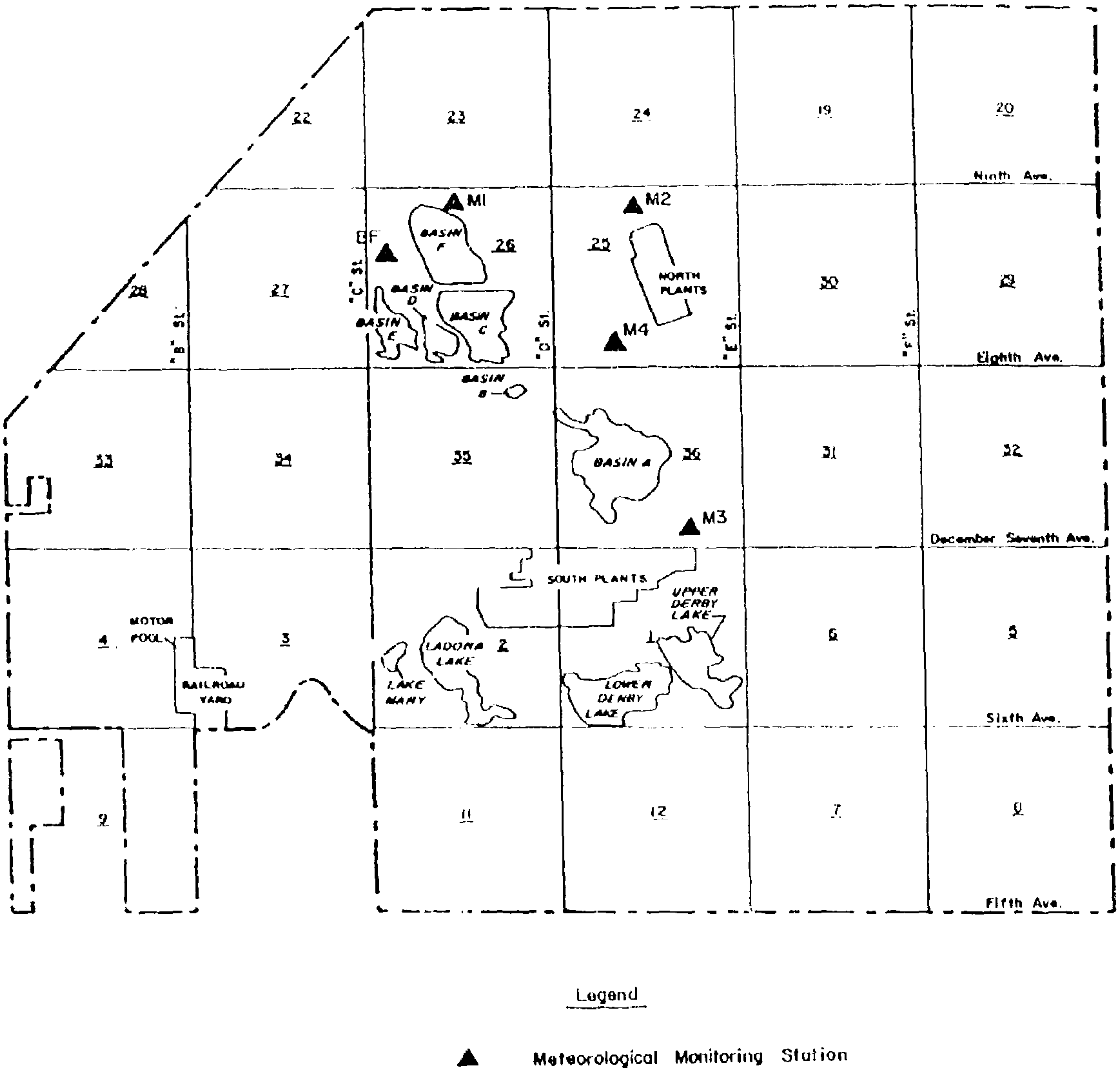
The IRA-F program monitored the integrity of the waste pile and restored basin caps, as well as the potential total emissions from the waste pile, tank farm, and pond vents. Total organics were monitored with an HNU and an OVA monitor at selected grid points on the waste pile and basin caps and at each of the vents on the waste pile, pond and tanks. Readings were taken monthly during June through September 1989. The results provide an estimate of total emissions, and they depict the monthly relative changes in any emissions. In 1990, three separate sampling efforts at the waste pile vents, pond vents, and tank farm were undertaken using stainless steel canisters (EPA Method TO-14). Three separate flux chamber episodes were also conducted over the waste pile and the restored Basin F floor.

3.5 METEOROLOGICAL MONITORING PROGRAM

Meteorological parameters were monitored at four locations within RMA's boundaries. Three stations were established in 1981 and were maintained by RMA. During CMP FY89, a modification to the Technical Plan placed meteorological monitoring and data processing under CMP responsibilities. The network was upgraded to include radio-telemetry from the three original sites to a central computer facility which was also the location of the continuous gaseous monitoring site. A fourth meteorological station was erected at this location. Operation of the upgraded meteorological network was initiated on February 1, 1989, and continued through FY90. Results of the meteorological monitoring program are provided in Section 6.0; detailed data are also shown in Appendix J.

3.5.1 LOCATION OF METEOROLOGICAL MONITORING STATIONS

The separate meteorological monitoring sites were set up to be as close as possible to potentially major sources of contaminants at RMA. These are indicated as M1, M2, M3 and M4 for the CMP and as BF for the Basin F project (Figure 3.5-1). The Basin F station was dismantled in FY89, therefore, data were not collected from that tower during FY90.



Prepared for:

U.S. Army Program Manager for
Rocky Mountain Arsenal
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Prepared by:

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Ebasco Services, Inc.

Figure 3.5-1

RMA Meteorological
Monitoring Stations

CMP AR FY90

Meteorological Station 1 (M1) was located in Section 26, approximately 200 yards south of Ninth Avenue and 700 yards west of "D" Street. Meteorological Station 2 (M2) was located in Section 25, north of the North Plants complex, approximately 200 yards south of Ninth Avenue and 700 yards east of "D" Street. Meteorological Station 3 (M3) was located approximately 50 yards north of December Seventh Avenue and 500 yards west of "E" Street in Section 36. Meteorological Station 4 (M4) was located approximately 15 yards north of Eighth Avenue and 350 yards east of "D" Street in Section 25. The Basin F Station was located west of Basin F in Section 26. The meteorological monitoring stations were previously installed to depict potential local and micrometeorological influences that may occur within the Arsenal compound. One of the objectives of the CMP has been to analyze the collected data and determine air quality impacts, if any, that may result from local topographical differences and the resultant drainage differences within the Arsenal. Results of this analysis are included in this report.

3.5.2 MONITORING EQUIPMENT AND STRATEGY

Monitoring sensors were fixed on 10-meter meteorological towers or at the base of the stations. Wind speed, wind direction, sigma theta, temperature and relative humidity were monitored at 10 m above ground level while solar radiation, barometric pressure and precipitation were all monitored at the surface. Temperature was monitored at M1 at both the 10 m and 2 m levels, and temperature difference (10 m - 2 m) between the two sensors was calculated. A depiction of parameters monitored at each site is shown in Table 3.5-1.

3.5.3 DATA ACQUISITION

Meteorological data were downloaded automatically each night from each CMP site onto the base computer through telemetry, modems and phone lines. This database was closely checked each day by CMP personnel.

Table 3.5-1 Meteorological Parameters Monitored at RMA During FY90

Parameter	Site M1	M2	M3	M4	BF
Wind Speed	X	X	X	X	X
Wind Direction	X	X	X	X	X
Sigma Theta*	X	X	X	X	X
Temperature	X	X	X	X	X
Temperature (2-meters)	X				
Relative Humidity	X				X
Barometric Pressure				X	X
Solar Radiation		X	X		X
Precipitation	X	X	X	X	X

* A computed value equivalent to a running average standard deviation of wind direction.

3.5.4 DATA APPLICATIONS

Meteorological data were used in several ways during the CMP. Wind speed, wind direction and temperature were used to select sampling days and identify high event periods favorable for collection of contaminants. Temperature and barometric pressure were employed to compute standardized volumes for air quality data. All parameters, including atmospheric stability and precipitation data, were collected and correlated with long-term regional data in order to determine the representativeness of the sampling period. The various meteorological parameters were employed to compare the data monitored with potential source impacts as predicted by atmospheric dispersion models.

3.6 CONTINUOUS AIR MONITORING PROGRAM

The operation of the continuous air monitoring station under the CMP began on May 6, 1989, and continued through FY90. The continuous air monitoring station was located within the RMA boundaries, approximately 350 yards east and 50 yards north of the intersection of Eighth Avenue and "D" Street. For a second point of reference, this station was located 100 feet north-northeast of Meteorological Tower M4 (refer to Figure 3.5-1).

The Continuous Air Monitoring Program was designed to monitor the so-called criteria or "regulated" pollutants, including carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). In accordance with EPA guidance for monitoring these pollutants, the data were monitored continuously, with digital retrieval on an automated data acquisition system every 2 seconds and storage of hourly averages. Analog chart records were used as a back-up data source. Although nitric oxide (NO) and nitrogen oxides (NOx) are not designated as criteria pollutants, their values were also reported. When summarized, the data represent virtually a continuous recording of ambient air quality. A list of the parameters monitored, along with the analyzer model number, the full scale range, method of detection, the EPA sampling method, and data recovery percentage is summarized in Table 3.6-1.

3.7 LABORATORY ANALYSIS PROGRAM

The objective of the laboratory analysis program was to provide PMRMA with reliable, statistically supportable, and legally defensible air quality data for airborne contaminants at RMA. As noted in the previous section, laboratory analysis procedures (except those for TSP, PM-10, and asbestos) were reviewed and certified by PMRMA. Volatile and semi-volatile organic compounds were analyzed by certified semi-quantitative GC/MS methods. OCP (aldrin, dieldrin, endrin, isodrin, PPDDE and PPDDT), ICAP metals (cadmium, chromium, copper, lead and zinc) and other metals (arsenic and mercury) were analyzed by certified quantitative methods. TSP, PM 10 and asbestos analyses were determined using standard NIOSH and EPA analytical methods.

The target analytes for the program were selected from an evaluation of contaminant sources at RMA, the compounds associated with previous activities at these sites, and compounds previously detected in past air, soil, and water monitoring investigations. Table 3.7-1 lists the analyses, along with the type of certification procedure, the reference method and the type of analytical method. These are described in some detail in Section 3.2.4.

Table 3.6-1 RMA Continuous Gaseous Air Monitoring Program Summary

Parameter and Full Scale Range	Analyzer Used	Method of Detection	EPA Sampling Method	Recent Recovery of Hourly Values
Carbon Monoxide * (CO) 50.0 ppm	TECO Model - 48	Gas Filter Correlation	RFCA-0981-054 September, 1981	97.0
Ozone ** (O3) 1.0 ppm	TECO Model - 49	Time-shared Dual Cell U.V. Photometric	EQOA-0880-047 August 27, 1980	98.1
Sulfur Dioxide * (SO2) 0.5 ppm	TECO Model - 43A	Pulsed Fluorescent	ESQA-0486-060 February 18, 1975	94.6
Nitric Oxide * (NO) 0.5 ppm	TECO Model - 14B/E	Chemiluminescent	No Method Available	96.9
Nitrogen Dioxide * (NO2) 0.5 ppm	TECO Model - 14B/E	Chemiluminescent	As specified in 40 CFR, Part 53 ***	96.9
Nitrogen Oxides * (NO_x) 0.5 ppm	TECO Model - 14B/E	Chemiluminescent	No Method Available	96.9

* System used for calibration includes TECC Model - 146 Multigas Dilution Calibrator, TECO Model - 111 Zero Air Supply, and a span gas source traceable to EPA protocol #2 (U.S. EPA, 1987).

** System used for calibration includes TECO Model - 146 Multigas Dilution Calibrator, TECO Model - 111 Zero Air Supply, and TECO Model - 49PS Photometric Ozone Source Calibrator.

*** Analyzer must be operated on 0 to 0.500 ppm range scale.

Table 3.7-1 Analytical Methods for Air Quality Monitoring Program

Parameter	Reference Certification	Certification Methods	Method	PMRMA Method Number/Laboratory* MRI	ESE
TSP	None	40 CFR Part 50 Appendix B	Gravimetric		
PM-10	None	40 CFR Part 50 Appendix B	Gravimetric		
Asbestos	None	NIOSH 7400	Phase Contrast Microscopy		
VOC	Semi-quantitative	EPA TO-1 with EPA Method 624	GC/MS	E-7	CM04
SVOC	Semi-quantitative	EPA Method TO-4	GC/MS	F-7/CM02	CM03
OCP	Quantitative	Modified EPA Method 608	GC/ECD	H-7	CH01
Metals	Quantitative	NIOSH 7300	ICAP	G-7	RS9D
Lead	Quantitative	40 CFR Part 50, Appendix G	ICAP	G-7	RS9D
Arsenic	Quantitative	EPA Method 206.2, 1979	AA-Graphite Furnace	G-7	AS01
Mercury	Quantitative	AIHA, 1976	AA-Cold Vapor	J-7	

* MRI (Midwest Research Institute) and ESE (Environmental Science & Engineering) are analytical laboratories authorized to provide results for the CMP.

The defensibility and technical quality of data generated in this program were assured by documenting all the analytical procedures and by requiring all data to exceed minimum analysis method requirements with respect to instrument calibration and quality control. Sample preparation, materials shipping, handling, and chain-of-custody procedures followed the protocol outlined in the Quality Assurance/Quality Control Manual for the CMP (Stollar, 1988). These are discussed further in Section 8.0.

For each target compound, there is a lower certified reporting limit (CRL). This CRL refers to the lower detection limit of the analytical technique that can assure a 95 percent confidence limit of positive detection. The CRL is based on a mass per sample and is limited by instrumentation and methodology. (Below this limit, any detection must be regarded as not detected or below the CRL.) Table 3.7-2 lists the compounds and groups of compounds along with their lower CRL. Note that within the VOC and SVOC groups, there is a wide range of lower CRL which vary according to target analyte sensitivity in relation to the method employed. Also provided in Table 3.7-2 is a detection limit converted to atmospheric concentration based on the reported lower CRL and an estimated target volume for each sample group.

There is also an upper certified reporting limit (UCRL) for each target compound. The CRL and UCRL define the accepted linear range for each target analyte, and is limited by instrumentation and methodology. Any detection above the UCRL must be labelled as an estimated value since it falls outside of the certified linear range.

Table 3.7-2 Analytes and Certified Reporting Limits for Air Quality Monitoring Program

Parameter	Certified Reporting Limit (Lower Certified Range) MRI*	 ESE*	Atmospheric Detection Limit (MRI)	Atmospheric Detection Limit (ESE)
TSP	2 µg		0.001 µg/m^3	
PM-10	2 µg		0.001 µg/m^3	
Asbestos	7 particles/mm^2		0.002 part./ml	
VOC	0.005 to 0.085 µg		0.071-1.214 µg/m^3	
SVOC	4.100 to 42.00 µg	5.16 to 40 µg	0.056-0.583 µg/m^3	0.070 to 0.556 µg/m^3
OCP	0.100 µg	0.100 µg	0.0004 µg/m^3	0.0004 µg/m^3
Metals				
cadmium	0.648 µg	4.0 µg	0.0004 µg/m^3	0.0025 µg/m^3
chromium	8.360 µg	20.0 µg	0.005 µg/m^3	0.012 µg/m^3
copper	14.20 µg	10.0 µg	0.009 µg/m^3	0.006 µg/m^3
lead	8.190 µg	40.0 µg	0.005 µg/m^3	0.024 µg/m^3
zinc	5.650 µg	20.0 µg	0.003 µg/m^3	0.011 µg/m^3
Arsenic	0.625 µg	1.41 µg	0.0004 µg/m^3	0.0009 µg/m^3
Mercury	0.089 µg	0.100 µg	0.809 µg/m^3	0.909 µg/m^3

* MRI (Midwest Research Institute) and ESE (Environmental Science & Engineering) are analytical laboratories authorized to provide results for the CMP.

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