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SECTIONS 1.0, 2.0 and 3.0
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TECHNICAL SUPPORT FOR

ROCKY MOUNTAIN ARSENAL

FINAL
REMEDIAL INVESTIGATION SUMMARY REPORT
SECTIONS 1.0, 2.0, AND 3.0
VERSION 3.2

January 1992

Contract Number DAAA15-88-D-0024

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Remedial Investigation Summary Report

ERRATA

Page No.	Location	Comments
1-11	Table RISR 1.2-2 Page 1 of 7	NCSA-3, Basin F, Site Description: "... 1957..." change to "... 1956..."
1-11	Table RISR 1.2-2 Page 1 of 7	NCSA-5a, Basin B, Site Description: "... 1943 - 1957" change to "... 1946 - 1956."
1-13	Table RISR 1.2-2 Page 3 of 7	CSA-1d, "Sanitary Landfill and Incinerator 634" and Site Description: "... Incinerator 634..." change both to "... Incinerator 834..."
1-14	Table RISR 1.2-2 Page 4 of 7	NPSA-4, Site Description: change Building "1606" to "1608"
1-15	Table RISR 1.2-2 Page 5 of 7	"Windblown Contamination" change to "Surficial Soil and Other Predominantly Near-Surface Contamination"
1-16	Table RISR 1.2-2 Page 6 of 7	NCSA-9p, Site Description: "... arsenic and mercury" change to "... arsenic, mercury, copper, and zinc"
1-49	Table RISR 1.4-3 Page 1 of 9	"Draft Final Phase I - Introduction to the CARs" replace "Draft" with "RI Program"
1-56	Table RISR 1.4-3 Page 8 of 9	Other Reports "RMA Chemical Index Vol. I, II, and III. Overall Soils Assessment and Groundwater Integration - Proposed Final Report" delete "Overall ... Integration"
1-56	Table RISR 1.4-3 Page 8 of 9	Insert additional citation under Other Reports between "Development and Evaluation..." and "Determination of Partition ..." as follows: "Overall Soils Assessment and Groundwater Integration - Draft Final Report (Version) 2.2 (Date) 9/88 (Task) 23 (RIC Number) 88344R01"
3-5	References: RIC 88344R01, ESE. 1988; September.	"Overall Soils Assessment and Groundwater Integration Determination of Partition Coefficients for the Primary Contaminant Sources of Section 36 Draft Final Report. Version 2.2, Task No. 23." Remove "Determination ... sources of Section 36" and generate additional citation as follows: "RIC 88264R01 ESE. 1988 in September. Determination of Partition Coefficients for the Primary Contaminant Sources of Section 36, Draft Final Report, Version 2.1, Task No. 23."
3-2	References, and A4-1 References for RIC 88306R02	"Final Summary of Results, Structures Survey Report, Vol. I, II, and III, delete "Summary of Results, ..."
A2-50	Section A2.1.4.1	(ESE, 1988h/RIC 88344R01) change to (ESE, 1988k/RIC 88264R01)
A4-3	References: RIC 88344R01, ESE. 1988h, September.	See page 3-5 Errata, and generate additional identical citation as above except "1988k."
Plate RISR 2.0-1		"North Plants Study Area: NPSA-4, Fuze and Detonator Magazine; Site Description: Area around Building 1606..." change to "...Building 1608..."
Plate RISR 2.0-1		"North Central Study Area: NCSA-3, Basin F; Site Description: "... 1957 - 1981" change to "... 1956 - ..."

ERRATA

Page No.	Location	Comments
Plate RISR 2.0-1		"North Central Study Area: NCSA-5, Basin B and Associated Drainage Features; NCSA-5a, Site Description:" . . . 1943 - 1957" change to ". . . 1946 - 1956"
Plate RISR 2.0-1		"North Central Study Area: NCSA-9, Balance of Areas Investigated; NCSA-9p, Site Description: add "copper and zinc"
Plate RISR 2.0-1		"Central Study Area: CSA-1, Landfill/Burial/Burn Sites; CSA-1d, Site Description:" . . . incinerator 634 used . . . " change to " . . . incinerator 834 used. . . "
F1-2	Response to EPA Comment 3: Table	In the column entitled "Method," change every "2" to a "Z".

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APPENDIX A

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LIST OF ABBREVIATIONS

Analyte Groups and Selected Analytes

DBCP	Dibromochloropropane
DCPD	Dicyclopentadiene
DDT	Dichlorodiphenyltrichloroethane
DIMP	Diisopropylmethyl phosphonate
DMMP	Dimethylmethyl phosphonate
GB	Nerve agent Sarin
ICP metals	Metals analyzed for by inductively coupled argon plasma spectroscopy; includes cadmium, chromium, copper, lead, and zinc
OCP	Organochlorine pesticides
UDMH	Unsymmetrical dimethylhydrazine

National Acts and Organizations

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
EPA	U.S. Environmental Protection Agency
NCP	National Contingency Plan
NPL	National Priorities List
SARA	Superfund Amendments and Reauthorization Act
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USFWS	U.S. Fish and Wildlife Service

Local Terminology

CAR	Contamination Assessment Report
CMP	Comprehensive Monitoring Program
EA	Endangerment Assessment
FS	Feasibility Study
FY	Fiscal year
HBSF	Hydrazine blending and storage facility
IRA	Interim Response Action
IRDMIS	Installation Restoration Data Management Information System
JP-4	Aviation fuel
JPX	Jet propellant
OAS	Organizations and State
PEO-PMCD	Program Executive Officer-Program Manager for Chemical Demilitarization
PM-10	Respirable particulates (less than 10 microns)
PMRMA	U.S. Army Program Manager for Rocky Mountain Arsenal
QA	Quality assurance
QC	Quality control

RI	Remedial Investigation
RISR	Remedial Investigation Summary Report
RMA	Rocky Mountain Arsenal
RMACCPMT	Rocky Mountain Arsenal Contamination Control Program Management Team
SAR	Study Area Report
TSP	Total suspended particulates
TX	Crop agent for "wheat rust"
UXO	Unexploded ordnance
VX	Nerve agent

Companies

CF&I	Colorado Fuel and Iron
EBASCO	Ebasco Services Incorporated
ESE	Environmental Sciences and Engineering, Inc.
MKE	Morrison-Knudsen Engineering
Shell	Shell Oil Company

Measurements, Quantities, and Parameters

b.c.y.	Bank cubic yards
ft	Foot, feet
lb	Pound
mm	Millimeters
pH	A measure of acidity or alkalinity
ppb	Parts per billion
ppm	Parts per million
sq mi	Square mile
µg/g	Micrograms per gram (equivalent to parts per million)
µg/kg	Micrograms per kilogram
µg/l	Micrograms per liter

Analytical Methods

GC/MS	Gas chromatography/mass spectrometry
CVAA	Cold vapor atomic absorption

Executive Summary

Remedial Investigation Summary Report

EXECUTIVE SUMMARY

The Remedial Investigation Summary Report (RISR) presents a summary of the program and findings of the U.S. Army's Remedial Investigation (RI) conducted at Rocky Mountain Arsenal (RMA).

A variety of contaminants were released to the environment at RMA during nearly 40 years of military, agricultural, and industrial chemical manufacturing, storage, handling, and disposal activities. In 1984, this 27-square-mile facility became the subject of one of the most complex and challenging remedial investigations in history. The RI included the detailed study of each of the five environmental media at RMA (soils, water, structures, air, and biota) and consisted of historical document searches, personnel interviews, field inspections, sample collection and analysis, and various specialty studies such as soil gas and geophysics surveys, soil/water partitioning studies, aquifer tests, and others.

The investigation included the entire facility, and was coordinated with similar investigation efforts in adjacent off-post areas. During the course of the on-post RI, the following numbers of samples were collected:

Medium	Sampling Locations	Number of Samples
Soils	4,015 bores, 39 nonbore	9,692
Surface Water	27 locations	297
Groundwater	619 wells	1,982
Structures	110 locations	151
Air	13 stations	886
Biota	96 locations	494

Samples were analyzed for as many as 60 target analytes and were screened for thousands of nontarget organic analytes. Volatile and semivolatile organics were analyzed using gas chromatography and gas chromatography/mass spectrometry (GC/MS) techniques, metals by atomic absorption techniques, Army chemical warfare agents by specialized instruments and

techniques, and rocket fuels and breakdown products by high pressure liquid chromatography, GC/MS, and spectrophotometry techniques.

Contaminants were initially introduced into the RMA environment via liquid waste disposal in open basins, solid waste burial in trenches, accidental spills of feedstock and product chemicals, leakage from sewer and process water systems, emissions from permitted air stacks, and use of commercial chemical products during normal facility operation. The RI investigated over 320 locations of suspected contamination and identified 178 contaminated sites at RMA. The bulk of these contaminated sites are in the central sections of RMA, in and around manufacturing complexes, solid waste disposal areas, and liquid waste disposal basins. Other contaminated sites include storage areas, maintenance areas, and sewer lines. Infiltration of contaminated water and liquid wastes from these source areas transported contaminants into subsurface environments including the unsaturated zone and the unconfined flow system. The resultant contaminant plumes are moving towards the north and northwest boundaries of RMA where they are intercepted by boundary containment systems designed to prevent further migration of contaminated groundwater off post. Although local volatilization and eolian mechanisms have introduced contaminants into the air medium, RI data show RMA air quality to be superior to that of nearby urban areas with respect to criteria National Ambient Air Quality Standard (NAAQS) pollutants. Detections of organochlorine pesticides in surficial soils indicate that eolian processes have caused redistribution of contaminants in surficial soils. Elevated concentrations of organochlorine pesticides, arsenic, and mercury detected in biota samples collected in the central portions of RMA indicate that these contaminants have entered the food chain via contaminated soil and water.

All five environmental media listed above were found to be impacted by the contamination. The contaminants of greatest concern included organochlorine pesticides, arsenic, mercury, volatile halogenated organics, volatile aromatic organics, volatile hydrocarbons, semivolatile halogenated organics, dibromochloropropane, and fluoroacetic acid.

This report summarizes the findings of the RI, and serves as a guide to the 216 Contamination Assessment Reports, Phase II Data Addenda, and Data Presentation Reports prepared on a site-by-site basis; the four media reports for water, structures, air, and biota; and the seven Study Area Reports which, on a geographic basis, integrated the soils data with information from the other media reports. The Chemical Index and the Toxicity and Exposure Assessment Reports (not discussed in this report) provide a description of the contaminants, an analysis of the effects of the contaminants on potential human receptors, and an analysis of the likelihood of threats to projected human populations.

By its very nature, this summary report excludes many of the details of the investigative techniques and results; however, together with the reports listed above, this report and its appendices fully document the findings of the RI program at RMA. Included in the appendices are discussions of the environmental setting at RMA and the investigative strategies employed in the RI; presentations of the RI findings regarding the nature and extent of on-post contamination for the various environmental media; results of a database analysis regarding the vertical extent of groundwater contamination; results of special investigations of surficial (0 to 2 inch depth) soils and ground disturbances; a review of the interim response actions (IRAs); and a detailed discussion of contaminant fate and transport, and migration pathways for the groups of target analytes investigated and detected at RMA. The reader is encouraged to explore the appendices to this report, and the more detailed reports described above, and the vast collection of technical reports, agreements, maps, and other documents that form the administrative record for the RMA RI program.

The comments of the organizations and State (the parties), and the responses of the Army, are appended to and constitute an integral part of this report. In order to gain a complete understanding of this document, the reader's attention is directed to these appendices.

Section 1.0

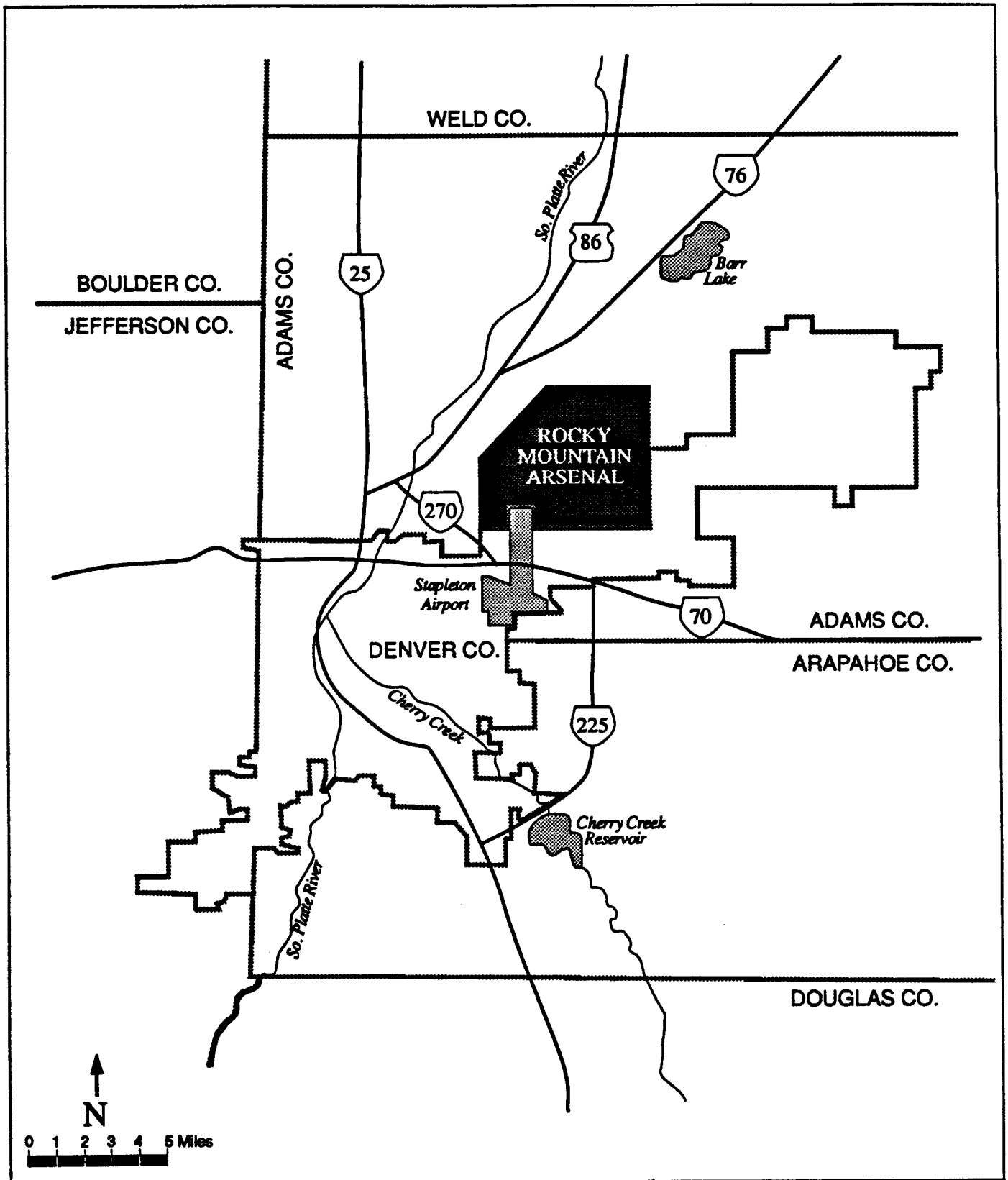
Introduction

Remedial Investigation Summary Report

1.0 INTRODUCTION

The Remedial Investigation Summary Report (RISR) introduces and summarizes the Remedial Investigation (RI) conducted at Rocky Mountain Arsenal (RMA) for the purpose of determining the nature and extent of contamination associated with past activities at the site. RMA is a 27-square-mile (sq mi) U.S. Army facility located northeast of Denver, Colorado (Figure RISR 1.0-1), that was formerly used for the production of munitions, chemical warfare agents, industrial chemicals, and agricultural chemicals. Pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), 42 U.S.C. S9605, RMA in its entirety has been listed on the National Priorities List (NPL) of hazardous waste sites designated for long-term remedial evaluation and response. The RI at RMA was initiated in October 1984 at the direction of the Acting Assistant Secretary of the Army, Installations, and Logistics. The RI is an integral part of the Remedial Investigation/ Feasibility Study (RI/FS) and Remedy Selection Process that has been developed in conformity with the requirements of CERCLA, 42 U.S.C. S9601 et seq., and the National Contingency Plan (NCP) as revised 40 CFR Part 300, for the reduction of actual and potential risks to human health and the environment, both on- and off-post, through the implementation of measures designed to remove or to prevent the further spread of existing contamination.

Results of the RI have been published previously in 124 Contamination Assessment Reports (CARs), 2 Data Presentation Reports, and 90 Phase II Data Addendum Reports prepared for each potential hazardous waste site and for each nonsource area (the balance of each square-mile section on post not considered likely to harbor contaminant sites); 4 media reports, prepared for the water, structures, air, and biota environmental media; and 7 Study Area Reports (SARs), prepared for each geographical study area at RMA, with primary emphasis on the soils/sewers environmental media. In addition, analytical results of the investigative programs conducted during the RI, as well as prior and subsequent to it, are stored and



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

Figure RISR 1.0-1
Location Map
Prepared by: Ebasco Services Incorporated

maintained in the RMA Installation Restoration Data Management and Information System (IRDMIS) database by the Program Manager for RMA (PMRMA).

The RISR is a formal RI Product prepared in accordance with the terms of the proposed Consent Decree in United States v. Shell Oil Company (Shell), Civil Action No. 83-C-2379 (D.Colo) (1988/RIC 88341R01), the Federal Facility Agreement of February 17, 1989 (U.S. Environmental Protection Agency [EPA], U.S. Department of the Army [U.S. Army], U.S. Department of the Interior, and the Agency for Toxic Substances and Disease Registry, 1989/RIC 89068R01), the Settlement Agreement of February 17, 1989 between the United States and Shell concerning the Rocky Mountain Arsenal, (U.S. Army, 1989/RIC 89068R02), the RMA Final Technical Program Plan FY88-FY92 (U.S. Army Program Manager for Rocky Mountain Arsenal [PMRMA], 1988/RIC 88131R01), the June 1985 RI/FS Guidance Document (EPA, 1985/RIC 88341R02), and the October 1988 RI/FS Guidance Document (EPA, 1988) (Figure RISR 1.0-2). The parties participating in or signatories to the Federal Facility Agreement, and the State of Colorado, are jointly referred to as the organizations and State or OAS, throughout the administrative record of the Remedial Investigation/ Endangerment Assessment/Feasibility Study (RI/EA/FS) and in this report. Signatories to the Federal Facility Agreement include the U.S. Army, EPA, U.S. Fish and Wildlife Service (U.S. Dept. of Interior), Agency for Toxic Substances and Disease Registry (U.S. Dept. of Health and Human Services), U.S. Dept. of Justice, and Shell Oil Company. This summary report, and the related documents previously mentioned, collectively fulfill the requirements of defining the nature and extent of contamination and complete a comprehensive RI for the on-post operable unit of RMA as required by CERCLA and the National Contingency Plan.

These documents also provide the site-specific information required as input to the EA and FS. As a summary document, this report cannot and does not provide the level of detail of the CARs, SARs, and media reports. Rather, it provides a broad overview of the RI program and serves as a road map to the more detailed information in other RI documents.

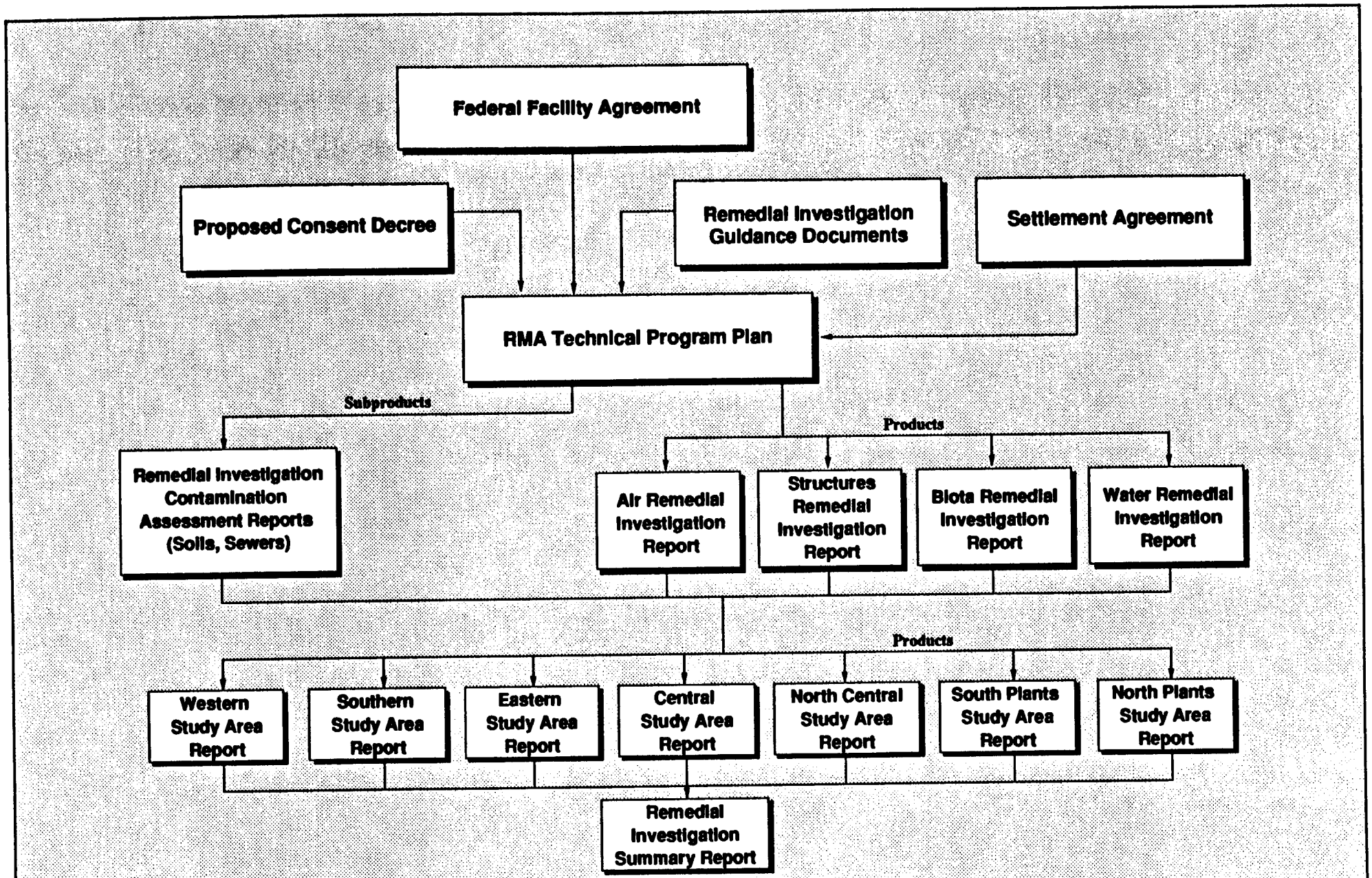


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Figure RISR 1.0-2
Remedial Investigation Products

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1.1 OBJECTIVES

The purpose of the RISR is to summarize the Army's RI program and its findings. The RISR also describes the interrelationships between the contamination conditions and the various environmental media of RMA, and provides a road map to the RI reports that document the contamination at RMA. Appendix A presents background information on the environmental setting; the RI investigative approach, media sampling and analysis programs, and the nature and extent of contamination. Appendices B, C, and D supply information on the vertical extent of groundwater contamination, the interim response actions (IRAs), and the results of the surficial soil and ground disturbance investigations, respectively. Appendix E describes the physical and chemical properties that influence contaminant mobility, environmental fate and transport, and migration pathways.

To help identify the contaminants and develop and implement remedial actions, RMA and the surrounding impacted area are considered as two operable units, the on-post unit and the off-post unit. This report addresses only the on-post operable unit. Separate reports address the off-post operable unit.

1.2 ORGANIZATION

The structure of the RI/FS process at RMA is defined by the Technical Program Plan, which was prepared by PMRMA pursuant to Section 120 of CERCLA and approved by EPA and Shell. The Technical Program Plan conforms with the subsequent Federal Facility Agreement and outlines the manner in which the Army and other parties responsible for the RMA site intend to comply with CERCLA. As required by the Technical Program Plan, information obtained in the RI is presented in 12 designated Product Reports and a number of Subproduct Reports. The 12 RI Products (Table RISR 1.2-1) designated by the Technical Program Plan include four RI media reports (water, air, structures, and biota), seven SARs, and the RISR. RI Subproducts include Phase I CARs and Data Presentation reports and Phase II Data Addendum reports, all of which concern specific contamination sites.

Table RISR 1.2-1. RMA Remedial Investigations and Study Area Reports. Page 1 of 1.

Report	Volume
Remedial Investigation Summary Report	I
Water Remedial Investigation Report	II
Air Remedial Investigation Report	III
Biota Remedial Investigation Report	IV
Structures Survey Report	V
Southern Study Area Report	VI
Eastern Study Area Report	VII
South Plants Study Area Report	VIII
North Plants Study Area Report	IX
Central Study Area Report	X
North Central Study Area Report	XI
Western Study Area Report	XII

Although the RI/FS process at RMA is an iterative and interactive process in which data and information developed under the RI, EA, and FS are freely exchanged, it is also a concurrent and sequential progression of activities, as shown in Figure RISR 1.2-1. The RI was separated into discrete media-oriented tasks that addressed individual contamination issues because of the complex, interactive nature of the environmental media. The internal structural subdivision of the RI into specific tasks was necessary to ensure that multiple undertakings necessary for the comprehensive investigations of this highly complex site were coordinated and accomplished both expeditiously and economically within the overall scope of the program. An awareness of the RI task subdivisions helps to facilitate an understanding of the components comprising the RI for RMA.

Subproduct Reports were prepared for specific site and nonsource area investigations as data were received and evaluated in order to identify significant aspects of the emerging findings, focus additional studies, and facilitate the interactive nature of the overall process. Figure RISR 1.2-2 summarizes the RI tasks and identifies the various Products and Subproducts to which these activities contributed data. Product Reports incorporated and synthesized data presented elsewhere with other task findings as appropriate.

Prior to the initiation of field work, technical plans were prepared by PMRMA and reviewed by the organizations and State. Each technical plan commonly cross-references universal investigation methods (i.e., sampling techniques and health and safety plans) and should be consulted for investigative rationale and the approach specific to each task. The Technical Program Plan provides a more detailed discussion of the media investigative approach. It also highlights more specific information about the organization and scope of the RI/EA/FS process at RMA.

Aside from this summary report, the on-post RI Product Reports are of two types: RI media reports and SARs. The media approach to the RI was chosen to address the unique data collection needs of the various media and to most efficiently provide information to the FS.

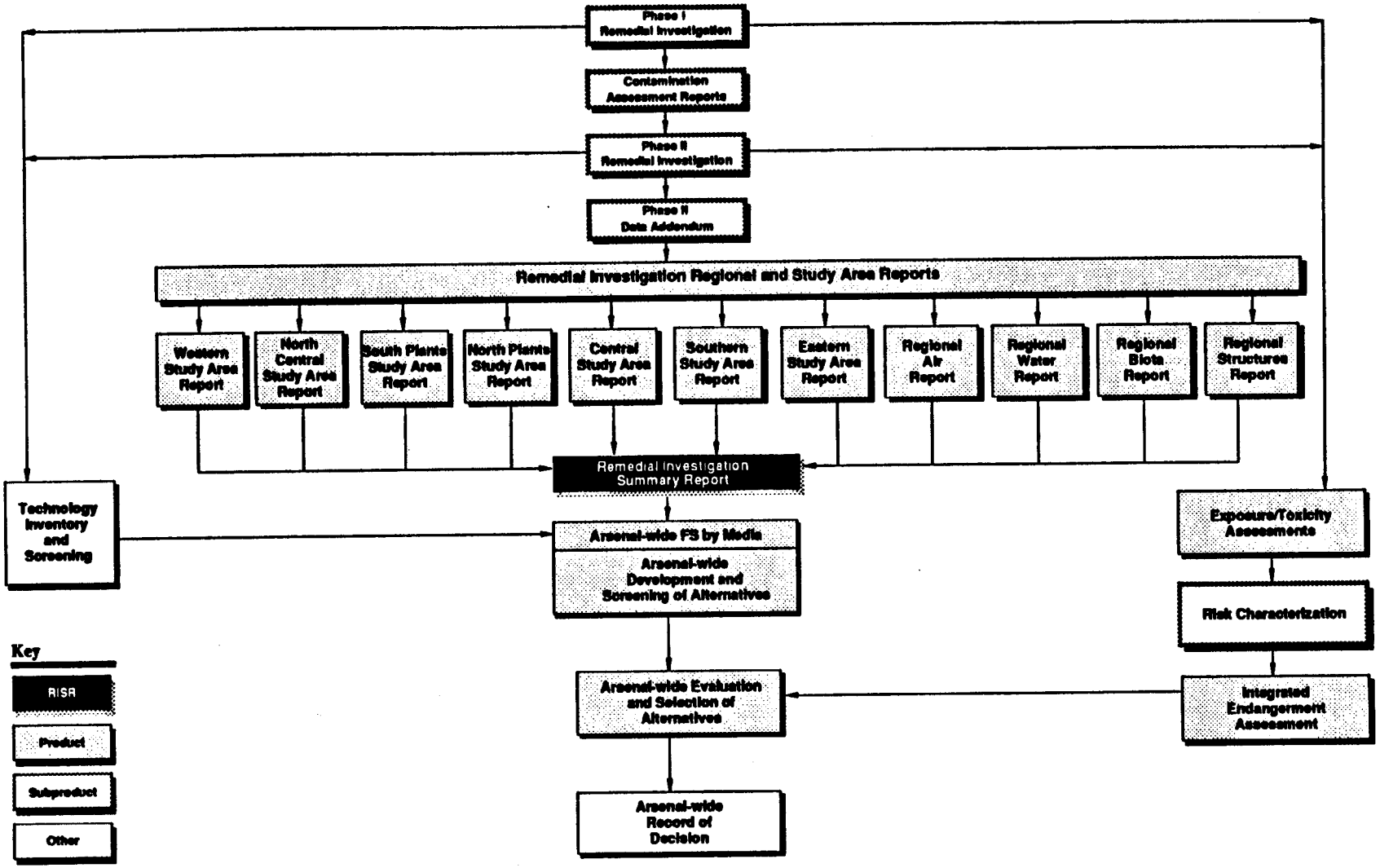

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Figure RISR 1.2-1
Rocky Mountain Arsenal RI/EA/FS Process Flow Diagram

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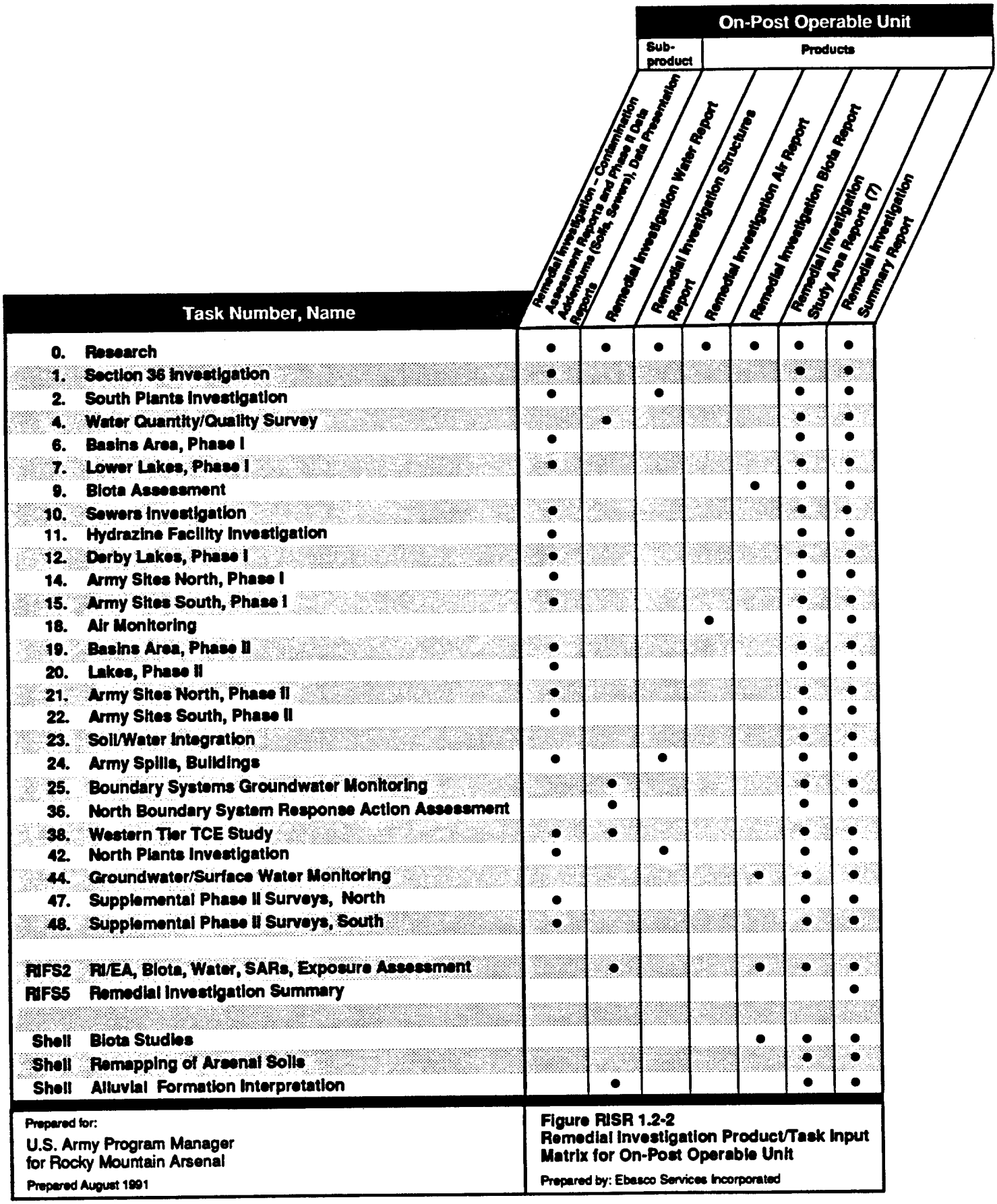

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Figure RISR 1.2-2
Remedial Investigation Product/Task Input Matrix for On-Post Operable Unit
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Five environmental media have been identified at RMA, soils/sewers, water, structures, air, and biota. The four RI media reports address the water, air, structures, and biota media on an RMA-wide basis. The water, air, and biota media are treated as separate RI entities as these media do not represent original sources of contamination; rather, they are migration pathways and receptors of contamination. Structures (buildings, tanks, tank farms, sumps, etc.) are treated as a separate medium because they possess a unique character as centers that once housed chemical and waste generation, handling, and/or storage processes. Soils and sewers were considered to be so intimately linked that they are treated as a single medium. The soils/sewers medium is the primary repository of solid wastes disposed at RMA, and is typically the first medium into which wastes are introduced by accidental spills, leaks, or seepage. Soils/sewers are commonly the primary source for secondary releases into the other environmental media by way of available migration pathways. The soils/sewers medium is addressed in multiple CARs (RI Subproducts) due to its complex and varied nature.

The soils/sewers medium was divided into distinct sites for investigation based on the 1984 report, Decontamination Assessment of Land and Facilities at Rocky Mountain Arsenal, prepared by the Rocky Mountain Arsenal Contamination Control Program Management Team (RMACCPMT, 1984/RIC 84034R01). The map accompanying that report, commonly referred to as the "Tricolor Map," depicts the entire facility, using three colors to represent the likelihood of contamination at each site. Potential or suspected contamination sites were identified through historical information, and preliminary site designations were assigned as the basis for the Phase I RI. As field and historical studies progressed in the RI, several additional sites were added, modified, or determined to more appropriately belong in nonsource areas. All portions of RMA were investigated, including those that had no documented history of contamination. The revised site lists (Table RISR 1.2-2) and boundaries are presented in the SARs and are based on the overall assessment of all RI data.

Site Designation	RMACCPMT Site Number(s)	Site Description
Basins, Lagoons		
SPSA-1c, Lime Pits	1-5	Lime pits used for lime slurries and limited chemical disposal
SPSA-1e, Buried M-1 Pits	1-13	Buried M-1 pits that received neutralized waste streams from lewisite production and related activities.
SPSA-7b, Lagoon	2-3	Topographic depression that collected surface runoff
SPSA-12a, Aeration Basin	2-7	Aeration basin used to cool and recirculate process water from the power plant condenser and turbine
SPSA-12b, Sedimentation Pond	SPRS	Sedimentation pond used to settle particulate matter from cooling tower blowdown water
NCSA-1a, Basin A	36-1	Basin A; received South and North Plants aqueous wastes
NCSA-1b, Lime Settling Basins Area	36-4, 36-5, 36-10	Lime settling basins area; primary repository for South Plants aqueous wastes; acetylene production waste disposal
NCSA-1d, Liquid Storage Pool	36-11	Liquid storage pool that received runoff from South Plants
NCSA-2a, Basin C	26-3	Basin C; primary repository for Basin B overflow, 1954-57
NCSA-2b, Basin D	26-4	Basin D; received Basin B overflow, 1943-54 and Basin C overflow, 1954-57
NCSA-2e, Basin E	26-5	Basin E; received Basin D overflow, 1954-57
NCSA-3, Basin F	26-6	Basin F; primary repository for North and South Plants aqueous wastes, 1957-81
NCSA-5a, Basin B	35-3	Basin B; received Basin A overflow, 1943-57
NCSA-9s, Isolated Detection	36-22	Localized area of mercury detections
Ditches, Lakes, Ponds		
SSA-1a, East Upper Derby	6-2	Eastern Upper Derby Lake, received overflow process water from Upper Derby Lake
SSA-1b, Upper Derby	1-2	Upper Derby Lake; formerly part of process water return system
SSA-1c, Lower Derby	1-2	Lower Derby Lake; formerly part of process water return system
SSA-1d, Rod and Gun Club	12-2	Rod and Gun Club Pond; depression receiving overflow from Lower Derby Lake
SSA-1e, Lake Ladora	2-17	Lake Ladora; formerly part of process water return system
SSA-1f, Lake Mary	2-17	Lake Mary; used for recreational purposes
SSA-2a, Process Water Ditch System	1-1	Process water ditch system used as a conduit for cooling waters from the South Plants
SSA-2b, Sand Creek Lateral	2-1	Sand Creek Lateral; receives drainage from South Plants and off-post sources
SSA-2c, Overflow Basin and Ditch	3-2, 3-3	Overflow basin and ditch that receive overflow from Lake Mary and Lake Ladora
SSA-5b, Havana/Peoria St. Ponds	11-UNC	Havana/Peoria Streets ponds and ditches; receive runoff from off-post areas south of RMA
SSA-5e, Uvalda Ditch	11-UNC	Uvalda Ditch; carries runoff from off-post areas south of RMA
ESA-3h, Open Storage Area Ditch	31-7	Open storage area ditch; reported agent migration from ESA-3g
ESA-3i, Toxic Storage Plots Ditch	31-7	Toxic storage plots ditch; reported agent migration from Toxic Storage Yard Plots
ESA-6c, Ditch from North Plants	30-UNC, 25-UNC	Isolated detection of arsenic in ditch
SPSA-1d, Drainage Ditches	1-1	Drainage ditches that carried surface runoff and process water from the Processing Area (SPSA-1a)

Site Designation	RMACCPMT Site Number(s)	Site Description
SPSA-2d, Drainage Ditches	1-1, 1-8, PWS	Drainage ditches that carried surface water runoff and process water from the Processing Area (SPSA-1a)
SPSA-3a, Drainage Ditches	2-1	Drainage ditches used to carry surface runoff away from the chlorine plant area
SPSA-4a, Drainage Ditches	2-1, SPRS	Drainage ditches used to carry surface runoff and process water
SPSA-5a, Drainage Ditches	*	Drainage ditch used to carry surface runoff and process water
SPSA-7a, Drainage Ditches	2-1	Drainage ditches used to carry surface runoff
SPSA-8b, Drainage Ditches	2-1, 1-UNC	Drainage ditches used to carry surface runoff and process water
SPSA-9a, Drainage Ditches	1-1	Drainage ditches used to carry surface runoff and process water
NPSA-8a, Miscellaneous Drainages	25-UNC	Surface drainage features known or inferred to contain contaminants
NPSA-8b, Miscellaneous Drainages	25-UNC	Surface drainage features known or inferred to contain contaminants
NPSA-8c, Miscellaneous Drainages	25-UNC	Surface drainage features known or inferred to contain contaminants
NCSA-1c, Basin A to Basin B Ditch	36-7, 36-8	Drainage ditch used to transport liquid waste from Basin A to Basin B
NCSA-1f, South Plants Drainage Ditches	36-8	South Plants drainage ditches that currently receive runoff from South Plants; continues into Section 35 as NCSA-5d
NCSA-2d, Basin B to Basin C Ditch	26-3, 26-5, 26-UNC, 35-4	Pre-RMA drainage ditches; transported wastes from Basin B to D, 1943-54; from Basin B to C, present
NCSA-5b, Drainage Ditches	35-4, 26-7	Miscellaneous drainage ditches between Basins A, B, D, and D
NCSA-5c, Sand Creek Lateral	35-UNC	Sand Creek Lateral; transported South Plants wastewaters to First Creek; Basin B overflow to Basin C
NCSA-5d, Surface Drainage Canal	35-UNC	Surface drainage canal dug in 1975 to channel South Plants runoff away from Basin A; continues into Section 36 as NCSA-1f
NCSA-7, North Bog	24-7	North Bog occasionally used as a recharge basin for the NBCS before 1983; in continuous use from 1983 to present
NCSA-8b, Sewage Treatment Plant	24-6	Domestic sewage treatment plant area
WSA-6a, Drainage Ditch	4-6	Drainage ditch receiving motor pool area runoff
WSA-6d Drainage Area	4-6	Drainage area for Buildings 624 and 631
WSA-6e, Culvert Outfall	4-6	Culvert outfall from south motor pool area
Ordnance Testing and Disposal		
ESA-1a, Section 19 Surface Burn	19-1	Surface burn determined by analytical data and visible boundary of surface slag
ESA-1b, Section 20 Surface Burn	20-1	Surface burn determined by analytical data and visible boundary of surface slag
ESA-1c, Section 29 Surface Burn	29-1	Surface burn determined by analytical data and visible boundary of surface slag
ESA-1d Section 30 Surface Burn	30-2	Surface burn determined by analytical data and visible boundary of surface slag
ESA-2a, Section 32 Burn Pits	32-5	Burn pits used to incinerate munitions and incendiary devices, numbered 1-7
ESA-2c, Open Trenches	30-6	Open trenches used for disposal of ammunition and empty shells

Site Designation	RMACCPMT Site Number(s)	Site Description
ESA-4a, Impact Area	30-1	Impact area with possible remnant unexploded ordnance
ESA-4b, Demolition Area	29-4	Bermed demolition area used for detonating explosives
ESA-4c, Trench and Mound	28-4	Trench and mound with unknown use, scattered metal and wood debris
CSA-2a, Munitions Testing Area	36-2	Area including buildings 725, 726, NN3603, NN3604, and NN3605 used for testing various munitions
CSA-2c, Munitions Test Site	36-6/25-17	Incendiary munitions test site active from 1943-50
CSA-2d, Incinerator NN3601	36-7	Inferred contamination from incinerator NN3601 used from 1969-70 for mine destruction
Solid Waste Burial		
SSA-3a, Ladora Lake Sediments	11-1	Buried sediments dredged from Lake Ladora in 1964-65
SSA-3b, Derby Lakes Sediments	12-1	Buried sediments dredged from Upper and Lower Derby Lakes in 1964-65
ESA-2b, Sanitary Landfill	30-4	Sanitary landfill used for disposal of on-post sanitary wastes
ESA-3k, Suspected Trash Pit	*	Trash pit, reported trash disposal area south of Plot 8
SPSA-1f, Buried Hex Pit	1-13	Buried barrels containing residue from the production of hexachlorocyclopentadiene
SPSA-8a, Sanitary Landfill	2-14	Sanitary landfill used for disposal of domestic solid wastes
CSA-1a, Pesticide Pits	36-3	Pesticide pits used for pesticide waste disposal from 1952-65
CSA-1b, Complex Disposal Area(S)	36-17, 36-16	Complex disposal area (south) used contaminated waste storage and disposal
CSA-1c, Complex Disposal Area (N)	36-17, 36-16	Complex disposal (north) used for burning of waste and contaminated equipment, and for munitions destruction
CSA-1d, Sanitary Landfill and Incinerator 634	36-7	Sanitary landfill and Incinerator 634 used for burning and burial of rubbish in trenches
NCSA-1e, Burn Site	36-15	Burn site for miscellaneous trash from South Plants operations
WSA-2, West Landfill	4-2	Landfill trenches used for disposal and burning of potentially contaminated wastes
WSA-3b, Disposal Pit	4-3	Disposal pit
WSA-3c, Surface Disposal Area	4-3	Main surface disposal area
WSA-5a, Inferred Trench	4-5	Inferred landfill trench indicated by magnetometer survey
WSA-5b, Burn Pit	4-5	Burn pit
WSA-5c, Inferred Trench	4-5	Inferred landfill trench indicated by air photo
WSA-5d, Trenches	4-5	Landfill trenches
Storage Sites, Buildings, Equipment		
SSA-4, Trash Dump	1-12	Former trash dump used for surface disposal of miscellaneous debris
ESA-3a, Section 5 Storage Yard	5-2	Storage yard used for agent-filled bombs
ESA-3b, Section 6 Old Storage Yard	6-6	Old toxic storage yard used for storage of agent-filled bombs and toxic gas containers
ESA-3c, Section 31 New Storage Yard	31-4	New toxic storage yard used for storage of incendiary and agent-filled bombs

Site Designation	RMACCPMT Site Number(s)	Site Description
ESA-3d, Section 31 Toxic Yard Plots	31-6, 31-7	Toxic yard plots used for storage of incendiary and agent-filled bombs
ESA-3e, VX Demilitarization Pad	31-4	Concrete VX demilitarization pad
ESA-5, Demilitarization Activity	30-5	Area around buildings used for GB-bomb fuze
ESA-6a, Stored Ton Containers	6-UNC	Isolated detections of chromium, copper, lead, and zinc near ton container storage area
SPSA-1a, Processing Area	1-13, SPRS, SSS, AMSS	Army agents and Shell pesticides processing area
SPSA-1b, Mounded Material	1-3	Location of historic mounds of unknown materials
SPSA-2a, South Tank Farm	1-10	South tank farm area surrounding eleven 200,000 to 400,000 gallon chemical storage tanks
SPSA-2b, Open Storage Area	1-9	Open storage area used to store chemicals in barrels and tanks
SPSA-2c, Salvage Yard	1-8	Salvage yard used to store tanks, barrels, and equipment
SPSA-3b, Salt Storage Pad	2-6	Concrete salt storage pad used to store GB brine, pesticide and mustard wastes, contaminated dirt-debris
SPSA-3c, Former Tank Storage Area	2-8	Former tank storage area used for the storage and treatment of brine, crude caustic, and chlorine
SPSA-3d, Revetted Tank Storage	2-12	Revetted tank storage area used to store diesel fuel and fuel oil
SPSA-6, Hydrazine Area	1-7	Hydrazine rocket fuel blending and storage facility
NPSA-2, Tank Farm	25-3	Area surrounding Tank Farm 1403 and associated under- and above-ground piping
NPSA-3, GB Manufacturing Area	25-2, 25-4, 25-5, 25-6, 25-7, 25-9	Areas surrounding GB manufacturing Buildings 1501, 1503, 1504, 1506, 1602, and 1603
NPSA-4, Fuze and detonator Magazine	25-2	Area around Building 1606 fuze and detonator magazine and downgradient surface drainage
NPSA-5, Special Weapons Plant	25-2	Area surrounding Special Weapons Plant Building 1611
CSA-2b, Parking Lot/Scrap Storage	36-23	Parking lot used for storage of metal scrap and debris from Section 36 recovery operations
WSA-4b, Storage Area	4-4	Main storage area used as support for salvage yard operations
WSA-6b, Fuel Storage Area	4-6	Area surrounding fuel storage tanks
WSA-6c, Building 631 Area	4-6	Roundhouse (Building 631) area and old septic tank system
Spill Sites		
ESA-3f, Rail Loading Area	31-4	Rail spur and loading dock; reported agent spill
ESA-3g, Open Storage Area	31-7	Open drum storage area; reported agent spill
NPSA-6, Underground Spill Area	25-2, 25-14, 25-15	Underground diesel fuel spill area around Buildings 1703 and 1727
NPSA-7, Oil Spill Area	25-2, 25-15	Surface diesel fuel spill area around Building 1705
NPSA-9a, Isolated Detection	25-UNC	Isolated detections of benzene and several polynuclear aromatic compounds along railroad tracks
NPSA-9d, Isolated Detection	25-UNC	Isolated detections of benzene and zinc
NPSA-9e, Isolated Detection	25-UNC	Isolated detections of 2-butoxyethanol along railroad tracks
NCSA-8c, Lift Station No. 2	34-UNC	Isolated detection of mercury in overflow basin at Lift Station No. 2
WSA-1a, Isolated Detection	3-UNC	Isolated detection of pyrene or fluoranthene
WSA-1b, Isolated Spill	3-4	Isolated spill and wood preservative derivative along railroad tracks

Site Designation	RMACCPMT Site Number(s)	Site Description
WSA-1c, Wood Preservatives	3-UNC	Wood preservative derivative along railroad tracks
WSA-1d, Isolated Detection	3-4	Isolated detection of zinc
WSA-1e, DBCP Spill Area	3-4	Dibromochloropropane (DBCP) spill area
WSA-7b, Sanitary Sewer Overflow	34-2	Sanitary sewer overflow area
Sewer Systems		
SPSA-10, Chemical Sewer System	1-13/2-18	Chemical sewer system that carried aqueous wastes from the process facilities in the SPSA to Basins A and F
SPSA-11, Sanitary Sewer System	1-13/2-18	Sanitary sewer system that carried domestic sewage from buildings in the SPSA to the Sewage Treatment Plant
SPSA-12, Process Water Lines		Lines distributing water to the process facilities and returning water to the lakes
NPSA-1, Chemical Sewer System	25-3	System that carried industrial aqueous wastes from North Plants complex to Basins A and F
CSA-3, Chemical Sewer	36-20	Chemical sewer system that carried North Plants aqueous wastes to Basins A and F
NCSA-4a, Deep Disposal Well Facility	26-1	Deep disposal well facility used to inject Basin F fluid to deep bedrock, 1962-66
NCSA-6a, South Plants Chemical Sewer	35-2/26-9	Chemical sewer system that carried South Plants aqueous waste to Basin F
NCSA-6b, North Plants Chemical Sewer	MKE Chemical Sewer	Chemical sewer system that carried North Plants aqueous waste to Basin F
NCSA-8a, Sanitary Sewer Lines	24-5, 25-2, 26-8, 35-1	Sanitary sewer lines that carried domestic sewage to the Sewage Treatment Plant
WSA-7a, Sanitary Sewer Sediment	34-2	Sanitary sewer internal sediment
Windblown Contamination		
SPSA-1g, Balance of Subarea	1-5, 1-UNC, SPRS, AMSS, 1-13	Locations of known or inferred contaminants attributed to wind/surface water transport
SPSA-2e, Balance of Subarea	1-UNC, 1-3	Locations of known or inferred contaminants attributed to wind/surface water transport
SPSA-3c, Balance of Subarea	2-18	Locations of known or inferred contaminants attributed to wind/surface water transport
SPSA-4b, Balance of Subarea	2-1, 2-18	Locations of known or inferred contaminants attributed to wind/surface water transport
SPSA-5b, Balance of Subarea	1-11, 1-UNC, SPRS, AMSS	Locations of known or inferred contaminants attributed to wind/surface water transport
SPSA-7c, Balance of Subarea	2-2, 2-4, 2-13, 2-14b, 2-UNC	Locations of known or inferred contaminants attributed to wind/surface water transport
SPSA-8c, Balance of Subarea	2-UNC	Locations of known or inferred contaminants attributed to wind/surface water transport
SPSA-9b, Balance of Subarea	1-UNC	Locations of known or inferred contaminants attributed to wind/surface water transport
CSA-4, Balance of Areas Investigated	36-2, 36-12, 36-19, 36-UNC	Shallow, low-level OCP contamination attributed to wind dispersion from nearby sites

Site Designation	RMACCPMT Site Number(s)	Site Description
NCSA-1g, Inferred Wind Dispersion	36-5	Inferred surficial contamination attributed to wind dispersion
NCSA-4b, Basin F Exterior	26-6	Basin F exterior area attributed to wind dispersion of contaminants from Basin F
Isolated Contamination		
SSA-5a, Isolated Detection	1-UNC	Isolated detection of dibromochloropropane (DBCP)
SSA-5c, Isolated Detection	12-UNC	Isolated detection of lead
SSA-5d, Isolated Detection	12-UNC	Isolated detection of lead
ESA-3j, Toxic Storage Yard Fence	31-7	Toxic storage yard fence; reported pesticide spraying around fence
ESA-6b, Trench	30-1	Isolated detection of fluoroacetic acid in trench
ESA-6d, Isolated Detection	20-UNC	Isolated detection of hexachlorobenzene not associated with any identifiable feature
NPSA-9b, Isolated Detection	25-UNC	Isolated detection chromium
NPSA-9c, Isolated Detection	25-UNC	Isolated detection zinc
NPSA-9f, Isolated Detection	25-UNC	Isolated detection arsenic
NCSA-9a, Isolated Detection	23-UNC	Localized area of diisopropylmethyl phosphonate
NCSA-9b, Isolated Detection	23-UNC	Isolated detection of cadmium
NCSA-9c, Isolated Detection	23-UNC	Isolated detection of cadmium
NCSA-9d, Isolated Detection	23-UNC	Isolated detection of cadmium
NCSA-9e, Isolated Detection	24-UNC	Isolated detection of zinc
NCSA-9f, Isolated Detection	25-UNC	Isolated detection of zinc and copper
NCSA-9g, Isolated Detection	26-UNC	Isolated detection methylene chloride
NCSA-9h, Isolated Detection	26-UNC	Isolated detection cadmium
NCSA-9i, Isolated Detection	26-UNC	Isolated detection butoxyethanol
NCSA-9j, Isolated Detection	26-UNC	Isolated detection of mercury
NCSA-9k, Isolated Detection	26-UNC	Isolated detection trichloropropene
NCSA-9l, Isolated Detection	27-UNC	Isolated detection of arsenic
NCSA-9m, Isolated Detection	35-6	Isolated detection of zinc in a bedrock sample
NCSA-9n, Isolated Detection	35-UNC	Isolated detection trichloropropene
NCSA-9o, Isolated Detection	35-UNC	Isolated detection of arsenic
NCSA-9p, Isolated Detection	36-7	Isolated detection of arsenic and mercury
NCSA-9q, Isolated Detection	36-10	Isolated detection of mercury
NCSA-9r, Isolated Detection	36-10	Isolated detection of cadmium
WSA-1f, Isolated Detection	3-4	Isolated detection of aldrin and dieldrin
WSA-1g, Isolated Detection	3-4	Isolated detection of mercury
WSA-3a, Isolated Detection	4-3	Isolated detections of toluene, trichloropropene, and cadmium
WSA-3d, Isolated Detection	4-3	Isolated detection of methylisobutyl ketone
WSA-4a, Isolated Detection	4-4	Isolated detection of methyl cyclohexane

Table RISR 1.2-2. Sites Identified During the RI by FS Site Type

Site Designation	RMACCPMT Site Number(s)	Site Description
WSA-8a, Isolated Detection	33-UNC	Isolated detection of copper
WSA-8b, Isolated Detection	33-UNC	Isolated detection of zinc
WSA-8c, Isolated Detection	4-UNC	Isolated detection of 1,1,2,2-tetrachloroethane in salvage yard
WSA-8d, Isolated Detection	3-UNC	Isolated detection of phosphoric acid, tributyl ester
WSA-8e, Isolated Detection	3-UNC	Isolated detection of phosphoric acid, tributyl ester
WSA-8f, Isolated Detection	9-UNC	Isolated detection of methyl naphthalene

AMSS = Army Spill Sites
PWS = Process Water System
RMACCPMT = Rocky Mountain Arsenal Contamination Control Program Managers Team
SPRS = South Plants Regional Study
SSS = Shell Spill Sites
UNC = Nonsource area of numbered section, formerly referred to as uncontaminated area.
* = Includes nonsource areas not investigated as potential contamination sites in RMACCPMT (1984)

The on-post operable unit was subdivided into seven separate study areas for the purpose of the RI because of the size, geographic diversity, and varied land use history of RMA. The seven study areas include the following (Figure RISR 1.2-3):

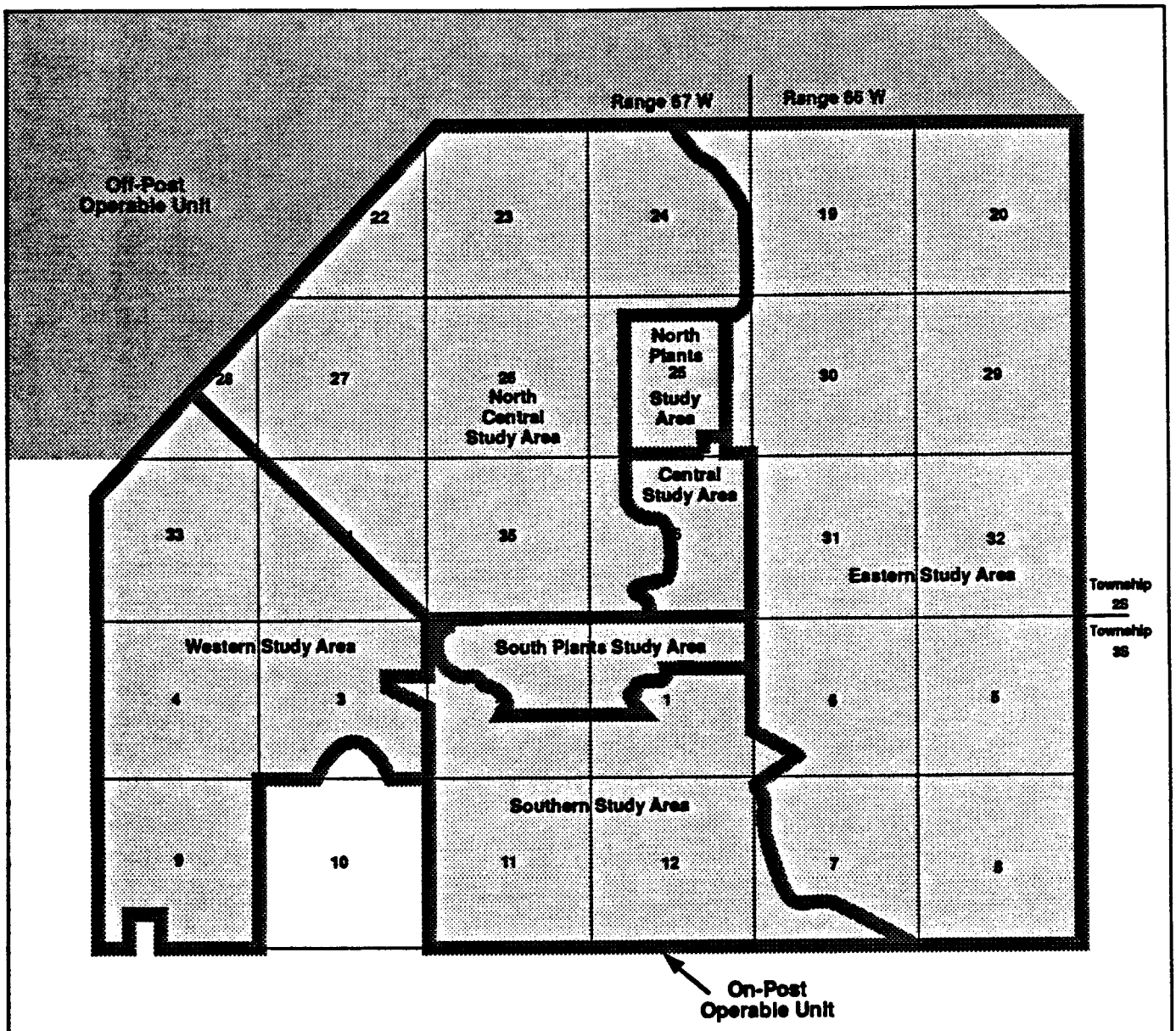
- Southern Study Area
- Eastern Study Area
- South Plants Study Area
- North Plants Study Area
- Central Study Area
- North Central Study Area
- Western Study Area.

For each study area, a SAR was compiled from the RI media reports and from the pertinent CARs.

As part of the RI process, a system of review and comment was provided to the organizations and State to allow input into the RI and subsequent FS. The review and comment process is described in detail in the Technical Program Plan and the Federal Facility Agreement. In all phases of the program, comments by the organizations and State have been considered. Modifications to the RI have been made in many areas to address both specific and general concerns of the organizations and State, including comments on the RI approach in the guidance documents and technical plans, as well as reports presenting results and conclusions regarding the assessment of contamination. In both Product and Subproduct Reports, responses to comments comprise an integral part of the total document and should be consulted for a complete perspective on the contamination assessment at RMA.

1.3 HISTORY

The history of RMA was originally researched as part of the RI in order to determine potential contaminants, possible quantities and modes of occurrence, probable areas of contamination, and potential pathways of contaminant migration (e.g., ditches, abandoned



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

Figure RISR 1.2-3
On-Post Operable Unit and Study Areas
Prepared by: Ebasco Services Incorporated

wells, sewers, air, etc.). An accurate history of RMA was a prerequisite to developing an appropriate analytical strategy to determine the actual nature and extent of contamination. Sources of historical information included facility engineering drawings, operating records, historical aerial photographs, and personal interviews (depositions). Historical details pertinent to individual sites, nonsource areas, and media are documented in individual CARs, SARs, and RI media reports. RMA history is summarized here for the purpose of explaining the activities and events leading up to the RI and how they contributed to the documented contamination of RMA.

A discussion of World War II and post-World War II military operations is presented first. This is followed by a discussion of post-World War II industrial operations and the resultant contamination of the lakes region south of South Plants. Finally, waste disposal operations are discussed, including a brief history of environmental investigations, control, and litigation.

1.3.1 Military Operations

The U.S. Army established RMA in 1942 to manufacture chemical warfare agents and agent-filled munitions and to produce incendiary munitions for use in World War II. Initial facility building activities included construction of the South Plants manufacturing complex, extension of the Union Pacific and Chicago and Burlington and Quincy railway systems onto RMA, construction of a railway classification yard and service and maintenance facilities in Sections 3 and 4, modifications to preexisting irrigation reservoirs (Lake Ladora, Lower Derby Lake) and construction of a new reservoir (Upper Derby Lake) to supply the South Plants complex with process cooling water, and construction of three seepage ponds in a large earthen depression in Section 36 (which eventually overflowed to form Basin A for the disposal of liquid industrial wastes). A map of the RMA cultural features is presented as Plate RISR 1.3-1. Prior to this date the area was largely undeveloped ranch and farm land.

From December 31, 1942, to May 28, 1943, the Army manufactured the chemical warfare agent Levinstein Mustard (dichloroethyl sulfide) in the South Plants area. Lewisite

(chlorovinyldichloroarsine) was manufactured only between April and November 1943. When lewisite production ended in November 1943, virtually all finished product lewisite was transferred from RMA to the U.S. Army Arsenal at Pine Bluff, Arkansas. In late 1944 or early 1945, the Army developed a water wash/distillation process to remove various impurities in finished product Levinstein (or "crude") Mustard. With the passage of time, these impurities caused the agent to deteriorate, whether the agent was in storage or in filled munitions. Between July 5, 1945, and November 1, 1946, the Army purified all existing stockpiles of Levinstein Mustard at RMA using the water wash/distillation method. Mustard- and lewisite-filled munitions, as well as bulk mustard and lewisite in 55-gallon drums and 1-ton containers, were stored in toxic storage yards in Sections 5, 6, and 31. These compounds are classified as vesicant or blister agents due to the severe blistering they cause upon contact with human tissues, especially the skin, eyes, and upper respiratory tract. In addition, lewisite contains arsenic, which exerts a systemic poisoning effect (Prentiss, 1937). Acetylene, chlorine/caustic, sulfur monochloride, sulfur dichloride, arsenic trichloride, and thionyl chloride were produced as feedstock chemicals for manufacture of these agents. Phosgene, although not manufactured at RMA, was shipped to RMA, stored in RMA's toxic storage yards, and loaded into 500- and 1,000-pound (lb) bombs (EBASCO, 1989e/RIC 89166R04; EBASCO, 1988d/RIC 88306R02). Phosgene gas (carbonyl chloride) is a lung-injurant agent that corrodes lung tissue, leading to pulmonary edema and, often, death (Prentiss, 1937).

Incendiary munitions were produced at RMA both during and after World War II. Five types of incendiary bombs were either filled or produced at RMA from 1942 to 1946. The 100-lb M-47 bomb was filled with a napalm gel that was produced at RMA. The 10-lb M-74 bomblet was filled with a pyrotechnic incendiary mixture, not produced at RMA, that was composed primarily of magnesium dust, sodium nitrate, and gasoline. The bomblets were subsequently assembled into 500-lb cluster bombs. Other bomblets, cluster bombs, and fire bomb igniters were filled with white phosphorus, which was also shipped to RMA (EBASCO, 1988d/RIC 88306R02). Once filled, incendiary and cluster bombs were stored both in open

storage areas and in storage bunkers in Sections 5, 6, 7, and 8, east and southeast of South Plants (EBASCO, 1989c/RIC 89166R02). Typically, when munitions were shipped off post, they were transported from storage areas to the railyard west of South Plants in Sections 3 and 4.

Military activities continued at the South Plants after the end of World War II, but parts of the South Plants complex were leased out to private industry. Existing stocks of Levinstein Mustard were distilled until November 1946. At various times between 1946 and 1966, the Army used buildings it had not leased in the South Plants to demilitarize munitions containing mustard and cyanogen chloride and to recondition 1-ton containers that had stored mustard, phosgene, and lewisite. From 1953 to 1955, the Army filled 105-millimeter (mm) shells and 4.2-inch mortars with distilled mustard, and from 1952 to 1954, intermittently renovated mustard-filled bombs. The Army manufactured approximately 1,700,000 10-lb M-74 bomblets at RMA. Stockpiles of 10-lb bomblets, 6-lb bomblets, and 4-lb bomblets were routinely tested in a munitions testing facility in Section 36. In 1951, during the Korean conflict, the Army reworked approximately 36,000 incendiary bomb clusters and proof-tested them on a weekly basis. In 1952 and 1955, approximately 785,000 white phosphorus grenades were filled and proof-tested. During the Vietnam conflict, the Army manufactured various antipersonnel devices including approximately 1,270,000 white phosphorus grenades, 7,760,000 button bombs, 12,200,000 microgravel units, and 7,000,000 experimental sandwich button bombs (EBASCO, 1989e/RIC 89166R04).

During the 1950s and into the 1960s, obsolete and deteriorating World War II ordnance were demilitarized at RMA by either draining and neutralizing the contents and burning the remains, or by controlled detonation or open burning. From 1957 to 1959, four areas in Sections 19, 20, 29, and 30 were used for surface detonation and burning of more than 22,000 500-lb incendiary bombs. Two open trenches in Section 30 were used for disposal of white phosphorus-filled grenades and demilitarized artillery shells; however, these trenches were routinely excavated and emptied. In 1953 and 1954, more than 86,000 white phosphorus-

filled incendiary bombs were demilitarized by burning in seven open pits in Section 32. Boxed bombs were dumped into the pits and ignited, causing the bombs to detonate. Each pit was reportedly allowed to cool for at least one day prior to being refilled for another burn. Other materials incinerated in the Section 32 pits during the 1950s and 1960s include: 500- and 1,000-lb cluster bombs containing magnesium, white phosphorus, and black powder; incendiary bombs; incendiary bomb clusters; rocket motors containing solid propellants; and other incendiary munitions including napalm bombs (EBASCO, 1989c/RIC 89166R02).

From 1950 to 1952, the Army designed and constructed the North Plants complex in Section 25 to manufacture the nerve agent GB, also called Sarin (isopropylmethyl phosphonofluoridate). Nerve agents, including GB, are probably the most potent of chemical warfare agents as exposure may result in almost immediate disruption of nerve function and death (PEO-PMCD, 1988). GB was manufactured in the North Plants from 1953 to 1957, and filled into munitions shortly after its manufacture was initiated in 1953 to 1969 on an intermittent basis. GB was redistilled from 1964 to 1970. GB munitions were demilitarized in the early 1970s. One-ton containers of bulk GB, bulk VX nerve agent, GB-filled bomb clusters, and GB-filled Weteye bombs were stored in toxic storage yards in Sections 5, 6, and 31. Chemical compounds used in the manufacture of GB included methylphosphonic dichloride (dichlor), hydrofluoric acid, isopropyl alcohol, tributylamine, methyl alcohol, carbon tetrachloride, methylene chloride, calcium chloride, and diisopropylcarbodiimide. Chemical wastes generated in the course of GB manufacture contained diisopropylmethyl phosphonate (DIMP), isopropylmethyl phosphonochloridate, isopropylmethyl phosphonic acid, sodium isopropylmethyl phosphonate, isopropanol, methanol, carbon tetrachloride, sodium fluoride, and sodium hydroxide. Dimethylmethyl phosphonate (DMMP) has been identified as both a by-product of GB manufacture and organophosphorous pesticide manufacture (EBASCO, 1988c/RIC 90326R01).

From the 1950s through the 1980s, a wide variety of items were demilitarized at the North Plants, including GB-filled munitions, VX-filled munitions, phosgene-filled munitions,

chemical agent identification sets, bulk Adamsite, and Adamsite-filled grenades. Adamsite is a riot-control agent that contains arsenic. There is evidence of possible release of arsenic to the environment as a result of the incineration of Adamsite in Building 1611 (EBASCO, 1989/RIC 89166R05).

Between 1962 and 1968, wheat was cultivated on nearly 600 acres in portions of Sections 23, 24, 25, and 26 for the purpose of producing TX, a crop agent. TX consists of uredospores of Puccinia graminis, var. tritici, a plant pathogen commonly known as "wheat rust," that does not affect animals or humans (ESE, 1988b/RIC 88063R09). In 1972, stockpiled TX was incinerated and the ash buried in Section 19 (Kuznear and Trautmann, 1980/RIC 84269R01).

The Hydrazine Blending and Storage Facility (HBSF), located just east of the South Plants in Section 1, is owned by the U.S. Air Force and was operated by the Army between 1961 and May 5, 1982. The facility was used to blend equal quantities of anhydrous hydrazine and unsymmetrical dimethylhydrazine (UDMH) to produce Aerozine 50, a rocket fuel primarily used in the Titan and Delta missile programs (EBASCO, 1988c/RIC 90326R01). An estimated 40 to 50 million pounds of Aerozine 50 were produced. In addition, the HBSF was used between 1967 and 1973 to blend JPX jet propellant at the request of the U.S. Air Force. JPX consists of JP-4 aviation fuel and UDMH blended in various ratios (60/40, 50/50, and 83/17). Blending operations at the HBSF were halted in 1982 because nitrosodimethylamine, a suspected carcinogen formed when UDMH contacts air, was detected in the ambient air within the facility. Operations never resumed, and hazard abatement plans, including removal of all fuel and decontamination of the entire facility, were implemented (EBASCO, 1988b/RIC 88287R01).

In addition to its military operations, at various times the Army purchased and applied a variety of pesticides, including DDT, in various areas on RMA.

1.3.2 Industrial Operations

Portions of the South Plants manufacturing complex were leased to private industry following World War II, primarily for the production of pesticides. The conversion to pesticide production was a logical step in the transition to a peace-time economy because the organic insecticides as a group were discovered during the World War II era and some (e.g., organophosphate insecticides) were discovered in the chemical warfare laboratories of World War II (Carson, 1962). Records have been located of nine companies that conducted manufacturing or processing operations in the South Plants between 1946 and 1982, when all manufacturing operations in the South Plants ceased. The two major lessees of facilities in the South Plants were Julius Hyman and Company (1947-1954) and Shell Chemical Company, a division of Shell (1954-1987) (EBASCO, 1988d/RIC 88306R02).

Colorado Fuel and Iron (CF&I) manufactured chlorinated benzenes, chlorine, naphthalene, and caustic, and undertook the manufacture of dichlorodiphenyltrichloroethane (DDT) at the South Plants between 1946 and 1948. Julius Hyman and Company (Hyman) occupied South Plants facilities beginning in 1947. In 1952, Shell acquired the Stock of Hyman, which continued as a lessor until 1954, when it was merged into Shell Chemical Company. Hyman manufactured chlorinated pesticides including aldrin, dieldrin, and chlordane, and also manufactured or brought to RMA feedstock chemicals used in manufacturing its commercial products. These included thermal hexachlorocyclopentadiene, bicycloheptadiene, dicyclopentadiene (DCPD), cyclopentadiene, hydrogen peroxide, acetylene, and chlorine. Hyman also operated a muriatic (hydrochloric) acid recovery unit associated with the thermal hexachlorocyclopentadiene production and laboratory facilities to support all of its RMA activities (EBASCO, 1987b/RIC 87196R04).

In 1942, a tank farm was constructed in the northwest quarter of Section 1 in an area in the southern part of South Plants as part of the initial construction at RMA. The south tank farm included 11 storage tank locations that were used for storage of fuel oil and alcohol by the Army, and subsequently for storage of dicyclopentadiene, crude bicycloheptadiene bottoms,

isopropyl alcohol, sulfuric acid, D-D fumigant, and dibromochloropropane by Hyman and Shell. In 1948, during the period when CF&I was leasing facilities at South Plants, 100,000 gallons of benzene were spilled in an undisclosed location. In 1979, Shell detected benzene in soil samples collected in the south tank farm area (EBASCO, 1987a/RIC 87127R01). Subsequent RI sampling detected benzene, toluene, xylene, dicyclopentadiene, and bicycloheptadiene in groundwater in the area.

In 1952, Shell acquired the stock of Hyman, and following the Hyman merger with Shell in 1954, subsequently leased and constructed additional facilities in the South Plants. Shell began leasing RMA facilities effective July 6, 1955. At RMA, Shell produced chlorinated hydrocarbon insecticides, organophosphate insecticides, carbamate insecticides, herbicides, and soil fumigants. These products include Akton, aldrin, Azodrin, Bidrin, Bladex, Ciodrin, Dibrom, dieldrin, endrin, ethyl parathion, Gardona, Landrin, methyl parathion, Nemagon (dibromochloropropane, or DBCP), Nudrin, Phosdrin, Planavin, Pydrin, ravap, and Supona. Other products manufactured in the South Plants include bisphenol A, Vapona (a forerunner of NO-PEST insecticide strip), vincofos, epon adhesive and curing agent, ional antioxidant, gear oil and cutting oil additives, and Shell poultry spray. Chlorine, acetylene, DCPD, bicycloheptadiene, thermal hexachlorocyclopentadiene (including muriatic acid recovery), and hydrogen peroxide were used as feedstock chemicals. Shell also operated a monomethylamine dilution unit associated with its Azodrin production process, and laboratory facilities to support all of its manufacturing operations in the South Plants. Shell products were shipped off-post via the railyard in Sections 3 and 4, which had been installed by the Army in the 1940s to handle railcars entering and leaving RMA. DBCP was shipped by rail from RMA as late as 1976 and was probably spilled in the railyard (EBASCO, 1985/RIC 87006R01; EBASCO, 1988d/RIC 88306R02; EBASCO, 1989a/RIC 89166R03; Knaus, 1977; Shell, Undated-a; Shell, Undated-b; Shell, 1964; Shell, 1977; Shell, 1978).

The process water system installed by the Army in 1942 circulated cooling waters from lakes south of South Plants through the South Plants and back to the lakes. In May 1951 there was

an accidental discharge of caustic soda into the process water system at RMA, resulting in a massive fish kill in Lake Ladora (Armitage, 1951; Goodall, 1951). In 1952, dieldrin was detected in Lake Ladora water and aldrin was detected in Lake Ladora surface foam (Julius Hymand and Co., 1952). In 1959, dieldrin was detected in the tissues of animals collected near the lakes, and both aldrin and dieldrin were detected in sediment samples from Upper Derby Lake, Lower Derby Lake, and Lake Ladora (Finley, 1959/RIC 87091R06). In 1964, dieldrin and aldrin were detected in sediments from the lakes (DOD, 1964). In 1970, water from the inlet to Lake Ladora was found to contain very low concentrations (<1 ppb) of aldrin and dieldrin (Ferentchak, 1970), and in 1972, aldrin and dieldrin were detected in Lower Derby Lake water (Kauffman, 1972). Contamination was also suspected in Upper and Lower Derby Lakes. Because there was no indication of direct waste disposal in the lakes, contamination was attributed to either accidentally contaminated process water or to surface runoff (RMA, 1964; Lang, 1967; Adcock, 1978; Unauthored, 1952; Wingfield, 1977/RIC 81266R68; Lando, 1957). In 1964 a closed-loop cooling system was installed in the "East Plants" section of the South Plants.

In the early 1950s, field and laboratory studies were conducted by the U. S. Fish and Wildlife Service (USFWS) after observing a substantial number of waterfowl deaths on RMA (Sciple, 1952). Pesticide poisoning was indicated. A subsequent USFWS study found a significant correlation between duck mortality and the amount of exposed contaminated lakebed (Finley, 1959b). In 1964, contaminated sediments from Lower Derby Lake, portions of Upper Derby Lake, and Lake Ladora were dredged and disposed south of the lakes in Sections 11 and 12 (Sheldon and Crabtree, 1965/RIC 87091R03; Messex, 1966). In the early 1980s, mercury contamination was identified in the South Lakes (Myers et al., 1983/RIC 84086R01; Myers and Gregg, 1984/RIC 86192R01), and in 1984 tissue samples from fish were found to contain elevated levels of mercury (Rosenlund et al., 1986/RIC 86041R02).

1.3.3 Waste Disposal Operations

During the history of RMA, both solid and liquid waste stream handling procedures were developed and modified along with the various military and industrial operations. Wastes from a variety of chemical manufacturing, munitions production, testing, and demilitarization activities, off-post sources, shipping and handling procedures, and associated operations were generated and disposed in various manners. Some of these wastes, their residues and byproducts, and wastes form ancillary activities associated with the operation and maintenance of RMA ultimately found their way into the soils, water, air, and biota.

Throughout the 1940s, 1950s, and 1960s solid wastes generated at RMA were disposed in Section 36, east of Basin A. The Army's operations at RMA generated miscellaneous solid chemical wastes, as well as potentially contaminated tools, equipment, unwanted containers, rejected incendiaries, and empty munitions casings. These materials were decontaminated with caustic or other appropriate decontaminating agents and the residue was hauled to burning pits for incineration. Medical materials from off-post and overseas sources, including drugs, chemicals, bandages, and medicines may also have been disposed by incineration and burial at RMA.

The burn pits or trenches were normally 8 to 10 feet (ft) deep and 100 to 200 ft long, and were usually dug with earth moving equipment and draglines. Four to five tons of lumber were placed in the bottom of the pit and the potentially contaminated materials were placed on top of the lumber. When the pit became full, additional wood was placed on top of the materials, 300 to 500 gallons of fuel oil were poured onto the heap, and the contents were burned. Sometimes rejected lots of napalm or M-47 incendiary bombs were used as fuel for the fire. After burning, the metal was tested to determine whether it was free of contamination. If testing revealed contaminants, the metal was burned again. In 1957, several hundred tons of scrap metal were recovered from the burn pits and sold. In addition, 16 mustard-contaminated forklifts were retrieved and salvaged. After use, burn pits were backfilled with excavated soil. In 1969, the Army halted decontamination of contaminated

materials by open pit burning; contaminated material was subsequently stored in contaminated equipment dumps, which began to increase substantially in size. Open pit burning continued only for the purpose of destroying explosives, burster charges, rocket propellant, and rocket motors (EBASCO, 1989h/RIC 89166R07).

In addition to the solid waste burn pits, the Army operated a number of sanitary landfills in Section 36 (north of South Plants), in Section 4 (west of South Plants), and in Section 30 (northeast of North Plants). Although sanitary landfills were generally used for disposal of uncontaminated wastes, contaminated wastes may have been occasionally disposed at these sites.

Part of the solid waste disposal area in the south central portion of Section 36 was set aside for the exclusive use by Hyman in 1952. From 1952 through 1965, a variety of solid and liquid wastes from Hyman and later Shell's production facilities were buried at the site, both in bulk form and in drums. The area became known as the Insecticide Pits. In 1966, Shell discontinued burial of contaminated waste in the area and installed an incinerator for the purpose of waste decontamination and disposal. The incinerator was used by Shell and occasionally by the Army from 1966 to 1970, but was eventually shut down due to particulate emissions levels.

Beginning in 1942, most aqueous wastes from South Plants operations were treated with sodium hydroxide, calcium hydroxide, or calcium hypochlorite and were discharged through the chemical sewer into the Basin A area. Aqueous waste from the chlorine plant at the west end of South Plants was initially discharged into the Sand Creek Lateral, and ultimately into First Creek in Section 25. However, the resulting dissolved solids levels in First Creek were considered too high, so this waste stream was subsequently diverted into unimproved Basins D and E in Section 26. In 1946, overflow from Basin A was channeled into Basin B and subsequently into Basins D and E (EBASCO, 1989f/RIC 89166R05).

In 1953, the unlined basin network was upgraded to facilitate handling of all liquid wastes from both the North Plants and the South Plants. Basin C was constructed to handle all liquid wastes from the South Plants plus overflow from Basin A. Overflows from Basin C were in turn channeled into Basins D and E.

In 1954 and 1955, farmers irrigating crops adjacent to the northwest boundary of RMA with well water reported severe crop losses. They believed their crops had been damaged by groundwater contaminated with chemicals manufactured at RMA. Several studies were undertaken to investigate the groundwater chemistry, determine if there was a toxic component in the groundwater, identify it, and recommend corrective procedures (Ralph M. Parsons Co., 1955/RIC 84192R06; Petri and Smith, 1956/RIC 81325R22; Bonde et. al, 1959/RIC 84262R01; Walton, 1959/RIC 81325R23).

In an effort to consolidate aqueous wastes, and in response to complaints by nearby residents about contaminated groundwater, the Army constructed Basin F in late 1956 (Kuznear and Trautmann, 1980/RIC 84269R01). Basin F was the only disposal basin at RMA equipped with a catalytically blown asphalt liner to protect the substrate from infiltration by contaminated material. In 1957, Basins A and C were used to temporarily hold Basin F wastes while wave damage to the Basin F liner was being repaired. With this exception, Basin F was the only basin used for aqueous waste disposal after 1956.

In 1961, the Army commenced what was hoped to be the final solution to RMA's chemical waste disposal problem. An injection well was drilled 12,045 ft deep into Precambrian rocks beneath Basin F. Between March 8, 1962, and September 30, 1963, approximately 103,600,000 gallons of treated effluent waste from Basin F were injected into the deep disposal well at rates of 100 to 300 gallons per minute. Disposal operations were suspended for one year, but resumed in September 1964, and another 60,960,000 gallons of waste were injected into the well. Operations were suspended again on February 20, 1966, due to growing suspicion that the injection operations had caused an unusual series of earthquakes

centered in the RMA area. The quakes came to be known as the "Denver earthquakes" or the "Derby earthquakes" and caused considerable public alarm and concern over the Army's activities at RMA (Healy et al., 1968; Major and Simon, 1968). Injection of wastes never resumed after February 1966. In July and August 1968, the Army Corps of Engineers performed a series of cleanout operations at the deep disposal well including scraping the scale from inside the 5.5-inch casing, and the removal of contaminated fluid from the well. In September and October 1968 the Army Corps of Engineers conducted four pump tests at the deep well, removing approximately 367,000 gallons of contaminated fluid from the well. At least 4,960 gallons were later returned to the well, and the remainder were pumped to Basin F. During the test operations in 1968 it was noted that the hole appeared to be cored below the casing shoe, although comparison of actual to theoretical productivity index showed well bore improvement (Van Poollen, 1989). In October 1985, materials including drill casing, sucker rod, a stringer and instrument package, copper tubing, a packer, and waste fluid were retrieved from the well and the well was plugged with cement and abandonment mud (Harrison-Western, 1985/RIC 88130R02).

Wastes from GB manufacture and munition-filling production activities were carried by the chemical sewer system to a chemical sump in Building 1727, where they were treated with a sodium hydroxide solution to convert the waste stream components into their corresponding sodium salts. From October 1956 until 1973, with the exception of a brief period in 1957, waste from the Building 1727 sump was discharged via the chemical sewer directly to Basin F. In 1973 and 1974, these and other wastes (contaminated wash-down water and spent scrubbing solution) associated with the Project Eagle GB demilitarization activities were desiccated using a spray dryer. The resulting solid waste was stored in 55-gallon drums and ultimately shipped to an EPA-approved storage site in Utah. Use of the spray dryer was halted in 1974 due to the excessive energy consumption associated with its use. Thereafter the wastes were treated in the Building 1727 sump and discharged directly to the chemical sewer. However, the Army continued to use the spray dryer for the desiccation of neutralized

GB agent that had been removed from bulk stocks and munitions throughout Project Eagle (Byrne, 1976; Thomas, 1976; Thomas, 1977; U.S. Army, 1978/RIC 83235R02).

Shell constructed and operated two waste disposal systems at the South Plants. The vent gas burner system was constructed in 1968 to burn and scrub vent gases and waste liquids from some of Shell's manufacturing buildings. The vent gas burner replaced an existing flare system. In 1975, Shell constructed the Denver Effluent Treatment Facility, which was designed to treat all the aqueous chemical wastes originating in the South Plants area (EBASCO, 1988d/RIC 88306R02). Prior to the completion of this system, Shell had discharged its aqueous chemical wastes into the chemical sewers system connecting to Basin F (EBASCO, 1989h/RIC 89166R07), but had stopped using these facilities for disposal of liquid wastes by March 31, 1978. The Denver Effluent Treatment Facility was responsible for pretreatment operations consisting of methyl chloride recovery units, copper removal, and a phase separator and yielded a clarified aqueous effluent free of heavy metals and organics. The final treatment involved distillation operations, incineration, vent gas burning, and a solids handling operation. The system was brought on line over a number of years as various units were completed. By March 1978, the effluent produced by Shell exceeded the capacity of the effluent treatment incinerator. The liquid wastes were temporarily stored in existing tanks in South Plants and were disposed in the Lowry Ponds off post beginning in 1979 (Knaus, 1978; Lundahl, 1978a, 1978b; Shell, 1979).

In addition to normal waste disposal, wastes, feedstock, and product chemicals have been inadvertently discharged into the RMA environment via accidental spills, which have occurred throughout RMA history. Spills have been associated with both military and industrial activities, and have occurred particularly in the South Plants, North Plants, railyard, motor pool, and toxic storage yard areas.

1.3.4 Environmental Investigations and Controls

Environmental investigations have been an increasingly important activity at RMA during the 1970s and 1980s. In May 1974, DIMP and DCPD were detected in surface water at the northern boundary of RMA. Later in 1974, the Colorado Department of Health detected DIMP in a groundwater well north of RMA.

Also in 1974, the Army established a Contamination Control Program at RMA to ensure compliance with federal environmental laws, including the National Environmental Policy Act of 1969 and the Federal Executive Order 11507 of February 1970, which directed federal installations to refrain from polluting groundwater through the discharge of wastes, and further directed these installations to prepare air and water pollution abatement projects for review by the Bureau of the Budget. As a part of the Contamination Control Program, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) conducted a number of investigations. These studies indicated that the contamination at RMA was concentrated mainly in the alluvial sediments and alluvial groundwater with minor amounts in the underlying Denver Formation. The contaminants apparently entered the surface water and groundwater from the basin network, the chemical sewer, the South Plants area, and from other storage, disposal, spill, and leak sites. Potential and actual sites of contamination were identified, pathways by which contaminants migrate into the environment were characterized, and three groundwater interception and treatment (boundary containment) systems were installed along the north and northwest borders of RMA to intercept contaminated groundwater (ESE, 1987a/RIC 88204R02). These boundary containment systems are the North Boundary Containment System, the Northwest Boundary Containment System, and the Irondale Containment System. All three systems include an array of extraction wells to remove contaminated groundwater, a carbon adsorber treatment plant to treat the water, and an array of recharge wells to reinject the treated water. In addition, the North Boundary Containment System and the Northwest Boundary Containment System contain a soil-bentonite barrier between the extraction wells and recharge wells. In addition, recharge

trenches have been installed at the North Boundary Containment System. These systems, along with other IRAs, are discussed in Appendix C of this report.

In April 1975, three administrative orders were issued to the Army and/or Shell. These Cease and Desist orders cited various sections of the Colorado Water Quality Control Act, Section 25-8-101 et seq., Colorado Revised Statutes 1973, and directed Shell and/or RMA to immediately stop the off-post discharge of DIMP and DCPD in surface and subsurface water (ESE, 1987a/RIC 88204R02).

Two lawsuits were filed in 1983 as a result of the contamination at RMA. The first suit was filed by the U.S. Department of Justice on behalf of the U.S. Department of the Army against Shell for reimbursement of environmental response costs and for damages to the natural resources at RMA. The second suit was filed by the State of Colorado on behalf of the Colorado Department of Health against Shell and the U.S. Department of the Army for both on- and off-site environmental damages.

In September 1983, the RMACCPMT outlined the procedures for the development of a contamination control strategy for RMA (RMACCPMT, 1983/RIC 83326R01). The report documented the results of a 2-1/2-year study of potential contamination control strategies to ensure compliance with pertinent state and federal statutes. The report included an extensive technical review and analysis of the sources and migration pathways of hazardous contaminants, an assessment of applicable environmental laws, development of corrective strategies within available technology constraints, screening and evaluation of alternative strategies, and the selection of a preferred strategy.

Based on the 1983 RMACCPMT report and on personal interviews, the Army produced the Decontamination Assessment of Land and Facilities at RMA Report (RMACCPMT, 1984/RIC 84034R01). This report identified and classified more than 150 potential sites of contamination. These sites were depicted on the RMA Tricolor Map, and provided a

preliminary assessment of the extent, probable use, boundaries, and possible contamination profile of each site. The report also discussed environmental laws affecting decontamination activities and evaluated technical approaches for attaining decontamination. Cost estimates for four cleanup scenarios were developed.

USATHAMA, under a separate division created specifically to deal with the contamination at RMA (the PMRMA), initiated an RI, an EA, and an FS to remediate RMA. The RI commenced in October 1984 and culminates with the present report. Remediation of RMA will proceed with the acceptance of the Record of Decision, currently planned for 1994.

Limited remedial activities are taking place in various areas of RMA prior to the Record of Decision as a part of interim response actions. These include such things as groundwater treatment system construction, operation, and improvement; fugitive dust control; asbestos abatement; and other activities as discussed in Appendix C of this report. In addition, the South Adams County Water and Sanitation District completed the Klein Water Treatment Facility in Section 33 in November 1989. The purpose of this facility is to remove volatile organic contaminants originating at multiple sources, the majority of which are off post and unrelated to RMA activities from groundwater withdrawn from municipal supply wells near the western boundary of RMA and in the Commerce City Area. The facility has a capacity of 12 million gallons per day.

1.4 SCOPE OF INVESTIGATION

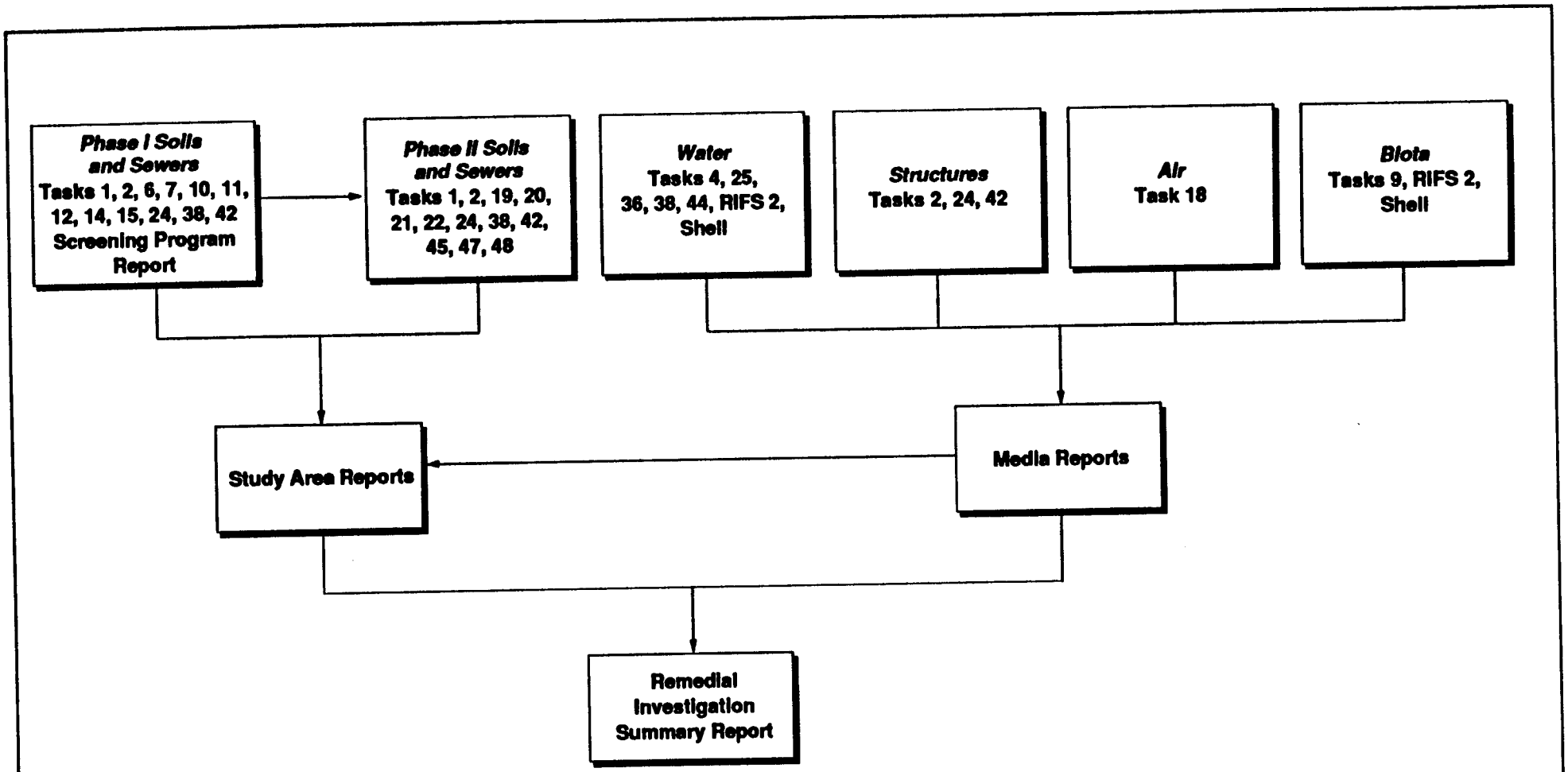
The RI was designed to define the nature and extent of contamination on RMA to a degree sufficient to permit an assessment and selection of viable cleanup options for RMA. It was not designed to collect all possible information about contamination or the RMA ecosystem. The RI program was divided into five major categories, namely soil/sewers, water, buildings, air, and biota. This section discusses the scope and components of the RI, and describes the various RI reports that have been produced. The detailed scope and rationale of each

environmental medium investigation are presented in one or more task technical plans. The task versus Product breakdown is presented in Section 1.2 and Figure RISR 1.4-1. Table RISR 1.4-1 lists technical plans issued for the RI tasks. These include stand-alone technical plans such as those for Tasks 1 and 2, as well as work plans for specific sites such as CARs with proposed Phase II soil sampling plans. Table RISR 1.4-1 is organized by medium.

RI results were assessed and presented in a variety of reports. CARs and Phase II Data Addenda were initial subproduct reports of the RI, characterizing the nature and extent of the contamination at RMA. The Data Addenda augmented the CARs and presented results of specific investigations proposed in the CARs to further characterize the contamination in the water and soils. The four media reports for water, structures, biota, and air, as well as the SARs, were products of the RI, but dealt with contamination in each medium individually. The seven SARs, while emphasizing the soils/sewers media, included summaries of the results for the other four media investigations. Other results were included in subproduct technical reports that addressed a particular time interval of data collection, such as the Initial Screening Program Report (ESE, 1987b/RIC 87203R07) and the Final Screening Program Report (ESE, 1988d/RIC 88173R06) completed under Task 4. Additional reports addressed a specific operational component at RMA, such as the North Boundary Containment System Component Response Action Assessment Draft Final Report (ESE, 1988l/RIC 88344R02). The ground disturbance and surficial soils programs were initiated after the SARs were completed to investigate other areas of potential ground disturbance and contamination in the 0- to 2-inch depth interval, respectively.

1.4.1 Components and Results

Each medium required a specific investigative approach. Table RISR 1.4-2 shows the media-specific applications of each of the six investigation components. Some elements, such as the IRDMIS database and quality assurance/quality control (QA/QC) procedures, are common to



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

Figure RISR 1.4-1

Remedial Investigation Flow Diagram for On-Post Operable Unit

Prepared by: Ebasco Services Incorporated

Table RISR 1.4-1. List of Technical Plans for RMA On-Post Operable Unit

Media	Title	Version	Date	Task	Contents	RIC Number
Soils/Sewers	Final Technical Program Plan, FY88-FY92		3/88		RI/EA/FS and IRA program overview	88131R01
	Procedures Manual to the Technical Plan. Vol I: Sampling	**	8/85		Sampling methods overview	86241R01
	Procedures Manual to the Technical Plan. Vol II: Project Quality Assurance Plan	**	8/85		QA methods overview	86241R02
	Procedures Manual to the Technical Plan. Vol III: Project Health and Safety Plan	**	8/85		Health and safety protocols.	86241R03
	Procedures Manual to the Technical Plan. Vol. IV: Project Specific Analytical Methods Manual	**	8/85		Analytical methods overview	86241R04
	Section 36 Contamination Survey Final Technical Plan	**	3/85	1	Sample locations and methods overview	86246R04
	South Plants Contamination Survey Final Technical Plan	Rev. 1	8/85	2	Sample locations and methods overview	87006R01
	Sections 26 and 35 Contamination Survey Final Technical Plan	**	12/87	6	Sample locations and methods overview	87343R01
	Phase I Survey of Lower Lakes Area Final Technical Plan	**	2/86	7	Sample locations and methods overview	86238R02
	Sewers and Process Water System Investigations Final Technical Plan	3.1	11/87	10	Sample locations and methods overview	87336R03
	Hydrazine Blending and Storage Facility Final Technical Plan	**	3/86	11	Sample locations and methods overview	86238R03
	Phase I Survey of the Derby Lakes Area Final Technical Plan	**	2/86	12	Sample locations and methods overview	86238R01
	Phase I Survey of Army Sites - North, Final Technical Plan	**	12/87	14	Sample locations and methods overview	87343R02
	Phase I Survey of Army Sites - South, Final Technical Plan	3.2	11/87	15	Sample locations and methods overview	87336R02
	Final Letter Technical Plan, Phase II Survey of the Lakes Area, from Program Manager to Parties and State, Dated Nov. 23, 1987	**	11/87	20	Sample locations	--

UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.

** -Publications printed prior to 1988 were not required to have a version number; version numbers were not required for all technical plans.

RIFS 5/Table 1.4-1 RISR - 11/5/91 11:22 AM tjr

Media	Title	Version	Date	Task	Contents	RIC Number
Soils/Sewers (continued)	Overall Soil Assessment and Ground Water Integration Final Technical Plan, Volumes I and II	3.2	7/88	23	Fate/transport of contaminants; methods overview	88203R05
	Technical Plan - Determination of Partition Coefficients for the Primary Contaminant Sources of Section 36	**	10/86	23	Partition coefficient study for selected contaminants in Section 36	87013R10
	Program for Army Spill Sites Final Technical Plan, Volume I	3.2	11/87	24	Sample locations and methods overview	87336R06
	Sampling Wastes Handling Final Technical Plan	3.2	11/87	32	Procedures for wastes generated during field activities	88076R03
	Western Tier Trichloroethylene Investigation Final Technical Plan	3.1	10/87	38	Sample locations and methods overview	87336R08
	Phase I Survey of North Plants Final Technical Plan	3.2	11/87	42	Sample locations and methods overview	87336R01
	Final Phase I CAR, North Plants Complex	3.2	9/88	42	Sample locations - Phase II Survey	88256R05
	Final Phase I CAR, Section 1 - Uncontaminated Area	3.3	4/87	7	Sample locations - Phase II Survey	87127R06
	Final Phase I CAR, Site 1-1, Drainage Ditches	3.4	5/87	7	Sample locations - Phase II Survey	87196R01
	Final Phase I CAR, Site 1-2, Upper and Lower Derby Lakes	3.2	6/87	12	Sample locations - Phase II Survey	87196R02
	Final Phase I CAR, Site 1-3, Mounded Material	3.2	2/88	2	Sample locations - Phase II Survey	88046R04
	Final Phase I CAR, Site 1-5, Lime Pits	3.2	2/87	2	Sample locations - Phase II Survey	87006R15
	Final Phase I CAR, Site 1-8, Salvage Yard	3.3	5/87	2	Sample locations - Phase II Survey	87127R05
	Final Phase I CAR, Site 1-9, Open Storage Area	3.4	5/87	7	Sample locations - Phase II Survey	87127R07
	Final Phase I CAR, Site 1-10, South Tank Farm	3.2	4/87	2	Sample locations - Phase II Survey	87127R01
	Final Phase I CAR, Site 1-11, Sanitary Landfill	3.3	7/87	2	Sample locations - Phase II Survey	87216R01

UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.

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RIFS 5/Table 1.4-1 RISR - 11/5/91 11:22 AM tjr

Media	Title	Version	Date	Task	Contents	RIC Number
Soils/Sewers (continued)	Final Phase I CAR, Site 1-12, Trash Dump	3.2	3/87	12	Sample locations - Phase II Survey	87127R03
	Final Phase I CAR, Site 2-1, Drainage Ditches	3.3	7/87	7	Sample locations - Phase II Survey	87216R06
	Final Phase I CAR, Site 2-2, Test Site	3.2	7/87	2	Sample locations - Phase II Survey	87216R02
	Final Phase I CAR, Site 2-3, Lagoon	**	2/87	2	Sample locations - Phase II Survey	87006R16
	Final Phase I CAR, Site 2-5, Trench	3.2	7/87	2	Sample locations - Phase II Survey	87216R03
	Final Phase I CAR, Site 2-6, Salt Storage Area	3.2	4/87	2	Sample locations - Phase II Survey	87127R02
	Final Phase I CAR, Site 2-7, Aeration Basin	**	2/87	2	Sample locations - Phase II Survey	87006R18
	Final Phase I CAR, Site 2-8, Former Tank Storage Area	3.2	5/88	2	Sample locations - Phase II Survey	88166R01
	Final Phase I CAR, Site 2-9, Open Storage Area	**	2/87	2	Sample locations - Phase II Survey	87006R19
	Final Phase I CAR, Site 2-12, Revetted Tank Storage Area	**	2/87	2	Sample locations - Phase II Survey	87006R20
	Final Phase I CAR, Site 2-13, Former Open Storage Area	3.2	7/87	2	Sample locations - Phase II Survey	87216R04
	Final Phase I CAR, Site 2-14a and 2-14b, Sanitary Landfills	3.2	7/87	2	Sample locations - Phase II Survey	87216R05
	Final Phase I CAR, Site 2-17, Lakes Ladora and Mary	3.2	7/87	7	Sample locations - Phase II Survey	87216R07
	Final Phase I CAR, Site 3-2/3-3, Drainage Ditch and OverFlow Basin	3.2	12/87	7	Sample locations - Phase II Survey	87336R12
	Final Phase I CAR, Site 3-4, Nemagon Spill Area	3.2	3/88	7	Sample locations - Phase II Survey	88076R04
	Final Phase I CAR, Section 4 Nonsource Area	3.1	6/88	15	Sample locations - Phase II Survey	88196R01
	Final Phase I CAR, Site 4-2, Burning Pit	3.2	1/88	15	Sample locations - Phase II Survey	88046R02

UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.
** -Publications printed prior to 1988 were not required to have a version number; version numbers were not required for all technical plans.
RIFS 5/Table 1.4-1 RISR - 11/5/91 11:22 AM tjr

Media	Title	Version	Date	Task	Contents	RIC Number
Soils/Sewers (continued)	Final Phase I CAR, Site 4-3, Burning Pit	3.2	4/88	15	Sample locations - Phase II Survey	88126R01
	Final Phase I CAR, Site 4-4, Open Storage and Salvage Yard Support Areas	3.2	4/88	15	Sample locations - Phase II Survey	88126R03
	Final Phase I CAR, Site 4-5, Burning Pits	3.2	2/88	15	Sample locations - Phase II Survey	88076R02
	Final Phase I CAR, Site 5-2, Potential Mustard and Distilled Mustard Contamination	3.2	5/88	15	Sample locations - Phase II Survey	88196R05
	Final Phase I CAR, Section 6 Nonsource Area	3.1	6/88	15	Sample locations - Phase II Survey	88196R08
	Final Phase I CAR, Site 6-2, Eastern Upper Derby Lake	3.2	5/87	12	Sample locations - Phase II Survey	87196R03
	Final Phase I CAR, Site 6-6, Former Toxic Gas Storage Yard	3.2	6/88	15	Sample locations - Phase II Survey	88196R02
	Final Phase I CAR, Section 9, Uncontaminated Area	3.2	12/87	15	Sample locations - Phase II Survey	87336R10
	Final Phase I CAR, Section 11 - UNC*, Nonsource Area	3.1	7/87	15	Sample locations - Phase II Survey	87216R10
	Final Phase I CAR, Site 11-1, Buried Lake Sludge	3.3	6/87	12	Sample locations - Phase II Survey	87196R04
	Final Phase I CAR, Section 12 Uncontaminated Area	3.2	7/87	15	Sample locations - Phase II Survey	87216R11
	Final Phase I CAR, Site 12-1, Buried Lake Sludge	3.2	12/87	12	Sample locations - Phase II Survey	88096R01
	Final Phase I CAR, Site 12-2, Rod and Gun Club Pond	3.3	4/87	12	Sample locations - Phase II Survey	87127R04
	Final Phase I CAR, Site 19-1, Burn Site, Incendiaries	3.2	1/88	14	Sample locations - Phase II Survey	88063R02
	Final Phase I CAR, Site 24-6, Sewage Treatment Plant	3.2	7/87	7	Sample locations - Phase II Survey	87216R08
	Final Phase I CAR, Site 24-7, North Bog	3.2	3/88	7	Sample locations - Phase II Survey	88076R05
	Final Phase I CAR, Section 25-Nonsource Area	3.2	3/88	14	Sample locations - Phase II Survey	88063R09

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RIFS 5/Table 1.4-1 RISR - 11/5/91 11:22 AM tjr

Media	Title	Version	Date	Task	Contents	RIC Number
Soils/Sewers (continued)	Final Phase I CAR, Site 36-6, Probable Test Site with Trench (Site 25-17)	3.2	2/88	14/21	Sample locations - Phase II Survey	88063R05
	Final Phase I CAR, Section 26-Nonsource Area	3.3	9/87	6	Sample locations - Phase II Survey	87293R02
	Final Phase I CAR, Site 26-1, Deep Disposal Well and Chemical Sewers	3.2	3/88	6	Sample locations - Phase II Survey	88103R02
	Final Phase I CAR, Site 26-3, Basin C	3.3	12/87	6	Sample locations - Phase II Survey	87343R03
	Final Phase I CAR, Site 26-4, Basin D	3.3	10/87	6	Sample locations - Phase II Survey	87293R01
	Final Phase I CAR, Site 26-5, Basin E	3.2	7/87	6	Sample locations - Phase II Survey	87203R04
	Final Phase I CAR, site 26-6, Basin F	3.3	5/88	6	Sample locations - Phase II Survey	88173R02
	PMRMA. Oct. 12, 1988. Letter to Jeff Edson, CDH; from D.L. Campbell, Deputy Program Manager, RMA Subject: Modified Phase II Sampling Plan for Basin F		10/88	6	Sample locations - Phase II Survey	--
	Final Phase I CAR, Section 29 - Nonsource Area	3.2	3/88	14	Sample locations - Phase II Survey	88063R12
	Final Phase I CAR, Site 29-4, Disposal Site, Explosives, and Incendiaries	3.2	4/88	14	Sample locations - Phase II Survey	88103R04
	Final Phase I CAR, Section 30 - Nonsource Area	3.1	4/88	14	Sample locations - Phase II Survey	88133R01
	Final Phase I CAR, Site 30-1, and 30-7 Impact Area/Ground Disturbance	3.3	1/88	14	Sample locations - Phase II Survey	88033R03
	Final Phase I CAR, Site 30-5, M34 Demilitarization Operation Area	3.3	1/88	14	Sample locations - Phase II Survey	88013R07
	Final Phase I CAR, Site 30-6, Liquid Disposal Trenches	3.2	2/88	14	Sample locations - Phase II Survey	88063R03
	Final Phase I CAR, Section 31- UncontaminatedArea	3.2	12/87	15	Sample locations - Phase II Survey	87336R11

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Media	Title	Version	Date	Task	Contents	RIC Number
Soils/Sewers (continued)	Final Phase I CAR, Site 31-4, Toxic Storage Yard	3.1	6/88	15	Sample locations - Phase II Survey	88196R09
	Final Phase I CAR, Site 31-6, Toxic Storage Yard Storage Sheds	3.2	6/88	15	Sample locations - Phase II Survey	88196R03
	Final Phase I CAR, Site 31-7, Toxic Storage Yard Storage Sheds	3.1	5/88	15	Sample locations - Phase II Survey	88166R02
	Final Phase I CAR, Section 32- Nonsource Area	3.1	6/88	15	Sample locations - Phase II Survey	88196R10
	Final Phase I CAR, Site 32-5, Burning Pits	3.2	7/88	15	Sample locations - Phase II Survey	88256R01
	Final Phase I CAR, Site 32-6, Burning Pits	3.2	8/88	15	Sample locations - Phase II Survey	88256R02
	Final Phase I CAR, Section 35 - Nonsource Area	3.3	11/87	6	Sample locations - Phase II Survey	87313R01
	Final Phase I CAR, Site 35-3, Basin B	3.3	7/87	6/19	Sample locations - Phase II Survey	87203R05
	Final Phase I CAR, Site 35-4 and 26-7, Basin A Drainage Ditches	3.2	7/87	6/19	Sample location - Phase II Survey	87203R06
	Final Phase I CAR, Site 35-7, Firing Range	3.1	3/88	14	Sample locations - Phase II Survey	88103R05
	Final Phase I CAR, Site 36-1, Basin A	3.2	7/87	1	Sample locations - Phase II Survey	87203R07
	Final Phase I CAR, Site 36-2, Munitions Test Area and Incendiary Drop Site	3.2	2/88	14	Sample locations - Phase II Survey	88063R04
	Final Phase I CAR, Site 36-3, Insecticide Pit	3.3	6/87	1	Sample locations - Phase II Survey	87203R01
	Final Phase I CAR, Site 36-4, Lime Settling Basins	3.3	6/87	1	Sample locations - Phase II Survey	87203R02
	Final Phase I CAR, Site 36-7, Solid Waste Burial/Sanitary Pits	3.1	2/88	1	Sample locations - Phase II Survey	88063R07
	Final Phase I CAR, Site 36-8, Chemical Drainage Ditch	3.2	4/87	1	Sample locations - Phase II Survey	87113R01

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Media	Title	Version	Date	Task	Contents	RIC Number
Soils/Sewers (continued)	Final Phase I CAR, Site 36-11, Liquid Storage Pool	3.2	5/87	1	Sample locations - Phase II Survey	87113R01
	Final Phase I CAR, Site 36-15, Burning Site	3.2	7/87	1	Sample locations - Phase II Survey	87203R03
	Final Phase I CAR, Site 36-17, RMA Complex Disposal Activity	3.2	1/88	1	Sample locations - Phase II Survey	88013R05
	Final Phase I CAR, Site 36-20, Chemical Sewer	3.1	8/88	1	Sample locations - Phase II Survey	87133R02
	Final Phase I CAR, Site 36-21, Drainage Ditch	3.2	4/87	1	Sample locations - Phase II Survey	87133R03
	Various Letter Technical Plans appended to Final Phase I CARs or Final Task Technical Plans				Sample locations or geophysical surveys	--
Water	Final Technical Program Plan, FY88-FY92		3/88		RI/EA/FS and IRA program overview	88131R01
	Procedures Manual to the Technical Plan. Vol. I: Sampling	**	8/85		Sampling methods overview	86241R01
	Procedures Manual to the Technical Plan. Vol. II: Project Quality Assurance Plan	**	8/85		QA methods overview	86241R02
	Procedures Manual to the Technical Plan. Vol. III: Project Health and Safety Plan	**	8/85		Health and safety protocols	86241R03
	Procedures Manual to the Technical Plan. Vol. IV: Project Specific Analytical Methods Manual	**	8/85		Analytical methods overview	86241R04
	Section 36 Contamination Survey Final Technical Plan	**	3/85	1	Sample locations and methods overview	86246R04
	South Plants Contamination Survey Final Technical Plan	Rev. 1	8/85	2	Sample locations and methods overview	87006R01
	RMA Water Quantity/Quality Survey Final Technical Plan	**	9/86	4	Sample locations and methods overview	87103R01
	Overall Soil Assessment and Ground Water Integration Final Technical Plan, Volumes I and II	3.2	7/88	23	Fate/transport of contaminants; methods overview	88203R05

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Media	Title	Version	Date	Task	Contents	RIC Number
Water (continued)	Boundary Systems Monitoring Final Technical Plan		9/88	25	Sample locations and methods overview	88293R10
	Sampling Wastes Handling Final Technical Plan	3.2	11/87	32	Procedures for wastes generated during field activities	88076R03
	North Boundary System Component Response Action Assessment, Final Technical Plan	3.2	5/88	36	Investigation overview	9023R01
	Western Tier Trichloroethylene Investigation Final Technical Plan	3.1	10/87	38	Sample locations and methods overview	87336R08
	Letter Technical Plan for Installation of Monitoring Wells in RMA North Plants (Section 25) under Task 42 appended to Final Phase I CAR, North Plants Complex	3.2	9/88	42	Sample locations and methods overview	88256R05
	On-Post/Off-Post Ground/Surface Water Monitoring Program Final Technical Plan		3/88	44	Sample locations and methods overview	88063R11
Structures	Final Technical Program Plan, FY88-FY92		3/88		RI/EA/FS and IRA program overview	88131R01
	Procedures Manual to the Technical Plan. Vol. I: Sampling	**	8/85		Sampling methods overview	86241R01
	Procedures Manual to the Technical Plan. Vol. II: Project Quality Assurance Plan	**	8/85		QA methods overview	86241R02
	Procedures Manual to the Technical Plan. Vol. III: Project Health and Safety Plan	**	8/85		Health and safety protocols	86241R03
	Procedures Manual to the Technical Plan. Vol. IV: Project Specific Analytical Methods Manual	**	8/85		Analytical methods overview	86241R04
	Structures Survey Program Final Technical Plan, Vol. II	3.1	11/87	24	Sample locations and methods overview	87336R07
	South Plants Contamination Survey Final Technical Plan	Rev. 1	8/85	2	Methods overview	87006R01

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Table RISR 1.4-1. List of Technical Plans for RMA On-Post Operable Unit

Media	Title	Version	Date	Task	Contents	RIC Number
Air	Final Technical Program Plan, FY88-FY92		3/88		RI/EA/FS and IRA program overview	88131R01
	Procedures Manual to the Technical Plan. Vol. I: Sampling	**	8/85		Sampling methods overview	86241R01
	Procedures Manual to the Technical Plan. Vol. II: Project Quality Assurance Plan	**	8/85		QA methods overview	86241R02
	Procedures Manual to the Technical Plan. Vol. III: Project Health and Safety Plan	**	8/85		Health and safety protocols	86241R03
	Procedures Manual to the Technical Plan. Vol IV: Project Specific Analytical Methods Manual	**	8/85		Analytical methods overview	86241R04
	Task 18 (Air Monitoring) Final Technical Plan	**	2/87	18	Sample location and methods overview	88203R02
Biota	Final Technical Program Plan, FY88-FY92		3/88		RI/EA/FS and IRA program overview	88131R01
	Procedures Manual to the Technical Plan. Vol. I: Sampling	**	8/85		Sampling methods overview	86241R01
	Procedures Manual to the Technical Plan. Vol. II: Project Quality Assurance Plan	**	8/85		QA methods overview	86241R02
	Procedures Manual to the Technical Plan. Vol. III: Project Health and Safety Plan	**	8/85		Health and safety protocols	86241R03
	Procedures Manual to the Technical Plan. Vol. IV: Project Specific Analytical Methods Manual	**	8/85		Analytical methods overview	86241R04
	Biota Assessment Final Technical Plan	3.2	7/88	9	Program overview	88243R05

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Medium	Investigation Component					
	Historical Research	Field Studies	Field Sampling	Analyses	QA/QC	Data Management
Soil/Sewers	Personnel interviews, facilities records, aerial photographs, previous investigations, Shell and Juris databases	Site conditions, soil types, surface features, geophysics, trenching, geologic logging of bores	Spatial and vertical intervals, physical and chemical parameters, suspected sources and nonsource areas	Phase I screen for organics by GC/MS, agent screening (likely areas); Phase II specific GC methods for organics; metals; arsenic, mercury	Field data, laboratory data	IRDMIS database
Water	Previous investigations, RMA database review, DP Associates database, well records, facilities records	Water levels, well installation, geologic logging, geophysical logging, aquifer tests	Physical and chemical parameters, water quality, spatial and temporal components	Specific GC methods for organics, 10% GC/MS organics screening, metals; fluoride, chloride, major ions; arsenic, mercury	Field data, laboratory data	IRDMIS database
Structures	Facilities records, aerial photographs, Juris and Shell databases	Visual inspection, buildings inventory	Limited sampling of standing liquids and building materials	GC/MS organics screening; metals; asbestos; arsenic, mercury	Field data, laboratory data	Structures database, IRDMIS database
Air	Facilities records, previous investigations, Stapleton Airport data	Meteorological data	Particulates, metals, organics; temporal and spatial components at ambient conditions, high-event conditions	Total suspended and respirable particulates; GC/MS organics screening; metals; asbestos; arsenic, mercury	Field data, laboratory data	IRDMIS database
Biota	Previous investigations, aerial photographs	Biota surveys, off-post control surveys	Representatives of food web levels, spatial and temporal components, contaminated vs control populations	Specific GC methods for organics; arsenic, mercury	Field data, laboratory data	IRDMIS database

all media, while other elements such as historical research, field studies, field sampling, and analytical methods differ for each medium.

Media investigations were generally conducted in two phases to allow the screening analyses to be followed by more site-specific determinations. Only media with substantial amounts of data available from previous investigations (i.e., groundwater and structures) were investigated in a single phase. A brief review of each medium investigation follows. Each discussion is supported by a flow chart that outlines the typical investigation. A detailed discussion of media sampling and analysis strategies is presented in Appendix A.2 of this report. Table RISR 1.4-3 is a tabulation of all reports that present data and/or provide assessments of contamination at RMA.

1.4.1.1 Soils/Sewers

A phased field investigation to determine the nature and extent of soils/sewers contamination was conducted. The objectives of Phase I were to verify or refute the existence of contamination and to screen each site for a wide variety of potential contaminants. Sample collections and GC/MS analytical methodologies were employed to establish the presence or absence of organic contaminants at suspected sites and in nonsource areas. Inorganics were analyzed using inductively coupled argon plasma spectroscopy (ICP) and graphite furnace and cold vapor atomic absorption (CVAA) methods. The Phase II objectives were to verify Phase I results and further characterize contaminant distribution and migration potential. Detailed sampling and specific analytical methodologies were employed to establish the general areal and vertical extent of contamination and contaminant concentrations, and to provide data to determine transport mechanisms.

The soils/sewers investigation at RMA was the most extensive component of the RI and yielded the largest volume of data. The soils investigation was initiated with a historical records review that included interpretation of aerial photographs and field reconnaissance of all suspected sites and nonsource areas. The Phase I investigation commenced after the

Table RISR 1.4-3 List of Remedial Investigation Reports for RMA On-Post Operable Unit

Media	Title	Version	Date	Task	RIC Number
	CONTAMINATION ASSESSMENT REPORTS				
Soils/Sewers	Draft Final Phase I - Introduction to the CARs	2.3	4/87	1	88204R02
	Final Phase I CAR, Section 1 - Uncontaminated Area	3.3	4/87	7	87127R06
	Final Phase I CAR, Site 1-1, Drainage Ditches	3.4	5/87	7	87196R01
	Final Phase I CAR, Site 1-2, Upper & Lower Derby Lakes	3.2	6/87	12	87196R02
	Final Phase I CAR, Site 1-3, Mounded Material	3.2	2/88	2	88046R04
	Final Phase I CAR, Site 1-4, Borrow Pit	3.2	4/87	2	87097R08
	Final Phase I CAR, Site 1-5, Lime Pits	3.2	2/87	2	87006R15
	Final Phase I CAR, Site 1-7, Hydrazine Blending and Storage Facility	3.2	9/88	11	88286R09
	Final Phase I CAR, Site 1-8, Salvage Yard	3.3	5/87	2	87127R05
	Final Phase I CAR, Site 1-9, Open Storage Area	3.4	5/87	7	87127R07
	Final Phase I CAR, Site 1-10, South Tank Farm	3.2	4/87	2	87127R01
	Final Phase I CAR, Site 1-11, Sanitary Landfill	3.3	7/87	2	87216R01
	Final Phase I CAR, Site 1-12, Trash Dump	3.2	4/87	12	87127R03
	Final Phase I CAR, Site 1-13, 2-18, South Plants Manufacturing Complex Shell Chemical Co. Spill Sites	3.1	7/88	2	88286R07
	Final Phase I CAR, Section 2 - Uncontaminated Area	3.3	5/87	7	87127R08
	Final Phase I CAR, Site 2-1, Drainage Ditches	3.3	7/87	7	87216R06
	Final Phase I CAR, Site 2-2, Test Site	3.2	7/87	2	87216R02
	Final Phase I CAR, Site 2-3, Lagoon		2/87	2	87006R16
	Final Phase I CAR, Site 2-4, Excavation Pit		2/87	2	87006R17
	Final Phase I CAR, Site 2-5, Trench	3.2	7/87	2	87216R03
	Final Phase I CAR, Site 2-6, Salt Storage Pad	3.2	4/87	2	87127R02
	Final Phase I CAR, Site 2-7, Aeration Basin		2/87	2	87006R18
	Final Phase I CAR, Site 2-8, Former Tank Storage Area	3.2	5/88	2	88166R01
	Final Phase I CAR, Site 2-9, Open Storage Area		2/87	2	87006R19
	Final Phase I CAR, Site 2-12, Revetted Tank Storage Area		2/87	2	87006R20
	Final Phase I CAR, Site 2-13, Former Open Storage Area	3.2	7/87	2	87216R04
	Final Phase I CAR, Site 2-14a/2-14b, Sanitary Landfills	3.2	7/87	2	87216R05
	Final Phase I CAR, Site 2-17, Lake Ladora and Lake Mary	3.2	7/87	7	87216R07
	Final Phase I CAR, Section 3 - Nonsource Area	3.2	2/88	15	88076R01
	Final Phase I CAR, Site 3-2/3-3, Drainage Ditch & Overflow Basin	3.2	12/87	7	87336R12
	Final Phase I CAR, Site 3-4, Nemagon Spill Area	3.2	3/88	7	88076R04

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Media	Title	Version	Date	Task	RIC Number
Soils/Sewers (continued)	Final Phase I CAR, Section 4 - Nonsource Area	3.1	6/88	15	88196R01
	Final Phase I CAR, Site 4-2, Burning Pit	3.2	1/88	15	88046R02
	Final Phase I CAR, Site 4-3, Burning Pit	3.2	4/88	15	88126R01
	Final Phase I CAR, Site 4-4, Open Storage and Salvage Yard Support Areas	3.2	4/88	15	88126R03
	Final Phase I CAR, Site 4-5, Burning Pits	3.2	2/88	15	88076R03
	Final Phase I CAR, Site 4-6, Motor Pool Area	3.1	7/88	38	88196R12
	Final Phase I CAR, Section 5 - Nonsource Area	3.1	1/88	15	88046R03
	Final Phase I CAR, Site 5-2, Potential Mustard and Distilled Mustard Contamination	3.2	5/88	15	88196R05
	Final Phase I CAR, Section 6 - Nonsource Area	3.1	6/88	15	88196R08
	Final Phase I CAR, Site 6-2, Eastern Upper Derby Lake	3.2	5/87	12	87196R03
	Final Phase I CAR, Site 6-6, Former Toxic Gas Storage Yard	3.2	6/88	15	88196R02
	Final Phase I CAR, Section 7 - Nonsource Area	3.2	12/87	15	87336R13
	Final Phase I CAR, Section 8 - Nonsource Area	3.3	12/87	15	88006R01
	Final Phase I CAR, Section 9 - Unconaminated Area	3.2	12/87	15	87336R10
	Final Phase I CAR, Section 11 - UNC*, Nonsource Area	3.3	7/87	15	87216R10
	Final Phase I CAR, Site 11-1, Buried Lake Sludge	3.3	6/87	12	87196R04
	Final Phase I CAR, Section 12 - Uncontaminated Area	3.2	7/87	15	87216R11
	Final Phase I CAR, Site 12-1, Buried Lake Sludge	3.2	12/87	12	88096R01
	Final Phase I CAR, Site 12-2, Rod and Gun Club Pond	3.3	4/87	12	87127R04
	Final Phase I CAR, Section 19 - Nonsource Area	3.1	12/87	14	88013R06
	Final Phase I CAR, Site 19-1, Burn Site, and Incendiaries	3.2	1/88	14	88063R02
	Final Phase I CAR, Section 20 - Nonsource Area	3.1	5/88	14	88173R05
	Final Phase I CAR, Site 20-1, Burn Site, and Incendiaries	3.2	9/88	14	88293R01
	Final Phase I CAR, Section 22 - Nonsource Area	3.1	12/87	14	88013R01
	Final Phase I CAR, Section 23 - Nonsource Area	3.3	8/88	14	88243R02

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Media	Title	Version	Date	Task	RIC Number
Soils/Sewers (continued)	Final Phase I CAR, Section 24 - Nonsource Area	3.2	6/88	14	88203R03
	Final Phase I CAR, Site 24-6, Sewage Treatment Plant	3.2	7/87	7	87216R08
	Final Phase I CAR, Site 24-7, North Bog	3.2	3/88	7	88076R05
	Final Phase I CAR, Section 25 - Nonsource Area	3.2	3/88	14	88063R09
	Final Phase I CAR, Section 26 - Nonsource Area	3.3	9/87	6	87293R02
	Final Phase I CAR, Site 26-1, Deep Disposal Well and Chemical Sewers	3.2	3/88	6	88103R02
	Final Phase I CAR, Site 26-3, Basin C	3.3	12/87	6	87343R03
	Final Phase I CAR, Site 26-4, Basin D	3.3	10/87	6	87293R01
	Final Phase I CAR, Site 26-5, Basin E	3.2	7/87	6, 19	87203R04
	Final Phase I CAR, Site 26-6, Basin F	3.3	5/88	6	88173R02
	Final Phase I CAR, Section 27 - Nonsource Area	3.1	12/87	14	88013R02
	Final Phase I CAR, Section 28 - Nonsource Area	3.1	12/87	14	88013R03
	Final Phase I CAR, Section 29 - Nonsource Area	3.2	3/88	14	88063R12
	Final Phase I CAR, Site 29-1, Burn Site, Incendiaries	3.1	12/87	14	88013R04
	Final Phase I CAR, Site 29-4, Disposal Site, Explosives, and Incendiaries	3.2	4/88	14	88103R04
	Final Phase I CAR, Site 29-5/32-1, Bomb Disposal Site	3.2	9/88	14	88293R02
	Final Phase I CAR, Section 30 - Nonsource Area	3.1	4/88	14	88133R01
	Final Phase I CAR, Site 30-1/30-7, Impact Area/ Ground Disturbance	3.3	1/88	14	88033R03
	Final Phase I CAR, Site 30-2, Burn Site, and Incendiaries	3.2	9/88	14	88293R03
	Final Phase I CAR, Site 30-3, Mustard Training Area	3.1	5/88	14	88173R03
	Final Phase I CAR, Site 30-4, Sanitary Landfill	3.2	7/87	7	87216R09
	Final Phase I CAR, Site 30-5, M34 Demilitarization Operation Area	3.3	1/88	14	88013R07
	Final Phase I CAR, Site 30-6, Liquid Disposal Trenches	3.2	2/88	14	88063R03
	Final Phase I CAR, Section 31 - Uncontaminated Area	3.2	12/87	15	87336R11
	Final Phase I CAR, Site 31-4, Toxic Storage Area	3.1	6/88	15	88196R09
	Final Phase I CAR, Site 31-6, Toxic Storage Yard Storage Sheds	3.2	6/88	15	88196R03
	Final Phase I CAR, Site 31-7, Toxic Storage Yard Storage Sheds	3.1	5/88	15	88166R02
	Final Phase I CAR, Section 32 - Nonsource Area	3.1	6/88	15	88196R10

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Media	Title	Version	Date	Task	RIC Number
Soils/Sewers (continued)	Final Phase I CAR, Site 32-5, Burning Pits	3.2	7/88	15	88256R01
	Final Phase I CAR, Site 32-6, Burning Pits	3.2	8/88	15	88256R02
	Final Phase I CAR, Section 33 - Nonsource Area	3.1	4/88	15	88126R02
	Final Phase I CAR, Section 34 - Nonsource Area	3.2	7/88	14	88203R04
	Final Phase I CAR, Section 35 - Uncontaminated Area	3.3	11/87	6	87313R01
	Final Phase I CAR, Site 35-2/26-9, Chemical Sewer	3.1	5/88	14	88133R02
	Final Phase I CAR, Site 35-3, Basin B	3.3	7/87	6,19	87203R05
	Final Phase I CAR, Site 35-4/26-7, Basin A Drainage Ditches	3.2	7/87	6,19	87203R06
	Final Phase I CAR, Site 35-6, Possible Munitions Test Area	3.2	9/88	14	88293R04
	Final Phase I CAR, Site 35-7, Firing Range	3.1	3/88	14	88103R05
	Final Phase I CAR, Section 36 - Nonsource Area	3.2	5/88	1	88173R01
	Final Phase I CAR, Site 36-1, Basin A	3.2	7/87	1	87203R07
	Final Phase I CAR, Site 36-2, Munitions Test Area and Incendiary Drop Site	3.2	2/88	14,21	88063R04
	Final Phase I CAR, Site 36-3, Insecticide Pit	3.3	6/87	1	87203R01
	Final Phase I CAR, Site 36-4, Lime Settling Basins	3.3	6/87	1	87203R02
	Final Phase I CAR, Site 36-5, Mercury Spill	3.3	1/88	1	88063R01
	Final Phase I CAR, Site 36-6/25-17, Probable Test Site with Trench	3.2	2/88	14,21	88063R05
	Final Phase I CAR, Site 36-7, Solid Waste Burial/ Sanitary Pits	3.1	2/88	1	88063R07
	Final Phase I CAR, Site 36-8, Chemical Drainage	3.2	4/87	1	87113R01
	Final Phase I CAR, Site 36-9, Incendiary or Munitions Test Area	3.3	9/88	14,21	88293R05
	Final Phase I CAR, Site 36-10, Pit	3.2	1/88	1	88033R02
	Final Phase I CAR, Site 36-11, Liquid Storage Pool	3.2	5/87	1	87133R01
	Final Phase I CAR, Site 36-12, Pits/ Trenches	3.2	1/88	1	88013R08
	Final Phase I CAR, Site 36-13, Trenches	3.2	9/88	14	88293R06
	Final Phase I CAR, Site 36-14, Mustard Plant Disposal Site	3.2	9/88	14	88293R07
	Final Phase I CAR, Site 36-15, Burning Site	3.2	7/87	1	87203R03
	Final Phase I CAR, Site 36-16, Incendiary Burial Site	3.2	9/88	14,21	88293R08
	Final Phase I CAR, Site 36-17, Complex Disposal Activity	3.2	1/88	1	88013R05
	Final Phase I CAR, Site 36-18, Possible Trench Disposal Site	3.2	2/88	14	88063R06
	Final Phase I CAR, Site 36-19, Grading Scars	3.2	2/88	14,21	88063R10
	Final Phase I CAR, Site 36-20, Chemical Sewer	3.2	4/87	1	87133R02
	Final Phase I CAR, Site 36-21, Drainage Ditch	3.2	4/87	1	87133R03
	Final Phase I CAR, Site 36-22, Liquid Storage Pool	3.2	3/88	1	88103R01

*UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.

Media	Title	Version	Date	Task	RIC Number
Soils/Sewers (continued)	Final Phase I CAR,. Site 36-23, Scrap Metal Storage/Parking Lot	3.1	5/88	14,21	88173R04
	Final CAR, Sanitary Sewer - Railyard and Administration Areas	3.2	8/88	10	88256R03
	Final CAR, Sanitary Sewer - South Plants	3.2	6/88	10	88196R06
	Final Phase I CAR, Chemical Sewers - North Plants and South Plants	3.2	9/88	10	88286R08
	Final Phase I CAR, Sanitary Sewer - North Plants	3.2	4/88	10	88126R07
	Final Phase I CAR, Sanitary Sewer Interceptor Line	3.2	4/88	10	88126R06
	Final Phase I CAR, Process Water System	3.2	8/88	10	88256R04
	Final Phase I Data Presentation Report, South Plants Regional Study	3.2	10/88	2	88306R01
	Final Phase I Data Presentation, Army Spill Sites (South Plants)	3.2	9/88	24	88286R10
	Final Phase I CAR, North Plants Complex	3.2	9/88	42	88256R05
	Final Phase II Data Addendum, Section 1-UNC, Nonsource Area	3.1	10/88	20	87127R06A
	Final Phase II Data Addendum, Site 1-1, Drainage Ditches	3.1	10/88	20	87196R01A
	Final Phase II Data Addendum, Site 1-2, Upper & Lower Derby Lakes	3.1	10/88	20	87196R02A
	Final Phase II Data Addendum, Site 1-3, Mounded Material	3.1	10/88	2	88046R04A
	Final Phase II Data Addendum, Site 1-5, Lime Pits	3.1	9/88	2	87006R15A
	Final Phase II Data Addendum, Site 1-6, Former Ton Container Storage Area	3.1	10/88	20	88306R03
	Final Phase II Data Addendum, Site 1-7, Hydrazine Blending and Storage Facility	3.1	2/89	11, RIFS2	88286R09A
	Final Phase II Data Addendum, Site 1-8, Salvage Yard	3.1	10/88	2	87127R05A
	Final Phase II Data Addendum, Site 1-9, Open Storage	3.1	10/88	20	87127R07A
	Final Phase II Data Addendum, Site 1-10, South Tank Farm	3.1	10/88	2	87127R01A
	Final Phase II Data Addendum, Site 1-11, Sanitary Landfill	3.1	9/88	2	87216R01A
	Final Phase II Data Addendum, Site 1-12, Trash Dump	3.1	10/88	20	87127R03A
	Final Phase II Data Addendum, Site 2-1, Drainage Ditches	3.1	10/88	20	87216R06A
	Final Phase II Data Addendum, Site 2-2, Test Site	3.1	9/88	2	87216R02A
	Final Phase II Data Addendum, Site 2-3, Lagoon	3.1	9/88	2	87006R16A
	Final Phase II Data Addendum, Site 2-5, Trench	3.1	10/88	2	87216R03A
	Final Phase II Data Addendum, Site 2-6, Open Storage Area	3.1	10/88	2	87127R02A
	Final Phase II Data Addendum, Site 2-7, Aeration Basin	3.1	9/88	2	87006R18A
	Final Phase II Data Addendum, Site 2-8, Former Tank Storage Area	3.1	10/88	2	88166R01A
	Final Phase II Data Addendum, Site 2-9, Open Storage Area	3.1	9/88	2	87006R19A
	Final Phase II Data Addendum, Site 2-10, Ground Scar	3.1	10/88	20	88306R04
	Final Phase II Data Addendum, Site 2-11, Open Storage	3.1	10/88	20	88306R04
	Final Phase II Data Addendum, Site 2-12, Former Tank Location	3.1	10/88	2	87006R20A
	Final Phase II Data Addendum, Site 2-13, Former Open Storage Area	3.1	9/88	2	87216R04A

*UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.

Media	Title	Version	Date	Task	RIC Number
Soils/Sewers (continued)	Final Phase II Data Addendum, Site 2-14a, Sanitary Landfill	3.1	10/88	2	87216R05A
	Final Phase II Data Addendum, Site 2-15, Open Storage	3.1	10/88	20	88306R04
	Final Phase II Data Addendum, Site 2-16, Pit	3.1	10/88	20	88306R04
	Final Phase II Data Addendum, Site 2-17, Lake Ladora and Lake Mary	3.1	10/88	20	87216R07A
	Final Phase II Data Addendum, Site 3-2/3-3, Drainage Ditch & Overflow Basin	3.1	10/88	20	87336R12A
	Final Phase II Data Addendum, Site 3-4, Nemagon Spill Area	3.1	10/88	20	88076R04A
	Final Phase II Data Addendum, Section 4-UNC, Nonsource Area	3.1	10/88	22	88196R01A
	Final Phase II Data Addendum, Site 4-2, Burning Pit	3.1	10/88	22	88046R02A
	Final Phase II Data Addendum, Site 4-3, Burning Pit	3.1	10/88	22	88126R01A
	Final Phase II Data Addendum, Site 4-4, Open Storage and Salvage Yard Support Areas	3.1	10/88	22	88126R03A
	Final Phase II Data Addendum, Site 4-5, Burning Pits	3.1	10/88	22	88076R02A
	Final Phase II Data Addendum, Site 5-2, Potential Mustard and Distilled Mustard Contamination	3.1	10/88	22	88196R05A
	Final Phase II Data Addendum, Site 6-UNC, Nonsource Area	3.1	10/88	22	88196R08A
	Final Phase II Data Addendum, Site 6-2, Eastern Upper Derby Lake	3.1	10/88	20	87196R03A
	Final Phase II Data Addendum, Site 6-6, Former Toxic Gas Storage Yard	3.1	10/88	22	88196R02A
	Final Phase II Data Addendum, Section 9-UNC, Nonsource Area	3.1	10/88	22	87336R10A
	Final Phase II Data Addendum, Section 11-UNC, Nonsource Area	3.1	10/88	20	87216R10A
	Final Phase II Data Addendum, Site 11-1, Buried Lake Sludge	3.1	10/88	20	87196R04A
	Final Phase II Data Addendum, Section 12-UNC, Nonsource Area	3.1	10/88	22	87216R11A
	Final Phase II Data Addendum, Site 12-1, Buried Lake Sludge	3.1	10/88	20	87216R01A
	Final Phase II Data Addendum, Site 12-2, Rod and Gun Club Pond	3.1	10/88	20	87127R04A
	Final Phase II Data Addendum, Site 19-1, Burn Site	3.1	10/88	21	88063R02A
	Final Phase II Data Addendum, Section 23 - Nonsource Area	3.1	4/89	21,RIFS2	88243R02A
	Final Phase II Data Addendum, Site 24-6, Sewage Treatment Plant	3.1	10/88	20	87216R08A
	Final Phase II Data Addendum, Site 24-7, North Bog	3.1	10/88	20	88076R05A
	Final Phase II Data Addendum, Section 25 - Nonsource Area	3.1	10/88	14,21	88063R09A

*UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.

Media	Title	Version	Date	Task	RIC Number
Soils/Sewers (continued)	Final Phase II Data Addendum, Site 25-16, North Plants Complex	3.2	11/88	42,45,48	88256R05A
	Final Phase II Data Addendum, Site 25-17/36-6, Probable Test Site with Trench	3.1	9/88	21	88063R05A
	Final Phase II Data Addendum, Section 26 - Nonsource Area	3.1	8/88	19	87293R02A
	Final Phase II Data Addendum, Site 26-1, Deep Disposal Well	3.2	8/88	19	88103R02A
	Final Phase II Data Addendum, Site 26-3, Basin C	3.1	9.88	19	87343R03A
	Final Phase II Data Addendum, Site 26-4, Basin D	3.1	9/88	19	87293R01A
	Final Phase II Data Addendum, Site 26-5, Basin E	3.1	9/88	19	87203R04A
	Final Phase II Data Addendum, Site 26-6, Basin F	3.1	9/88	19	88173R02A
	Final Phase II Data Addendum, Site 26-6, Basin F	3.1	1/89	19	88173R02B
	Final Phase II Data Addendum, Section 29 - Nonsource Area	3.1	8/88	21	88063R12A
	Final Phase II Data Addendum, Site 29-4, Disposal Site, Explosives, and Incendiaries	3.1	8/88	21	88103R04A
	Final Phase II Data Addendum, Section 30-Nonsource Area	3.1	8/88	21	88133R01A
	Final Phase II Data Addendum, Site 30-1, Impact Area	3.1	9/88	21	88033R03A
	Final Phase II Data Addendum, Site 30-4, Sanitary Landfill	3.1	10/88	20	87216R09A
	Final Phase II Data Addendum, Site 30-5, Liquid Disposal Area	3.1	9/88	21	88013R07A
	Final Phase II Data Addendum, Site 30-6, Liquid Disposal Trenches	3.1	9/88	21	88063R03A
	Final Phase II Data Addendum, Section 31-UNC, Nonsource Area	3.1	10/88	22	87336R11A
	Final Phase II Data Addendum, Site 31-4, Toxic Storage Yard	3.1	10/88	22	88196R09A
	Final Phase II Data Addendum, Site 31-6, Toxic Storage Yard Storage Sheds	3.1	10/88	22	88196R03A
	Final Phase II Data Addendum, Site 31-7, Toxic Storage Yard Storage Sheds	3.1	10/88	22	88166R02A
	Final Phase II Data Addendum, Section 32-UNC, Nonsource Area	3.1	10/88	22	88196R10A
	Final Phase II Data Addendum, Site 32-5, Burning Pits	3.1	10/88	22	88256R01A
	Final Phase II Data Addendum, Site 32-6, Burning Pits	3.1	10/88	22	88256R02A
	Final Phase II Data Addendum, Section 35-UNC, Nonsource Area	3.1	9/88	19	87313R01A
	Final Phase II Data Addendum, Site 35-3, Basin B	3.1	9/88	19	87203R05A
	Final Phase II Data Addendum, Site 35-4, Drainage Ditches	3.1	9/88	19	87203R06A
	Final Phase II Data Addendum, Site 35-7, Firing Range	3.1	8/88	21	88103R05A
	Final Phase II Data Addendum, Site 36-1, Basin A	3.1	9/88	1,47	87203R07A
	Final Phase II Data Addendum, Site 36-2, Munitions Test Area and Incendiary Drop Site	3.1	9/88	21	88063R04A
	Final Phase II Data Addendum, Site 36-3, Insecticide Pits	3.1	9/88	1,47	87203R01A

*UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.

Media	Title	Version	Date	Task	RIC Number
Soils/Sewers (continued)	Final Phase II Data Addendum, Site 36-4, Lime Settling Basins	3.1	9/88	1	87203R02A
	Final Phase II Data Addendum, Site 36-7, Solid Waste Burial/ Sanitary Pit	3.1	9/88	1,47	88063R07A
	Final Phase II Data Addendum, Site 36-8, Chemical Drainage Ditches	3.1	8/88	1	87113R01A
	Final Phase II Data Addendum, Site 36-11, Liquid Storage Pool	3.1	8/88	1	87133R01A
	Final Phase II Data Addendum, Site 36-15, Burning Site	3.1	8/88	1	87203R03A
	Final Phase II Data Addendum, Site 36-17, Complex Disposal Activity	3.1	9/88	1,47	88013R05A
	Final Phase II Data Addendum, Site 36-19, Grading Scars	3.1	9/88	21	88063R10A
	Final Phase II Data Addendum, Site 36-20s, Chemical Sewer	3.1	8/88	1	87133R02A
	Final Phase II Data Addendum, Site 36-21, Drainage Ditch	3.1	8/88	1	87133R03A
	Final Phase II Data Addendum, Site 36-23, Scrap Metal Storage/ Parking Lot	3.1	9/88	21	88173R04A
	OTHER REPORTS				
	Final Summary Report, Western Tier TCE Soil Gas Investigation	3.2	1/88	38	88046R01
	RMA Chemical Index Vol. I, II and III Overall Soils Assessment and Groundwater Integration - Proposed Final Report		8/88		90326R01
	Development and Evaluation of Analytical Methodologies Used in RMA Soil Investigations		4/88		88127R02
	Determination of Partition Coefficients for the Primary Contaminant Source of Section 36 - Draft Final Report	2.1	9/88	23	88264R01
	Soil Investigation and Inventory of RMA		10/88	(MKE)	[Not in RIC]
	Final Ground Disturbance Investigation Data Summary Report	3.1	8/90	RIFS2	90247R01
	Final Surficial Soils Investigation Data Summary Report	3.1	4/91	RIFS2	91121R01
	STUDY AREA REPORTS				
	Final Remedial Investigation Report, Volume VI, Southern Study Area	3.3	6/89	RIFS 2	89166R01
	Final Remedial Investigation Report, Volume VII, Eastern Study Area	3.3	6/89	RIFS 2	89166R02
	Final Remedial Investigation Report, Volume VIII, South Plants Study Area	3.3	7/89	RIFS 2	89166R04
	Final Remedial Investigation Report, Volume IX, North Plants Study Area	3.3	7/89	RIFS 2	89166R05
	Final Remedial Investigation Report, Volume X, Central Study Area	3.3	7/89	RIFS 2	89166R06
	Final Remedial Investigation Report, Volume XI, North Central Study Area	3.3	7/89	RIFS 2	89166R07
	Final Remedial Investigation Report, Volume XII, Western Study Area	3.3	5/89	RIFS 2	89166R03
Water	Water Quantity/Quality Survey-Final Initial Screening Program Report, Vol. 1-3		8/87	4	87253R01
	Water Quantity/Quality Survey - Final Screening Program Report 3rd/4th Quarter 1987		5/88	4	88173R06
	Final Water Remedial Investigation Report	3.3	7/89	44,RIFS2	89186R01
	Overall Soils Assessment and Groundwater Integration - Draft Final Report	2.2	9/88	23	88344R01

*UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.

Media	Title	Version	Date	Task	RIC Number
	Determination of Partition Coefficients for the Primary Contaminant Sources of Section 36 - Draft Final Report	2.1	9/88	23	88264R01
	Boundary Control Systems Assessment Remedial Investigation Draft Final Report	2.1	12/88	25	89024R02
	North Boundary System Component Response Action Assessment Draft Final Report, Vol. I, II, and III	3.1	2/89	36	89103R01
	Composite Well Program Draft Final Report	2.3	7/88	44	88244R02
Structures	Final Structures Survey Report, Vol. I, II, and III	2.2	10/88	24	88306R02
Air	Air Remedial Investigation Report	3.1	8/88	18	88263R01
Biota	Biota Remedial Investigation Final Report, Vol. I, II, and III	3.2	5/89	9	89186R01
	Biota Assessment Bald Eagle Study, Winters 1986-1987/1987-1988 Final Report	3.1	9/88	9	88293R09
	Black-Tailed Prairie Dog Populations of Rocky Mountain Arsenal Draft Final Report	2.1	5/88	9	88204R01

*UNC and NSA are used interchangeably in CARs and SARs; nonsource area is the appropriate definition for both.

technical work plans were developed for each task investigating soil contamination. Typically, soil borings were drilled after geophysical surveys and/or site clearance were completed for health and safety reasons. Chemical analyses were performed on soil samples using the Phase I screening methods. Field and analytical data were checked by QA/QC procedures and stored in the IRDMIS database.

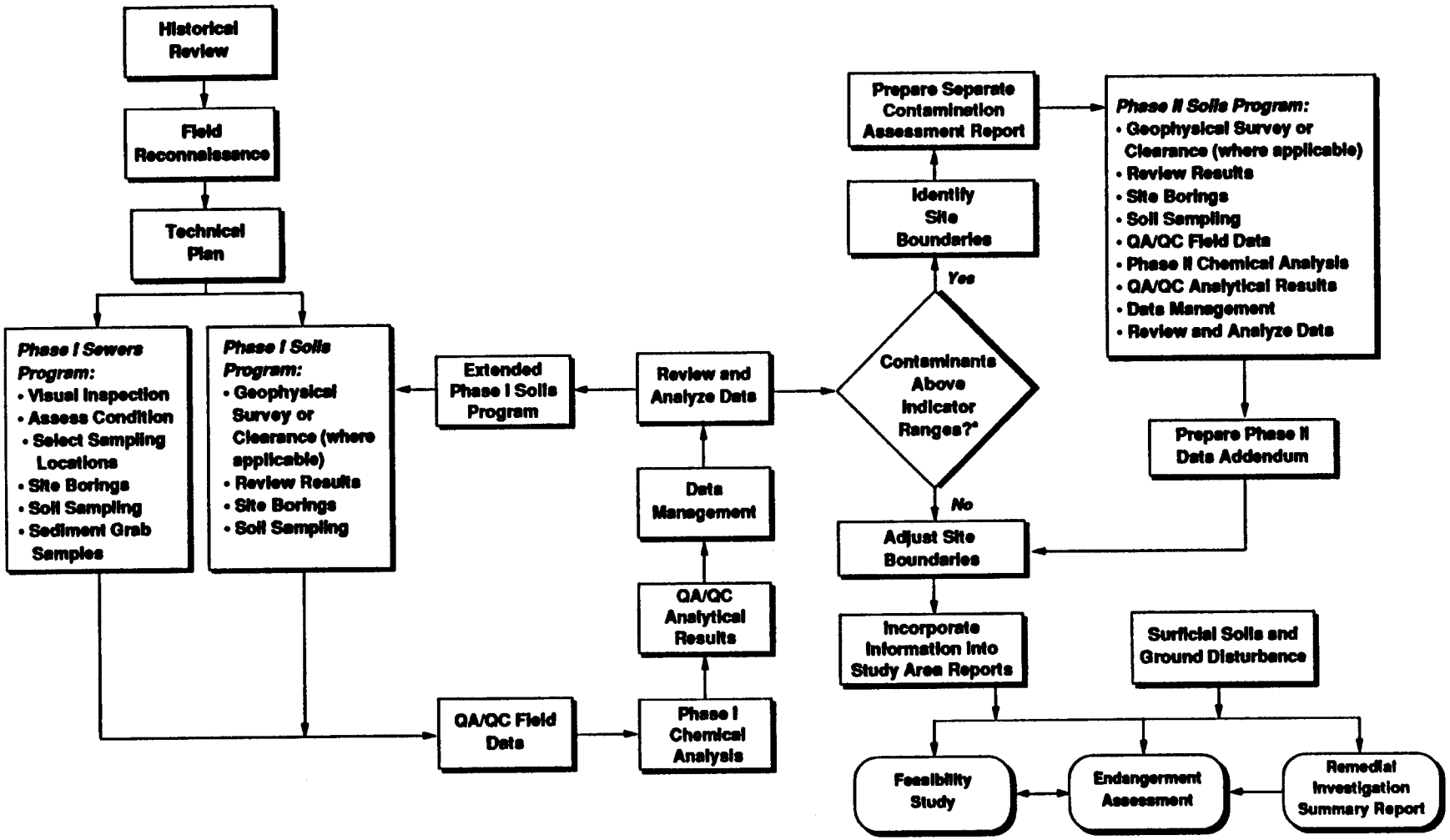
Phase I soils/sewers investigations results were evaluated and presented in the CARs. The CAR for each site describes the site's physical setting and history and presents Phase I analytical results, a contamination assessment, the proposed Phase II program (if any), and a preliminary contaminated soil volume (if any) for individual sites and nonsource areas. In addition to CARs for individual contaminated sites, 28 CARs were compiled for all of the areas not suspected to be contaminated (nonsource areas) in each of the 28 sections that RMA occupies. Site boundaries were adjusted at that time to reflect areas of potential contamination, and a Phase II program was proposed if appropriate. The purpose of the Phase II assessments was to collect the additional information necessary to refine and more thoroughly assess the boundaries and depths of suspected areas of contamination. In addition, the Phase II Program was used to evaluate several additional areas identified subsequent to or not previously studied in the Phase I program.

Phase II data were collected using the same procedures as in Phase I, except that compound-specific analytical procedures generally achieved lower reporting limits for the organic compounds identified in the Phase I program. These data were compiled, checked, and entered into the IRDMIS database. When a Phase II program was conducted, results were published in the Final Phase II Data Addenda. Phase I and Phase II data were assessed on a study-area basis in the SARs. The SARs characterize the study areas at RMA in terms of environmental setting and history, present all Phase I and Phase II soil data, incorporate analytical data from other media, and provide an integrated assessment of the nature and extent of contamination. Pathways and receptors of contamination are identified, and preliminary contaminated soil volume estimates, based on indicator levels, are presented.

Indicator levels vary for specific analytes, and are taken at the upper end of the indicator range. An indicator range is the range of concentration for a specific analyte indicative of natural or background concentrations. A more detailed discussion of indicator ranges is presented in Appendix A2.

Similar investigations were conducted for the sewers. However, because of the unique character of the sewers (including the chemical sewers, sanitary sewers, and the process water system) as linear systems where leaks may occur at discrete and difficult to identify points, an IRA was initiated to cutoff contamination migration routes at key locations, and visual inspection and historical documentation were used to focus sampling efforts on lines in the worst condition. In addition to the soil samples collected from beneath sewer lines in the sewers investigation, sediment samples from within the sewer lines were also collected and analyzed. Results from sampled sections of the sewers system were extrapolated to other portions of the intact and removed sewers system. Data were handled and assessed in the same manner as soils data. Figure RISR 1.4-2 outlines the soils/sewers RI process.

In addition, there are a number of other soils/sewers-related reports. The introduction to the CARs (ESE, 1987a/RIC 88204R02) discusses the investigative strategy of the Phase I and Phase II soil investigations. The Overall Soil Assessment and Groundwater Integration, Interim Draft Final Report (ESE, 1988f/RIC 88203R05) provides an RMA-wide assessment of soil and groundwater contamination, and discusses contaminant fate and transport processes in both media. The Determination of Partition Coefficients for the Primary Contaminant Sources of Section 36, Draft Final Report (ESE, 1988j/RIC 88344R01) discusses the complex interaction of contaminants with both sediment and groundwater in the saturated zone below three highly contaminated sites in Section 36. The Final Summary Report, Western Tier TCE Soil Gas Investigation (EBASCO, 1988a/RIC 88046R01), summarizes the results of the soil gas investigation in the Western Study Area. The Final Ground Disturbance Investigation Data Summary Report (EBASCO, 1990/RIC 90247R01) presents results of the ground disturbance investigation conducted following the completion of the SARs. Results of the



*See Appendix A.2 for discussion of Indicator Ranges

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Prepared August 1991

Figure RISR 1.4-2
Soils/Sewers Remedial Investigation Process

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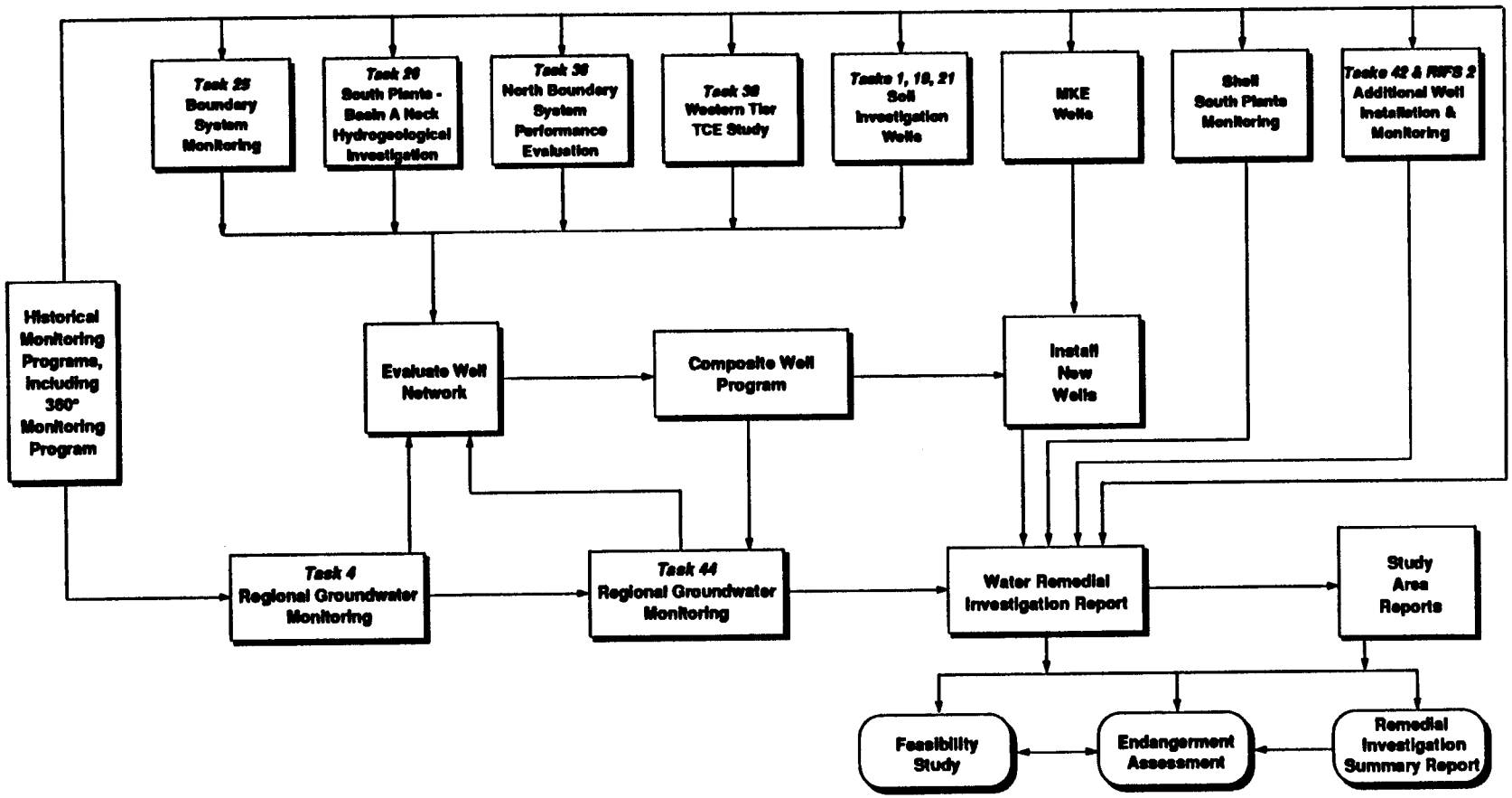
surficial soil investigation were published in the Surficial Soil Program Data Summary Report (EBASCO, 1991/RIC 91121R01). Both programs are summarized in Appendix D.

1.4.1.2 Water

The water medium, including surface water and groundwater, was investigated on regional, local, and temporal scales. The substantial number of previous water investigations, including the expansive 360° Monitoring Program initiated in 1976 and the resulting large water database provided a basis for designing the RI water investigation. Initially, building on the 360° Monitoring Program, wells in the available well network were evaluated in terms of location, depth, and construction method and material for inclusion in a regional monitoring program sampling network (Task 4). In addition, appropriate task-specific well subsets for contaminant source definition and operation and maintenance considerations of existing groundwater containment systems were also selected for sampling. Details of the water medium sampling and analytical program strategies are presented in Appendix A.2 of this report.

Samples were analyzed using parameters that were based on the results of previous sampling programs. Subsequent sampling was based on the assessment of previous RI data. Sites were selected and prioritized for well installation on the basis of geologic, hydrologic, and geochemical criteria. In addition, some wells were selected for replacement on the basis of construction criteria. Well installation was coordinated through the Composite Well Program Technical Plan (ESE, 1988g/RIC 88244R02). Data from the water samples were evaluated by the established QA/QC procedures and compiled into the IRDMIS database for storage and retrieval. Data were assessed in individual task reports and as part of the Water RI report (EBASCO, 1989d/RIC 89186R01). Figure RISR 1.4-3 shows the water RI process.

In addition, to ensure continuity of adequate data collection beyond the RI-specific tasks, the Comprehensive Monitoring Program (CMP) was instituted to conduct regularly scheduled water quality, air, and biota sampling throughout the RI/EA/FS process.



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

Figure RISR 1.4-3
Water Remedial Investigation Process

Prepared by: Ebasco Services Incorporated

Results of RI groundwater and surface water studies are presented in regional reports focusing on a specific sampling event at one short time interval, and in local reports that focus on a limited geographic area while integrating several sampling events covering longer time intervals. The regional reports include the Water Quantity/Quality Final Initial Screening Program and Final Screening Program reports (ESE, 1987c/RIC 87253R01; ESE, 1988a/ RIC 88034R03), the Water RI Report (EBASCO, 1989d/RIC 89186R01), and the SARs (EBASCO, 1989a-c, e-h/RIC 89166R01 through 89166R07). The first three reports present and assess data from the combined first and second quarters, FY 86, the third and fourth quarters, FY 86, and the third quarter, FY 87, respectively.

Several local groundwater reports have been generated, including the Boundary Control Systems Assessment Remedial Investigation Draft Final Report (ESE, 1988k/RIC 89024R02), which assesses groundwater quality in the vicinity of the North Boundary and Northwest Boundary Containment Systems and the North Boundary System Component Response Action Assessment Final Report (ESE, 1989a/RIC 89103R01) which discusses the quality of groundwater upgradient and downgradient of the North Boundary Containment System.

An evaluation and assessment of all Denver Formation groundwater data was conducted following completion of the Water RI in order to determine the vertical extent of groundwater contamination at RMA. Details of that study and its results are presented in Appendix B.

1.4.1.3 Structures

Beginning in fall 1987, the structures survey conducted a records search for physical setting, description, history, references, and relevant drawings for each existing structure including buildings, foundations, and tanks. Each structure was assigned a contamination classification based on historical information. A field reconnaissance program verified the presence, use, condition, and material volume of each structure. It also verified electrical substations and miscellaneous piping. A database was developed to manage the data gathered, and existing Basic Information Maps were updated to reflect the current configuration and location of each

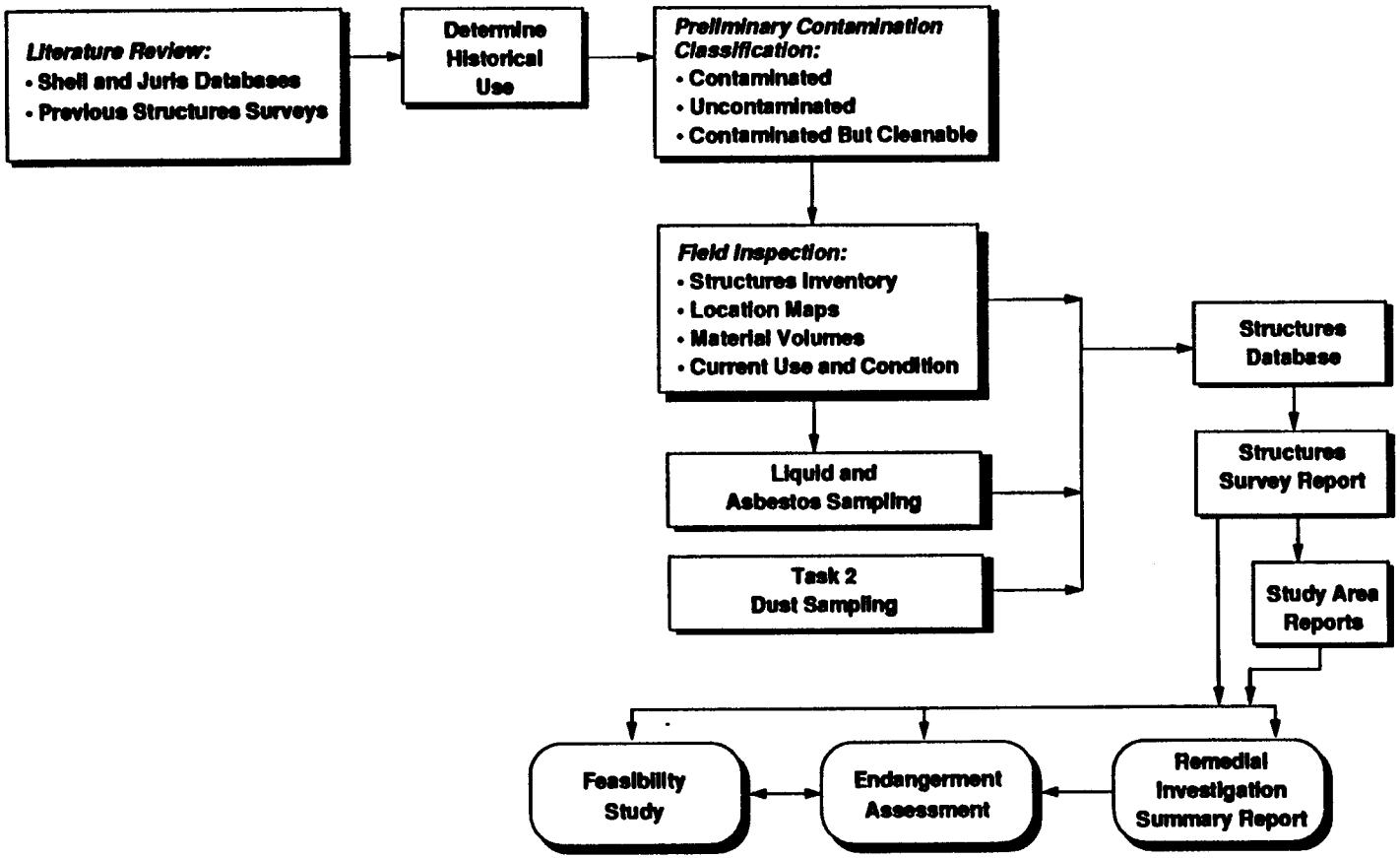
structure. Limited sampling of materials that typically contain asbestos and of liquids found in structures was undertaken to identify contaminants in structures. The Structures Survey Report (EBASCO, 1988d/RIC 88306R02) summarizes the results of the investigation and previous investigations and cites relevant references. Figure RISR 1.4-4 outlines the Structures RI process.

The Structures Survey Report consists of three volumes. Volume I explains the purpose and objectives of the investigation; structure categorization procedures; the survey, sampling, analysis, and data management methods; and tables summarizing the inventory, contamination classifications, estimated material volumes, and sampling results for the structures medium. Volume II, divided into 11 separate subvolumes, lists the buildings identified during the literature search, and the physical setting, facility description and history, any available drawings and references, and an output from the structures database. Volume III describes the data contained in each field of the database, the assumptions used during the estimation of material volumes, and structure location maps.

1.4.1.4 Air

The air medium was monitored and studied under Task 18 at RMA in order to evaluate ambient air quality and to establish baseline conditions against which to compare levels attained during and after remediation activities, and to support the EA/FS. Historical records, in conjunction with meteorological records, were used to site permanent air quality stations in appropriate locations to monitor ambient conditions as well as major emission sources.

Sampling was conducted on both a spatial and a temporal basis. In addition, portable air quality stations monitored high wind events for a variety of contaminants. The analyte suite for the air medium was selected to monitor organic and inorganic contaminants common to the other media, as well as standard air quality parameters such as total suspended particulates (TSP), particulate material finer than 10 microns (PM-10), and asbestos. As with the other media, the data were subjected to standard QA/QC procedures and incorporated into the



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

Figure RISR 1.4-4
Structures Remedial Investigation Process

Prepared by: Ebasco Services Incorporated

IRDMIS database. The Air RI Report (ESE, 1988h/RIC 88263R01) presents and assesses air quality sampling data collected during the RI, and discusses RMA's air quality and meteorological setting. Figure RISR 1.4-5 illustrates the Air RI process. Air quality continues to be monitored on a regular basis as part of the ongoing CMP.

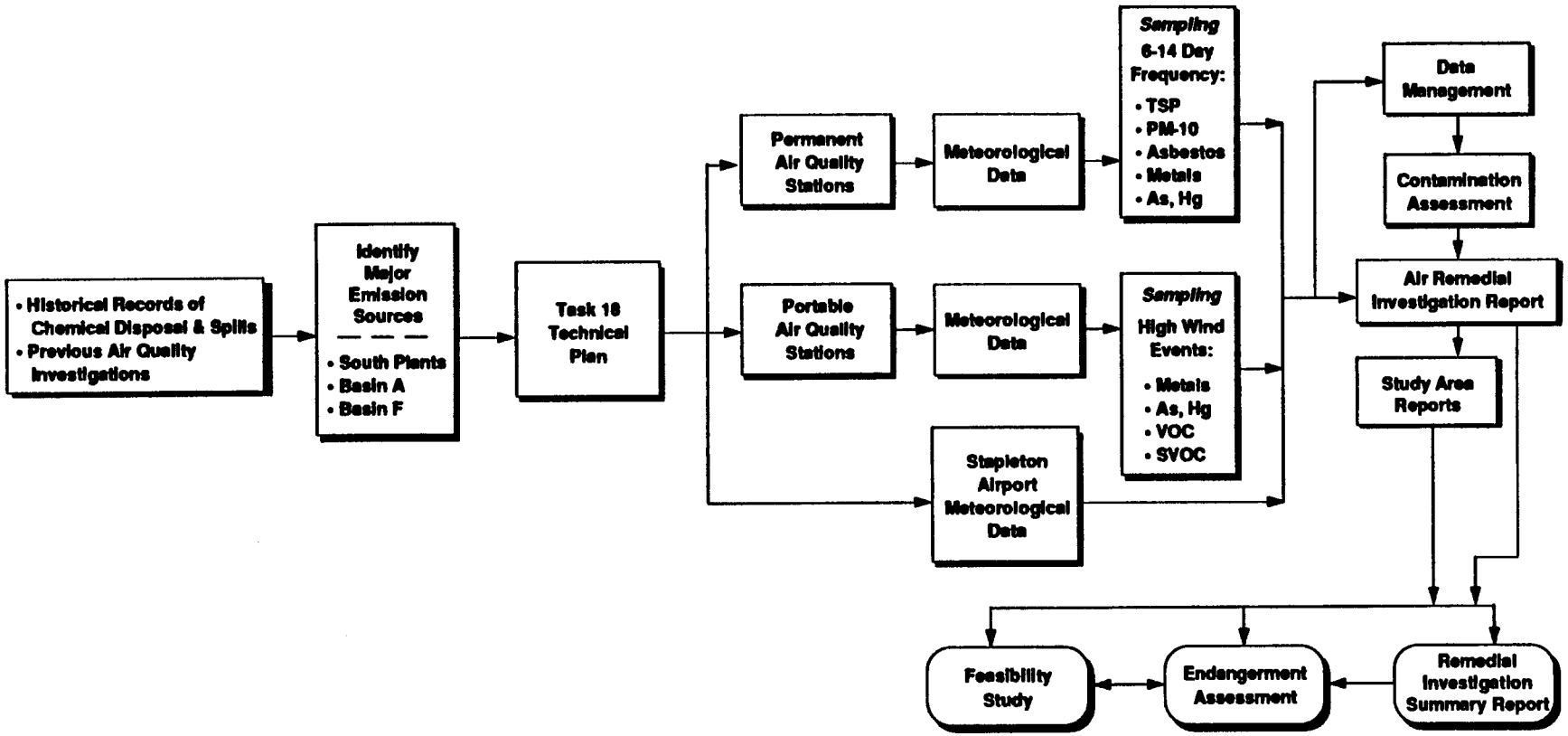
1.4.1.5 Biota

Figure RISR 1.4-6 presents the Biota RI process. The objectives of the biota investigation were to evaluate the collected and historical data regarding sources, types, distribution, and concentration of RMA contaminants in biota; provide specific information on pathways for the movement of contaminants through regional food webs in relation to important species and overall ecosystem effects; and assess the environmental effects of contamination of the biota medium. Details of the investigative strategy employed for the Biota RI are summarized in Appendix A.2.

The Biota RI Report (ESE, 1989b/RIC 89173R02) characterizes the biological resources of RMA and evaluates the analytical results of the biota sampling program. Data were assessed on a regional scale in the report. In addition, preliminary soil and water criteria for 39 contaminants of concern are presented, based on a preliminary assessment of biota exposure to RMA contaminants. Statistical analyses and pathways analyses were conducted after appropriate QA/QC and data management procedures were performed as part of the Biota RI.

Other reports prepared as part of the Biota RI include the Bald Eagle RI Report (ESE, 1988i/RIC 88293R09) which presents the findings of the bald eagle study, and the Black-Tailed Prairie Dog Populations of RMA Draft Final Report (ESE, 1988e/RIC 88204R01), which characterized the prairie dog population on RMA.

The RI Product and Subproduct documents collectively satisfy the RI objective of describing the nature and extent of contamination at RMA. The description of contaminant conditions



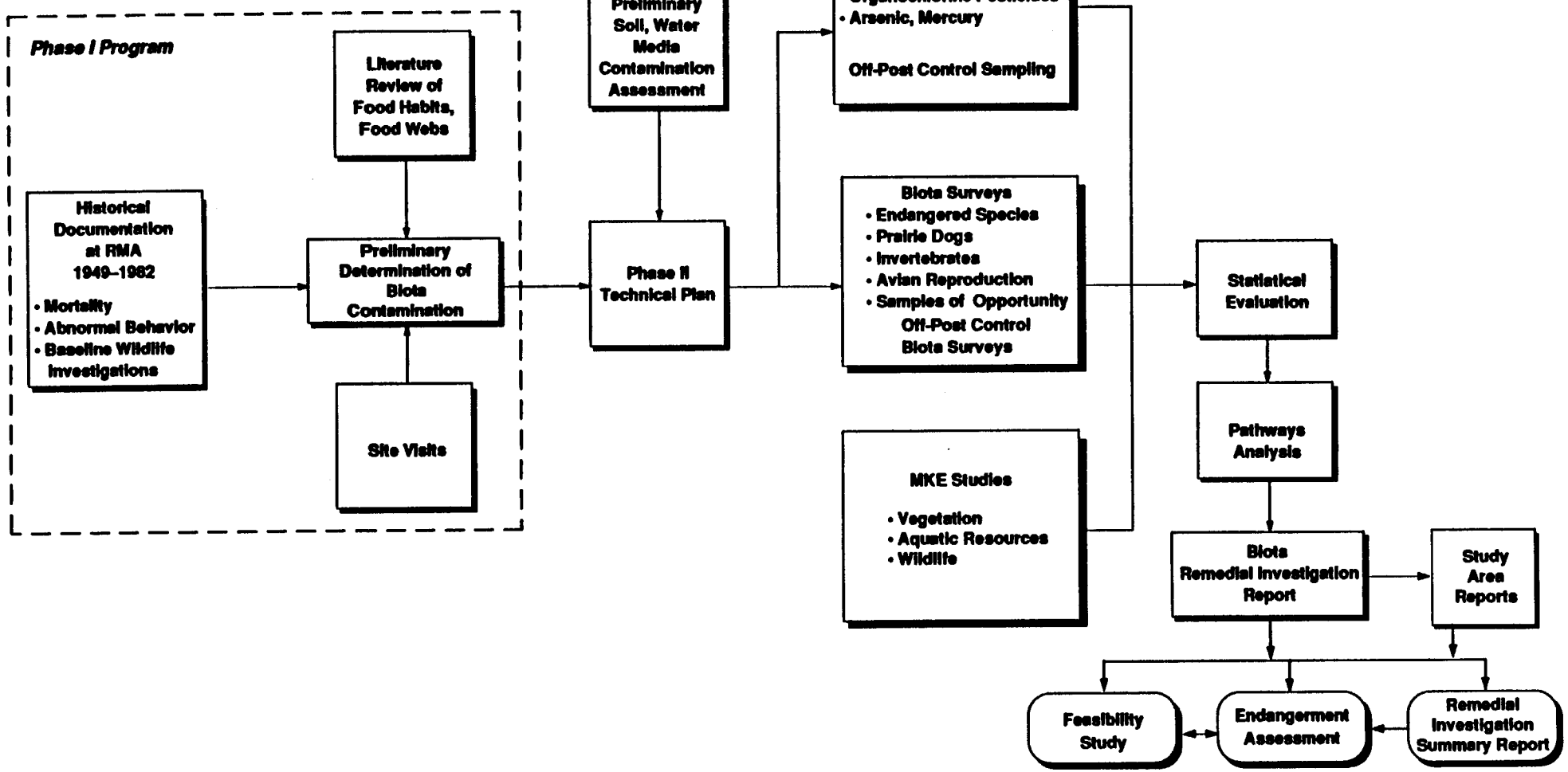
Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

Figure RISR 1.4-5
Air Remedial Investigation Process

Prepared by: Ebasco Services Incorporated



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

Figure RISR 1.4-6
Biota Remedial Investigation Process

Prepared by: Ebasco Services Incorporated

presented in these documents will support the data needs of both the EA and FS. Additional data may be collected throughout the FS as necessary to satisfy specific needs.

Section 2.0

Interpretations and Conclusions

Remedial Investigation Summary Report

2.0 INTERPRETATIONS AND CONCLUSIONS

The fundamental objectives of the RI data collection effort were to develop a database and formulate conclusions regarding the nature and extent of contamination at RMA sufficient for the EA to assess the human health and environmental effects of contaminant exposure, and to aid the FS in evaluating remedial alternatives. Every effort was made to ensure the adequacy and relevance of the RI for this purpose. Detailed integration of the RI, EA, and FS planning processes at the early stage of the RI/FS program allowed substantial achievement of this objective.

The selection of sampling and analytical strategies employed in Phase I and Phase II of the RI for the soils/sewers medium represented the best available methods for screening, identifying, and quantifying the extent of soil contamination within reasonable limits of time and funding. One-hundred-seventy-eight sites with varying degrees of contamination, ranging from areas of several hundred acres with multiple contaminant occurrences at concentrations up to a few parts per hundred, to isolated occurrences of single analytes at a few parts per billion, were delineated. The water medium investigations identified and determined the locations, concentrations, and movement dynamics of multiple-contaminant plumes. In conjunction with the soil data and historical records, specific source-plume relationships were identified where possible; more commonly, areas where plumes originated were defined. A total of 1,285 structures were investigated in the structures survey and classified by contamination condition. Air quality was monitored and sampled on both a routine and an "event" basis. Event-related volatile and semivolatile emissions from specific sources were observed. Lower overall TSP and PM-10 levels were detected in the RMA interior than at the boundaries, where urban and other off-post influences are felt. Biota samples collected throughout RMA showed the presence of certain contaminants and, although detections were sporadic and in some cases ambiguous, a pattern of contaminant migration through the RMA ecosystem was revealed.

A comprehensive database containing all RI data was created to manage the more than 600,000 records generated by the RI, as well as by other investigative programs at RMA. This database was the source for the tables and graphics compiled to support the summary of the nature and extent of contamination in Appendix A3 and the evaluation of the vertical extent of contamination in the Denver Formation presented in Appendix B. The site characterization and investigative strategies employed in the RI are summarized in Appendix A.

Conclusions presented in this report are based not only on the results of the environmental studies and mitigation efforts undertaken in the course of the RI/FS, EA, and IRAs, but also on previous studies completed under RMA and Defense Installation Restoration Program direction. These results are, therefore, the comprehensive compilation of more than 15 years of investigative effort. A vast amount of new information was obtained during the RI regarding the boundaries of plumes and sites, the identity of the contaminants found in these locations, and contaminant concentrations. The results obtained are generally consistent with those of earlier studies and tend to validate previous understandings of the general location of plumes and sites, the identification of major contaminants, and the magnitude of contamination. The identification of the 178 designated sites of soil contamination shown on Plate RISR 2.0-1 is a major result of the RI. In addition, as a result of special investigations conducted after completion of the SARs (see Appendix D1), generally low-level organochlorine pesticide contamination (0.002 µg/g to ≈ 4 µg/g outside designated sites) has been identified in the surficial soils (0- to 2-inch depth interval) throughout most of RMA. These sites form the basis for the EA and represent the starting point for the FS. While remedial alternatives for mitigating or eliminating contamination in the other media are also evaluated by the FS, the soil sites compose the bulk of the primary contamination sites, that is, sites with the potential to impact other media via ongoing transport mechanisms and available migration pathways. Several high-priority areas so identified are being addressed by IRAs and other contaminant mitigation measures. In particular, impounded liquid and contaminated bottom sludges and underlying soils have been removed from or contained

within a double-lined and capped waste pile at the location of the former Basin F, and boundary containment systems have been constructed to intercept and treat contaminated groundwater that previously flowed off site. These early corrective actions have largely controlled these contaminant sources and associated transport mechanisms. Appendix C summarizes the IRA activities.

Although nearly 14,000 samples were collected and analyzed during the RI, the data collection effort continues. For instance, programs to further investigate ground disturbances and surficial soils have been undertaken, and additional data for all five environmental media will continue to be collected under the CMP and the FS data collection program. Appendix D summarizes the results of the surficial soil and ground disturbance programs. The long-term monitoring efforts of the CMP will provide a continuing source of information regarding contamination at RMA and the effectiveness of programs undertaken to remediate the site. The FS data collection effort will gather specific data required to adequately evaluate remedial alternatives. Further sampling will be undertaken during and after remediation activities in order to assess their effectiveness.

2.1 CONTAMINANT SOURCES AND PATHWAYS

The RI identified many areas of soil contamination that are potential sources of exposure to environmental receptors. For purposes of the RISR, these sites are grouped into site types, and these site types are qualitatively ranked and discussed in order of decreasing relative importance with respect to their potential to continue releases to the other environmental media. One of the first criteria for ranking sites and site types as sources is the presence of contaminant migration pathways. Other criteria include the variety and concentration of contaminants and the lateral and vertical extent of contamination. The site types are discussed in subsections 2.1.1 through 2.1.11 in descending order of importance.

Table RISR 2.1-1 lists 178 sites by site type and gives the approximate volume of contaminated material associated with each site, as determined from estimates developed and

Table RISR 2.1-1. Estimated Volumes of Contaminated Soils by Site*

Site Designation	Estimated Contaminated Volume (b.c.y.)	Potentially Affected Media ** (excluding biota)
Basins, Lagoons		
SPSA-1c, Lime Pits	10,000	Soil
SPSA-1e, Buried M-1 Pits	31,000	Soil, Groundwater
SPSA-7b, Lagoon	2,600	Soil
SPSA-12a, Aeration Basin	830	Soil
SPSA-12b, Sedimentation Pond	800	Soil, Groundwater
NCSA-1a, Basin A	520,000	Soil, Groundwater
NCSA-1b, Lime Settling Basins Area	88,000	Soil, Groundwater
NCSA-1d, Liquid Storage Pool	47,000	Soil
NCSA-2a, Basin C	2,000,000	Soil, Groundwater
NCSA-2b, Basin D	160,000	Soil, Groundwater
NCSA-2c, Basin E	410,000	Soil, Groundwater
NCSA-3, Basin F	1,000,000	Soil, Groundwater
NCSA-5a, Basin B	37,000	Soil, Groundwater
NCSA-9s, Isolated Detection	23	Soil
SUBTOTAL	4,300,000	
Ditches, Lakes, Ponds		
SSA-1a, East Upper Derby	88,000	Surface Water, Groundwater, Lake Sediment
SSA-1b, Upper Derby	400,000	Surface Water, Groundwater, Lake Sediment
SSA-1c, Lower Derby	430,000	Surface Water, Groundwater, Lake Sediment
SSA-1d, Rod and Gun Club	78,000	Surface Water, Groundwater, Lake Sediment
SSA-1e, Lake Ladora	240,000	Surface Water, Groundwater, Lake Sediment
SSA-1f, Lake Mary	63,000	Surface Water, Groundwater, Lake Sediment
SSA-2a, Process Water Ditch System	52,000	Soil, Surface Water
SSA-2b, Sand Creek Lateral	77,000	Soil, Surface Water
SSA-2c, Overflow Basin and Ditch	54,000	Soil, Surface Water
SSA-5b, Havana/Peoria St. Ponds	160,000	Soil
SSA-5e, Uvalda Ditch	4,000	Soil
ESA-3h, Open Storage Area Ditch	2,600	Soil
ESA-3i, Toxic Storage Plots Ditch	5,300	Soil
ESA-6c, Ditch from North Plants	5,200	Soil
SPSA-1d, Drainage Ditches	2,900	Soil, Surface Water
SPSA-2d, Drainage Ditches	3,200	Soil, Surface Water, Groundwater

*These volume estimates are based on detections only and are not indicative of actual volumes that will require remediation as determined by the EA, risk assessments, and FS.

**The air media can theoretically be affected by virtually any site for short durations given the proper meteorological conditions and/or a physical disturbance at the site.

Table RISR 2.1-1. Estimated Volumes of Contaminated Soils by Site*

Site Designation	Estimated Contaminated Volume (b.c.y.)	Potentially Affected Media ** (excluding biota)
SPSA-3a, Drainage Ditches	2,900	Soil, Surface Water
SPSA-4a, Drainage Ditches	20,000	Soil, Surface Water, Groundwater
SPSA-5a, Drainage Ditches	950	Soil, Surface Water
SPSA-7a, Drainage Ditches	900	Soil, Surface Water
SPSA-8b, Drainage Ditches	1,200	Soil, Surface Water, Groundwater
SPSA-9a, Drainage Ditches	15,000	Soil, Surface Water, Groundwater
NPSA-8a, Miscellaneous Drainages	130	Soil, Surface Water
NPSA-8b, Miscellaneous Drainages	200	Soil, Surface Water
NPSA-8c, Miscellaneous Drainages	4,900	Soil, Surface Water
NCSA-1c, Basin A to Basin B Ditch	22,000	Soil, Surface Water, Groundwater
NCSA-1f, South Plants Drainage Ditches	4,000	Soil, Surface Water
NCSA-2d, Basin B to Basin C Ditch	11,000	Soil, Surface Water, Groundwater
NCSA-5b, Drainage Ditches	12,000	Soil, Surface Water, Groundwater
NCSA-5c, Sand Creek Lateral	67,000	Soil, Surface Water, Groundwater
NCSA-5d, Surface Drainage Canal	1,300	Soil, Surface Water
NCSA-7, North Bog	4,400	Soil, Surface Water, Groundwater
NCSA-8b, Sewage Treatment Plant	77,000	Soil
WSA-6a, Drainage Ditch	1,800	Soil, Surface Water, Groundwater
WSA-6d Drainage Area	390	Soil, Surface Water, Groundwater
WSA-6e, Culvert Outfall	34	Soil
SUBTOTAL	1,900,000	
Ordnance Testing and Disposal		
ESA-1a, Section 19 Surface Burn	6,400	Soil, Surface Water, Air
ESA-1b, Section 20 Surface Burn	4,600	Soil, Surface Water, Air
ESA-1c, Section 29 Surface Burn	32,000	Soil, Surface Water, Air
ESA-1d Section 30 Surface Burn	43,000	Soil, Surface Water, Air
ESA-2a, Section 32 Burn Pits	200,000	Soil, Groundwater
ESA-2c, Open Trenches	12,000	Soil
ESA-4a, Impact Area	100,000	Soil
ESA-4b, Demolition Area	7,400	Soil
ESA-4c, Trench and Mound	900	Soil
CSA-2a, Munitions Testing Area	3,300	Soil
CSA-2c, Munitions Test Site	2,200	Soil
CSA-2d, Incinerator NN3601	550	Soil
SUBTOTAL	410,000	

*These volume estimates are based on detections only and are not indicative of actual volumes that will require remediation as determined by the EA, risk assessments, and FS.
**The air media can theoretically be affected by virtually any site for short durations given the proper meteorological conditions and/or a physical disturbance at the site.

Table RISR 2.1-1. Estimated Volumes of Contaminated Soils by Site*

Site Designation	Estimated Contaminated Volume (b.c.y.)	Potentially Affected Media ** (excluding biota)
Solid Waste Burial		
SSA-3a, Ladora Lake Sediments	100,000	Soil
SSA-3b, Derby Lakes Sediments	100,000	Soil
ESA-2b, Sanitary Landfill	440,000	Soil, Groundwater, Air
ESA-3k, Suspected Trash Pit	7,400	Soil
SPSA-1f, Buried Hex Pit	1,200	Soil, Groundwater
SPSA-8a, Sanitary Landfill	10,000	Soil, Groundwater
CSA-1a, Pesticide Pits	110,000	Soil, Groundwater
CSA-1b, Complex Disposal Area(S)	200,000	Soil, Groundwater
CSA-1c, Complex Disposal Area (N)	710,000	Soil, Groundwater
CSA-1d, Sanitary Landfill and Incinerator 634	180,000	Soil
NCSA-1e, Burn Site	10,000	Soil, Groundwater
WSA-2, West Landfill	110,000	Soil, Groundwater
WSA-3b, Disposal Pit	2,000	Soil
WSA-3c, Surface Disposal Area	3,600	Soil
WSA-5a, Inferred Trench	17,000	Soil
WSA-5b, Burn Pit	8,500	Soil
WSA-5c, Inferred Trench	3,800	Soil
WSA-5d, Trenches	21,000	Soil
SUBTOTAL	2,000,000	
Buildings, Equipment, and Storage Sites		
SSA-4, Trash Dump	12,000	Soil
ESA-3a, Section 5 Storage Yard	3,700	Soil
ESA-3b, Section 6 Old Storage Yard	130,000	Soil, Surface Water, Groundwater
ESA-3c, Section 31 New Storage Yard	78,000	Soil
ESA-3d, Section 31 Toxic Yard Plots	190,000	Soil, Surface Water, Groundwater
ESA-3e, VX Demilitarization Pad	57,000	Soil
ESA-5, Demilitarization Activity	420	Soil
ESA-6a, Stored Ton Containers	4,800	Soil
SPSA-1a, Processing Area	160,000	Soil, Surface Water, Groundwater
SPSA-1b, Mounded Material	1,600	Soil
SPSA-2a, South Tank Farm	7,500	Soil, Groundwater
SPSA-2b, Open Storage Area	4,600	Soil, Groundwater

*These volume estimates are based on detections only and are not indicative of actual volumes that will require remediation as determined by the EA, risk assessments, and FS.
**The air media can theoretically be affected by virtually any site for short durations given the proper meteorological conditions and/or a physical disturbance at the site.

Table RISR 2.1-1. Estimated Volumes of Contaminated Soils by Site*

Site Designation	Estimated Contaminated Volume (b.c.y.)	Potentially Affected Media ** (excluding biota)
SPSA-2c, Salvage Yard	14,000	Soil, Groundwater, Surface Water
SPSA-3b, Salt Storage Pad	32,000	Soil
SPSA-3c, Former Tank Storage Area	8,700	Soil
SPSA-3d, Revetted Tank Storage	1,400	Soil
SPSA-6, Hydrazine Area	25,000	Soil
NPSA-2, Tank Farm	17,000	Soil, Groundwater
NPSA-3, GB Manufacturing Area	17,000	Soil, Groundwater
NPSA-4, Fuze and detonator Magazine	1,500	Soil
NPSA-5, Special Weapons Plant	8,100	Soil
CSA-2b, Parking Lot/Scrap Storage	89,000	Soil
WSA-4b, Storage Area	24,000	Soil, Groundwater
WSA-6b, Fuel Storage Area	370	Soil, Groundwater
WSA-6c, Building 631 Area	23	Soil, Groundwater
SUBTOTAL	890,000	
Spill Sites		
ESA-3f, Rail Loading Area	56,000	Soil
ESA-3g, Open Storage Area	230	Soil
NPSA-6, Underground Spill Area	52,000	Soil, Groundwater
NPSA-7, Oil Spill Area	2,900	Soil
NPSA-9a, Isolated Detection	500	Soil
NPSA-9d, Isolated Detection	23	Soil
NPSA-9e, Isolated Detection	23	Soil
NCSA-8c, Lift Station No. 2	180	Soil, Groundwater
WSA-1a, Isolated Detection	23	Soil
WSA-1b, Isolated Spill	34	Soil, Groundwater
WSA-1c, Wood Preservatives	330	Soil
WSA-1d, Isolated Detection	110	Soil, Groundwater
WSA-1e, DBCP Spill Area	8,700	Soil, Groundwater
WSA-7b, Sanitary Sewer Overflow	89	Soil
SUBTOTAL	120,000	
Sewer Systems		
SPSA-10, Chemical Sewer System	120,000	Soil, Groundwater
SPSA-11, Sanitary Sewer System	38,000	Soil

*These volume estimates are based on detections only and are not indicative of actual volumes that will require remediation as determined by the EA, risk assessments, and FS.
**The air media can theoretically be affected by virtually any site for short durations given the proper meteorological conditions and/or a physical disturbance at the site.

Table RISR 2.1-1. Estimated Volumes of Contaminated Soils by Site*

Site Designation	Estimated Contaminated Volume (b.c.y.)	Potentially Affected Media ** (excluding biota)
SPSA-12, Process Water Lines	380,000	Soil, Groundwater
NPSA-1, Chemical Sewer System	130,000	Soil, Groundwater
CSA-3, Chemical Sewer	53,000	Soil
NCSA-4a, Deep Disposal Well Facility	39,000	Soil
NCSA-6a, South Plants Chemical Sewer	30,000	Soil, Groundwater
NCSA-6b, North Plants Chemical Sewer	25,000	Soil
NCSA-8a, Sanitary Sewer Lines	81,000	Soil
WSA-7a, Sanitary Sewer Sediment	100	Soil
SUBTOTAL	900,000	
Surficial Soil and Other Predominantly Near-Surface Contamination		
SPSA-1g, Balance of Subarea	150,000	Soil, Surface Water
SPSA-2e, Balance of Subarea	74,000	Soil, Groundwater
SPSA-3e, Balance of Subarea	68,000	Soil
SPSA-4b, Balance of Subarea	99,000	Soil
SPSA-5b, Balance of Subarea	74,000	Soil
SPSA-7c, Balance of Subarea	70,000	Soil
SPSA-8c, Balance of Subarea	22,000	Soil
SPSA-9b, Balance of Subarea	97,000	Soil
CSA-4, Balance of Areas Investigated	360,000	Soil
NCSA-1g, Inferred Wind Dispersion	21,000	Soil
NCSA-4b, Basin F Exterior	950,000	Soil
SUBTOTAL	2,000,000	
Isolated Contamination		
SSA-5a, Isolated Detection	57	Soil
SSA-5c, Isolated Detection	57	Soil
SSA-5d, Isolated Detection	57	Soil
ESA-3j, Toxic Storage Yard Fence	460	Soil
ESA-6b, Trench	5,400	Soil
ESA-6d, Isolated Detection	23	Soil
NPSA-9b, Isolated Detection	20	Soil
NPSA-9c, Isolated Detection	34	Soil
NPSA-9f, Isolated Detection	57	Soil
NCSA-9a, Isolated Detection	330,000	Soil

*These volume estimates are based on detections only and are not indicative of actual volumes that will require remediation as determined by the EA, risk assessments, and FS.
**The air media can theoretically be affected by virtually any site for short durations given the proper meteorological conditions and/or a physical disturbance at the site.

Table RISR 2.1-1. Estimated Volumes of Contaminated Soils by Site*

Site Designation	Estimated Contaminated Volume (b.c.y.)	Potentially Affected Media ** (excluding biota)
NCSA-9b, Isolated Detection	58	Soil
NCSA-9c, Isolated Detection	58	Soil
NCSA-9d, Isolated Detection	58	Soil
NCSA-9e, Isolated Detection	58	Soil
NCSA-9f, Isolated Detection	23	Soil
NCSA-9g, Isolated Detection	35	Soil
NCSA-9h, Isolated Detection	23	Soil
NCSA-9i, Isolated Detection	23	Soil
NCSA-9j, Isolated Detection	23	Soil
NCSA-9k, Isolated Detection	57	Soil
NCSA-9l, Isolated Detection	35	Soil
NCSA-9m, Isolated Detection	210	Soil
NCSA-9n, Isolated Detection	57	Soil
NCSA-9o, Isolated Detection	58	Soil
NCSA-9p, Isolated Detection	87	Soil
NCSA-9q, Isolated Detection	23	Soil
NCSA-9r, Isolated Detection	87	Soil
WSA-1f, Isolated Detection	57	Soil
WSA-1g, Isolated Detection	86	Soil
WSA-3a, Isolated Detection	110	Soil
WSA-3d, Isolated Detection	23	Soil
WSA-4a, Isolated Detection	23	Soil
WSA-8a, Isolated Detection	57	Soil
WSA-8b, Isolated Detection	57	Soil
WSA-8c, Isolated Detection	57	Soil
WSA-8d, Isolated Detection	57	Soil
WSA-8e, Isolated Detection	57	Soil
WSA-8f, Isolated Detection	23	Soil
SUBTOTAL	340,000	
TOTAL	13,000,000	

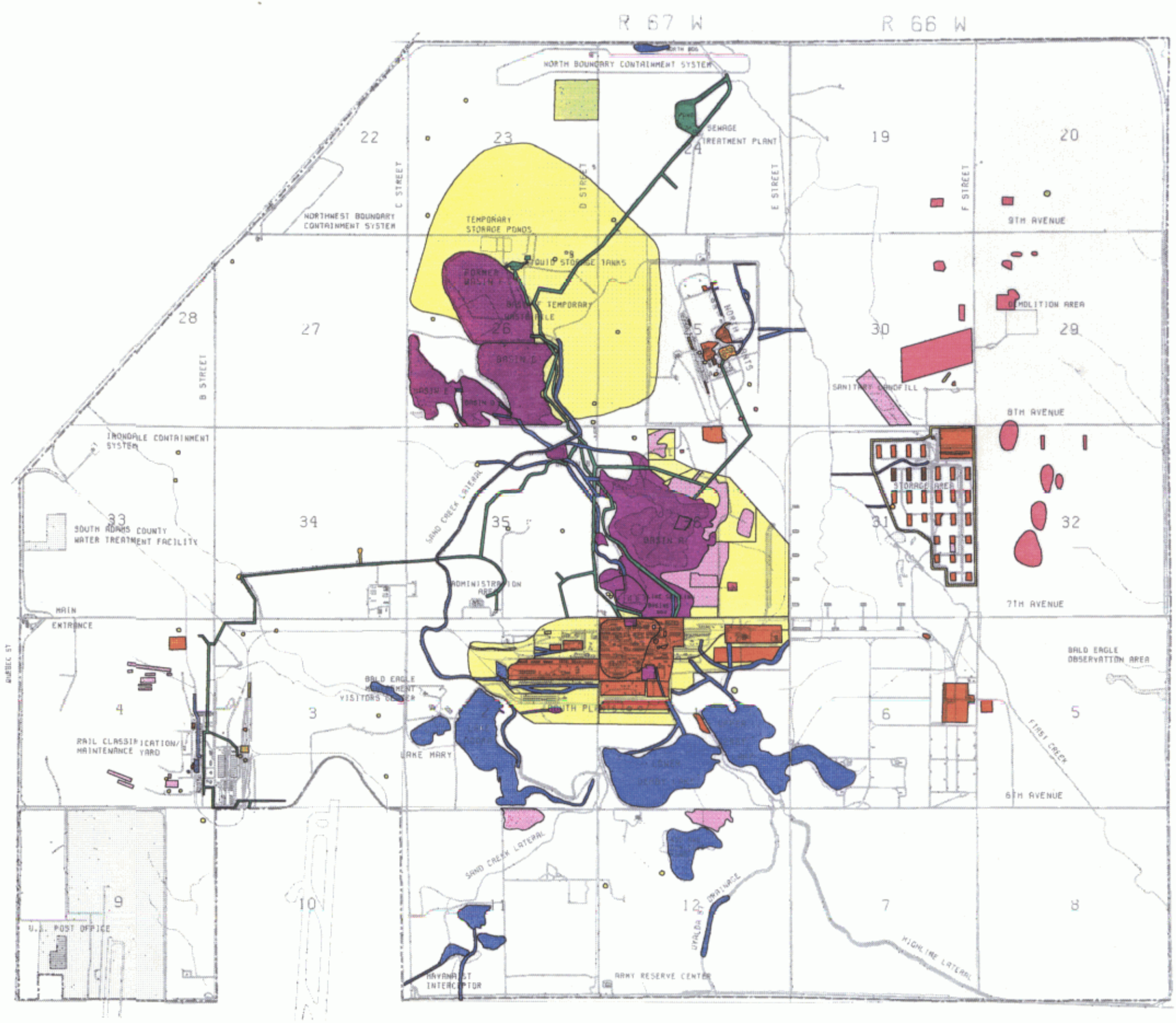
*These volume estimates are based on detections only and are not indicative of actual volumes that will require remediation as determined by the EA, risk assessments, and FS.
**The air media can theoretically be affected by virtually any site for short durations given the proper meteorological conditions and/or a physical disturbance at the site.

presented in the SARs. Figure RISR 2.1-1 shows the location of each site and site type. A total of approximately 13 million bank cubic yards (b.c.y.) of soil materials are estimated to be contaminated by organic and/or inorganic analytes at RMA. These volume estimates are based on detections only, and are not indicative of actual volumes that will require remediation as determined by the EA, risk assessment, and FS. It should be emphasized that the distribution of contaminants in soils is typically irregular because of the heterogenous nature of the soil matrix; therefore, these volume estimates can only be considered approximate.

Direct exposure to these sources and to the migration pathways potentially threatens human and other biological receptors. By relating contaminants, contamination sources, and migration pathways, the interactive nature of contaminants and the environment into which they are introduced can be understood.

Contamination was detected in soils, ditches, stream, and lakebed sediments, sewers, groundwater, surface water, biota, structures, and, although to a much lesser extent, air. Soil and alluvial aquifer materials in the central and northern portions of RMA contain most of the contaminant sources. Less extensive or less concentrated sources occur only sporadically within the relatively uncontaminated buffer zone along the eastern, southern, and western boundaries. The most highly-contaminated sites (highest concentrations and/or greatest variety of contaminants) are concentrated in the central manufacturing, transport, and waste disposal areas. The greatest contaminant concentrations and distributions tend to occur in the upper 5 ft of the soil column, although exceptions are noted, particularly in the case of waste burial trenches and leaks from subsurface structures. In general, contaminant distribution is influenced most significantly by the physical and chemical properties governing contaminant behavior, by soil type, and by former manufacturing and disposal practices.

Groundwater contaminant plumes predominantly consist of organic compounds and arsenic, fluoride, and chloride. The relative contributions of various sources to groundwater plumes



LEGEND

- Major Drainage
- Minor Drainage
- Railroad Tracks
- Basin
- Former Basin
- Lakes and Ponds
- RMA Property/Leased
- Road
- 3 Section Number
- Structure
- Former Structure
- Arsenal Boundary

Site Types

- Basins and Lagoons
- Ditches,Lakes, and Ponds
- Ordnance Testing and Disposal Areas
- Solid Waste Burial Sites
- Buildings, Equipment, and Storage Sites
- Spill Sites
- Sewer Sites

Surficial Soil and Other Predominantly Near-Surface Contamination

- Predominantly Near-Surface
- 0 – 2 inch
- Isolated Contamination

Note 1: Sites of contamination are grouped by similar physical characteristics and/or historical use

Note 2: Due to scale of this map, details of the chemical, sanitary sewers, and the process water systems are not shown

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

U.S. Army Program Manager for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR 2.1-1

Location of Soil Contaminant Site Types at Rocky Mountain Arsenal

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

are often difficult to ascertain. Rarely are unique contaminants present at a source to unequivocally associate to a groundwater plume. Therefore, conclusions focus on contaminant sources, emphasizing their relationships to migration pathways.

The principal contaminants at RMA are pesticides, metals (including arsenic and mercury), Army agent degradation products, and chlorinated or aromatic solvents. Contamination in soils and groundwater is dominated by relatively mobile volatile compounds (volatile halogenated organics, volatile hydrocarbon compounds, and volatile aromatic organics) and less mobile contaminants, principally organochlorine pesticides and arsenic, which were detected over widespread areas at low to high concentrations.

Plate RISR 2.1-1 is an exploded three-layer isometric view of RMA displaying RMA sources (as soil contamination sites) in the top layer, the alluvial groundwater aquifer with the 1989 total organic analytes plume in the middle layer, and contaminant occurrences in the confined Denver Formation aquifer on the bottom layer. One purpose of this graphic presentation is to relate RMA sources to migration pathways in the alluvial aquifer. In this manner, sources may be spatially related to plumes. Comparison of these two layers, with the Denver Formation aquifer detections mapped on the lowest layer, shows the spatial relationship between sources, plumes, and underlying contamination. Although this graphic is useful for visualizing major contaminant pathways, it should be noted that plumes may have migrated downgradient from their original sources, and preferred pathways are not always apparent. However, many of the conclusions presented here are illustrated on Plate RISR 2.1-1.

2.1.1 Basins and Lagoons

There are 14 basin and lagoon sites containing approximately 4.3 million b.c.y. of contaminated material (Table RISR 2.1-1). Basins and lagoons formerly used for liquid waste disposal are among the most contaminated sites at RMA. Although the degree of contamination varies among sites within this site type, basins and lagoons are important contaminant sources because they generally exhibit a wide variety of contaminants at a wide

range of concentrations and are really extensive. Contaminant concentrations in soils at several of these sites exceed levels detected elsewhere at RMA, and groundwater contaminant plumes are observed to originate below basin sources. The continuous presence of contaminant occurrences throughout the unsaturated soil column below many of these sites supports the conclusion that the more contaminated basins and lagoons are sources of groundwater contamination.

Basin F, Basin A, and the lime settling basins are (or were) of primary concern due to their high potential for contaminant release to the environment. Although the Basin F IRA has contained contaminated liquids and surface soils, a 40-ft column of contaminated soil that remains at this site is a possible source of groundwater contamination. The highest concentrations of volatile halogenated organics in soils were detected throughout the soil column below the eastern margin of Basin F. Other volatile organics, pesticides, and agent degradation products were also detected. Inorganic contaminants are primarily confined to shallow soils and were not observed to impact groundwater quality in the area.

Basin A and the lime settling basins in Section 36 contain a wide variety of contaminants, representing nearly all contaminant groups analyzed during the RI. Basin A is known to have received indeterminate amounts of nearly every chemical (or breakdown product thereof) used or demilitarized in the South Plants and North Plants until 1956. RI data also indicate that Basin A and related sites are sources of many contaminants in groundwater. However, contaminant loading from upgradient sources in the South Plants area and the Section 36 disposal trenches have also contributed to contamination in groundwater below Basin A. The depth to the water table in the area ranges from 1.5 ft to 10 ft. The proximity of the water table to these liquid waste storage and treatment basins is a major factor in assigning a high priority to these sites. The potential for rapid infiltration and groundwater-surface water interchange greatly facilitates contaminant migration in the area. The potential for eolian transport of contaminated dust is high because these sites are sparsely vegetated. This problem also exists for other poorly vegetated basin and lagoon sites. Air monitoring has

shown very erratic results indicating that while volatile and semivolatile organic compounds were sporadically detected during "event" sampling, air impacts are primarily limited to particulate transport during high wind conditions. The Fugitive Dust Control IRA (see Appendix C) implemented at Basin A and Basin F is expected to minimize and mitigate windblown transport of dust from these sites.

Other basins and lagoons may exhibit a wide variety of contaminants; however, their contaminant concentrations and areal extent are smaller than those in Basin F, Basin A, and the lime settling basins. As contaminated liquids were stored in these basins, the potential for infiltration and downward transport to the water table has been greater for this site type than for all other site types except the ditches, lakes and ponds, and sewer sites.

2.1.2 Solid Waste Burial Sites

There are 18 solid waste burial sites containing approximately 2.0 million b.c.y. of contaminated material (Table RISR 2.1-1). Solid waste burial sites exhibit a high potential for environmental release of contamination. The Army and Shell disposal trenches in Section 36 warrant the greatest concern. Like the disposal basins, these burial trenches contain a wide variety of contaminants, most notably Army agent breakdown products, volatile organic compounds, and metals. Some of these trenches were originally excavated to the water table. Consequently, favorable conditions for leaching and infiltration of waste materials have minimized the opportunity for attenuation of contaminants such as volatile organic compounds and the Army agent breakdown product DIMP, which tend to partition to the aqueous rather than the solid phase. These trenches have been identified as sources of pesticides, agent breakdown products, and volatile organics in groundwater. However, metals at these sites appear to concentrate in soils at or near the bottom of the trenches. Concentrations of organochlorine pesticides in soils from the Shell trenches are some of the highest at RMA. Potential for unexploded ordnance and Army chemical agents exists in the Army trenches, despite geophysical screening and exploratory excavation conducted at this

site. Although these sites may exhibit contaminant distribution at depth throughout the unsaturated zone, the distributions are not really extensive when compared to other site types.

Other solid waste burial sites include landfills in the Western and Eastern Study Areas and buried lakebed sediments in the Southern Study Area. Potentially hazardous materials were not disposed at these sites in large quantities. Thus, contaminant concentrations are generally low when compared to the trenches in Section 36. In addition, these less contaminated solid waste burial sites were typically separated from the water table by unsaturated zones 5 to 60 ft thick; three to six times as thick as those at the Section 36 trenches. These thicker unsaturated zones provided greater opportunity for attenuation, mitigation, or isolation of contaminants and therefore reduce the potential for releases to groundwater. Nonetheless, RI data provide some evidence indicating limited groundwater impact from the Western Study Area landfills, primarily from volatile organic compounds.

2.1.3 Buildings, Equipment, and Storage Sites

Twenty-five buildings, equipment, and storage sites containing approximately 0.89 million b.c.y. of contaminated soils (Table RISR 2.1-1) comprise this site type at RMA. In addition, 1,285 structures were catalogued as a part of the RI. These structures included buildings, tanks exterior to buildings, tank farms, foundations of former buildings, electrical substations, and pipe runs. RMA structures themselves consist of an estimated 250,000 b.c.y. of building materials, including 185,000 b.c.y. of concrete, brick, and structural steel; 10,000 b.c.y. of wood; 5,000 b.c.y. of asbestos-containing materials; and 50,000 b.c.y. of tile, piping, minor equipment, nonstructural steel, and miscellaneous building materials. The following discussion relates to contamination sites rather than the structures themselves. Also, since no bores were drilled beneath existing structures, these results (and volume estimates) do not address possible contaminant conditions in soils beneath structures.

As buildings, equipment, and storage sites vary in nature, the character of contamination varies from site to site. Only those sites that contain a wide variety of contaminants in soils

at concentrations comparable to those found at Basins A and F and the Section 36 disposal trenches are discussed here individually. They include the South Plants processing area, the South Plants tank farm, the HBSF, and several North Plants buildings and storage tank areas. A variety of contaminants occur in soils at these sites, most notably organochlorine pesticides, volatile organic compounds, DIMP, arsenic, and mercury. Spills of product and feedstock chemicals have occurred historically in these areas, and soil contamination at these sites is extensive and at sufficient concentrations to impact other media.

In the South Plants processing area volatile organic compounds, dibromochloropropane, and herbicide-related organosulfur compounds predominate in groundwater. The presence of Army agent breakdown products in soils or groundwater in the area is limited. However, lewisite contamination was detected in the M-1 settling basins. Concentrations of volatile organic compounds in groundwater at the South Plants tank farm exceed 10,000 µg/l, and appear to be the result of leaking storage tanks. Wind transport of surficial soils contaminated with organochlorine pesticides is also a notable migration pathway in this area. Volatile and semivolatile organic compounds, organochlorine pesticides, and inorganics were detected in the HBSF area of South Plants, and leaks and spills were documented at the facility during its operation. Hydrazine was not detected in the area because a certified method for detecting hydrazine was not available at the time of the RI.

In the North Plants, the GB manufacturing area, Buildings 1703 and 1727, and the North Plants tank farms are considered possible sources of groundwater contamination. While the North Plants chemical sewer may also have impacted groundwater, data do not confirm this suspicion. The primary contaminants at these North Plants sites are volatile organic compounds such as benzene and chloroform and the Army agent breakdown product DIMP.

IRAs have already been implemented or initiated to address contamination in North Plants Building 1727, and at the HBSF in the South Plants. Additional information regarding these IRAs can be found in Appendix C.

Other buildings, equipment, and storage sites typically showed less soil contamination (for example, lower target analyte concentrations), but did contain asbestos. Although there is no widely accepted method for assessing contamination within structures, the majority of structures on RMA, particularly those within the manufacturing areas, are suspected to be contaminated based on history of use, visual inspection, and limited sampling (see Appendix A3). However, the likelihood of migration and exposure from these sites is believed to be considerably less than for the specific areas described above.

2.1.4 Ditches, Lakes, and Ponds

There are 36 ditches, lakes, and pond sites containing approximately 1.9 million b.c.y. of contaminated material on RMA (Table RISR 2.1-1). This site type includes a variety of contaminant sources that exhibit variable potential for release and migration of contaminants. All of the lakes are hydrologically connected (to each other and) to the alluvial aquifer. Hence, any contamination observed in lake sediments must be considered a possible source of groundwater contamination. In addition, the lakes provide an opportunity for contaminant exposure to aquatic species, waterfowl, and other biota. Lakes have provided contaminant migration pathways resulting in documented adverse waterfowl impacts in the past. Dredging and burial of lakebed sediments, termination of South Plants manufacturing processes, and discontinued use of the ditch system have improved lake habitats considerably.

The enhanced sorptive capacity of the organically rich, fine-grained lake and pond sediments allows increased retardation for most analytes observed in these environments. Thus, although the opportunity for interaction with the alluvial aquifer exists, a natural sorption mechanism is also in place to mitigate contaminants currently present in lakebed sediments.

An analysis of Phase II RI data and Waterways Experiment Station data from Lower Derby Lake showed that aldrin concentrations in lake sediments range from the detection limit to 13,000 micrograms per kilogram (µg/kg), i.e., 13 parts per million (ppm), and dieldrin concentrations in lake sediments range from the detection limit to 320 µg/kg (0.32 ppm).

Aldrin/dieldrin ratios range from less than 1 in some shallow areas of the lake to over 100 in deep areas of the lake (Cushing, 1990). These results are surprising because, in general, most field and laboratory studies indicate that aldrin should be converted to dieldrin within a short time in an aquatic environment. The generally high aldrin/dieldrin ratios indicate that something is blocking the mechanisms available to convert aldrin to dieldrin. When taken in conjunction with evidence showing detectable aldrin and dieldrin in sediments and biota but not lake waters, and sedimentation rates showing aldrin/dieldrin persistence in lake sediments for up to 40 years, these data suggest that aldrin and dieldrin are so strongly sorbed to sediment materials that normal conversion mechanisms may not operate (Cushing, 1990). Due to the strong sorption of these compounds to sediments, the potential for groundwater migration of organochlorine pesticides from lake sediments should be reduced, although the potential for bioaccumulation may still remain as indicated by detections in biota.

For ditches that are presently dry except when carrying surface runoff or overflow, a direct hydraulic connection with groundwater is generally not present. Contaminants detected in dry ditch sediments may migrate by leaching during infrequent periods of surface water flow or by eolian transport. The rate of migration by these mechanisms is expected to be much slower than in the past when surface water transport was the dominant transport mechanism. However, if the ditches are to be returned to service in the future, they must be remediated to prevent ditch contaminants from migrating to the water table via direct hydraulic connection. The volume of contaminated soil assigned to ditches is considerably less (i.e., less than 1/10) than for larger sites discussed above.

A limited set of contaminants including low to high levels of organochlorine pesticides, dibromochloropropane, arsenic, mercury, cadmium, chromium, copper, lead, and zinc was commonly detected in ditches, lakes, and ponds. Despite a potential for biota and limited human exposure, the contamination at these sites is considered less threatening than that found at basins and lagoons, or other sites described above, due to the relatively low concentrations.

2.1.5 Sewer Sites

There are 10 sewer sites containing approximately 0.90 million b.c.y of contaminated material (Table RISR 2.1-1). The sewers site type consists of three systems: chemical sewers, sanitary sewers, and the process water system. The importance of the chemical sewers and process water systems far outweighs that of the sanitary sewers as an historical source of contamination. Due to the influence of other contamination sources, the contaminant contribution from chemical sewers is difficult to assess. However, groundwater contaminant plume configurations and localized high concentration occurrences within the plumes (hot spots) suggest influences from the South Plants and Basin F chemical sewers. Contributions from the North Plants chemical sewers are suspected but unconfirmed. Detections related to the sanitary sewer and sewage treatment plant are generally sporadic at low concentrations and do not follow apparent trends. Remediation of the sanitary sewers is the object of an ongoing IRA (Appendix C).

Chemical sewers, used to carry waste products from the manufacturing plants to the disposal basins, were critical sources by nature of their characteristically high flow of liquid wastes and their presence below the surface. Leakage from faulty joints and fractures historically allowed infiltration of wastewater into subsurface soils at various points along their routes. The excavations created during installation of the sewer pipes and trenches that were backfilled after removal of much of the pipe could also provide conduits for groundwater flow. The direct availability of groundwater pathways has apparently caused elevated concentrations and hot spots within plumes that are generally attributed to Basin A and former Basin F. Several portions of the chemical sewer are characterized by a wide variety of contaminants at moderate to high concentrations. Although these sites are not really extensive, they are significant because of their potential to contribute large volumes of contaminants to soil and groundwater. As these sites are underground, their potential for direct exposure to humans and biota is limited. Environmental impacts related to the sewers are largely restricted to adjacent subsurface soils and to the groundwater medium. Actions have been and are currently being undertaken to eliminate the sewers as active sources of

contamination. Contamination in soils adjacent to sewers will be handled by the FS when it addresses the sewers systems.

2.1.6 Spill Sites

Fourteen spill sites containing approximately 0.12 million b.c.y. of contaminated material (Table RISR 2.1-1) comprise this site type at RMA. The overall impact of spill sites on environmental media at RMA appears to be less important than impacts from the site types described above. Generally, contamination resulting from individual spills on soils is not laterally or vertically extensive, and involves a limited number of contaminants. Exceptions are in the Western Study Area, where a dibromochloropropane spill in the railyard and a possible trichloroethylene spill in the motor pool area have generated well-defined groundwater plumes in the alluvial aquifer. These soluble compounds are widely distributed once they reach the water table. The sandy soils of the Western Study Area have limited sorptive capacities for organic contaminants, and therefore do not significantly retard the migration of spill products in the 30- to 40-ft thick unsaturated zone. The impacts associated with the majority of spill sites, however, are far less significant. Most other spills occurred in the manufacturing areas where other contaminant sources are more significant and mask their effects.

2.1.7 Ordnance Testing and Disposal Areas

There are 12 ordnance testing and disposal sites at RMA containing approximately 0.41 million b.c.y. of contaminated material (Table RISR 2.1-1). Ordnance testing and disposal areas are generally characterized by lower contaminant concentrations, limited distribution, and a lower potential for contaminant migration than the sites described above. Typically, ordnance testing and disposal areas contain a limited variety of low-mobility contaminants such as heavy metals and polynuclear aromatic hydrocarbons. Although concentrations of metals have been detected as high as 10,000 micrograms per gram (µg/g), other contaminants generally are present at concentrations less than 10 µg/g. Most of these sites are shallow pits and trenches or artillery ranges, and much of the associated contamination occurs at less than

5 ft in the soil column. Deeper zones of contamination are associated with trenches, and do not necessarily represent enhanced migration and transport. Only one of these sites, a burn pit in the Eastern Study Area, is tentatively considered a potential source of groundwater contamination. This conclusion, however, is based on a single benzene detection noted in soils near the water table at this site.

2.1.8 Surficial Soil and Other Predominantly Near-Surface Contamination

There are 11 designated sites of windblown contamination (not including the surficial soil sampling locations) containing approximately 2.0 million b.c.y. of contaminated material (Table RISR 2.1-1) at RMA. Widespread areas of low concentration, surficial organochlorine pesticide and arsenic contamination surrounding Basin A, Basin F, and South Plants are inferred to have been transported by wind. Once in surface soils, organochlorine pesticides and arsenic are considered to exhibit low mobility, and are not expected to migrate downward. Areas of windblown contamination are not considered potential sources of groundwater contamination.

In addition, the surficial soil sampling program (Appendix D1) detected widespread organochlorine pesticide contamination in very shallow (0- to 2-inch depth) soils on post. This contamination is not caused by the direct release of contaminants but rather by the secondary airborne transport of contaminated dust or liquid spray, as from liquid-filled basins and lagoons. Although widespread contaminant distribution is associated with this transport mechanism, concentrations in near-surface soils (typically parts per billion) pose negligible potential for detectable release to other media. These occurrences do carry a potential for biota and human exposure. Direct exposure to the top few inches of soil is considered an important potential exposure pathway. An IRA to control fugitive dust at RMA is ongoing (Appendix C).

2.1.9 Off-Post Sources

Off-post sources are included here in recognition of their relative importance in contributing to on-post contamination conditions in the water medium. While off-post sources are not actually designated as site types, surface water and groundwater contamination that enters RMA along the southern boundary is significant. Routes of surface water transport from off-post sources to the south include the Peoria and Havana Interceptors. Contaminants in surface water entering RMA from the south include volatile organic compounds, organophosphorus and organosulfur compounds, semivolatile halogenated organics, pesticides, arsenic, and zinc. Concentrations are within the range of surface water contamination observed elsewhere at RMA. The occurrence of many of these compounds is consistent with manufacturing and industrial activity south of RMA.

Groundwater entering RMA from the south contains detectable volatile organic compounds and associated breakdown products. A site at 49th and Havana, less than 1-1/2 miles upgradient of the Western Study Area, is documented as a source of trichloroethane contamination to groundwater (E&E, 1989).

Plumes originating off-post merge with RMA plumes as they follow alluvial paleochannels that flow under the Western Study Area (see Appendix A). The volatile organic plume that flows below the Western Study Area and eventually flows off post at the western boundary appears to consist largely of contamination originating off post.

2.1.10 Isolated Contamination

There are 38 sites of isolated contamination containing approximately 0.34 million b.c.y. of contaminated material (Table RISR 2.1-1). These occurrences generally consist of a single detection that was anomalous, not repeated, or not associated with any recognized site, source, or historical use activity. These occurrences are not considered sources, as their isolated nature and the available data do not suggest associations with contamination in other locations or in other media via intervening migration pathways. While they may be the result of

anthropogenic or even anomalous natural occurrences in some cases, their potential for further releases is considered to be very low.

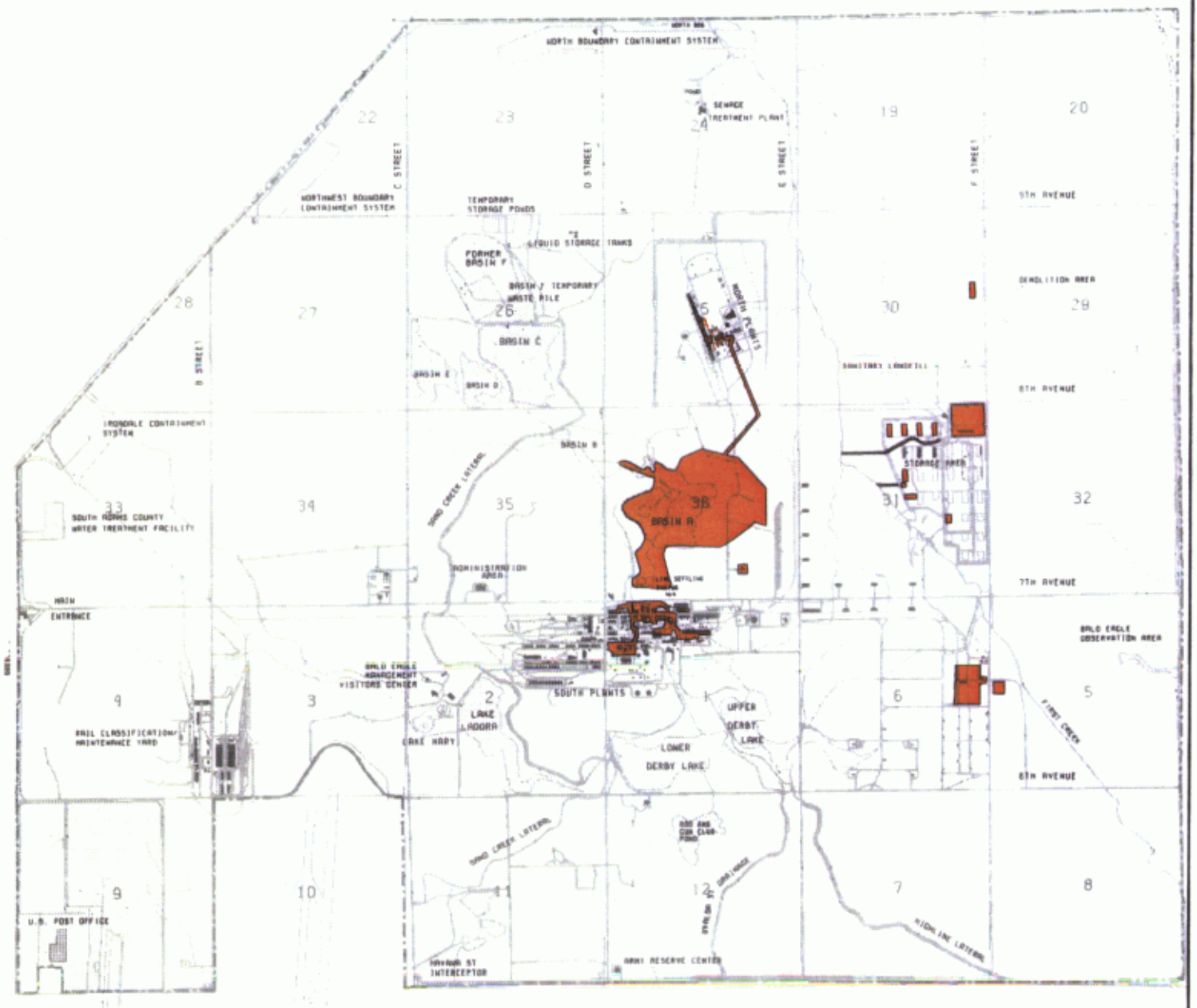
2.1.11 Balance of Areas Investigated

This group includes detections that have been attributed to sampling error, analytical error, or natural occurrences in the areas of RMA not included in designated sites (Plate 2.0-1). They are not considered sites or sources. Mildly elevated concentrations of arsenic and ICP metals encountered in bedrock and clay-rich soils were interpreted as natural occurrences. Anomalous methylene chloride detections at low concentrations have been attributed to laboratory contamination, and oxybisethanol detections are attributed to the antifreeze agents used in the steam cleaners for decontaminating sampling equipment during winter operations.

2.2 POTENTIAL FOR OCCURRENCE OF CHEMICAL WARFARE AGENTS AND UNEXPLODED ORDNANCE

The handling of chemical warfare agents has been strictly monitored throughout RMA history and agent compounds have been the focus of specific actions designed to mitigate the potential for their release to the environment. Furthermore, agents generally have short half-lives when exposed to the natural elements and, with the exception of mustard that may have been trapped in voids beneath buildings, are generally not persistent in soils. Agents occur within some buildings, containment vessels, piping, and other structures within which they were manufactured, handled, demilitarized, or stored.

Figure RISR 2.2-1 is a map of areas at RMA that are considered to have potential for the occurrence of agents. The map was drawn conservatively as a "worst-case" scenario representing the maximum possible geographic extent of potential agent occurrences. Areas on the map were delineated on the basis of a review of the RMA database, pertinent historical information and RI reports. Specifically, the SARs were surveyed and all references to agent occurrences noted. Individual CARs for those areas where agent presence at some time was referenced were reviewed by identifying on a map all locations and sample collection points



Legend

- Major Drainage
- Minor Drainage
- Railroad Tracks
- Basin
- Former Basin
- Lakes and Ponds
- RMA Property/Leased
- Road
- 3 Section Number
- Structure
- Former Structure
- Arsenal Boundary
- Areas of potential agent occurrences

N

0 2000 4000

Scale in Feet

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

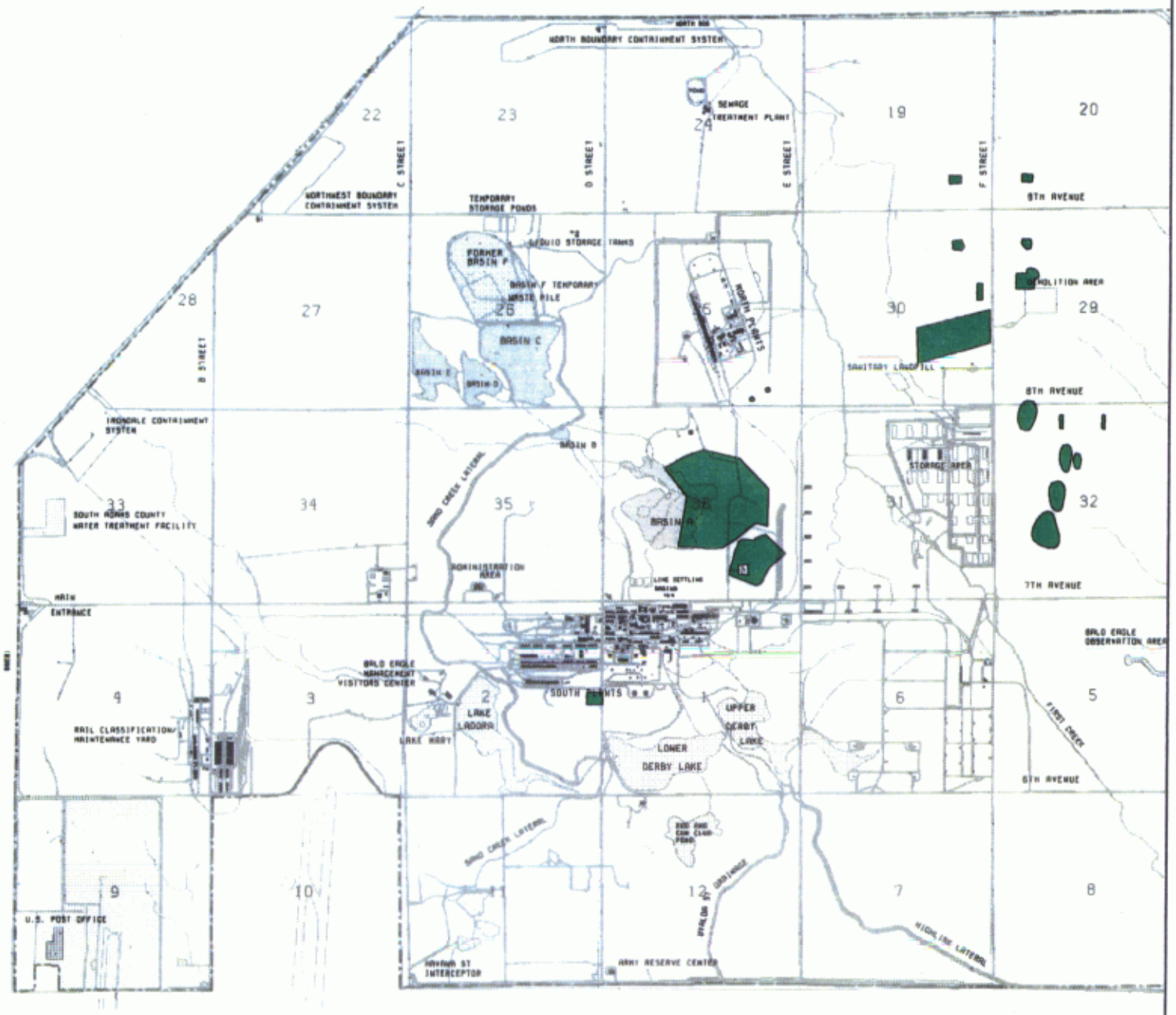
Prepared by: Ebasco Services Incorporated
August 1991

FIGURE RISR 2.2-1

Areas with Potential for Agent Occurrences at Rocky Mountain Arsenal

where agent occurrence was suspected, recounted, or analytically examined. An audit of the IRDMIS database consisting of a query and plot of the resulting data points for all agent detections was accomplished and compared and combined with the results of the literature review. Finally, a second review in the literature and by interview with knowledgeable individuals was accomplished to cross-check for all reported detections in the database only. While detections of both Lewisite and mustard are reported in the RMA database, it is considered unlikely that actual agent would be detected in the area delineated in Figure RISR 2.2-1. With the exception of mustard under certain conditions where it is protected from weathering effects (e.g., in soils beneath a concrete pad), chemical warfare agents are highly unstable and very rapidly degrade to breakdown products which, though still considered contaminants, do not constitute the immediate threat to life or health posed by the chemical warfare agents. Prior reports including the Basin A CAR (ESE, 1987b, RIC 87203R07) have erroneously reported that mustard was detected in Basin A during a study done by the Office of the Surgeon General (Cogley, 1976, RIC 81226R09). That study did not report the detection of mustard in Basin A. All reported mustard detections in soils on RMA (four records in the RMA database) were less than 50 percent of the CRL value for this agent. The Lewisite detections reported in the RMA database outside of the South Plants area are suspect; the method is known to give false positives and no detections were made in those samples collected for verification of specific detections. Historical accounts of agents are presented in the CARs and SARs, and by historical documentation and individual deposition in the administrative record; an account of sample collection and handling protocols for potential agent occurrence is presented in Appendix A2.

RMA has also been used historically to manufacture, store, test, demilitarize, and dispose a variety of conventional munitions. Figure RISR 2.2-2 is a map of areas of RMA that are considered to have potential for the occurrence of unexploded ordnance (UXO). These areas were delineated based on a review of pertinent historical information and RI reports. The map was drawn conservatively as a "worst-case" scenario representing the maximum possible geographic extent of potential UXO occurrences. It is emphasized that the likelihood of



Legend

- Major Drainage
- Minor Drainage
- Railroad Tracks
- Basin
- Former Basin
- Lakes and Ponds
- RMA Property/Leased
- Road
- 3 Section Number
- Structure
- Former Structure
- Arsenal Boundary
- Areas of potential unexploded ordnance

N

0 2000 4000

Scale In Feet

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated
August 1991

FIGURE RISR 2.2-2

Areas with Potential for Unexploded Ordnance at Rocky Mountain Arsenal

actual UXO occurrence in most of the areas indicated in Figure RISR 2.2-2 is low. The majority of areas considered to have potential for UXO are former munitions testing and disposal areas.

2.3 MIGRATION PATHWAYS

Historic and current migration pathways have been identified as a result of the observed contaminant distribution and the RI fate and transport studies. A summary of major contaminant migration pathways is useful to understanding RMA contaminant distribution and for prioritizing potential sources requiring remediation. These pathways provide a conceptual link between sources and receptors, a critical element of contaminant assessment. The following primary pathways are summarized:

- Unsaturated zone
- Unconfined groundwater flow
- Confined Denver Formation groundwater flow
- Wind
- Surface water.

A more detailed description of these pathways and their various transport mechanisms can be found in Appendix E.

Contaminants have historically migrated from production, transport, and disposal areas along unsaturated zone, surface water, groundwater, and eolian (windblown) pathways. In the past, human and other biological receptors, both on and off post, have potentially been exposed to contaminants via these pathways. The surface water pathway has been greatly reduced by discontinuing use of the liquid waste disposal and process water networks. IRAs have been designed to reduce and control the threats to off-post receptors, and land-use restrictions have minimized risks to humans on post. IRAs have also been designed to isolate biota from the most toxic sources, (Basin F liquids and Basin A dust). However, other sources continue to

pose a risk for exposure to biota; some contaminants are present and continue to migrate within the food chain. These risks are examined in the Biota RI.

Although on-post sources have historically generated the most concern, contamination from unidentified off-post sources is known to have migrated on post in groundwater and surface water.

2.3.1 Unsaturated Zone

The unsaturated zone is the usual pathway by which contaminants enter the alluvial aquifer. The properties of this zone as a pathway and as an attenuating medium are largely determined by its thickness, soil properties, and permeability. The unsaturated zone transmits contaminants to the alluvial aquifer most effectively when it is thin and/or highly permeable. High permeability allows rapid infiltration and vapor migration. A thin unsaturated zone is conducive to elevated transport rates and therefore diminishes the possibility for attenuation by retardation or degradation. The unsaturated zone at RMA is relatively thin beneath Basin A, the lime settling basins and the Section 36 disposal trenches and the northcentral portion of the South Plants. The thickest unsaturated zone at RMA occurs in the Western Study Area, but the soils and alluvium in that area are more permeable and the potential for release of contaminants to groundwater is greater there than in many other areas of RMA.

In some areas, where large volumes of concentrated liquid wastes were stored for relatively long periods of time, the effective thickness of the unsaturated zone may have been decreased at times by up to 100 percent due to saturation of all or part of the zone by downward-migrating contaminants. Such areas included portions of Basin F, Basin C, the Section 36 disposal trenches, and the North and South Plants tank farms. Removal of the Basin F liquids, sludges and soils, and capping of the Basin F area as part of an IRA have substantially altered conditions there, and reduced or eliminated the potential for further contaminant migration from beneath the former basin.

2.3.2 Unconfined Flow System

The unconfined flow system is a major migration pathway capable of transporting observable contamination over long distances. Groundwater transport is most efficient within the alluvial deposits overlying bedrock along fairly continuous paleochannels filled with sediments. These deposits are generally several orders of magnitude more permeable than the underlying Denver Formation. Unconfined groundwater follows the major flowpaths across RMA towards the Irondale, North, and Northwest Boundary Containment Systems. Contaminant plumes aid in identifying these flowpaths and depict the confinement of contaminants within these pathways. The unconfined flow system is also the route by which contaminants are introduced into the confined flow system in the Denver Formation aquifer.

Many RMA sources are capable of impacting the unconfined flow system. Sandy soils and topographic depressions allow infiltration of contaminated surface water that may result in recharge to the unconfined aquifer. In addition, wastewater discharges, sewer leaks, and chemical spills are capable of infiltrating directly to the water table. Direct introduction to groundwater may also occur at sources such as underground storage tanks, transfer pipelines, sewers, sumps, basins, ditches, and disposal pits that are in direct contact with the water table. Factors that affect the transport of analytes in groundwater include analyte solubility, dispersion, facilitated transport by colloids or cosolvents, retardation with respect to groundwater flow rates, biodegradability, aquifer composition, complexation, flow velocity, and analyte chemistry. The unconfined flow system exhibits variable retardation due to varying properties of aquifer materials.

The unconfined flow system has carried contaminants off post along paleochannels within the alluvial unit during RMA's 40-year history. Contamination has entered this uppermost aquifer primarily from sources in the waste disposal basins and manufacturing areas, and has migrated north and northwest of RMA. The most contaminated portions of the plume are below or downgradient of major sources in the RMA interior. The overall plume concentrations and configuration suggest that the greatest contaminant releases to the

unconfined flow system have occurred from Basin A and the lime settling basins, the South Plants chemical sewer, South Plants tank farm and production area, and the Army and Shell trenches in Section 36. Subsidiary contributions from former Basin F to the contaminant plume migrating beneath Section 26 are indicated. The motor pool area and rail classification yard in the Western Study Area, and sources in North Plants such as the tank farm, are major sources of contaminant releases to the unconfined flow system. Spatial relationships alone are not sufficient to identify a site as the source of an unconfined flow system contaminant plume. For the RI, extensive soil data in conjunction with the fate and transport studies (Appendix E) have been used to identify major sources to the unconfined flow system. However, in some areas, such as the North Plants and the southern part of Section 36, discrete contributions from one of many closely spaced sources cannot always be identified. For these cases, overall impacts are associated with several nearby sites.

2.3.3 Confined Denver Formation Aquifer

Contaminants have been identified in confined Denver Formation groundwater, although contaminant plumes have not been delineated. Unlike the unconfined flow system, pathways in the confined flow system in this aquifer are difficult to identify and generally consist of fine-grained, discontinuous sand lenses and lignites separated by fine-grained siltstones and claystones. Permeability and corresponding groundwater flow rates are significantly less than in the alluvium of the unconfined flow system.

As shown on Plate RISR 2.1-1, Denver Formation detections do not appear to be spatially related. However, confined flow system detections generally correspond spatially with plumes in the overlying unconfined flow system. These data suggest that, locally, contaminants migrate from the unconfined flow system to the confined flow system. The presence of detections at varying depths in the Denver Formation indicate that vertical pathways exist within this aquifer. Although contamination has migrated from the unconfined

flow system to the confined flow system within the Denver Formation, the degree and extent of confined flow system contamination, and its rate of migration, generally are substantially less than in the unconfined flow system. In isolated locations, however, contaminant concentrations in the confined flow system may approach or exceed those in the overlying unconfined flow system. Given the coal-bearing nature of the Denver Formation in the RMA area, and the occurrence of hydrocarbon deposits in the Denver in other localities, naturally occurring concentrations of some organic compounds such as benzene, cannot be ruled out.

2.3.4 Eolian Transport

Eolian transport appears to be the most important atmospheric migration pathway at RMA. Prior to the Basin F and Basin A IRAs, volatilization from surface water and soils accounted for low but detectable concentrations of volatiles and semivolatiles in air peripheral to these basins. IRAs have been instituted to mitigate these low-level releases (Appendix C).

Volatilization, photolysis, oxidation, and hydrolysis are responsible for transformation and attenuation of many organic contaminants that are transported by air pathways. Contaminants exhibiting relatively high environmental mobility due to their volatility or solubility have a limited ability to persist in surficial soils. Consequently, residual windblown contamination observed in surface soils is composed primarily of organochlorine pesticides, arsenic, and ICP metals. Windblown transport of these analytes is believed to be responsible for broad areas of low-level surficial contamination shown on Plate RISR 2.0-1. Further investigations of surficial soil (0- to 2-inch depth interval) contamination are discussed in Appendix D.

IRAs have addressed the most significant sources of windblown contamination originating from dust, and have contained volatile liquids from Basin F. Although disturbance of contaminated soils during implementation of IRAs and remedial actions will provide the potential for volatilization, suspension, and transport of contamination away from the contaminated areas, these effects can be controlled through the use of adequate engineering

and management measures. Air monitoring, which is currently part of the CMP, will continue to assess air impacts at RMA.

2.3.5 Surface Water Transport

Historically, surface water transport was a major contaminant transport pathway, contributing to the rapid and efficient spread of contaminants in basins, ditches, lakes, ponds, and land at RMA. Use of the disposal ditches and process water system has now been discontinued. The two most highly contaminated surface water samples were collected from the Basin A sampling station in Section 36 and the South Plants sedimentation pond in Section 1. Runoff from major storm events or snow melt is expected to transport contaminants present in surficial soils, although the efficiency of this mechanism is limited for most areas. The transport of contaminants in surface waters onto RMA from sources to the south has been documented, as has the past transport of contaminants from RMA to off-post areas north of RMA.

2.4 RECEPTORS

Contaminant sources and pathways are identified to allow a qualitative and conceptual assessment of the potential for exposure to human health and to the environment. Land-use restrictions and health and safety requirements for site workers have minimized the potential for human exposure to contaminants on post. Under current conditions, biota are the primary receptors of RMA contamination in surficial soils, lakebed sediments, and surface water. Because of this, significant wildlife management practices have been implemented to attract wildlife to uncontaminated areas of RMA and also to eliminated contaminated biota in contaminated area. A preliminary exposure assessment conducted as part of the Biota RI identified 39 contaminants of concern and established preliminary criteria for soil and water contamination. The primary routes for biota exposure are ingestion, dermal contact, and inhalation. Consumption of contaminated prey is a concern at higher trophic levels due to contaminants such as organochlorine pesticides, which are known to bioaccumulate and biomagnify in the food chain.

Arsenic levels in the terrestrial plant species sampled near Basin A (morning glory, common sunflower) were within the range that could produce phytotoxic effects; however, no such effects were noted. Organochlorine pesticides at nontoxic levels were also detected in these plant species. Organochlorine pesticides, in particular, are known to bioaccumulate and produce effects higher in food chains. Portions of Basin A are free of vegetation and the phytoxicity of overall contaminant conditions in Basin A is an obvious factor, as are high levels of physical soil disturbance and compaction.

Invertebrate populations did not appear reduced as an effect of RMA contamination. Organochlorine pesticides at levels that could prove hazardous to higher-trophic-level species were detected in invertebrates sampled at contamination sites. Mercury was detected in grasshoppers collected from Basin A and in earthworms collected from the southeast corner of Section 5 in the Eastern Study Area at concentrations exceeding recommended acceptable dietary levels for birds such as kestrels and young pheasants. Mercury was also detected in earthworms collected in the South Plants. Arsenic, which does not tend to bioaccumulate, was also detected in both invertebrate species.

Black-tailed prairie dog populations were not reduced as a result of RMA contamination, but organochlorine pesticides were detected in some prairie dog samples collected near the primary source areas in the central section of RMA at levels that could be hazardous to eagles, other raptors, and mammalian predators. While the two golden eagle samples of opportunity at RMA showed contaminant levels below those known to produce adverse effects in birds, ferruginous hawk, red-tailed hawk, and great-horned owl brain tissue samples from RMA showed lethal levels of dieldrin. Other data for these raptor samples indicated the typical signs of pesticide poisoning. Based on knowledge of foraging range, feeding habits, and seasonal use patterns of these species, the probable sources of the detected contaminants were interpreted to be within the RMA boundaries.

Avian reproductive success studies indicated significant reduction in mallard reproduction on post, apparently attributable to organochlorine pesticides contamination from RMA sources. In the case of mallards such reductions can probably be linked to contamination in lake sediments. Organochlorine pesticides and mercury were detected in these species both on-post and from off-post control locations. Pheasants collected from on- and off-post locations also contained organochlorine pesticides, and arsenic. However, tissue samples from pheasants, mourning doves, and waterfowl collected in interior regions of RMA contained dieldrin levels in excess of Food and Drug Administration action levels, and higher than for off-post controls.

Of the 14 mule deer collected on RMA, only one sample had detectable levels of any of the contaminants for which analyses were conducted. Dieldrin was detected in this sample, as it was in the one coyote sample of opportunity collected at RMA. The dieldrin level in the coyote sample was at the lower end of the lethal concentration range for dogs. Given the omnivorous behavior of coyotes, and the potentially large areal extent of their range, it cannot be concluded that RMA sources were solely responsible for the dieldrin level detected. In general, concentrations of dieldrin increase in higher trophic levels, indicating bioaccumulation of this analyte through the terrestrial food chain.

Data from aquatic plant, plankton, and fish samples collected from the lower lakes and the North Bog and from off-post control sites indicated that some aquatic communities on RMA are contaminated by organochlorine pesticides and mercury.

The frequency of organochlorine pesticide, arsenic, and mercury detections in soils corresponds to the frequency of detectable levels in terrestrial carnivores. Similar relationships are less apparent in aquatic systems, although contaminant detections in aquatic biota are widespread, and mortality attributed to contamination has been historically reported.

2.5 RMA ACTIONS TO CONTROL RELEASES AT PRIMARY SOURCES

Throughout the course of the RI, PMRMA has undertaken interim actions as necessary to restrict contaminant releases that posed an immediate threat to human health and the environment, and to partially fulfill the goals of the RI/EA/FS program.

Thirteen IRAs have been initiated or planned at RMA. The purpose of the IRAs is to proceed with actions considered "necessary and appropriate" for implementation prior to the final remedial decisions (FFA, 1989/RIC 89068R01). These actions are designed to control, reduce, prevent, or eliminate the potential for contaminant releases from the most important sources on post, and to reduce or eliminate further contaminant migration and the potential for human exposure, both on and off post.

IRAs have been instituted to:

- Contain contaminated basin liquids, sludges, soils, and vapors
- Control contaminant migration in groundwater, both on post and off post
- Dismantle, remove, clean, or remediate contaminated structures
- Eliminate the potential for the sanitary sewer to serve as a contaminant migration pathway
- Control fugitive dust from the Basin A and former Basin F areas
- Mitigate the potential for releases from other hot spot contamination sources.

The IRAs are discussed in more detail in Appendix C of this report.

In addition to the IRAs, the ongoing FS will identify and evaluate a variety of alternatives designed to remediate or isolate all sources of contamination at RMA. The FS will also control, mitigate, or eliminate transport of contaminants along active migration pathways. Data collected in the RI serve as the basis for the FS evaluations, but do not constitute the complete body of data that will eventually be available to characterize and understand

conditions at RMA. During remediation, data collection efforts will continue as necessary. Actions may be taken to reduce or prevent contaminant exposures whenever warranted by the available data and the overall goals of the RI/EA/FS program.

Section 3.0

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Plates

Remedial Investigation Summary Report

R 67 W

R 66 W

T 2 S

T 3 S

NORTH BOG

NORTH BOUNDARY CONTAINMENT SYSTEM

POND

SEWAGE TREATMENT PLANT

NORTHWEST BOUNDARY CONTAINMENT SYSTEM

TEMPORARY STORAGE PONDS

LIQUID STORAGE TANKS

FORMER BASIN F

BASIN F TEMPORARY WASTE PILE

NORTH PLANTS

BASIN C

BASIN E

BASIN D

BASIN B

BASIN A

IRONDALE CONTAINMENT SYSTEM

SOUTH ADAMS COUNTY WATER TREATMENT FACILITY

SAND CREEK LATERAL

ADMINISTRATION AREA

LIME SETTLING BASINS

MAIN ENTRANCE

BALD EAGLE MANAGEMENT VISITORS CENTER

SOUTH PLANTS

RAIL CLASSIFICATION/ MAINTENANCE YARD

LAKE LADORA

LAKE MARY

LOWER DERBY LAKE

UPPER DERBY LAKE

ROD AND GUN CLUB POND

UVALDA ST DRAINAGE

HAVANA ST INTERCEPTOR

ARMY RESERVE CENTER

U.S. POST OFFICE

SANITARY LANDFILL

STORAGE AREA

DEMOLITION AREA

BALD EAGLE OBSERVATION AREA

FIRST CREEK

HIGHLINE LATERAL

C STREET

D STREET

E STREET

F STREET

B STREET

QUEBEC ST

9TH AVENUE

8TH AVENUE

7TH AVENUE

6TH AVENUE

22 23 24 19 20

28 27 26 25 30 29

33 34 35 36 31 32

4 3 2 1 6 5

9 10 11 12 7 8

Legend

- Major Drainage or Ditch
- Minor Drainage or Ditch
- Railroad Tracks
- Basin
- Former Basin
- Lakes and Ponds
- RMA Property/Leased
- Road
- 3 Section Number
- Structure
- Former Structure
- Arsenal Boundary
- Current Bald Eagle Management Area (BEMA)
- Roost Exclusion Area

N

0 2000 4000

Scale In Feet

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

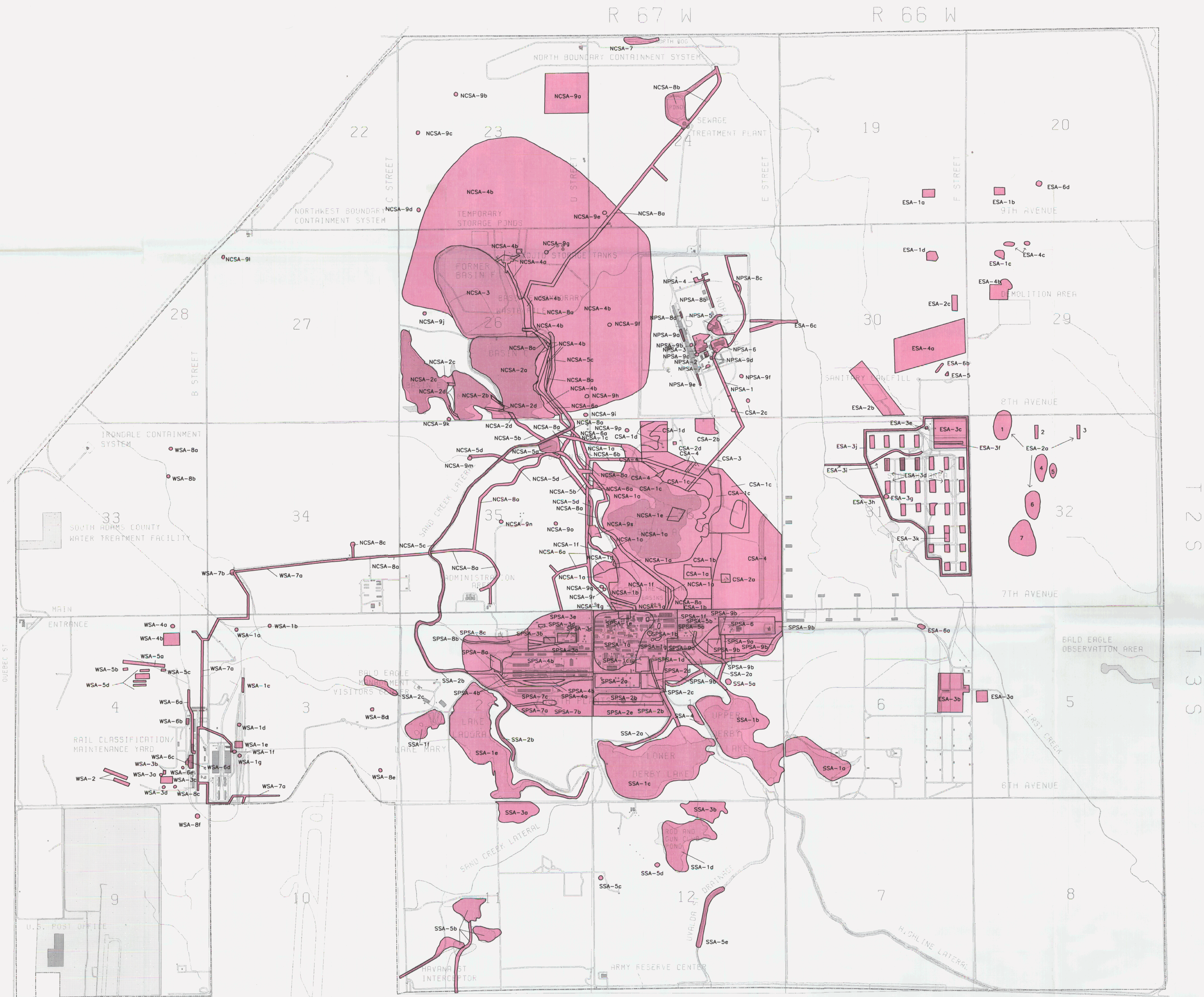
Prepared August 1991

PLATE RISR 1.3-1

RMA Cultural Features

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated



NORTH CENTRAL STUDY AREA

SITE DESIGNATION	RMACCPMT SITE NUMBER(S)	SITE DESCRIPTION
NCSA-1, Basin A and Adjoining Sites		
NCSA-1a	36-1 *	Basin A; received South and North Plants aqueous wastes; contains areas of inferred windblown contamination
NCSA-1b	36-4,-5,-10 *	Lime settling basins area; primary repository for South Plants aqueous wastes; acetylene production waste disposal
NCSA-1c	36-7,-8	Drainage ditch used to transport liquid waste from Basin A to Basin B
NCSA-1d	36-11	Liquid storage pool that received runoff from South Plants
NCSA-1e	36-15	Burn site for miscellaneous trash from South Plants operations
NCSA-1f	36-8	South Plants drainage ditches that currently receive runoff from South Plants; continues into Section 35 as NCSA-5d
NCSA-1g	36-5	Surficial contamination attributed to wind dispersion
NCSA-2, Basins C,D,and E and Interconnecting Ditches		
NCSA-2a	26-3 *	Basin C; primary repository for Basin B overflow, 1954-57
NCSA-2b	26-4	Basin D; received Basin B overflow, 1943-54, and Basin C overflow, 1954-57
NCSA-2c	26-5	Basin E; received Basin D overflow, 1954-57
NCSA-2d	26-3,-5,35-4*	Pre-RMA drainage ditches; transported wastes from Basin B to D, 1943-54; from Basin B to C, present
NCSA-3, Basin F		
NCSA-3	26-6	Basin F; primary repository for North and South Plants aqueous wastes, 1957-81
NCSA-4, Basin F Exterior,Deep Disposal Well Facility		
NCSA-4a	26-1	Deep disposal well facility used to inject Basin F fluid to deep bedrock, 1962-66
NCSA-4b	26-6	Basin F exterior area attributed to wind dispersion of contaminants from Basin F
NCSA-5, Basin B and Associated Drainage Features		
NCSA-5a	35-3	Basin B; received Basin A overflow, 1943-57
NCSA-5b	35-4,26-7	Miscellaneous drainage ditches between Basins A, B, C, and D
NCSA-5c	*	Sand Creek Lateral; transported South Plants wastewaters to First Creek; Basin B overflow to Basin C
NCSA-5d	*	Surface drainage canal dug in 1975 to channel South Plants runoff away from Basin A; continues into Section 36 as NCSA-1f
NCSA-6, Chemical Sewer System		
NCSA-6a	35-2/26-9	Chemical sewer system that carried South Plants aqueous waste to Basin F
NCSA-6b	MKE Chem Sewer	Chemical sewer system that carried North Plants aqueous waste to Basin F
NCSA-7, North Bog		
NCSA-7	24-7	North Bog occasionally used as a recharge basin for the North Boundary Containment System before 1983, in continuous use from 1983 to present
NCSA-8, Sanitary Sewer System		
NCSA-8a	24-5,25-2,26-8,35-1 *	Sanitary sewer lines that carried domestic sewage to the Sewage Treatment Plant
NCSA-8b	24-6	Domestic sewage treatment plant area
NCSA-8c	*	Isolated detection of mercury in overflow basin at Lift Station #2
NCSA-9, Balance of Areas Investigated		
NCSA-9a	*	Localized area of diisopropylmethylphosphonate detections
NCSA-9b	*	Isolated detection of cadmium
NCSA-9c	*	Isolated detection of cadmium
NCSA-9d	*	Isolated detection of cadmium
NCSA-9e	*	Isolated detection of zinc
NCSA-9f	*	Isolated detections of zinc and copper
NCSA-9g	*	Isolated detection of methylene chloride
NCSA-9h	*	Isolated detection of cadmium
NCSA-9i	*	Isolated detection of 2-butoxyethanol
NCSA-9j	*	Isolated detection of mercury
NCSA-9k	*	Isolated detection of trichloropropene
NCSA-9l	*	Isolated detection of arsenic
NCSA-9m	35-6	Isolated detection of zinc in a bedrock sample
NCSA-9n	*	Isolated detection of trichloropropene
NCSA-9o	*	Isolated detection of arsenic
NCSA-9p	36-7	Isolated detections of arsenic and mercury
NCSA-9q	36-10	Isolated detection of mercury
NCSA-9r	36-10	Isolated detection of cadmium
NCSA-9s	36-22	Localized area of mercury detections

SOUTH PLANTS STUDY AREA

SITE DESIGNATION	RMACCPMT SITE NUMBER(S)	SITE DESCRIPTION
SPSA-1, Central Subarea		
SPSA-1a	1-13,SPRS,SSS,AMSS	Army agents and Shell pesticides processing area
SPSA-1b	1-3	Location of historic mounds of unknown materials
SPSA-1c	1-5	Lime pits used for lime slurries and limited chemical disposal
SPSA-1d	1-1	Drainage ditches that carried surface runoff and process water from the processing area (SPSA-1a)
SPSA-1e	1-13	Buried M-1 pits that received neutralized waste streams from lewisite production and related activities
SPSA-1f	1-13	Buried barrels containing residue from the production of hexachlorocyclopentadiene
SPSA-1g	1-13,-5,SPRS,AMSS*	Balance of SPSA-1; locations of contaminants attributed to manufacturing/storage activities
SPSA-2, Southern Subarea		
SPSA-2a	1-10	South tank farm area surrounding eleven 200,000- to 400,000- gallon chemical storage tanks
SPSA-2b	1-9	Open storage area used to store chemicals in barrels and tanks
SPSA-2c	1-8	Salvage yard used to store tanks, barrels and equipment
SPSA-2d	1-1,1-8,PWS	Drainage ditches that carried surface water runoff and process water from the processing area (SPSA-1a)
SPSA-2e	1-3*	Balance of SPSA-2; locations of contaminants attributed to wind dispersion
SPSA-3, Chlorine Plant/Steam Plant Subarea		
SPSA-3a	2-1	Drainage ditches used to carry surface runoff away from the chlorine plant area
SPSA-3b	2-6	Concrete salt storage pad used to store GB brine, pesticide and mustard wastes, contaminated dirt/debris
SPSA-3c	2-8	Former tank storage area used for the storage and treatment of brine, crude caustic and chlorine
SPSA-3d	2-12	Revetted tank storage area used to store diesel fuel and oil; low-level OCP contamination attributed to wind dispersion
SPSA-3e	2-18	Balance of SPSA-3; locations of contaminants attributed to wind dispersion
SPSA-4, West Central Subarea		
SPSA-4a	2-1,SPRS	Drainage ditches used to carry surface runoff and process water
SPSA-4b	2-1,-18	Balance of SPSA-4; locations of contaminants attributed to surface water transport
SPSA-5, Northeast Subarea		
SPSA-5a	*	Drainage ditch used to carry surface runoff and process water
SPSA-5b	1-11,SPRS,AMSS*	Balance of SPSA-5; locations of contaminants attributed to wind dispersion
SPSA-6, Hydrazine Subarea		
SPSA-6	1-7	Hydrazine rocket fuel blending and storage facility
SPSA-7, Southwest Subarea		
SPSA-7a	2-1	Drainage ditches used to carry surface runoff
SPSA-7b	2-3	Topographic depression that collected surface runoff
SPSA-7c	2-2,-4,-13,-14*	Balance of SPSA-7; locations of contaminants attributed to wind dispersion
SPSA-8, Northwest Subarea		
SPSA-8a	2-14	Sanitary landfill used for disposal of domestic solid wastes
SPSA-8b	2-1*	Drainage ditches used to carry surface runoff and process water
SPSA-8c	*	Balance of SPSA-8; locations of contaminants attributed to wind dispersion
SPSA-9, East Subarea		
SPSA-9a	1-1	Drainage ditches used to carry surface runoff and process water
SPSA-9b	*	Balance of SPSA-9; locations of contaminants attributed to wind dispersion
SPSA-10, Chemical Sewer System +		
SPSA-10	1-13/2-18	Chemical sewer system that carried aqueous wastes from the process facilities in the SPSA to Basins A and F The chemical sewer system is contained in subareas SPSA 1,3,4,5, and 6. See Figure RISR A3.1-25 for the location of the chemical sewer system.
SPSA-11, Sanitary Sewer System +		
SPSA-11	1-13/2-18	Sanitary sewer system that carried domestic sewage from buildings in the SPSA to the Sewage Treatment Plant The sanitary sewer system is contained in subareas 1,3,4,5, and 7. See Figure RISR A3.1-25 for the location of the sanitary sewer system.
SPSA-12, Process Water System +		
SPSA-12a	2-7	Aeration basin used to cool and recirculate process water from the power plant condenser and turbine
SPSA-12b	SPRS*	Sedimentation pond used to settle particulate matter from cooling tower blowdown water
SPSA-12c	PWS	Lines distributing water to the process facilities and returning water to the lakes are not shown on map due to complexity of the system. The process water system is located in subareas SPSA 1,2,3,4,5,6,7, and 9. See Figure RISR A3.1-25 for location of the process water system.

+ Not shown on map due to complexity of system

EASTERN STUDY AREA

SITE DESIGNATION	RMACCPMT SITE NUMBER(S)	SITE DESCRIPTION
ESA-1, Surface Burns		
ESA-1a	19-1	Surface burn determined by analytical data and visible boundary of surface slag
ESA-1b	20-1	Surface burn determined by analytical data and visible boundary of surface slag
ESA-1c	29-1	Surface burn determined by analytical data and visible boundary of surface slag
ESA-1d	30-2	Surface burn determined by analytical data and visible boundary of surface slag
ESA-2, Burial Trenches		
ESA-2a	32-5,-6	Burn pits used to incinerate munitions and incendiary devices, numbered 1-7
ESA-2b	30-4	Sanitary landfill used for disposal of on-post sanitary wastes
ESA-2c	30-6	Open trenches used for disposal of ammunition and empty shells
ESA-3, Toxic Gas and Munitions Storage		
ESA-3a	5-2	Storage yard used for agent-filled bombs
ESA-3b	6-6	Old toxic storage yard used for storage of agent-filled bombs and toxic gas containers
ESA-3c	31-4	New toxic storage yard used for storage of incendiary and agent-filled bombs
ESA-3d	31-6,-7	Toxic yard plots used for storage of incendiary and agent-filled bombs
ESA-3e	31-4	Concrete VX demilitarization pad
ESA-3f	31-4	Rail spur and loading dock; reported agent spill
ESA-3g	31-7	Open drum storage area; reported agent spill
ESA-3h	31-7	Open storage area ditch; reported agent migration from ESA-3g
ESA-3i	31-7	Toxic storage plots ditch; reported agent migration from Toxic Storage Yard Plots
ESA-3j	31-7	Toxic storage yard fence; reported pesticide spraying around fence
ESA-3k	*	Trash pit; reported trash disposal area south of Plot 8
ESA-4, Munitions Activity		
ESA-4a	30-1	Impact area with possible remnant unexploded ordnance
ESA-4b	29-4	Bermed demolition area used for detonating explosives
ESA-4c	29-4	Trench and mound with unknown use, scattered metal and wood debris
ESA-5, Demilitarization Activity		
ESA-5	30-5	Area around buildings used for GB-bomb fuze removal
ESA-6, Balance of Areas Investigated		
ESA-6a	*	Isolated detections of chromium, copper, lead and zinc near ton container storage area
ESA-6b	30-1	Isolated detection of fluoroacetic acid in trench
ESA-6c	*	Isolated detection of arsenic in ditch
ESA-6d	*	Isolated detection of hexachlorobenzene not associated with any identifiable feature

UDY AREA

RMACCPMT SITE NUMBER(S)	SITE DESCRIPTION
3-4	Isolated detection of pyrene or fluoranthene
3-4	Isolated spill and wood preservative derivative along railroad tracks
*	Wood preservative derivative along railroad tracks
3-4	Isolated detection of zinc
3-4	Dibromochloropropane (DBCP) spill area
3-4	Isolated detection of aldrin and dieldrin
3-4	Isolated detection of mercury
4-2	Landfill trenches used for disposal and burning of potentially contaminated wastes
4-3	Isolated detections of toluene, trichloropropene, and cadmium
4-3	Disposal pit
4-3	Main surface disposal area
4-3	Isolated detection of methylisobutyl ketone
e Yard	
4-4	Isolated detection of methylcyclohexane
4-4	Main storage area used as support for salvage yard operations
4-5	Inferred landfill trench indicated by magnetometer survey
4-5	Burn pit
4-5	Inferred landfill trench indicated by air photo
4-5	Landfill trenches
4-6	Drainage ditch receiving motor pool area runoff
4-6	Area surrounding fuel storage tanks
4-6	Roundhouse (Building 631) area and old septic tank system
4-6	Drainage area for Buildings 624 and 631
4-6	Culvert outfall from south motor pool area
er	
34-2	Sanitary sewer internal sediment
34-2	Sanitary sewer overflow area
reas Investigated	
*	Isolated detection of copper
*	Isolated detection of zinc
*	Isolated detection of 1,1,2,2-tetrachloroethane in salvage yard
*	Isolated detection of phosphoric acid, tributyl ester
*	Isolated detection of phosphoric acid, tributyl ester
*	Isolated detection of methyl naphthalene

NTS STUDY AREA

RMACCPMT SITE NUMBER(S)	SITE DESCRIPTION
ewer System +	
25-3*	Chemical sewer system that carried aqueous wastes from North Plants complex to Basin A and F
25-3	Area surrounding Tank Farm 1403 and associated under- and above-ground piping
cturing Area	
25-2,-4 Thru -7,-9	Areas surrounding GB manufacturing Buildings 1501, 1503, 1504, 1506, 1602, and 1603
etonator Magazine	
25-2	Area around Building 1606 fuze and detonator magazine and downgradient surface drainage
apons Plant	
25-2	Area surrounding Special Weapons Plant Building 1611
d Spill Area	
25-2,-14,-15*	Underground diesel fuel spill area around Buildings 1703 and 1727
ll Area	
25-2,25-15*	Surface diesel fuel spill area around Building 1705
us Drainages	
*	Surface drainage features containing contaminants
*	Surface drainage features containing contaminants
*	Surface drainage features containing contaminants
Areas Investigated	
*	Isolated detections of benzene and several polynuclear aromatic compounds along railroad tracks
*	Isolated detection of chromium
*	Isolated detection of zinc
*	Isolated detections of benzene and zinc
*	Isolated detection of 2-butoxyethanol along railroad tracks
*	Isolated detection of arsenic

p in its entirety due to complexity of system

CENTRAL STUDY AREA

SITE DESIGNATION	RMACCPMT SITE NUMBER(S)	SITE DESCRIPTION
CSA-1, Landfill/Burial/Burn Sites		
CSA-1a	36-3	Pesticide pits used for pesticide waste disposal from 1952-65
CSA-1b	36-16,-17	Complex disposal area (south) used for contaminated waste storage and disposal; low-level mercury contamination attributed to wind dispersion
CSA-1c	36-16,-17	Complex disposal area (north) used for burning of waste, contaminated equipment, and munitions; low-level OCP, arsenic, cadmium, and mercury contamination attributed to wind dispersion
CSA-1d	36-7	Sanitary landfill and Incinerator 634 used for burning and burial of rubbish in trenches; low level OCP and cadmium contamination attributed to wind dispersion
CSA-2, Surface Activity Sites		
CSA-2a	36-2	Area including buildings 725, 726, NN3603, NN3604, and NN3605 used for testing various munitions
CSA-2b	36-23	Parking lot used for storage of metal scrap and debris from Section 36 recovery operations
CSA-2c	36-6/25-17	Incendiary munitions test site active from 1943-50
CSA-2d	36-7	Contamination from Incinerator NN3601 used from 1969-70 for mine destruction
CSA-3, Chemical Sewer		
CSA-3	36-20	Chemical sewer system that carried North Plants aqueous wastes to Basins A and F
CSA-4, Balance of Areas Investigated		
CSA-4	36-2,-12,-19*	Low-level OCP contamination attributed to wind dispersion of contaminants from nearby sites

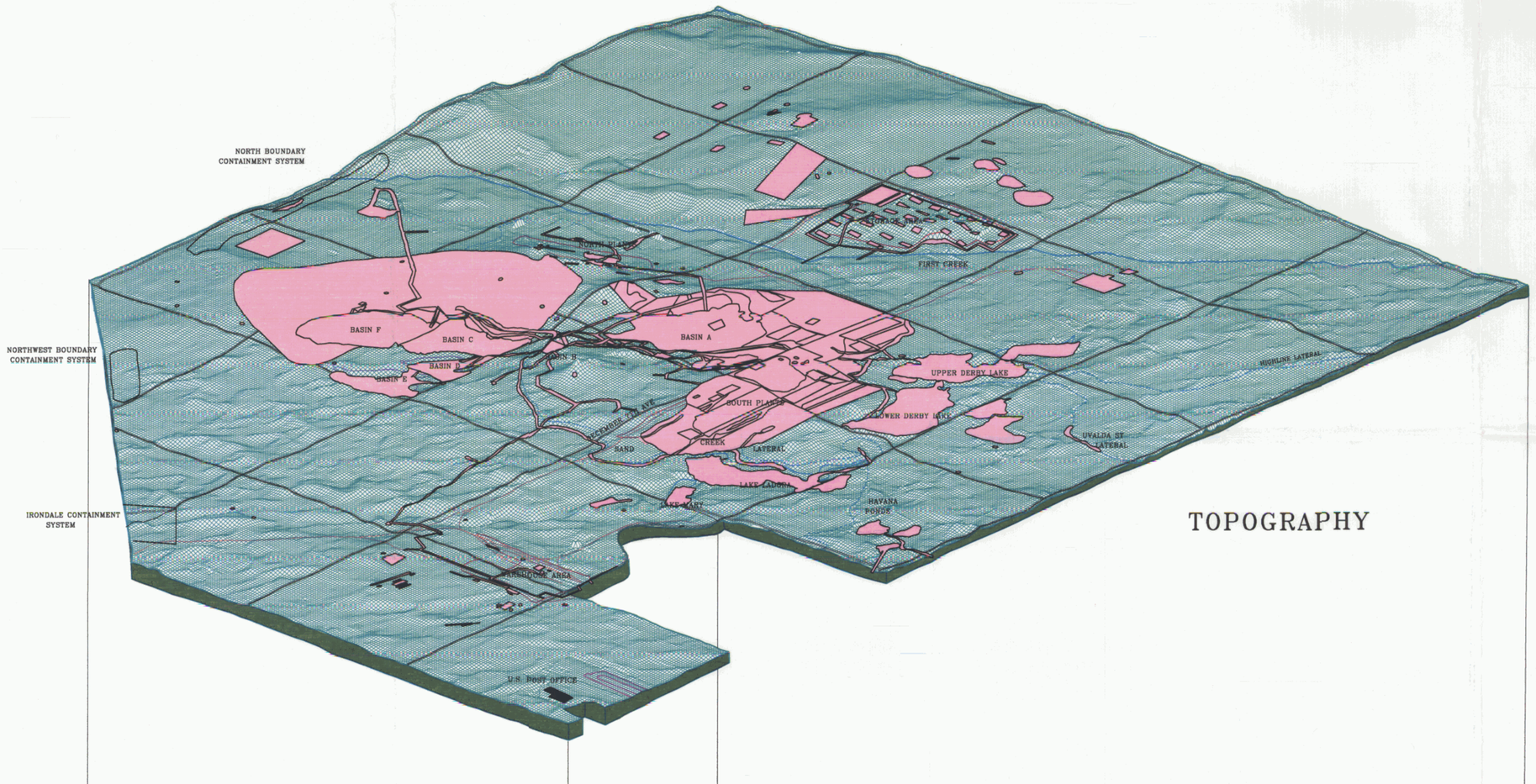
SOUTHERN STUDY AREA

SITE DESIGNATION	RMACCPMT SITE NUMBER(S)	SITE DESCRIPTION
SSA-1, Lakes		
SSA-1a	6-2	Eastern Upper Derby Lake; received overflow process water from Upper Derby Lake
SSA-1b	1-2	Upper Derby Lake; formerly part of process water return system
SSA-1c	1-2	Lower Derby Lake; formerly part of process water return system
SSA-1d	12-2	Rod and Gun Club Pond; depression receiving overflow from Lower Derby Lake
SSA-1e	2-17	Lake Ladora; formerly part of process water return system
SSA-1f	2-17	Lake Mary; used for recreational purposes
SSA-2, Ditches		
SSA-2a	1-1	Process water ditch system used as conduit for cooling waters from the South Plants
SSA-2b	2-1	Sand Creek Lateral; receives drainage from South Plants and off-post sources
SSA-2c	3-2/3-3	Overflow basin and ditch that receive overflow from Lakes Mary and Ladora
SSA-3, Buried Lake Sediments		
SSA-3a	11-1	Buried sediments dredged from Lake Ladora in 1964-65
SSA-3b	12-1	Buried sediments dredged from Upper and Lower Derby Lakes in 1964-65
SSA-4, Trash Dump		
SSA-4	1-12	Former trash dump used for surface disposal of miscellaneous debris
SSA-5, Balance of Areas Investigated		
SSA-5a	*	Isolated detections of dibromochloropropane (DBCP)
SSA-5b	*	Havana/Peoria Streets ponds and ditches; receive runoff from off-post areas south of RMA
SSA-5c	*	Isolated detection of lead
SSA-5d	*	Isolated detection of lead
SSA-5e	*	Uvalda Ditch; carries runoff from off-post areas south of RMA

* Includes nonsource areas (areas not identified on tricolor map as possible sources)
SPRS = South Plants Regional Study, PWS = Process Water System, AMSS = Army Spill Sites, SSS = Shell Spill Sites

NOTE 1: Isolated detections and narrow linear features are not shown to scale, but have been exaggerated for clarity
NOTE 2: Only metals concentrations above natural background levels are shown

TOPOGRAPHY



EXPLANATION

- ROAD
- RAILROAD
- CONTAINMENT SYSTEM
- STREAMS
- DRAINAGE – LATERALS
- AIRPORT RUNWAY
- SECTION LINES

Areas of Soil Contamination at Depths other than Surficial Only

— 50 — — — Contour, dashed where inferred

Contour Intervals CRL; 10; 50; 100; 1000; 10,000; 100,000; 1,000,000 ug/l

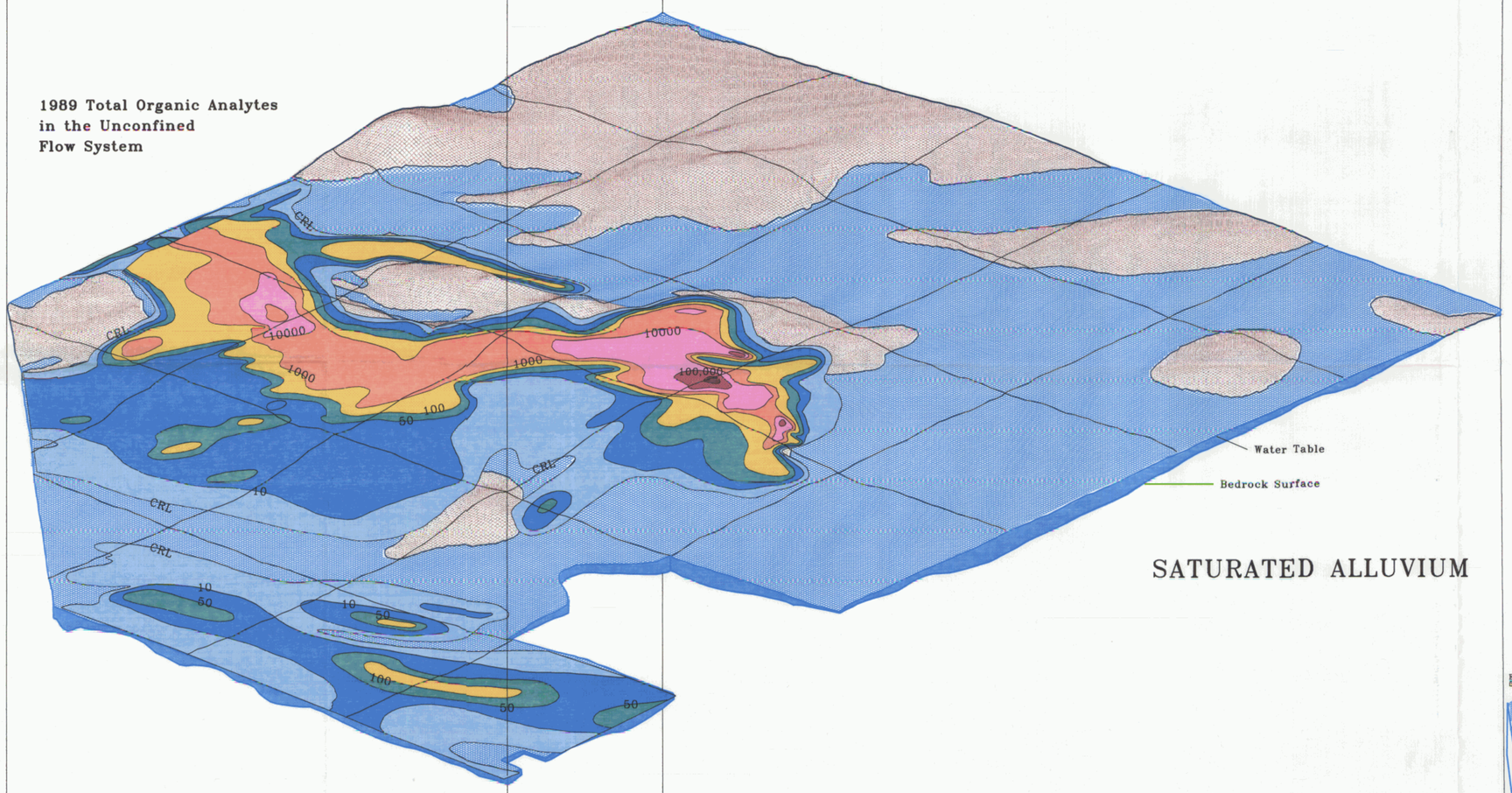
Concentration Ranges

- > 1,000,000 ug/l
- > 100,000 to 1,000,000 ug/l
- > 10,000 to 100,000 ug/l
- > 1000 to 10,000 ug/l
- > 100 to 1000 ug/l
- > 50 to 100 ug/l
- > 10 to 50 ug/l
- CRL to 10 ug/l

Note 1: Concentration ranges based on sum of detected organic analyte concentrations
CRL – Certified Reporting Limit

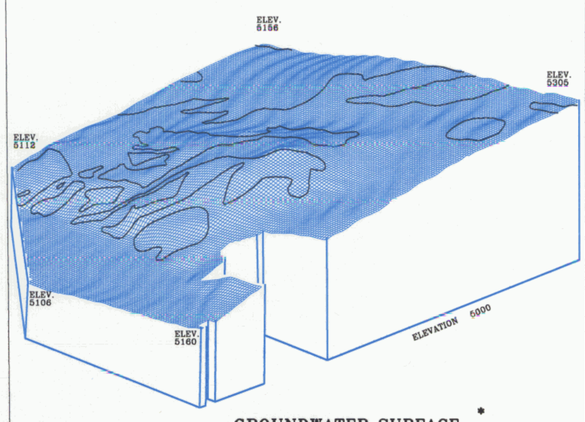
Note 2: Because certified reporting limits (CRL's) vary among analytes and analytical methods, there is no single value represented by the CRL contour.

1989 Total Organic Analytes in the Unconfined Flow System



SATURATED ALLUVIUM

- REGION OF SATURATED ALLUVIUM
- REGION OF UNSATURATED ALLUVIUM
- REGION OF SATURATED BEDROCK



GROUNDWATER SURFACE *

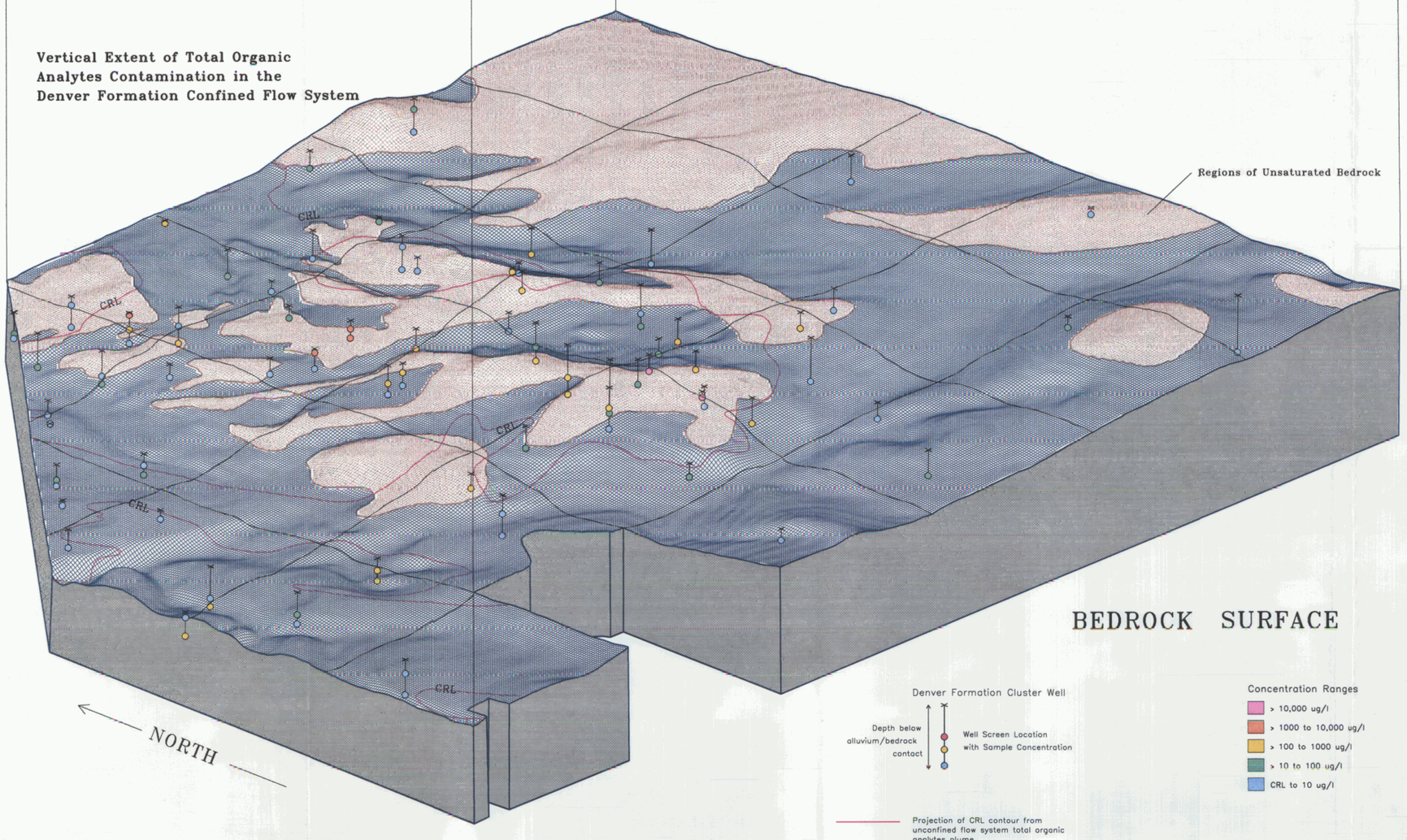
VERTICAL EXAGGERATION: 40X

6000 6000 0 150

Scale in Feet

(*generalized from potentiometric surface of the unconfined flow system, 4/87 – 6/87; Water Remedial Investigation Report, Figure 2.4; EBASCO, 1989d)

Vertical Extent of Total Organic Analytes Contamination in the Denver Formation Confined Flow System



BEDROCK SURFACE

Denver Formation Cluster Well

Depth below alluvium/bedrock contact

Well Screen Location with Sample Concentration

Projection of CRL contour from unconfined flow system total organic analytes plume

Concentration Ranges

- > 10,000 ug/l
- > 1000 to 10,000 ug/l
- > 100 to 1000 ug/l
- > 10 to 100 ug/l
- CRL to 10 ug/l

2000 2000 0 200

Scale in Feet

Vertical Exaggeration 10X

Prepared for:

U. S. Army Program Manager for Rocky Mountain Arsenal

Prepared August 1991

PLATE RISR 2.1–1

Integrated Soil and Groundwater Contaminant Distribution

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated

TECHNICAL SUPPORT FOR

ROCKY MOUNTAIN ARSENAL

FINAL
REMEDIAL INVESTIGATION SUMMARY REPORT
APPENDIX A - ENVIRONMENTAL SETTING, RI APPROACH, NATURE AND EXTENT OF CONTAMINATION - A1 AND A3
FIGURES AND PLATES
VERSION 3.2

January 1992

Contract Number DAAA15-88-D-0024

PREPARED BY:

EBASCO SERVICES INCORPORATED
APPLIED ENVIRONMENTAL, INC.
CH2M HILL DATACHEM, INC.
R.L. STOLLAR AND ASSOCIATES

PREPARED FOR:

U.S. ARMY PROGRAM MANAGER FOR
ROCKY MOUNTAIN ARSENAL

APPENDIX A1 - LIST OF FIGURES AND PLATES

APPENDIX A3 - LIST OF FIGURES AND PLATES

Figure

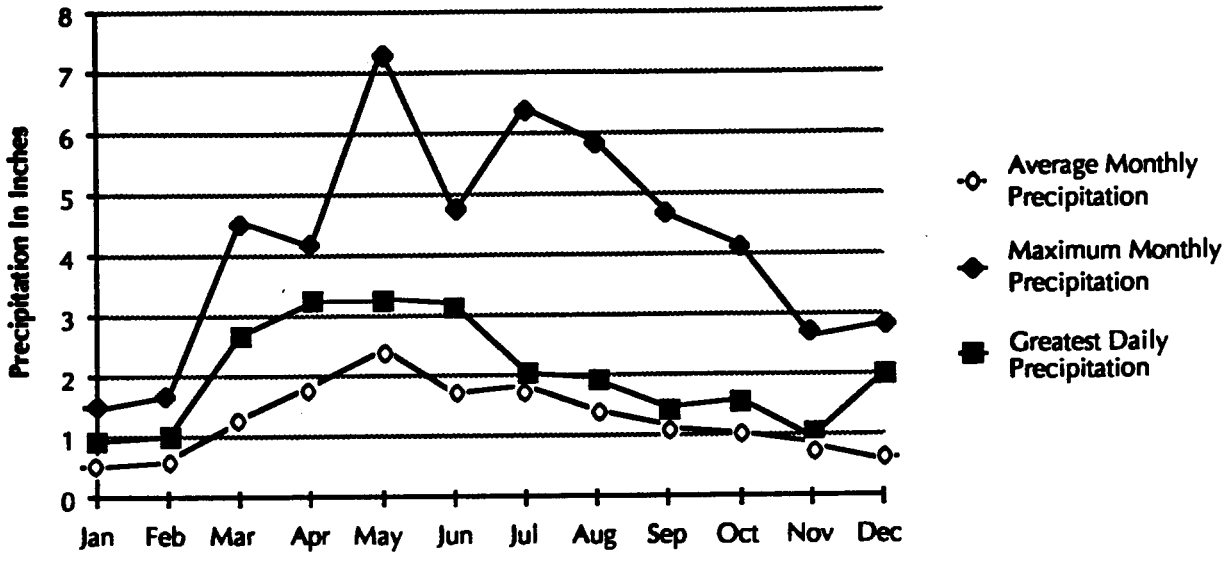
APPENDIX A3 - LIST OF FIGURES AND PLATES
(continued)

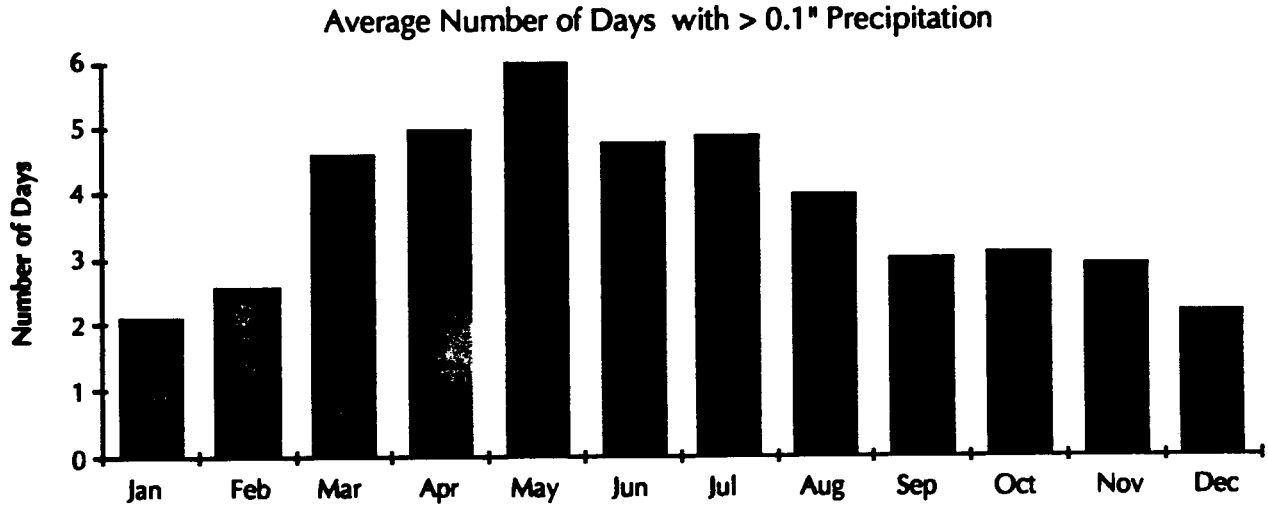
APPENDIX A3 - LIST OF FIGURES AND PLATES
(continued)

Appendix A1

Environmental Setting
Figures

Remedial Investigation Summary Report





Prepared for:

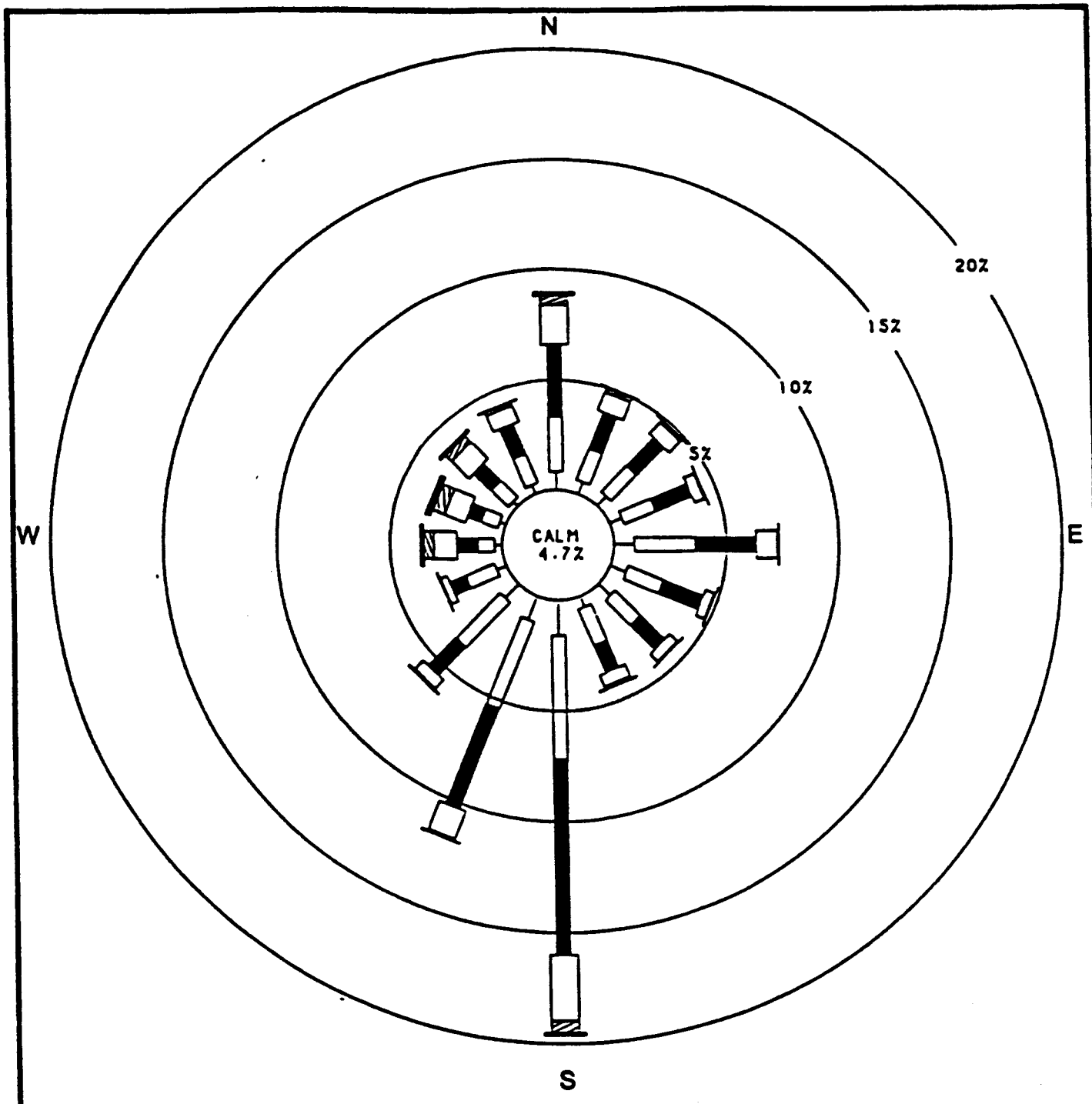
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

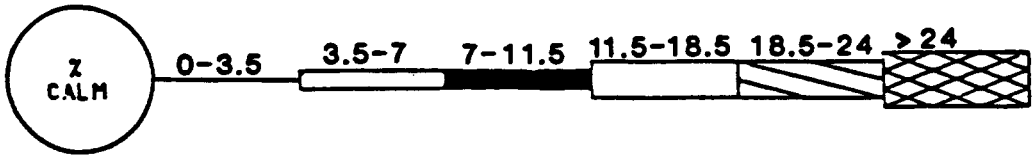
Figure RISR A1.2-1

Mean and Extreme Precipitation Data at Stapleton International Airport (1948-1986)

Prepared by: Ebasco Services Incorporated



WIND SPEED CLASSES (MPH)



Source: ESE, 1988

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

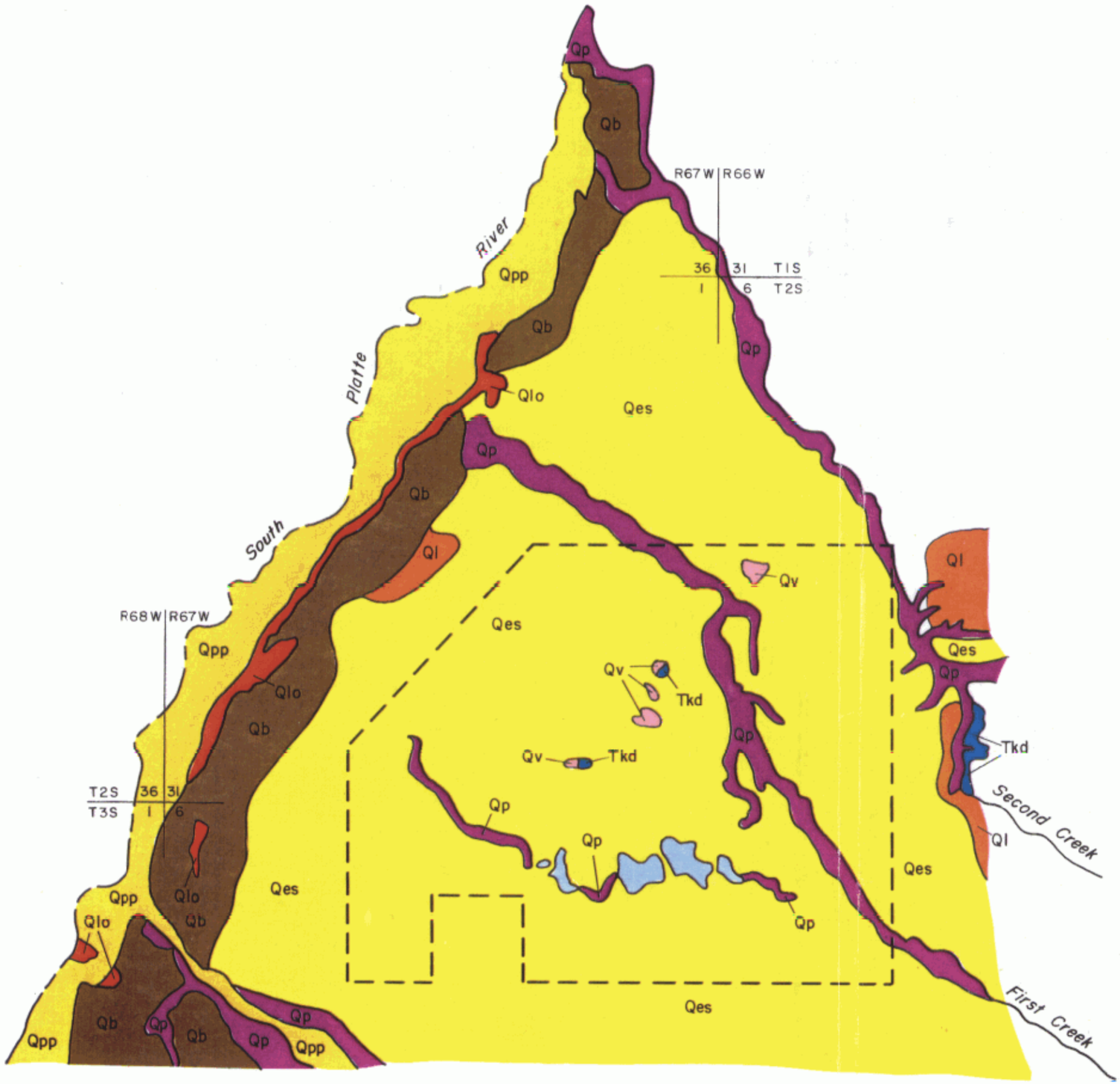
Prepared August 1991

FIGURE RISR AI.2-2

Annual Wind Rose for RMA Vicinity
(Stapleton International Airport 1975-1979)

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

T18D-AR-004



Legend

Qpp	Post Piney Creek Alluvium (Quaternary)
Qp	Piney Creek Alluvium (Quaternary)
Qes	Eolian Sand (Quaternary)
Ql	Loess (Quaternary)
Qb	Broadway Alluvium (Quaternary)
Qlo	Louviers Alluvium (Quaternary)
Qv	Verdos Alluvium (Quaternary)
Tkd	Denver Formation (Upper Cretaceous and Tertiary)
Lakes	
— —	Rocky Mountain Arsenal Boundary

Source: Lindvall, 1980a, b

N

0 2 4 Miles

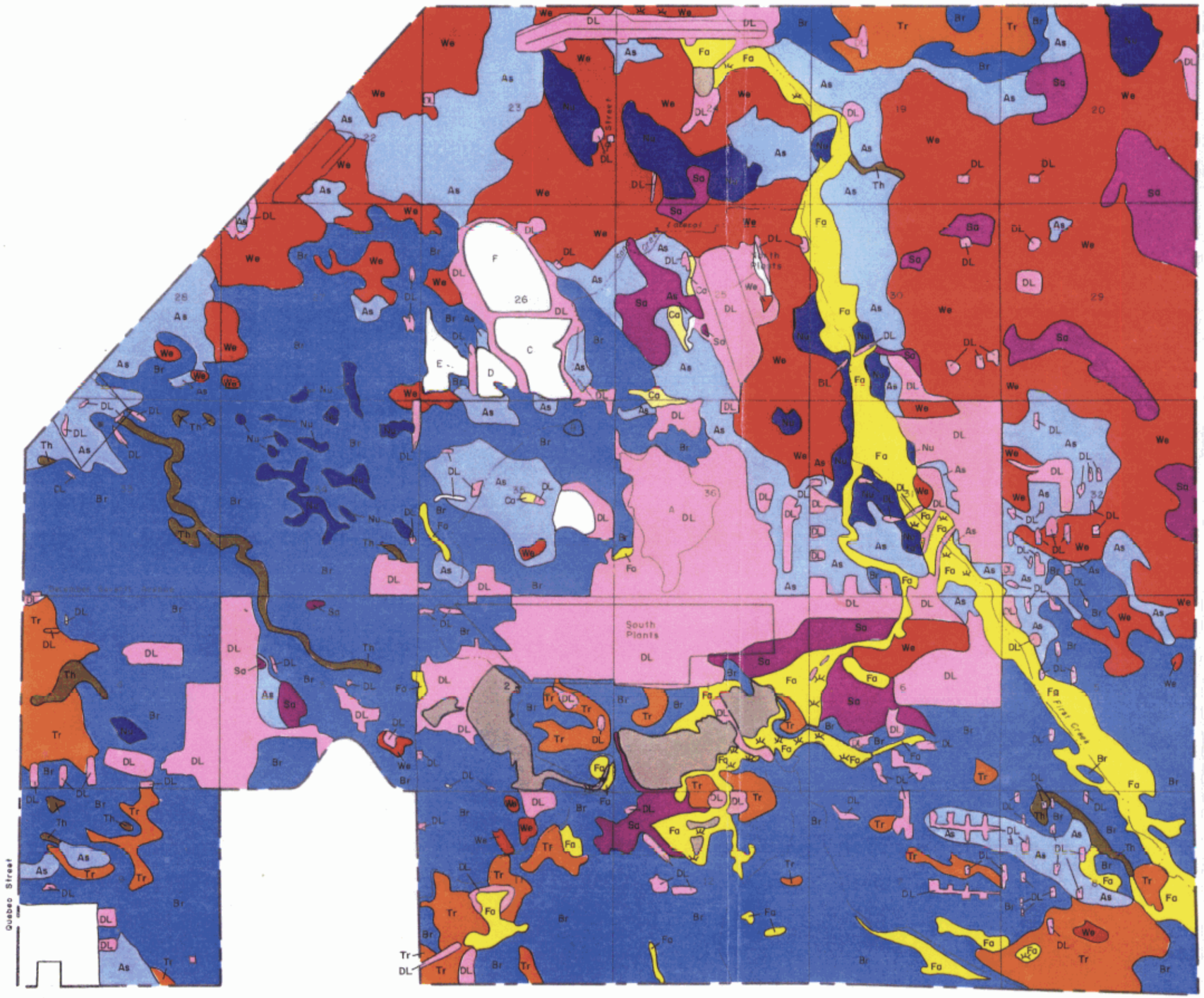
Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A1.4-1
Geologic Map of Rocky Mountain Arsenal Area

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

- Rocky Mountain Arsenal Boundary
- Road or Section Lines
- Stream or Drainage Ditch
- Lakes
- A — Waste Basins
- Intermittent Water Body
- Br — Bresser - sandy loam, 0-10% slopes
- We — Weld - loam, 0-3% slopes
- As — Ascalon - sandy loam, 0-10% slopes
- Nu — Nunn - clay loam, 0-10% slopes
- Sa — Satanta - loam, 0-10% slopes
- Tr — Truckton - loamy sand, 0-10% slopes
- Th — Typic Haplustolls - sandy loam, 0-3% slopes
- Fa — Aquic Haplustolls - sandy loam-loam, 0-3% slopes
- Co — Petrocalcic Paleustolls - 1-3% slopes
- DL — Disturbed Land - sandy to clayey, 0-3% slopes
- Uncharacterized Soil Types

Note: Soil types underlying lakes, ponds, and basins are shown where characterized.

N

0 3000 Feet

Scale: 1" = 3000'

Source: J.P. Walsh, 1988 (preliminary draft)

Prepared for:

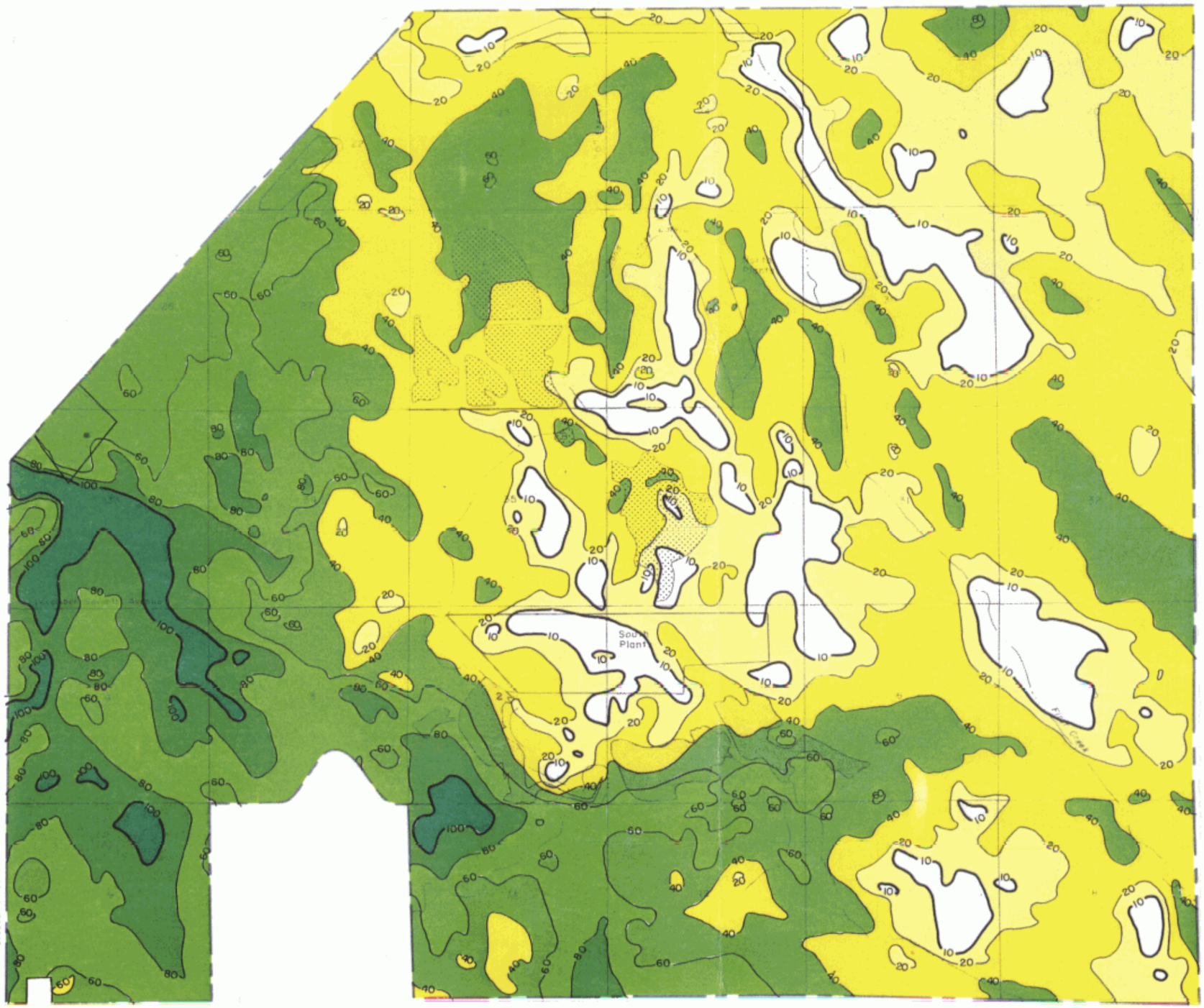
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR AI.4-2

Soil Types at Rocky Mountain Arsenal

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

- Rocky Mountain Arsenal Boundary
- Road or Section Lines
- Stream or Drainage Ditch
- Lakes
- A — Waste Basins

ALLUVIAL THICKNESS

- Less than 10 feet
- 10 to 20 feet
- 20 to 40 feet
- 40 to 60 feet
- 60 to 80 feet
- 80 to 100 feet
- Greater than 100 feet
- 20 — Contour Interval, Dashed where inferred

N

0 3000 Feet

Scale: 1" = 3000'

Source: Ebasco, 1989

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

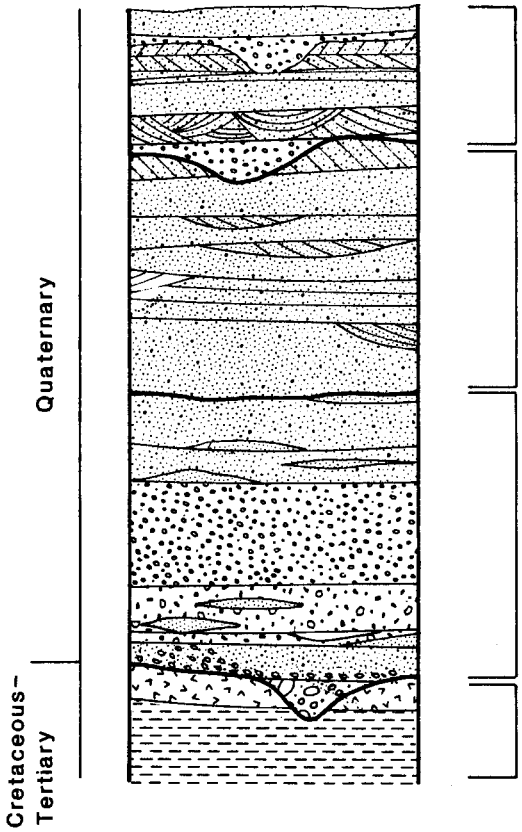
Prepared August 1991

FIGURE RISR A1.4-3

Alluvial Isopach Map

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Generalized Schematic Diagram Illustrating the Heterogeneous Nature of Alluvial Materials



Well-stratified, medium to fine-grained interbedded sand, silt and clay; channel fill and eolian loess deposits.

Well-stratified to massive, well-sorted, fine to coarse-grained sand and gravel; interbedded lenticular sands common.

Well-graded to well-sorted, fine to very coarse-grained sand, gravel, clay and silt; grades upward becoming finer-grained; lenticular sands common; paleochannels tend to be coarser-grained.

Denver Formation bedrock

Note: Thickness not shown to scale.

Prepared for:

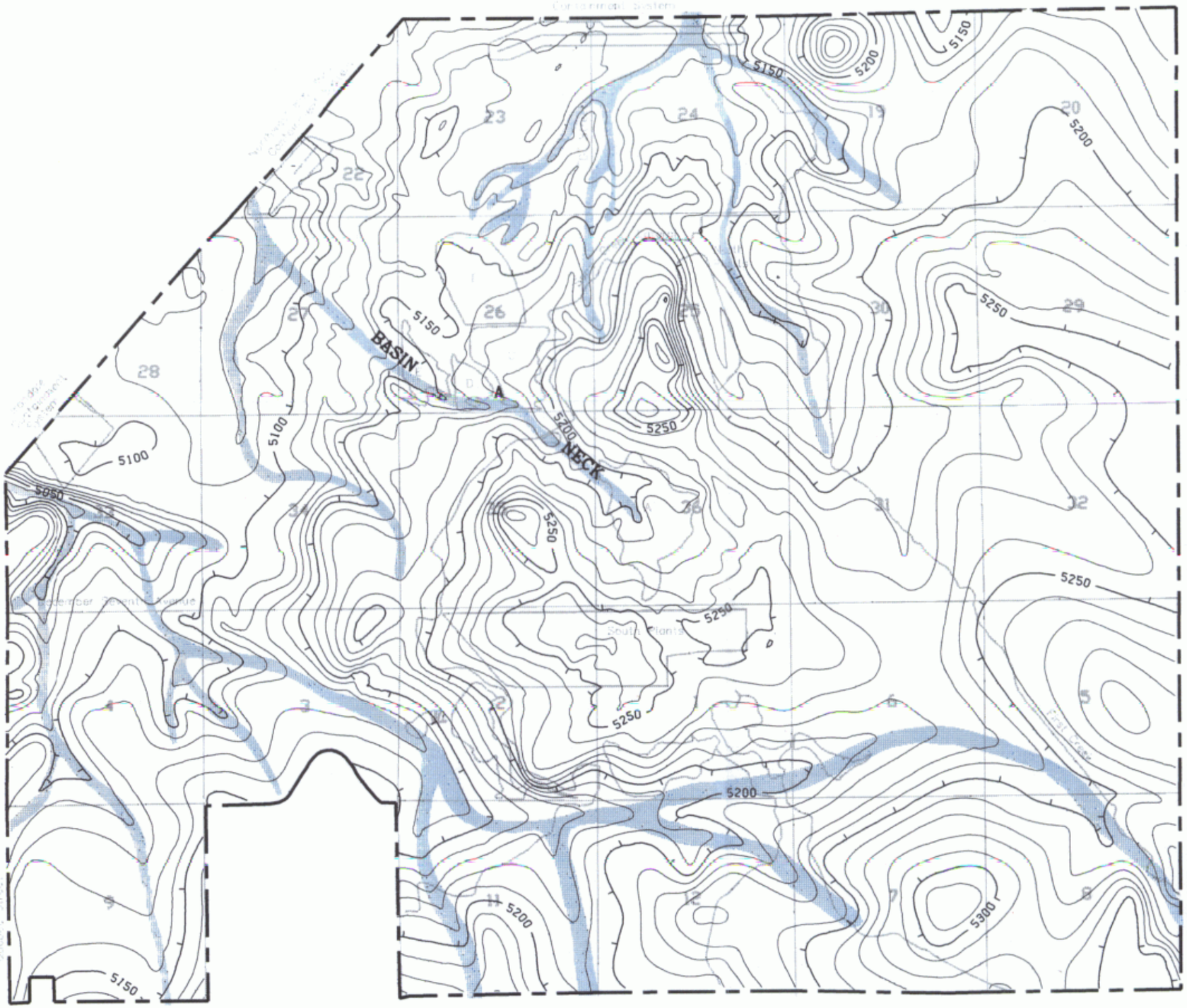
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR AI.4-4

Generalized Schematic Diagram of Alluvial Materials at RMA

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

- Rocky Mountain Arsenal Boundary
- Section Lines
- Streams
- Lakes
- Basins (A)
- 5250 — Bedrock surface elevation contour, bar on downslope side. Contour Interval = 10 ft
- Paleochannels, locations approximate

Note: Elevation contours drawn at the contact between the alluvium and the underlying Denver Formation.

Source: Water Remedial Investigation Report (EBASCO, 1989d)

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

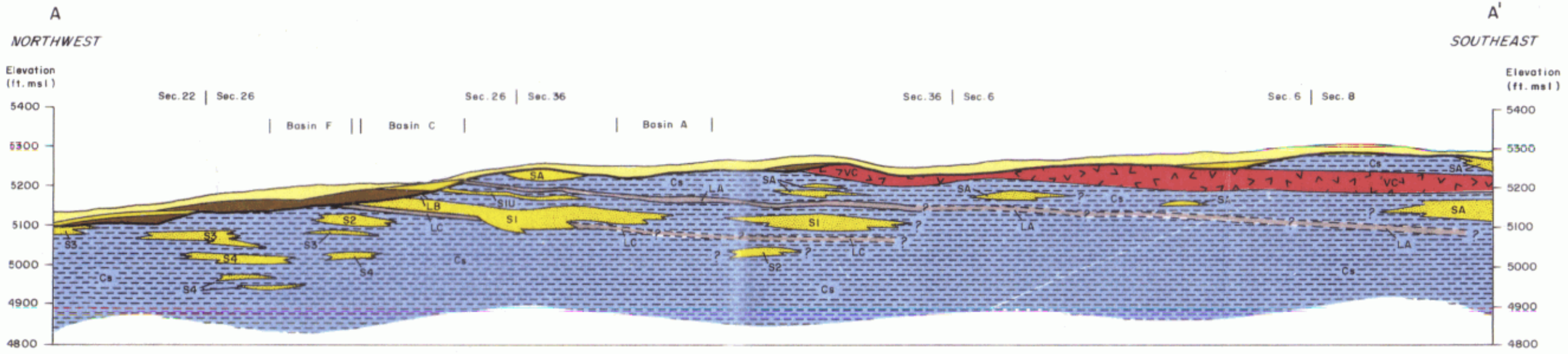
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A1.4-5

Bedrock Surface Elevations
and Prominent Paleochannels

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

LITHOLOGY

ALLUVIUM

Coarse Grained Units
Poor to well graded gravels, gravel-sand mixtures, clayey gravels, poor to well graded sands, gravelly sands, little or no fines.

Medium Grained Units
Silty clayey sands, poorly graded sand-silt, sandy-clay mixtures.

Fine Grained Units
Very fine sands and silts.

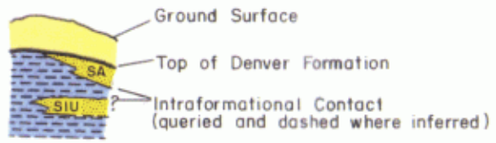
DENVER FORMATION

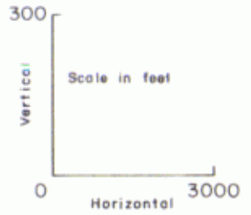
Sandstone Units - SA, SIU, SI, S2, S3, S4 - Sand Zones
Fine to coarse grained, friable to well cemented. Poorly to moderately sorted, poorly to well bedded.

Volcaniclastic - VC
Fine to coarse volcanic fragments in a bentonitic clay and silt matrix.

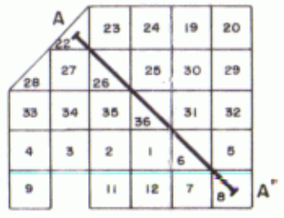
Claystone and Siltstone - Cs
Clayey to sandy, grades laterally and vertically into claystone and sandstones, poorly to well bedded.

Lignite Units - LA, LB, LC
Soft to brittle, lignite grades from subbituminous C coal into organic rich claystone, poorly to well defined bedding and joints.





Vertical Exaggeration - 10X



Scale: 1" = 4 Miles

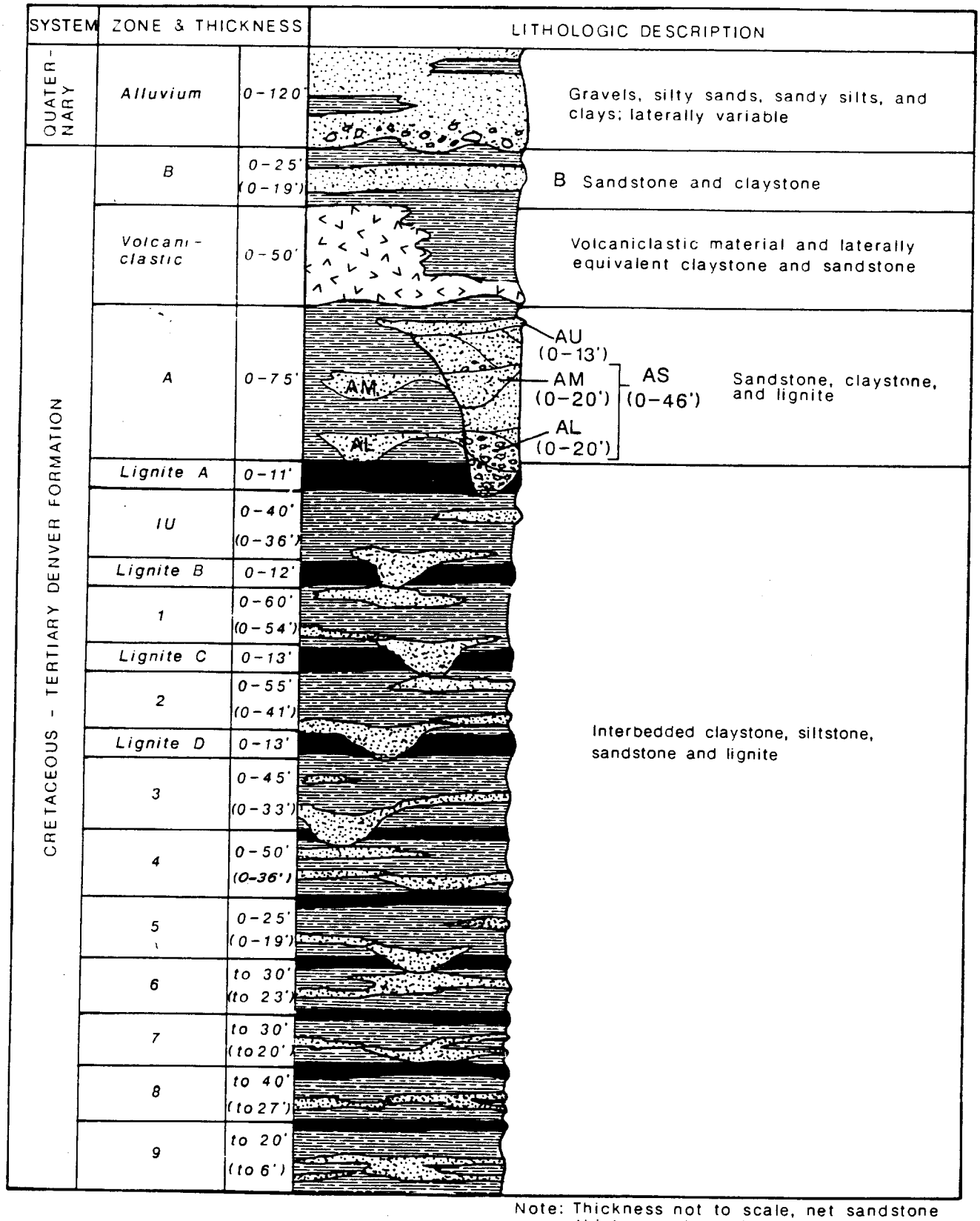
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR AI.4-6

Generalized Geologic Cross-Section A-A', Northwest Across RMA

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Note: Thickness not to scale, net sandstone thickness shown in parentheses.

Sources: HLA, ESE, 1988

Prepared for:

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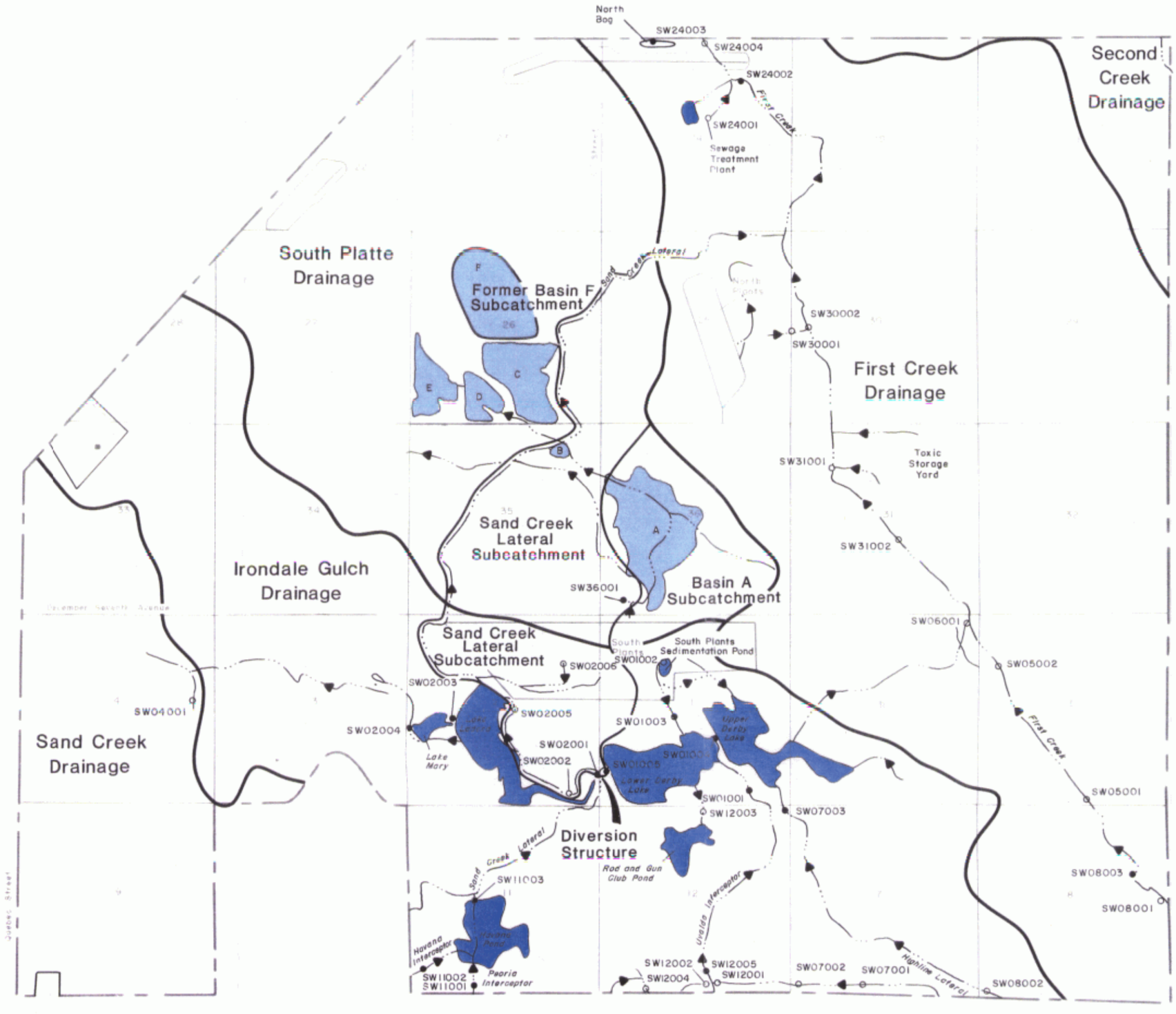
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A1.4-7

Generalized Stratigraphic Column of the Denver Formation at RMA

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

- Rocky Mountain Arsenal Boundary
- Road or Section Lines
- Stream or Drainage Ditch with Flow Direction
- Lakes
- A — Waste Basins
- SW24002 — Gaging Station with Continuous Discharge Record and Periodic Water-Quality Samples
- SW30001 — Monitoring Station with Periodic Discharge Measurements and Water-Quality Samples
- Drainage Basin Boundary
- Subcatchment Boundary

N

0 3000 Feet

Scale: 1" = 3000'

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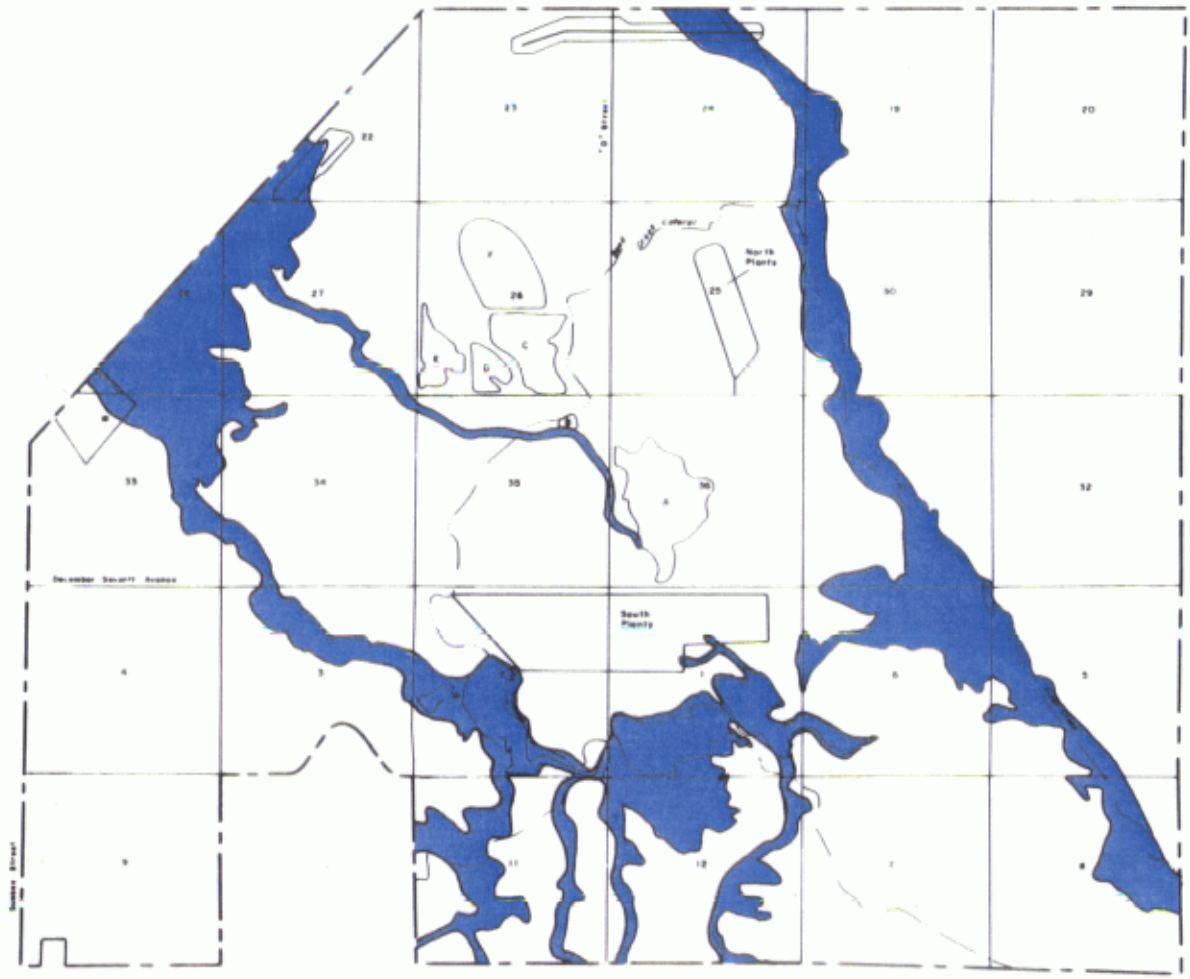
Prepared August 1991

FIGURE RISR AI.5-1

Surface Water Features and Monitoring Sites at RMA

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

100-Year Floodplain (U.S. Army Corps of Engineers, 1983)

N

0 1 Mile

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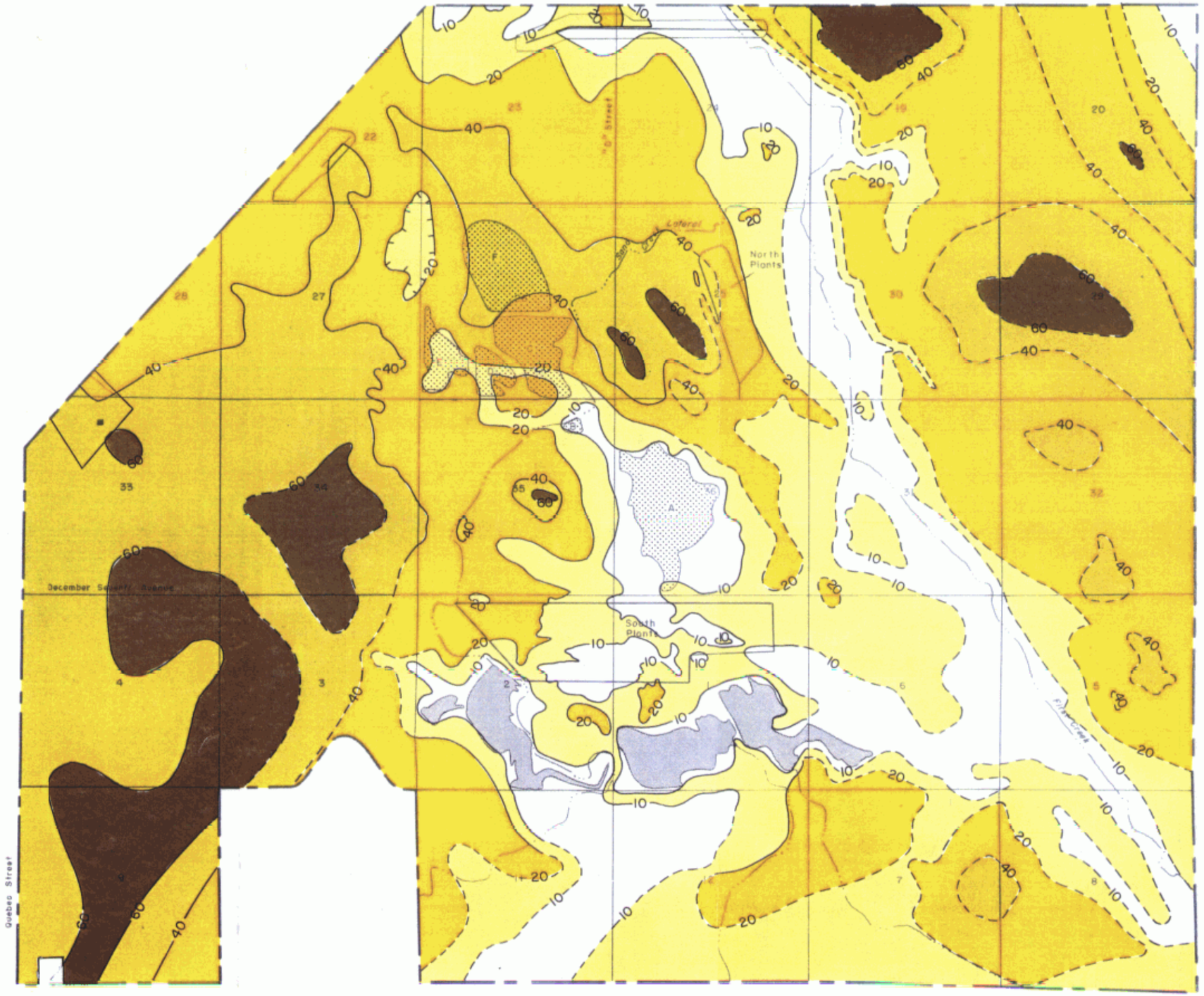
Prepared August 1991

FIGURE RISR A1.5-2

Projected 100-Year Floodplain

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

- Rocky Mountain Arsenal Boundary
- Road or Section Lines
- Stream or Drainage Ditch
- Lakes
- A — Waste Basins

UNSATURATED THICKNESS

- Less than 10 feet
- 10 to 20 feet
- 20 to 40 feet
- 40 to 60 feet
- Greater than 60 feet
- 40 — Contour, dashed where inferred

N

0 3000 Feet

Scale: 1" = 3000'

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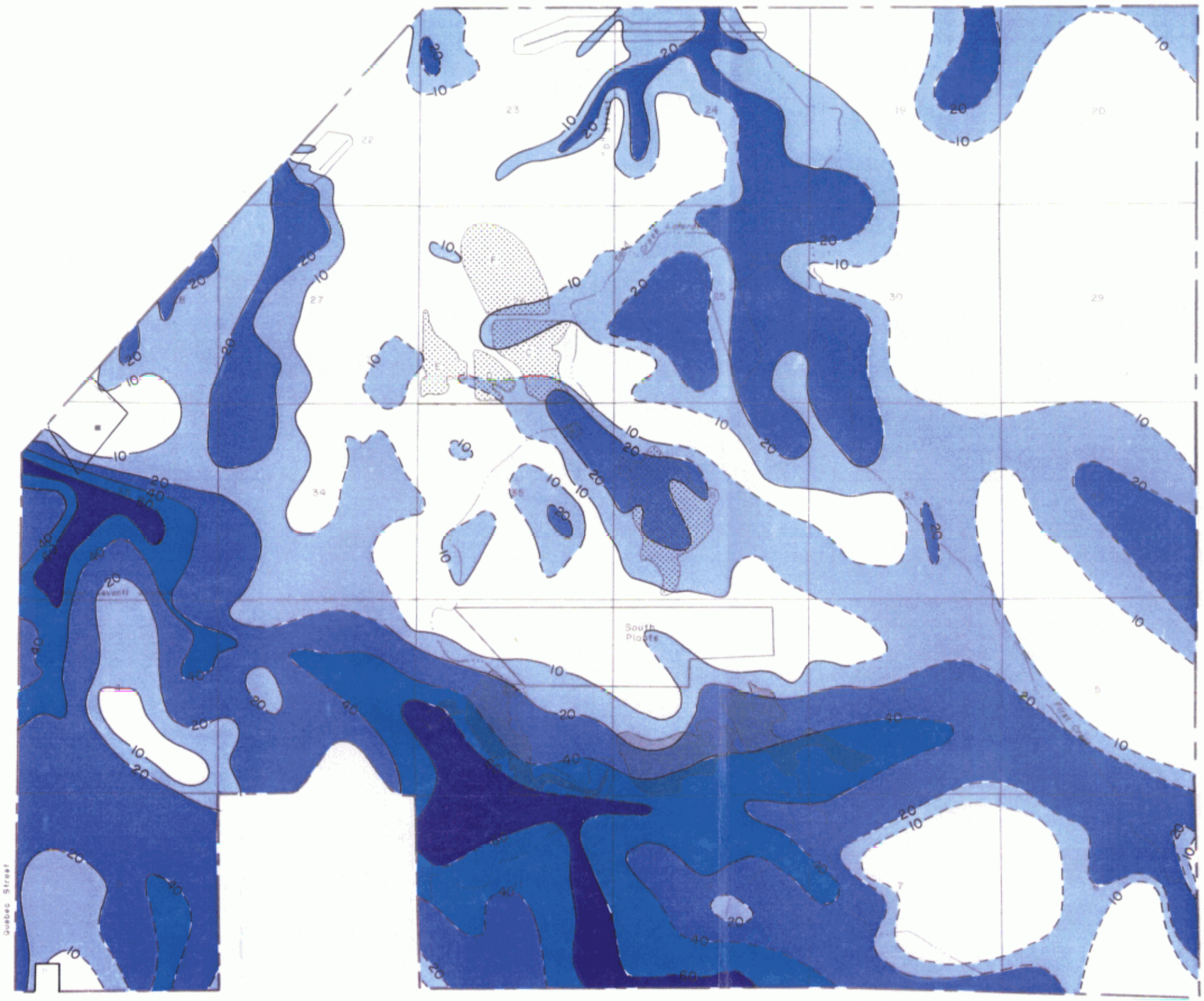
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR AI.5-3

Thickness of the Unsaturated Zone

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

- Rocky Mountain Arsenal Boundary
- Road or Section Lines
- Stream or Drainage Ditch
- Lakes
- A — Waste Basins

SATURATED THICKNESS

- Less than 10 feet
- 10 to 20 feet
- 20 to 40 feet
- 40 to 60 feet
- Greater than 60 feet
- 20 — Contour, dashed where inferred

N

0 3000 Feet

Scale: 1" = 3000'

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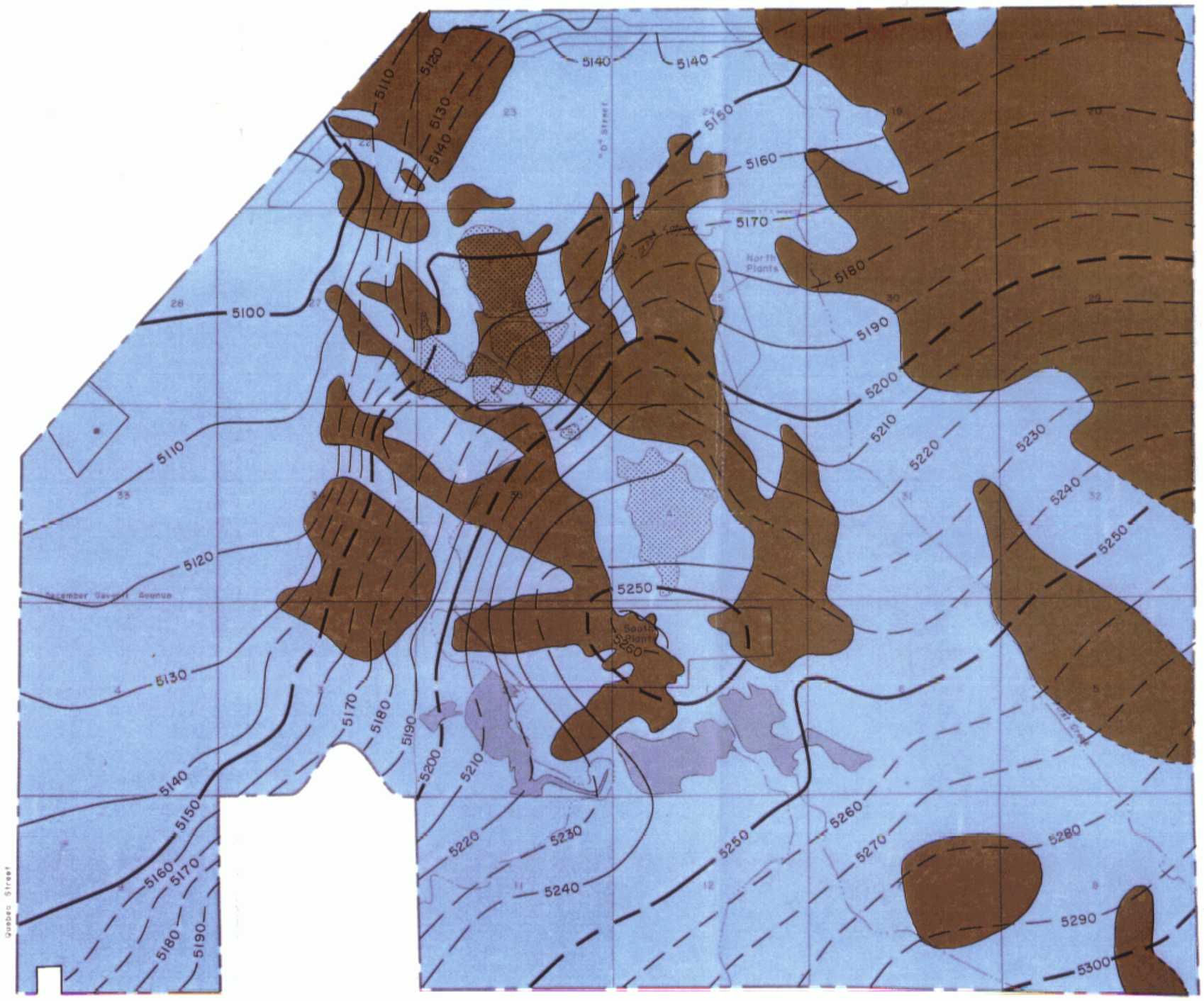
FIGURE RISR AI.5-4

Saturated Thickness of the Unconfined Flow System

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

- Rocky Mountain Arsenal Boundary
- Road or Section Lines
- Stream or Drainage Ditch
- Lakes
- Waste Basins (A)
- Unsaturated Alluvium
- Saturated Alluvium
- Contour, dashed where inferred

Contour interval is 10 feet.

N

0 3000 Feet

Scale: 1" = 3000'

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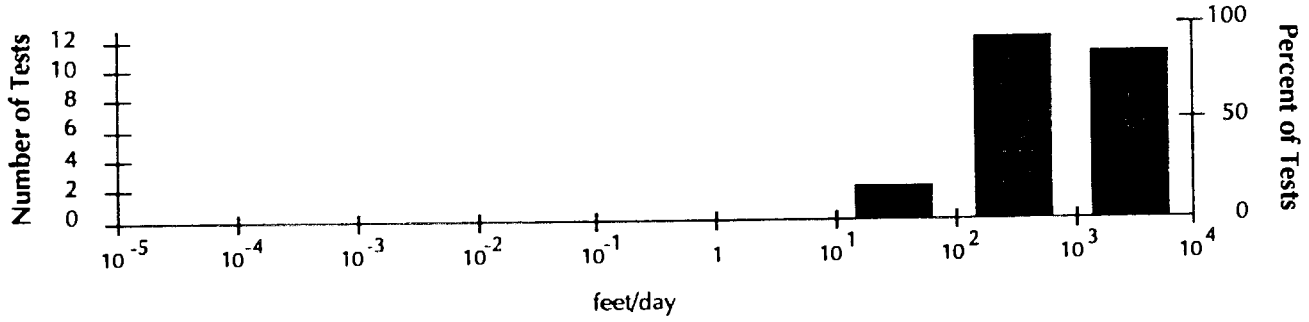
FIGURE RISR AI.5-5

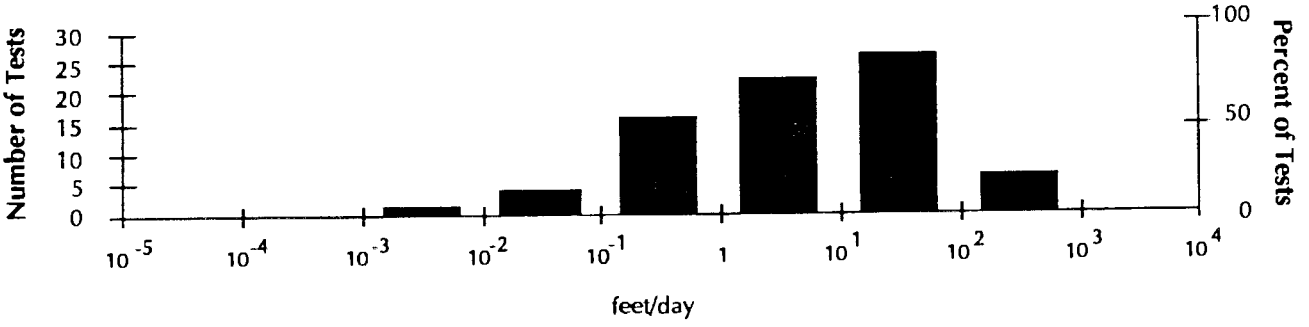
Potentiometric Surface of the Unconfined Flow System

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

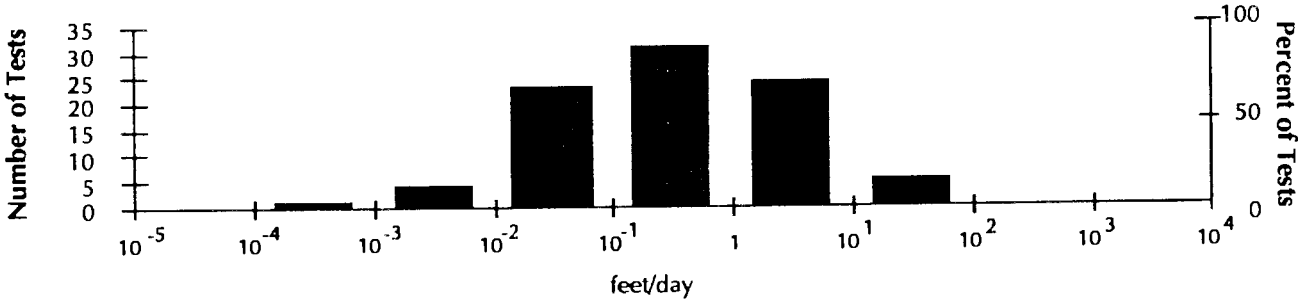
ALLUVIUM
(Pump Tests)



ALLUVIUM
(Slug Tests)



DENVER SANDS
(Slug Tests)



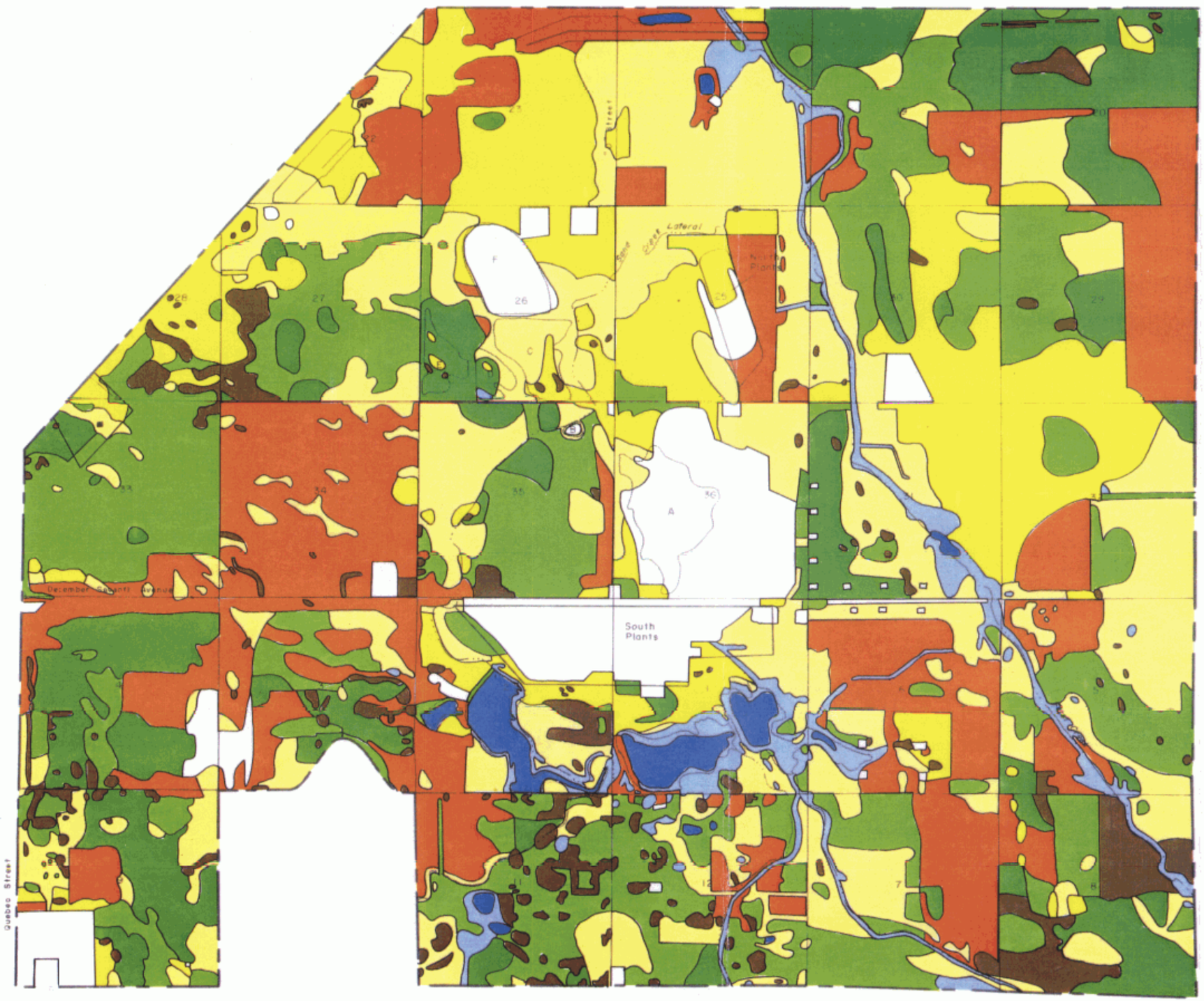
Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

Figure RISR A1.5-6

**Hydraulic Conductivity Histograms,
Aquifer Tests in Alluvium and the Denver Formation**

Prepared by: Ebasco Services Incorporated



Legend

- Rocky Mountain Arsenal Boundary
- Road or Section Lines
- Stream or Drainage Ditch
- Lakes
- A — Waste Basins

- Weedy Forb
- Cheatgrass/Weedy Forb
- Cheatgrass/Perennial Grass
- Native Perennial Grass
- Crested Wheatland
- Minor Vegetation Types
- Wetland/Riparian
- Water
- Unvegetated

N

0 3000 Feet

Scale: 1" = 3000'

Source: MKE, 1988

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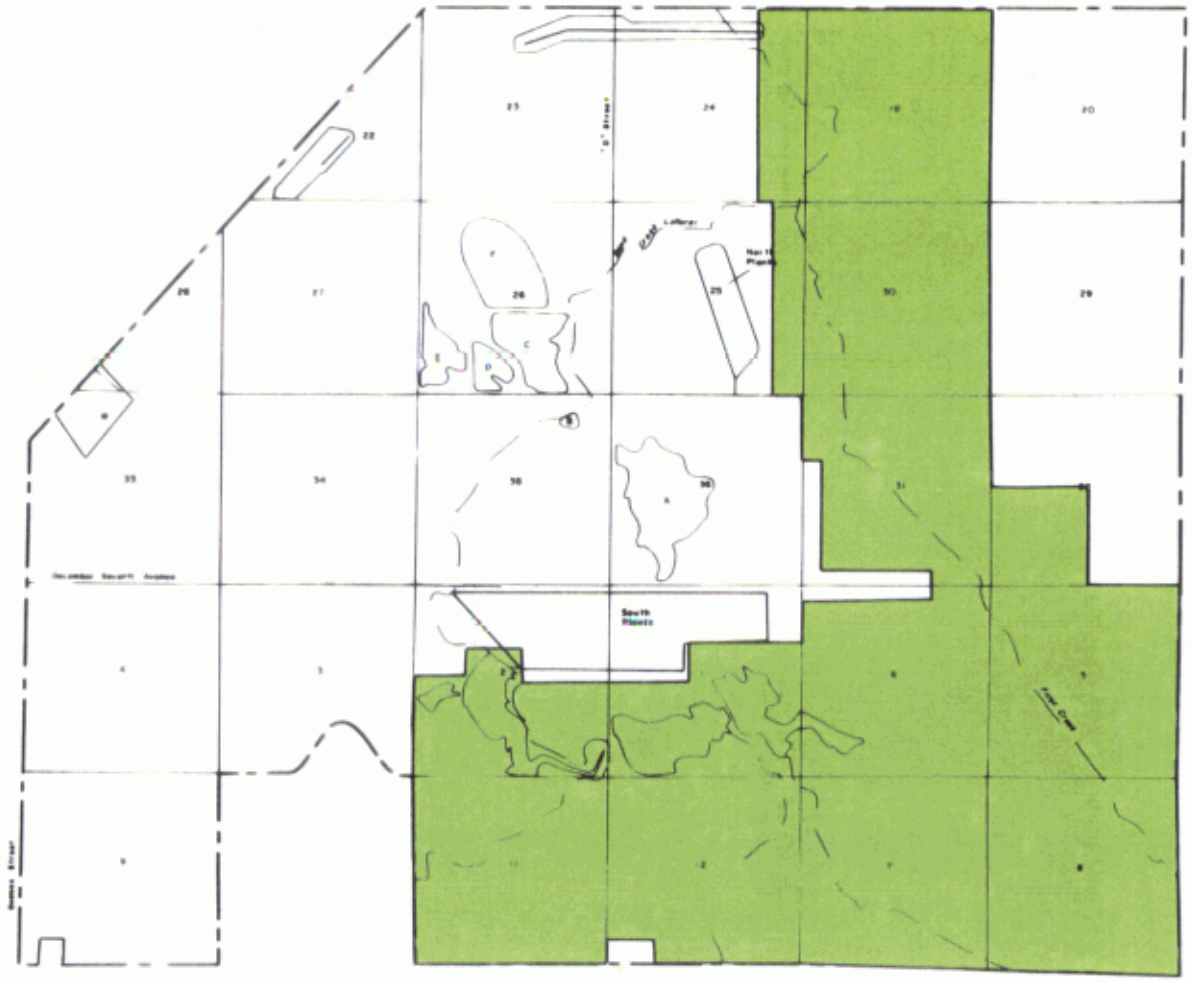
Prepared August 1991

FIGURE RISR A1.6-1

Vegetation Map of
Rocky Mountain Arsenal

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

Bald Eagle Management Area
(December 1989)

N

0 1 Mile

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR AI.6-2

Bald Eagle Management Area

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated