TECHNICAL SUPPORT FOR
ROCKY MOUNTAIN ARSENAL

Record of Decision for the On-Post Operable Unit

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U.S. Army Program Manager's Office for the
Rocky Mountain Arsenal

This document is intended to comply with the National Environmental Policy Act of 1969.

The information and conclusions presented in this report represent the official position of the Department of the Army unless expressly modified by a subsequent document. This report constitutes the relevant portion of the administrative record for this CERCLA operable unit.

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List of Acronyms and Abbreviations

°F	Degrees Fahrenheit
µg	Microgram
95% LCL	95 Percent Lower Confidence Limit
95% UCL	95 Percent Upper Confidence Limit
ACGIH	American Conference of Governmental Industrial Hygienists
ACM	Asbestos-Containing Material
AOC	Area of Contamination
APEN	Air Pollution Emission Notice
ARAR	Applicable or Relevant and Appropriate Requirements
Army	U.S. Army
ATM	Atmospheres
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
BAF	Bioaccumulation Factor
BAS	Biological Advisory Subcommittee
BCHPD	Bicycloheptadiene
BCRL	Below Certified Reporting Limits
BCY	Bank Cubic Yards
BDAT	Best Demonstrated Available Technology
BMF	Biomagnification Factor
BNA	Bureau of National Affairs
bw	Body Weight
CAC	Citizens Against Contamination
CAMU	Corrective Action Management Unit
CBSG	Colorado Basic Standards for Groundwater
CBSM	Colorado Basic Standards and Methodologies for Surface Water
CCR	Code of Colorado Regulations
CDD	CAMU Designation Document
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CF&I	Colorado Fuel and Iron
CFR	Code of Federal Regulations
CFS	Confined Flow System
CHWMA	Colorado Hazardous Waste Management Act
cm	Centimeter
cm^2	Centimeter Squared
cm^3	Centimeter Cubed
C_{max}	Maximum Contaminant Concentration
COC	Contaminant of Concern
Conceptual Remedy	Agreement for a Conceptual Remedy for the Cleanup of the Rocky Mountain Arsenal
CPMS	Chlorophenylmethylsulfide
$CPMSO_2$	Chlorophenylmethylsulfone
$C_{rep,mean}$	Arithmetic Mean of Contaminant Concentration
$C_{rep,upper}$	Arithmetic Mean of Contaminant Concentration, 95% Upper Confidence Limit
CSRG	Containment System Remediation Goal
CWA	Clean Water Act
DBCP	Dibromochloropropane
DCPD	Dicyclopentadiene
DDE	Dichlorodiphenyldichloroethene
DDT	Dichlorodiphenyltrichloroethane
DIMP	Diisopropylmethyl Phosphonate

D_T	Critical Toxicity Value
DW	Exposure Frequency
EPA	U.S. Environmental Protection Agency
ERC	Ecological Risk Characterization
ESC	Exposure Soil Concentration
FFA	Federal Facility Agreement
FS	Feasibility Study
FR	Dietary Fraction
ft	Foot/Feet
g/mole	Gram Per Mole
GAC	Granular Activated Carbon
GB	Sarin
GC/MS	Gas Chromatography/Mass Spectrometry
GIS	Geographic Information System
gpm	Gallons Per Minute
HCCPD	Hexachlorocyclopentadiene
HCL	Hydrogen Chloride
HD	Distilled Mustard
HE	High Explosive
HHEA	Human Health Endangerment Assessment
HHRC	Human Health Risk Characterization
HI	Hazard Index
HQ	Hazard Quotient
Hyman	Julius Hyman and Company
ICS	Irondale Containment System
IEA/RC	Integrated Endangerment Assessment/Risk Characterization
IMPA	Isopropylmethyl Phosphonate
IRA	Interim Response Action
JARDF	Joint Administrative Record Document Facility
kg	Kilogram
l	Liter
LANL	Light Nonaqueous Phase Liquid
lb	Pound
LDR	Land Disposal Restriction
LNAPL	Light Nonaqueous Phase Liquid
LOAEL	Lowest Observed Adverse Effect Level
LOEL	Lowest Observed Effect Level
m	Meter
m^3	Cubic Meter
MATC	Maximum Allowable Tissue Concentration
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg	Milligram
MMAG	Medical Monitoring Advisory Group
mph	Miles Per Hour
MSEC	Mountain State Employer's Council, Inc.
NBCS	North Boundary Containment System
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NDMA	N-Nitrosodimethylamine
NEPA	National Environmental Policy Act
NESHAPS	National Emissions Standards for Hazardous Air Pollutants
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No Observed Adverse Effect Level

NPL	National Priorities List
NRD	Natural Resource Damage
NWBCS	Northwest Boundary Containment System
O&M	Operations and Maintenance
OCP	Organochlorine Pesticide
OPHBG	Organophosphorus Compounds, Agent Related
OPHP	Organophosphorus Compounds, Pesticide Related
Organizations	U.S. Army, Shell Oil Company, U.S. Environmental Protection Agency, U.S. Fish and Wildlife, U.S. Agency for Toxic Substances and Disease Registry, and U.S. Department of Justice
OSCH	Organosulfur Compounds, Herbicide Related
OSCM	Organosulfur Compounds, Mustard Related
OSHA	Occupational Safety and Health Act
Parties	U.S. Army, Shell Oil Company, U.S. Environmental Protection Agency, U.S. Fish and Wildlife, and State of Colorado
PCB	Polychlorinated Biphenyl
PAO	Public Affairs Office
PMRMA	Program Manager for Rocky Mountain Arsenal
ppb	Part Per Billion
PPLV	Preliminary Pollutant Limit Value
ppm	Part Per Million
ppt	Part Per Trillion
PSCo	Public Service Company of Colorado
PVC	Polyvinyl Chloride
RAB	Restoration Advisory Board
RAF	Relative Absorption Factor
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RF	Radio Frequency
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RMA	Rocky Mountain Arsenal
RME	Reasonable Maximum Exposure
ROD	Record of Decision
SACWSD	South Adams County Water and Sanitation District
SD	Standard Deviation
SDWA	Safe Drinking Water Act
sec	Second
SEC	Site Evaluation Criteria
SF	Square Feet
SFS	Supplemental Field Study
Shell	Shell Oil Company
SHO	Semivolatile Halogenated Organic
SHPO	Colorado State Historical Preservation Office
SPPLV	Single-Pathway Preliminary Pollutant Limit Value
SQI	Submerged Quench Incinerator
SSAB	Site-Specific Advisory Board
SVE	Soil Vapor Extraction
SY	Square Yards
TAG	Technical Assistance Grant
TBC	To-Be-Considered Criteria
TCE	Trichloroethylene

TCLP	Toxicity Characteristic Leaching Procedure
TE	Exposure Duration
TEGD	Technical Enforcement Guidance Document
TM	Exposure Time
TMV	Toxicity, Mobility, or Volume
TRC	Technical Review Committee
TRV	Toxicity-Reference Value
TSCA	Toxic Substances Control Act
TSGM	Two-Step Geometric Mean
TX	Crop Agent for "Wheat Rust"
UF	Uncertainty Factor
UFS	Unconfined Flow System
ug	Microgram
USATHAMA	U.S. Army for Toxic and Hazardous Materials Agency
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
UTS	Universal Treatment Standard
UXO	Unexploded Ordnance
VAO	Volatile Aromatic Organics
VHC	Volatile Hydrocarbon Compound
VHO	Volatile Halogenated Organics
VOC	Volatile Organic Compound
VX	Nerve Agent
WP	White Phosporus
yr	Year

Declaration

Declaration

Site Name and Location
Rocky Mountain Arsenal
On-Post Operable Unit
Commerce City, Adams County, Colorado

Statement of Basis and Purpose
This Record of Decision (ROD) presents the selected remedial action for the Rocky Mountain Arsenal (RMA) On-Post Operable Unit in southern Adams County (east of Commerce City) Colorado. This remedy was selected based on the administrative record for the On-Post Operable Unit and chosen in accordance with the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986, and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

U.S. Army (Army) regulations allow for the integration of the requirements of both the National Environmental Policy Act (NEPA) and CERCLA into one document. This ROD is intended to comply with NEPA, except as related to the acquisition of permanent replacement water supplies, and as related to connecting residences in the Henderson, Colorado area to an existing domestic water system.

In accordance with federal law, the federal funding of the Army for implementation of the ROD is subject to appropriations from Congress and other requirements of the Anti-Deficiency Act, 30 USC 1341, et seq. The Army shall request, through the normal Army and U.S. Department of Defense budgetary processes, all funds and authorizations necessary to meet the conditions of, and to implement, the final remedy.

The U.S. Environmental Protection Agency (EPA) and the state of Colorado concur on the selected remedy.

Assessment of the Site
RMA was established in 1942 by the Army to manufacture chemical warfare agents and incendiary munitions for use in World War II. Following the war and through the early 1980s, the facilities continued to be used by the Army. Beginning in 1946, some facilities were leased to private companies to manufacture industrial and agricultural chemicals. Shell Oil Company (Shell), the principal lessee, primarily manufactured pesticides from 1952 to 1982. Common industrial and waste disposal practices used during these years resulted in contamination of structures, soil, surface water, sediment, and groundwater.

One hundred eighty-one sites with varying degrees of contamination, ranging from areas of several hundred acres with multiple contaminant detections at concentrations up to a few parts per hundred to isolated detections of single analytes at a few parts per billion, were delineated during the Remedial Investigation (RI) Program at RMA. Contamination was detected in soil, ditches, stream and lakebed sediments, sewers, groundwater, surface water, biota, structures, and, to a much lesser extent, air. Less extensive or less concentrated sources occur only sporadically within the relatively uncontaminated buffer zone along the boundaries of the site. The most highly contaminated sites (those showing the highest concentrations and/or the greatest variety of contaminants) are concentrated in the central manufacturing, transport, and waste disposal areas. The highest contaminant concentrations tend to occur in soil within 5 ft of the ground surface, although exceptions are noted, particularly at sites where burial trenches, disposal basins, or manufacturing complexes are located. In general, contaminant distribution is significantly influenced by the physical and chemical properties of the contaminants, the environmental media through which they are transported, and the characteristics of the sources, i.e., former manufacturing and disposal practices.

Groundwater contaminant plumes predominantly consist of organic compounds and arsenic, fluoride, and chloride. The organic compounds consist primarily of benzene, dibromochloropropane (DBCP), diisopropylmethyl phosphonate (DIMP), n-nitrosodimethylamine (NDMA), organochlorine pesticides (OCPs), and chlorinated solvents. In addition, elevated concentrations of sulfate are present at RMA's north boundary, chiefly due to natural sources. The unconfined flow system is the principal migration route for groundwater contaminants. The overall concentrations and configurations of the plumes 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, the Army and Shell trenches in Section 36, and the Former Basin F. Plumes emanating from the Motor Pool/Rail Yard and North Plants areas are other sources of contaminant releases to the unconfined flow system.

Contaminant sources and pathways were identified to allow a quantitative assessment of the potential for exposure to human and ecological receptors. Twenty-seven contaminants of concern (COCs) were identified for evaluation in the human health risk characterization and 14 COCs were identified for the ecological risk characterization. Most of the potential carcinogenic health risks for human receptors are caused by four chemicals: aldrin, dieldrin, DBCP, and arsenic. Potential excess cancer risks for these chemicals exceed 1 in 10,000 (1×10^{-4}) at some sites. Three chemicals, DBCP, aldrin, and arsenic, account for the majority of noncarcinogenic human health risks (hazard indices exceeding 1.0). The highest estimated risks occur in the central portions of RMA, coinciding with the former location of chemical processing and disposal areas (e.g., the South Plants manufacturing area, the disposal trenches and basins). The primary routes for exposure are consumption, dermal contact, and inhalation. Land-use restrictions and health and safety requirements for site workers and visitors, however, have minimized the potential for human exposure to contaminants on post.

Although it is believed that these COCs are inclusive of the contaminants representing the greatest potential for risk, there are other contaminants that exist that may in the future become a concern (e.g., dioxin). In such an instance, an evaluation of the contaminant with respect to the remedy selected, designed, or implemented will be performed to ensure that the remedy remains protective of human health and the environment.

Under current conditions, biota are the primary receptors of RMA contamination in surficial soil, lakebed sediments, and surface water. Potential risk varies depending on the biomagnification factor (the ratio between the concentration of a chemical in biota tissue to that in soil) used to calculate risk, the chemical or chemical group being considered, and the receptor (trophic box) being considered. Differences among receptors for a given chemical are partly due to differences in the toxicity threshold values that were used to calculate risk, and especially due to differences in the exposure range size. Terrestrial areas where all trophic boxes are expected to be at potential risk (based on cumulative risk from all of the biota COCs combined) are most of the central sections of RMA, even though the specific receptors evidencing risk in one area may be different from those evidencing risk elsewhere. Pesticides (especially aldrin and dieldrin) and metals (especially mercury, which had been conservatively assumed to be present in its most toxic organic form, methyl mercury, but which was later determined to be present primarily as inorganic mercury) are the primary biota COCs. The primary route for biota exposure is ingestion. Consumption of contaminated prey is a concern at higher trophic levels due to contaminants such as OCPs, which are known to bioaccumulate and biomagnify in the food chain.

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment.

Scope and Role of the On-Post Operable Unit

The On-Post Operable Unit is one of two operable units at RMA (Figure D-1). The On-Post Operable Unit addresses contamination within the fenced 27 square miles of RMA proper. The Off-Post Operable Unit addresses contamination north and northwest of RMA.

The contaminated areas within the On-Post Operable Unit include approximately 3,000 acres of soil, 15 groundwater plumes, and 798 remaining structures. The most highly contaminated sites are located at South Plants (i.e., Central Processing Area, Hex Pit, Buried M-1 Pits, Chemical Sewers), Basins A and F, Lime Basins, and the Army and Shell trenches. The primary contaminants found in soil and/or groundwater at these sites are pesticides, solvents, heavy metals, and agent byproducts.

The purpose of the on-post remedial action is to implement remedies that eliminate, reduce, or control current or future exposure to contaminated soil or structures; to reduce contaminant migration into the groundwater;

and to prevent contaminated groundwater from migrating off post. In addition, it addresses the arrangement for provision of potable water to community residents through the South Adams County Water and Sanitation District (SACWSD). The selected remedy described in this ROD will permanently address the threats to human health and the environment using a combination of containment (as a principal element) and treatment technologies to reduce the toxicity, mobility, or volume of contaminants in groundwater, structures, or soil; comply with applicable or relevant and appropriate requirements (ARARs); and be cost effective.

Since 1975, the Army and Shell have undertaken 14 Interim Response Actions (IRAs) at RMA. Of these, eight IRAs will be continued through incorporation with the selected on-post remedy. Continuing IRAs include groundwater intercept and treatment north of RMA, groundwater intercept and treatment north of Basin F, groundwater intercept and treatment in the Basin A Neck area, boundary systems operation, remediation of other contamination sources (Motor Pool and Rail Yard groundwater treatment), asbestos removal, CERCLA hazardous wastes, and chemical process-related activities. The IRAs were implemented in accordance with Section XXII of the Federal Facility Agreement (FFA) to expedite the mitigation of contamination prior to the selection of final remedial action. The FFA, which formalizes the framework for remediating RMA, was signed by the Army, Shell, EPA, U.S. Fish and Wildlife Service (USFWS), U.S. Department of the Interior, U.S. Department of Justice, and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) on February 17, 1989. Actions requiring removal of material have been carried out in accordance with CERCLA and its regulations and have been consistent with and contribute to the efficient performance of the final response action for the On-Post and Off-Post Operable Units. Examples of early remedial actions include the following:

- Constructing (from 1978 to 1984) and operating three boundary groundwater containment systems and six other systems that currently treat more than 1 billion gallons of groundwater per year (more than 10 billion gallons to date)
- Excavating and storing in an engineered wastepile approximately 600,000 cubic yards of Basin F soil and sludge, covering the remaining area of Basin F, and completing the on-site treatment of more than 11 million gallons of Basin F liquids in a specially designed incinerator
- Dismantling the hydrazine blending and storage facility and removing the debris to an off-post hazardous waste landfill
- Installing a soil cover and slurry wall to reduce movement of contaminants from the Shell Trenches in Section 36

More detailed information on the individual IRAs can be found in Section 2 of this ROD and in IRA-related documentation at the Joint Administrative Record Document Facility.

The selected remedy for the On-Post Operable Unit, integrated with the IRAs and the selected remedy for the Off-Post Operable Unit, will comprehensively address all contamination at RMA. If an IRA will not fully address the threat posed by a release and further response is required, the Army will ensure the IRA will either be incorporated as part of the final response action or end to avoid duplication between the IRA and final response action. The ROD for the On-Post Operable Unit will be the final response action at RMA.

Description of the Remedy

The selected remedy for the On-Post Operable Unit was developed based on the contaminated media present at the site. The major components of the selected remedy for contaminated water, structures, and soil are described below.

Water

The selected water alternative includes the following elements:

- Continued operation of the three RMA boundary groundwater containment and treatment systems, the North Boundary Containment System (NBCS), the Northwest Boundary Containment System (NWBCS), and Irondale Containment System (ICS), which treat groundwater to attain ARARs and health-based remediation goals. These systems and the on-post groundwater IRA systems (Basin A Neck, North of Basin F, Motor Pool, and Rail Yard) will continue to operate until shut-off criteria specified in Section 9.1 of this ROD are met. ARARs for chloride and sulfate at the NBCS will be achieved through natural attenuation as described in "Development of Chloride and Sulfate Remediation Goals for the North Boundary Containment System at the Rocky Mountain Arsenal" (MK 1996). Assessment of the chloride and sulfate concentrations will occur during the 5-year site reviews.
- Installation of a new extraction system to intercept and contain a contaminated groundwater plume in the northeast corner of Section 36 that will be treated at the Basin A Neck IRA system.
- Water levels in Lake Ladora, Lake Mary, and Lower Derby Lake will be maintained to support aquatic ecosystems. The biological health of the ecosystems will continue to be monitored.

  Lake-level maintenance or other means of hydraulic containment or plume control will be used to prevent South Plants plumes from migrating into the lakes at concentrations exceeding Colorado Basic Standards for Groundwater (CBSGs) in groundwater at the point of discharge. Groundwater monitoring will be used to demonstrate compliance.
- Monitoring and assessment of NDMA contamination in support of potential design refinement/design characterization to achieve remediation goals specified for boundary groundwater treatment systems.

Structures

The selected structures alternative includes the following elements:

- Demolition of structures with no planned future use in accordance with a refuge wildlife management plan and salvage of metals where appropriate.
- Disposal of demolition debris from structures with significant contamination in the new on-post hazardous waste landfill.
- Monitoring of all debris from structures associated with Army chemical agent manufacture and treatment by caustic washing for all debris testing positive for the presence of agent followed by disposal in the new on-post hazardous waste landfill.
- Disposal of debris from other structures under the Basin A cover.
- Disposal of process equipment structural debris contaminated with asbestos or polychlorinated biphenyls (PCBs) in the new on-post TSCA-compliant (Toxic Substances Control Act) hazardous waste landfill.

Soil

The selected soil alternative primarily contains soil with principal threat (1×10^{-3} excess cancer risk or hazard index exceeding 1,000) and human health exceedances (1×10^{-4} or hazard index exceeding 1.0) and treats the remaining principal threat soil. The selected soil alternative includes the following elements:

- Treatment of approximately 180,000 bank cubic yards (BCY) of soil at the Former Basin F site by in situ solidification/stabilization.
- Treatment of approximately 1,000 BCY of materials from the Hex Pit by an innovative thermal technology. Disposal of the remaining 2,300 BCY of soil in the on-post hazardous waste landfill. Solidification/stabilization will become the selected remedy if all evaluation criteria for the innovative thermal technology are not met.
- Excavation, solidification/stabilization, and disposal in the on-post hazardous waste landfill of approximately 26,000 BCY of material from the Buried M-1 Pits.
- Monitoring of excavated soil associated with Army chemical agent manufacture and treatment by caustic washing for all excavated soil testing positive for the presence of agent followed by disposal in the on-post hazardous waste landfill.
- Excavation, drying if necessary, and disposal of approximately 600,000 BCY of material from the Basin F Wastepile in dedicated triple-lined cells in the on-post hazardous waste landfill.
- Excavation and disposal of approximately 54,000 BCY of material from the Section 36 Lime Basins in a dedicated triple-lined cell in the on-post hazardous waste landfill.
- Off-post destruction (or on-post detonation if unstable) of any identified unexploded ordnance (UXO) and excavation and disposal of UXO debris and associated soil in the on-post hazardous waste landfill.
- Containment using a soil cover or excavation and disposal of PCB-contaminated soil in the on-post TSCA-compliant hazardous waste landfill
- Excavation and disposal of approximately 1.03 million BCY of contaminated soil exceeding the human health site evaluation criteria (1×10^{-4} excess cancer risk or hazard index exceeding 1.0) and surface soil debris from remaining soil sites in the on-post hazardous waste landfill. These remaining soil sites include the following: North Plants, Toxic Storage Yards, Lake Sediments, Surficial Soil, Secondary Basins, Chemical Sewers, Sanitary Landfills, South Plants Central Processing Area, South Plants Ditches, South Plants Balance of Areas, Buried Sediments, Sand Creek Lateral, Section 36 Balance of Areas, and Burial Trenches.
- Installation of slurry walls and RCRA-equivalent (Resource Conservation and Recovery Act) caps with biota-intrusion barriers for the Army Complex Trenches and Shell Trenches, where contamination will be left in place.
- Construction of a RCRA-equivalent cap over the Former Basin F site and soil covers with biota-intrusion barriers over Basin A and the South Plants Central Processing Area.
- Excavation of 1.5 million BCY of soil posing a potential risk to biota and use as fill under the Basin A and South Plants covers and Basin F cap.
- Construction of variable-thickness soil covers over the Secondary Basins, North Plants, South Plants Balance of Areas, and Section 36 Balance of Areas.

Other

Additional components of the on-post remedy that contribute to protection of human health and the environment are the following:

- Provision of $48.8 million held in trust to provide for the acquisition and delivery of 4,000 acre-feet of potable water to SACWSD and the extension of water-distribution lines from an appropriate municipal water supply distribution system to all existing well owners within the DIMP plume footprint north of RMA as defined by the detection limit for DIMP of 0.392 parts per billion (ppb). In the future, owners of any additional domestic wells, new or existing, found to have DIMP concentrations of 8 ppb (or other relevant CBSG at the time) or greater will be connected to a water-distribution system or provided a deep well or other permanent solution. The Army and Shell have reached an Agreement in Principle with SACWSD, enclosed as Appendix B of this ROD, regarding this matter.
- National Environmental Policy Act – The Program Manager for Rocky Mountain Arsenal will separately evaluate the potential impacts to the environment of both the acquisition of a replacement water supply for SACWSD and for the extension of water-distribution lines.
- The Army and Shell will fund ATSDR to conduct an RMA Medical Monitoring Program in coordination with the Colorado Department of Public Health and Environment. The primary goals of the Medical Monitoring Program are to monitor any off-post impact on human health due to the remediation and provide mechanisms for evaluation of human health on an individual and community basis until such time as the soil remedy is completed. Elements of the program could include medical monitoring, environmental monitoring, health/community education, or other tools. The program design will be determined through an analysis of community needs, feasibility, and effectiveness.
- Trust Fund – During the formulation and selection of the remedy, members of the public and some local governmental organizations expressed keen interest in the creation of a Trust Fund to help ensure the long-term operation and maintenance of the remedy once the remedial structures and systems have been installed. In response to this interest, the Parties (i.e., the Army, Shell, EPA, USFWS, and the state of Colorado) have committed to good-faith best efforts to establish a Trust Fund for the operation and maintenance of the remedy, including habitat and surficial soil. Such operation and maintenance activities will include those related to the new hazardous waste landfill; the slurry walls, caps, and soil and concrete covers; all existing groundwater pump-and-treat systems; the groundwater pump-and-treat system to intercept the Section 36 Bedrock Ridge Plume; the maintenance of lake levels or other means of hydraulic containment; all monitoring activities required for the remedy; design refinement for areas that may pose a potential risk to biota as described in Section 9.4; and any revegetation and habitat restoration required as a result of remediation.

  These activities are estimated to cost approximately $5 million per year (in 1995 dollars). The principal and interest from the Trust Fund would be used to cover these costs throughout the lifetime of the remedial program.

  The Parties recognize that establishment of such a Trust Fund may require special legislation and that there are restrictions on the actions federal agencies can take with respect to proposing legislation and supporting proposed legislation. In addition to the legislative approach, the Parties are also examining possible options that may be adapted from trust funds involving federal funds that exist at other remediation sites. Because of the uncertainty of possible legislative requirements and other options, the precise terms of the Trust Fund cannot now be stated.

  A trust fund group will be formed to develop a strategy to establish the Trust Fund. The strategy group may include representatives of the Parties (subject to restrictions on federal agency participation), local governments, affected communities, and other interested stakeholders, and will be convened within 90 days of the signing of the ROD.

  Notwithstanding these uncertainties, it is the intent of the Parties that if the Trust Fund is created it will include the following:

  - A clear statement that will contain the reasons for the creation of the Trust Fund and the purposes to be served by it.
  - A definite time for establishing and funding the Trust Fund, which the Parties believe could occur as early as 2008, when the remedial structures and systems may have been installed.

  - An appropriate means for competent and reliable management of the Trust Fund, including appropriate criteria for disbursements from the Trust Fund to ensure that the money will be properly used for the required purposes.

- Restrictions on land use or access are incorporated as part of this ROD. The Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 and the FFA restrict future land use and prohibit certain activities such as agriculture, use of on-post groundwater as a drinking source, and consumption of fish and game taken at RMA. Continued restrictions on land use or access are included as an integral component of all on-post alternatives. Long-term management includes access restrictions to capped and covered areas to ensure integrity of the containment systems.
- Continued operation of the existing CERCLA Wastewater Treatment Plant to support the remediation activities.
- Stored, drummed waste identified in the waste-management element of the CERCLA Hazardous Wastes IRA may be disposed in the on-post hazardous waste landfill in accordance with the Corrective Action Management Unit Designation Document.
- Continued monitoring as part of design refinement for the remediation of surficial soil and lake sediments that may pose a potential risk to wildlife (see Section 6.2.4.3).

Summary of the Off-Post Remedy

The Off-Post Operable Unit addresses groundwater contamination north and northwest of RMA. A ROD for this operable unit was issued on December 19, 1995. The selected remedies for both of the operable units, integrated with the IRAs, will comprehensively address all contamination at RMA. The components of the selected remedy for the Off-Post Operable Unit, presented below for informational purposes, are as follows:

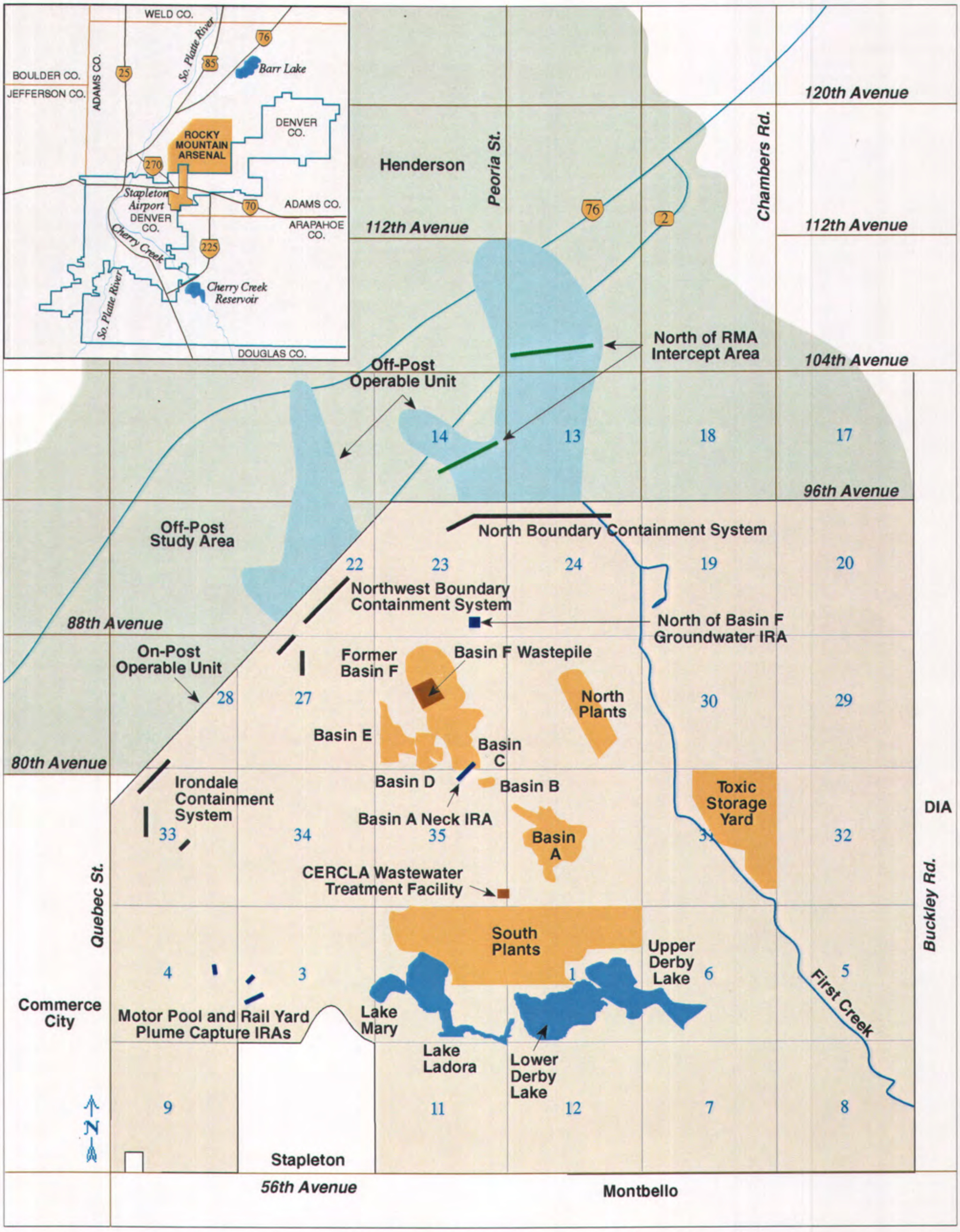
- Continued operation of the Off-Post Groundwater Intercept and Treatment System.
- Natural attenuation of inorganic chloride and sulfate concentrations to meet remediation goals for groundwater in a manner consistent with the on-post remedial action.
- Continued operation of the NWBCS, NBCS, and ICS as specified in Section 7.2 of the ROD for the On-Post Operable Unit.
- Improvements to the NBCS, ICS, NWBCS, and the Off-Post Groundwater Intercept and Treatment System as necessary.
- Long-term groundwater monitoring (including monitoring after groundwater treatment has ceased) to ensure continued compliance with the Containment System Remediation Goals (CSRGs).
- Five-year site reviews.
- Exposure control/provision of alternate water as detailed in the ROD for the Off-Post Operable Unit.
- Institutional controls, including deed restrictions on Shell-owned property, to prevent the use of groundwater exceeding remediation goals.
- Closure of poorly constructed wells within the Off-Post Study Area (see Figure D-1) that could be acting as migration pathways for contaminants found in the Arapahoe aquifer.
- Continuation of monitoring and completion of an assessment by the Army and Shell of the NDMA plume by June 13, 1996 using a 20 parts per trillion (ppt) method detection limit.
- Preparation of a study that supports design refinement for achieving NDMA remediation goals at the RMA boundary. The study will use a 7.0 ppt preliminary remediation goal or a certified analytical detection level readily available at a certified commercial laboratory (currently 33 ppt).

- Tilling and revegetation of approximately 160 acres in the southeast portion of Section 14 and the southwest portion of Section 13 by the Army and Shell.
- Treatment of any contaminated extracted groundwater prior to discharge or reinjection so that it meets CSRGs that meet or exceed the water quality standards established in the CBSGs and the Colorado Basic Standards and Methodologies for Surface Water.

Statutory Determinations

The selected remedy is protective of human health and the environment, complies with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost effective. The remedy uses permanent solutions and alternative treatment technologies to the maximum extent practicable. Components of the selected remedy satisfy the statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element. The large volume of contaminated soil present on the site precludes a remedy in which all contaminants could be excavated and cost effectively treated.

Because this remedy will result in hazardous substances remaining at RMA above health-based levels, a review will be conducted no less than every 5 years after commencement of remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment and complies with applicable regulations.



Legend

20 Section (1 section = 640 acres or 1 square mile)

Not to scale

Figure D-1
RMA Operable Units

Rocky Mountain Arsenal
Prepared by Foster Wheeler Environmental Corporation

RMA ROD 6.96 jb

Signature Page

For U.S. Environmental Protection Agency

Fred Hansen

Deputy Administrator

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For U.S. Army

Robert M. Walker

Assistant Secretary of the Army
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For State of Colorado

Roy R. Romer

Governor

Gail Schoettler

Lieutenant Governor

Shell Oil Company

c/o Holme Roberts & Owen LLC
Suite 4100
1700 Lincoln
Denver, CO 80203

June 11, 1996

Environmental Protection Agency
Region VIII
One Denver Place, 999 18th Street
Denver, Colorado 80202-2413

CERCLA Litigation Unit
Office of the Attorney General
1525 Sherman Street, 5th Floor
Denver, Colorado 80203

Re: Rocky Mountain Arsenal--On-Post ROD

Ladies and Gentlemen:

Shell Oil Company ("Shell") did not invoke dispute resolution on the draft final record of decision for the On-Post Operable Unit of Rocky Mountain Arsenal (the "ROD") under the Federal Facility Agreement dated effective February 17, 1989 (the "FFA"), among the United States Department of the Army, United States Environmental Protection Agency, United States Department of the Interior, Agency for Toxic Substances and Disease Registry, United States Department of Justice, and Shell. Pursuant to paragraph 25.7 of the FFA, Shell is therefore deemed to have concurred in the draft final ROD.

Shell also does not object to the minor changes that have been made since the draft final ROD was issued.

The final ROD is to be signed today. Shell confirms it will not challenge the final ROD under paragraph 25.13 of the FFA.

This letter affirms Shell Oil Company's long standing commitment to a protective and cost-effective remedy for Rocky Mountain Arsenal.

Very truly yours,

SHELL OIL COMPANY

By ______________________
Rand N. Shulman
Authorized Signatory

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Mountain-Prairie Region

IN REPLY REFER TO:

FWS/R6/RMA
Mail Stop 61170

MAILING ADDRESS:
Post Office Box 25486
Denver Federal Center
Denver, Colorado 80225

STREET LOCATION:
134 Union Blvd.
Lakewood, Colorado 80228

JUN 11 1996

Raymond J. Fatz, Acting Deputy
Assistant Secretary of the Army
(Environment, Safety and Occupational Health)
OASA (I, L & E)
110 Army Pentagon
Washington, D.C. 20310-0110

Dear Mr. Fatz:

On behalf of the Fish and Wildlife Service I am pleased to endorse and support the signing of this On Post Record of Decision for the remediation of the Rocky Mountain Arsenal. This ROD represents the culmination of years of effort and resolves many years of negotiations between the involved parties. It also represents a major milestone in transitioning the Arsenal to the Refuge as envisioned by Congress in the Rocky Mountain Arsenal National Wildlife Refuge Act of 1992.

There are issues yet to be resolved. The Service remains concerned that the Trust Fund becomes a reality, and it is essential that sufficient water is obtained for maintaining the lakes and revegetating the disturbed areas. It is my hope that the implementation of the ROD results in an expedient and effective remedy to enable the Rocky Mountain Arsenal to become one of the Nation's finest urban national wildlife refuges.

Sincerely,

Terry Terrell

Regional Director

Decision Summary

1.0 Site Name, Location, and Description

The Rocky Mountain Arsenal (RMA) National Priorities List (NPL) site is comprised of two **operable units**,[1] On Post and Off Post. The On-Post Operable Unit is encompassed by the boundaries of RMA; it occupies 27 square miles in southern Adams County, approximately 8 miles northeast of Denver (Figure 1.0-1). Areas bordering RMA exhibit varied land use. To the north and east the land is primarily agricultural, except for Denver International Airport, around which a great deal of business and residential activity is ongoing or scheduled. The southern boundary is adjacent to the Denver residential, commercial, and industrial community of Montbello and to the former Stapleton International Airport, and the western boundary is adjacent to Commerce City, where land use is residential, commercial, and industrial.

Future land use for the On-Post Operable Unit is addressed in the **Federal Facility Agreement (FFA)**, which was signed by the U.S. Army (Army), U.S. Environmental Protection Agency (EPA), U.S. Agency for Toxic Substances and Disease Registry (ATSDR), U.S. Fish and Wildlife Service (USFWS), U.S. Department of Justice, and Shell Oil Company (Shell) in 1989 (these entities are collectively referred to as the Organizations) pursuant to Section 120 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Among other provisions, the FFA states that it is a goal of the signatories to make significant portions of the site available for beneficial public use and requires the preservation of habitat to the extent required by the Endangered Species Act, Migratory Bird Treaty Act, and Bald Eagle Protection Act. In October 1992, in conjunction with the future goal of beneficial public use and in recognition of the unique urban wildlife resources provided by RMA, President George Bush signed the Rocky Mountain Arsenal National Wildlife Refuge Act, making RMA a national wildlife refuge following EPA certification that required response actions have been appropriately completed. Once the EPA Administrator declares the site protective, ownership of the site will be transferred to USFWS.

Restrictions on land use at RMA or access to RMA are agreed to by the Army, EPA, USFWS, Shell, and state of Colorado (Parties) and are included as part of this **Record of Decision (ROD)**. The Rocky Mountain Arsenal National Wildlife Refuge Act and the FFA restrict future land use, specify that the U.S. government shall retain ownership of RMA, and prohibit certain activities such as agriculture, use of on-post groundwater as a drinking source, and consumption of fish and game taken at RMA.

1.1 Environmental Setting

1.1.1 Physiography

RMA is located at the western edge of the Colorado Plains, near the foothills of the Rocky Mountains. It occupies an area of rolling terrain characterized by grasslands, shrublands, wetlands, aquatic habitats, and extensive weedy areas, and it supports a variety of plant and wildlife species. The elevation above mean sea level ranges from 5,330 ft at the southeastern boundary to 5,130 ft at the northwestern boundary.

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[1] Items printed in bold face are included in the glossary.

Regional surface drainage is toward the northwest into the South Platte River, which flows parallel to the northwest boundary of RMA and eventually joins the North Platte River in Nebraska. The land surface of RMA has largely been shaped by fluvial processes associated with the South Platte River and its tributaries. Wind-borne deposits cover the alluvial land surface in many areas, particularly in the southern and western portions of RMA.

1.1.2 Climate

According to the National Climatic Data Center records for Denver, the mean maximum temperatures range from 43°F in January to 88°F in July; mean minimum temperatures range from 16°F in January to 59°F in July.

Annual precipitation averages approximately 15 inches (water equivalent). Average monthly precipitation is highest in May and lowest from December through February. The maximum precipitation events are heavy localized thunderstorms that occur during late spring and summer. Tornadoes and severe hailstorms may occur in association with intense thunderstorm activity. Snowfall normally occurs from September through May. The average annual snowfall is 58 inches. Average monthly snowfall is highest in March, when snow also tends to have the highest moisture content. Snow generally melts or sublimates rapidly at RMA and normally does not cover the ground for extended periods.

The prevailing wind is from the south. In summer, the strongest winds are associated with thunderstorms. In other seasons, the strongest winds are generally from the northwest quadrant and are downslope "chinook" winds. The annual mean wind speed at RMA is approximately 9 mph, and the maximum hourly wind speed ranges from approximately 33 mph to 38 mph. A maximum wind gust of approximately 70 mph has been recorded at RMA.

1.1.3 Existing Cultural Features

Most military and industrial activities at RMA occurred in three areas: North Plants, South Plants, and the Rail Yard. Cultural features are generally associated with these areas. The primary roads at RMA form a grid that runs along the township section lines.

Structures at RMA include buildings, foundations, basements, tanks and tank farms, process and nonprocess equipment, pipelines, sewers, and other manmade items such as electrical substations. Most of these structures (53 percent) are located in the South Plants area. Two smaller groupings of structures occur in North Plants (12 percent) and in the Rail Yard (8 percent), and the rest (27 percent) occur as individual or small clusters throughout the site.

There are six former disposal basins at RMA. Basin A was originally developed as an unlined evaporative basin for disposal of aqueous waste from the production of mustard and lewisite. Basin B was used as a holding pond for overflow from Basin A. Basins C, D, and E were created from natural depressions to hold overflow aqueous wastes from preexisting basins. Basin F, partially remediated under the Basin F **Interim Response Action (IRA)**, was an asphalt-lined evaporation basin. Other disposal sites include the Army and Shell Trenches and sanitary landfills.

Three boundary groundwater containment systems, the North, Northwest, and Irondale systems (NBCS, NWBCS, and ICS, respectively), are present at RMA. These systems are designed to treat and to prevent the migration of groundwater contamination to off-post areas. Each system consists of an array of extraction wells, water treatment facilities, an array of injection wells, and, at the NBCS, recharge trenches.

There are also four internal groundwater treatment systems, the Motor Pool, Rail Yard, Basin F, and Basin A Neck IRA systems. Extraction wells in the Motor Pool and Rail Yard IRA systems pump water to the ICS for treatment prior to reinjection at the ICS. At the North of Basin F IRA, water is extracted and piped to the Basin A Neck IRA system for treatment. The Basin A Neck IRA is a pump-and-treat system that intercepts and treats contamination in groundwater as it moves northwest from Basin A. Water is reinjected at the Basin A Neck reinjection trenches.

1.1.4 Cultural Resources

Previous to Army operations at RMA, a patchwork of small irrigated farms occupied the southeastern and north-central portions of the site and larger dryland farms and ranches occupied the northeastern portion. Lakes in the southern portion are remnants of this agricultural past. Prior to 1850, the site was used by Native American tribes indigenous to the area, such as the Cheyenne and Arapaho.

The Army is in the process of completing cultural resource surveys that will identify structures or sites that may be protected under the National Historic Preservation Act (36 CFR 800) or the Archeological Resources Protection Act (16 USC Section 469 a-l). To determine the extent of historical and prehistorical resources existing on the current RMA site, several areas were investigated by different archeological teams. To bring all these studies together, as well as to close any information gaps, a complete RMA-wide surface sweep was conducted. A final report summarizing the results of this survey will be completed in summer 1996 prior to initiating on-post remedial actions. Native American sites and farmsteads at RMA were investigated.

No National Historic Register nominations have been made as a result of these activities, but two potentially eligible National Historic Districts were determined to exist, the North Plants manufacturing area and the South Plants manufacturing area. Due to their significant contribution in the Cold War, particularly the North Plants area, consultations were entered into with the Colorado State Historical Preservation Office (SHPO). Because contamination and Chemical Weapons Convention issues require the destruction of these potentially eligible districts, a Historic American Engineering Record of the districts is being prepared in advance of demolition, as is a video history of former residents and workers at RMA. Current projects in South and North Plants are carried out under an Interim Memorandum of Agreement between the Army, SHPO, and USFWS.

1.2 Geology

RMA is located within the Denver Basin, an asymmetrical depression approximately 300 miles long and 200 miles wide. The sedimentary rocks in the Denver Basin are more than 10,000 ft thick. Only the surficial soil, unconsolidated alluvium, and Denver Formation units are of interest for remedial actions at RMA.

Virtually all of RMA is covered with unconsolidated alluvial and windblown sediments that may locally reach thicknesses of 130 ft. Due to the nature of the alluvial deposition and erosion and the irregular bedrock surface on which the alluvium lies, there is little lateral continuity in the alluvial units, and the spatial relationships between them are complex. The thickest deposits of these alluvial sediments occur in paleochannels eroded into the underlying Denver Formation, which consists of sandstones, siltstones, and claystones. The paleochannels, which were incised in the bedrock surface and subsequently filled with alluvial deposits, influence regional groundwater flow and the direction and rate of movement of groundwater plumes at RMA. The major paleochannels on post, the First Creek and Irondale channels, direct regional groundwater flow to the north and north-northwest, respectively.

At RMA, the Denver Formation is exposed in only a few isolated outcrops. The unit ranges from approximately 200 to 500 ft in thickness, and is separated from the underlying Arapahoe Formation by a relatively impermeable claystone interval 30 to 50 ft thick. The Arapahoe Formation consists of 400 to 700 ft of interbedded conglomerate, sandstone, siltstone, and shale. The upper portion of the Arapahoe Formation consists predominately of 200 to 300 ft of blue to gray shale with some conglomerate and sandstone beds. The lower portion of the formation consists primarily of sand, gravel, and conglomerate and is a source zone for many water-supply wells in the area.

1.3 Hydrology

Flow of surface water at RMA occurs through a network of streams, lakes, and canals. Four principal drainage basins and three smaller subcatchments are recognized within RMA and include the First Creek, Irondale Gulch, Sand Creek, and Second Creek drainage basins and the Basins A and F and Sand Creek Lateral subcatchments.

Streamflow at RMA is highly variable. Seasonal variations in stream discharge are generally greater than average year-to-year variations and are strongly affected by the amount of urban runoff, released or diverted flow, and direct precipitation. Streams at RMA are generally intermittent, and highest flows tend to occur during spring runoff and during major storms. Water levels in the lakes are less variable than stream discharge and are regulated. Peak storage volumes usually occur in spring or early summer.

Groundwater flow occurring within the alluvium and the uppermost weathered portion of the Denver Formation has been designated as the unconfined flow system (UFS). Deeper water-bearing units within the Denver Formation, which are designated as the confined flow system (CFS), are separated from the UFS by low-permeability confining units. Depending on site-specific hydrological characteristics, varying degrees of hydraulic interchange are possible between surface water and groundwater and between the UFS and CFS. In general, analytical and hydraulic data indicate little hydraulic interchange between the UFS and CFS.

The UFS includes saturated portions of the unconsolidated materials overlying the Denver Formation, the weathered upper portion of the Denver Formation, and, where the Denver Formation is missing near the South Platte River, the weathered upper portion of the Arapahoe Formation. The CFS includes the deeper portions of the Denver Formation and the underlying Arapahoe Formation. Water enters the UFS as infiltration of precipitation; seepage from lakes, reservoirs, streams, canals, and buried pipelines; flow from upgradient regional flow; and flow from the underlying CFS. Water is discharged from the UFS as seepage to lakes and streams, underflow to off-post areas north and west of RMA, and downward flow into the CFS. The UFS may gain or lose water at various locations and at different times of the year.

The CFS consists of strata within the Denver Formation collectively referred to as the Denver aquifer, where water residing in permeable sandstone or fractured lignite is confined above and below by relatively impermeable shale or claystone. Water enters the CFS primarily through regional updip flow and vertical flow from the overlying UFS. Water is discharged from the CFS by lateral flow into the UFS (where the strata are transmissive) or by leakage to the Arapahoe aquifer. The UFS is the principal migration route for groundwater contaminants at RMA. Some low-level contamination is present in isolated portions of the CFS, but the spread of contamination has been minimal due to the limited permeability and discontinuous nature of the water-bearing zones in the CFS. No contaminant migration pathway has been identified for the CFS and no production wells at RMA currently obtain water from the CFS.

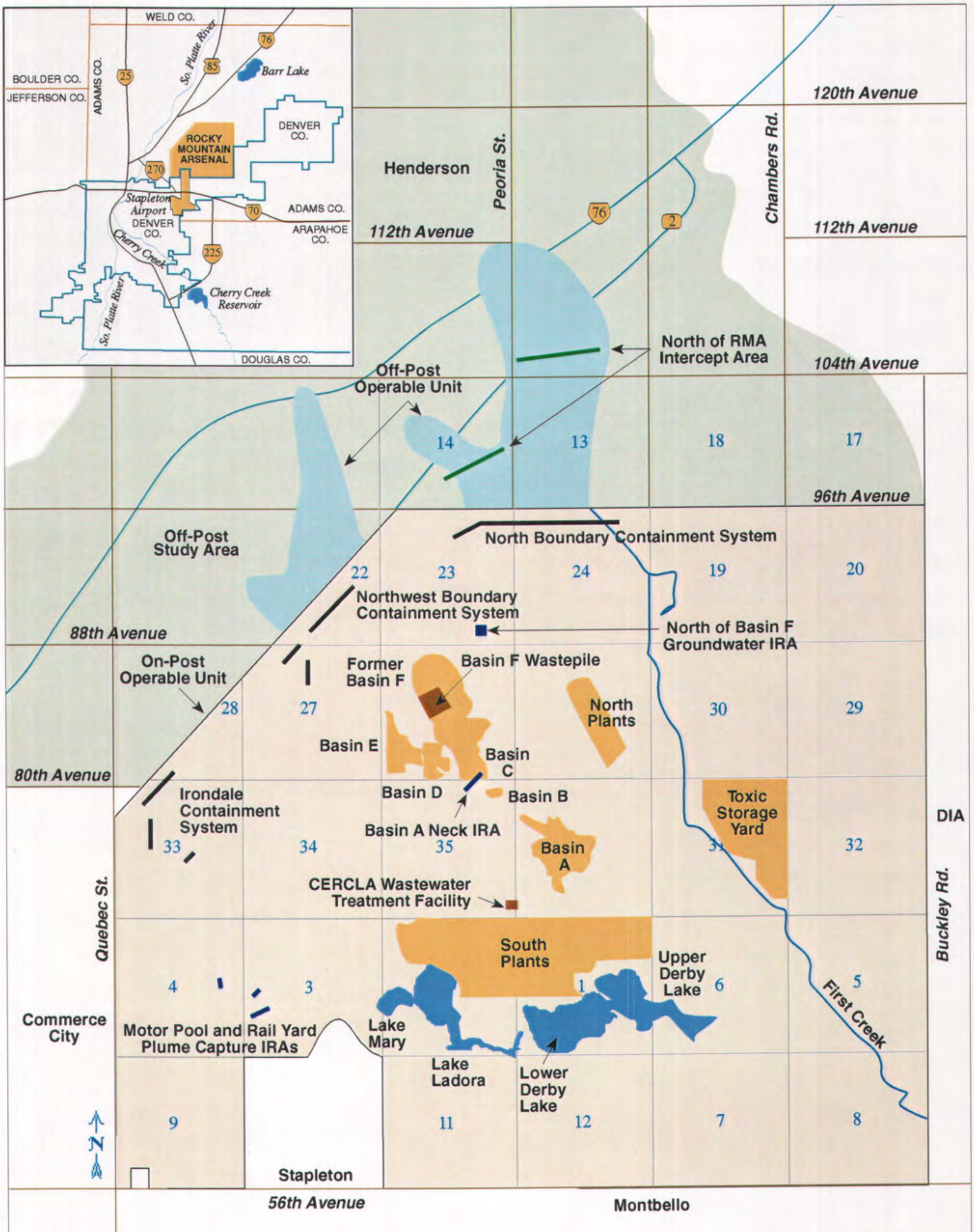
1.4 Biological Habitat

RMA is situated within a temperate grassland region and is part of a broad transition zone between mountain and plains habitats. Tall-grass species are common in moist areas and short-grass species prevail in dry areas. On-post human activity has resulted in vegetation dominated by weedy species and early successional colonists typical for the region. Currently, 88 percent of the RMA land surface is vegetated. Of this total, 41 percent supports early successional plant communities and 19 percent supports crested wheatgrass, which was used in the 1930s and 1940s to stabilize land susceptible to erosion. The remaining 28 percent supports shrubland, patches of yucca, riparian woodlands, cattail marshes and other wetland types, locust and wild plum thickets, upland groves of deciduous trees, and ornamental plantings. Each of these varied plant groups provides potential wildlife habitat.

Regional wildlife is dominated by species of prairie, steppe, and savanna communities. The wildlife species inhabiting RMA are those found in similar habitats off post. RMA supports populations of deer, hawks, and eagles, as well as numerous other mammals, birds, and other animals. In contrast to surrounding urban areas where these species are hunted or are sensitive to human presence, RMA provides a relatively less disturbed habitat that is attractive to wildlife. Its large acreage of diverse open habitats interspersed with lakes, small wooded areas, and a mixture of native grasses and tall weedy forbs, along with a lack of hunting pressure and disturbance, have contributed to an abundance of many wildlife species. The abundance and availability of prey species attracts avian and mammalian predators.

Twenty-six species of mammals have been observed at RMA, a number that includes all of the common mammals that inhabit the prairie grasslands of the Colorado Front Range. One hundred seventy-six species of birds have been observed at RMA, which is approximately 40 percent of all bird species recorded in the state of Colorado. The species richness of RMA birds is high relative to that of the region. At least two regionally rare or declining species (Cassin's sparrow and Brewer's sparrow) are relatively common breeding birds at RMA. Raptor population density and species diversity are comparable with those at other sites in the region. Winter raptor populations, particularly that of the bald eagle, are a primary attraction for the 20,000 to 30,000 visitors that come to RMA during this season.

Several species of reptiles and amphibians may be encountered in nearly every habitat type at RMA. Incidental observation has recorded 61 percent (or 17) of the 28 species of reptiles and amphibians that could potentially occur at RMA. The four lakes in the South Lakes area support aquatic communities, although aquatic insects appear to be largely absent.



Legend

20	Section (1 section = 640 acres or 1 square mile)

Not to scale

Figure 1.0-1
RMA Site Map

Rocky Mountain Arsenal
Prepared by Foster Wheeler Environmental Corporation

RMA ROD 6.96 jb

2.0 Site History and Enforcement Activities

2.1 Production and Operational History

RMA was established by an act of Congress 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 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. Prior to 1942, the area was largely undeveloped ranchland and farmland.

The first major products produced at RMA were mustard gas, lewisite, and chlorine gas. From 1942 to 1943, the Army manufactured Levinstein mustard in the South Plants. Lewisite was manufactured between April and November 1943. Mustard and lewisite-filled munitions, as well as bulk product in 55-gallon drums, were stored in "toxic storage yards" in Section 5, 6, and 31.

Incendiary munitions were produced at RMA during and after World War II. They included 100-lb M-47 bombs filled with napalm gel and 10-lb M-74 bomblets filled with an incendiary mixture composed of magnesium dust, sodium nitrate, and gasoline. These bomblets were assembled into 500-lb cluster bombs. Once filled, incendiary and cluster bombs were stored in open storage areas and bunkers in Sections 5, 6, 7, and 8. Stockpiles of 10-lb, 6-lb, and 4-lb bomblets were tested in a munitions facility in Section 36. During the Korean War conflict munitions filled with white phosphorus, artillery shells filled with distilled mustard, and incendiary cluster bombs were manufactured, and during the Vietnam conflict approximately 1.3 million white phosphorus grenades, 7.8 million button bombs, 12.2 million microgravel units, and 7 million experimental sandwich button bombs were manufactured at RMA.

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 twenty-two thousand 500-lb incendiary bombs. Between 1971 and 1973, 3,071 tons of obsolete mustard agent were destroyed.

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. GB was manufactured in the North Plants from 1953 to 1957, the major site for the free world's production of GB during this period. 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. Diisopropylmethyl phosphonate (DIMP) is a byproduct of GB manufacture.

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 is a plant pathogen commonly known as "wheat rust" that does not affect animals or humans. In 1972, stockpiled TX was incinerated and the ash disposed in Section 19.

The Hydrazine Blending and Storage Facility, located just east of the South Plants in Section 1, was owned by the U.S. Air Force and operated by the Army between 1961 and 1982. It was used to produce Aerozine 50, a rocket fuel primarily used in the Titan and Delta missile operations.

Portions of the South Plants manufacturing complex were leased to private industry following World War II, primarily for the production of pesticides. Nine companies conducted manufacturing or processing operations in South Plants between 1946 and 1982, when all Army manufacturing and processing operations in South Plants ceased. The two major lessees of facilities in South Plants were Julius Hyman and Company (Hyman) (1947–52) and Shell Chemical Company (1952–82). Colorado Fuel and Iron (CF&I) also manufactured chlorinated benzenes, chlorine, naphthalene, caustic, and dichlorodiphenyltrichloroethane (DDT) at South Plants between 1946 and 1948.

Hyman manufactured chlorinated pesticides including aldrin, dieldrin, and chlordane. The company also manufactured or brought to RMA feedstock chemicals used in manufacturing its commercial products. These included hexachlorocyclopentadiene (HCCPD), bicycloheptadiene (BCHPD), dicyclopentadiene (DCPD), cyclopentadiene, hydrogen peroxide, acetylene, and chlorine.

In 1942, the South 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 DCPD, crude BCHPD bottoms, isopropyl alcohol, sulfuric acid, D-D fumigant, and dibromochloropropane (DBCP) 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. Subsequent sampling under the **Remedial Investigation (RI)** Program (see Section 2.3) revealed the presence of benzene, toluene, xylene, DCPD, and BCHPD in groundwater in the area.

In 1952, Shell acquired the stock of Hyman, which continued as a lessor until 1954 when it was merged into Shell Chemical Company. Following the merger, Shell leased and constructed additional facilities in South Plants. From 1952 to 1982, 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 (DBCP), Nudrin, Phosdrin, Planavin, Pydrin, ravap, and Supona.

The process water system installed by the Army in 1942 circulated cooling waters from the South Lakes area of South Plants through South Plants and back to the lakes. In May 1951, an accidental discharge of caustic soda into the process water system at RMA occurred, resulting in a massive fish kill in Lake Ladora. Subsequently, samples of surface water, surface foam, green algae, and sediment from Lake Ladora and Lake Mary were found to contain concentrations of aldrin, dieldrin, Gardona, Bidrin, and heavy metals.

2.2 Waste Disposal Operations

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 decontaminants and the residue hauled to burning pits for incineration.

The burn pits or trenches were normally 8 to 10 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 was full, additional wood was placed on top of the materials, 300 to 500 gallons of fuel oil poured onto the heap, and the contents burned. Rejected lots of napalm or M-47 incendiary bombs were sometimes used as fuel for the fire. After burning, the metal was tested to determine whether it was free of contamination. If testing revealed the presence of contamination, 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.

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.

Beginning in 1942, most aqueous wastes from South Plants operations were treated with sodium hydroxide 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, where it ultimately discharged 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. The locations of these source areas are shown on Figure 1.0-1.

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

In a subsequent effort to consolidate aqueous wastes, and in response to complaints by nearby residents about contaminated groundwater, the Army constructed Basin F in late 1956. 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 1951, Shell disposed of approximately 1,000 cubic yards of materials resulting from the production of HCCPD. This tarry, chlorinated material was buried in thin-gauge caustic barrels and in bulk in an unlined pit in the South Plants Central Processing Area. Although potential migration pathways exist, groundwater data indicate that these wastes are immobile.

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 104 million gallons of treated effluent waste from Basin F were injected into the deep disposal well at rates of 100 to 300 gallons per minute (gpm). A total of 165 million gallons of waste were disposed using this method. Operations were suspended 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 well was properly plugged and abandoned on October 22, 1985.

2.3 Previous Investigations

Since the early 1950s potential contamination of the flora and fauna at RMA and various aspects of the ecology of these organisms have been studied. Initial studies were conducted in response to reports of wildlife mortality and agricultural damage. By the late 1950s, complaints of groundwater pollution north of RMA began to surface. In 1974, the Colorado Department of Health (now the Colorado Department of Public Health and Environment, or CDPHE) detected DIMP in a groundwater well north of RMA. Ecological investigations of broader scope were conducted in support of on-post contamination assessments and restoration planning programs that began in the

1970s, and it was during the mid-1970s that the first ecological surveys were conducted. Some of these studies had an RMA toxicological or ecological emphasis, while others were conducted at RMA in support of the proposed Stapleton International Airport expansion onto RMA property and county-wide wildlife habitat planning. More recent studies, initiated in the early 1980s, were performed in compliance with CERCLA and in support of active litigation involving the United States, the state of Colorado, and Shell.

In 1974, the Army established a Contamination Control Program at RMA designed to ensure compliance with federal environmental laws. Under the Contamination Control Program, a number of investigations were conducted by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) during the 1970s and early 1980s. The results of these investigations indicated that the contamination at RMA was concentrated mainly in the alluvial sediments and alluvial groundwater, with minor amounts of contamination in the Denver Formation. Based on this information and personal interviews, a contamination control strategy was developed for RMA that was designed to be consistent with pertinent state and federal statutes. In 1984, USATHAMA, under a separate division created specifically to deal with the contamination at RMA, i.e., Program Manager for Rocky Mountain Arsenal (PMRMA), initiated a series of investigations required under CERCLA, the RI/Feasibility Study (FS) and the Endangerment Assessment. A flow diagram of activities that have been and are currently being conducted under these programs is presented in Figure 2.3-1.

Six of the more recently conducted studies have direct relevance to the selection of the preferred remedial alternatives. These include the following:

- Human Health Exposure Assessment for Rocky Mountain Arsenal (Ebasco 1990)
- Remedial Investigation Summary Report (Ebasco 1992a)
- Development and Screening of Alternatives Report (Ebasco 1992b)
- Human Health Exposure Assessment Addendum for Rocky Mountain Arsenal (Ebasco 1992c)
- Integrated Endangerment Assessment/Risk Characterization Report (Ebasco 1994)
- Detailed Analysis of Alternatives Report (Foster Wheeler Environmental 1995a)

The general time frame under which major RMA documents were completed is presented in Table 2.3-1. These and other comprehensive documents regarding the remediation of RMA have been made available for public review at the Joint Administrative Record Document Facility (JARDF), which is located at the west entrance to RMA at 72nd Avenue and Quebec Street, and at eight area libraries (see Section 3).

2.4 Past and Ongoing Response Actions

Since 1975, the Army and Shell have undertaken numerous efforts to protect on- and off-post human health and the environment by implementing early remedial actions and IRAs to begin the remedial actions at the most highly contaminated sites. IRAs were undertaken at RMA in advance of the ROD to stop the spread of or eliminate contamination and to begin the actual remediation. A site investigation and alternative assessment was performed for each IRA. All IRAs that require the removal of material are carried out in accordance with applicable laws and regulations and are consistent with and contribute to the efficient performance of the preferred alternatives for the On-Post and Off-Post Operable Units.

Fourteen IRAs have been completed by the Army and Shell or will be incorporated into the final remedy as follows:

- Groundwater Intercept and Treatment North of RMA – This IRA was undertaken to address groundwater contamination that had migrated off post prior to installation of the boundary extraction and treatment systems on post. A groundwater extraction and treatment system is now in place north of RMA for treatment of DIMP, solvents, and pesticides. The IRA includes one extraction and reinjection system located along Highway 2 between 96th Avenue and 104th Avenue and another near 108th Avenue and Peoria. The extracted water is treated by **granular activated carbon (GAC)** to Containment System Remediation Goals (CSRGs) for **organics** at a treatment plant located on Peoria and reinjected into the aquifer. Construction of this IRA was completed in 1993; treatment of groundwater at the north boundary is ongoing.

- Improvement of North Boundary Containment and Treatment System and Evaluation of Existing Boundary Systems – The NBCS was originally designed to remove and treat contaminated water reaching the north boundary. Groundwater is extracted, treated by GAC, and reinjected into the ground. The primary contaminants at this location are chloroform, dieldrin, DIMP, DCPD, and organosulfur compounds. The original system consisted of extraction wells, a 6,740-ft slurry wall, a recharge sump, filters to remove particles from water, three large (20,000 lb) carbon adsorbers to treat organic contaminants to CSRGs from groundwater, and reinjection wells. Groundwater is treated at a rate of 220 to 300 gpm. Operational improvements were implemented as part of the IRA and the reinjection system for treated water was improved by addition of recharge trenches along the entire portion of the extraction well system and the slurry wall. Construction of the improvements to the NBCS was completed in 1993; treatment of groundwater is ongoing.

  The NWBCS was designed to remove and treat contaminated groundwater migrating toward the northwest boundary. The original system included an extraction system, GAC treatment, and a reinjection system as well as a slurry wall to control contaminant migration. The system has been improved under two different IRAs, the Short-Term Improvements and the Long-Term Improvements IRAs. The slurry wall, which originally measured 1,425 ft, was extended by 665 ft under the Short-Term Improvements IRA. Five extraction wells were added to the original 15 extraction wells, and the number of reinjection wells was increased from 21 to 25. The IRA modifications increased the amount of water treated in the NWBCS from approximately 900,000 to 1.4 million gallons per day. The Long-Term Improvements IRA involved the addition of seven monitoring wells, one extraction well, and an expansion of the monitoring program for the system. Groundwater is treated to CSRGs for organic contaminants. Construction of the improvements to the NWBCS was completed in 1993.

  The ICS was designed to remove and treat contaminated groundwater migrating toward the western boundary. The original system included two parallel rows of extraction wells, one row of reinjection (recharge) wells, and GAC treatment. This system was designed to treat a DBCP plume migrating from the Rail Yard. The system was improved during the IRA by installing four extraction wells approximately 2,000 ft upstream from the original system, adding nine new recharge wells adjacent to the original system, and converting three of the original extraction wells to recharge wells. Groundwater is treated to CSRGs for organic contaminants. Construction of the improvements was completed in 1991.

- Groundwater Intercept and Treatment North of Basin F – The purpose of the Basin F Groundwater IRA was to intercept and remove contaminated groundwater migrating from the Basin F area toward the northern boundary. The IRA involves extraction, treatment to CSRGs, and reinjection of groundwater. Water is extracted from a well north of Basin F at a rate of 1 to 4 gpm (approximately 1 million gallons per year). The extracted water is piped to a treatment system located at Basin A Neck for removal of volatile contaminants (solvents) by air stripping, and the remaining contaminants, such as pesticides, by GAC. Treated water is reinjected in recharge trenches at the Basin A Neck area. Construction of this IRA was completed in 1990; treatment of groundwater is ongoing.

- Closure of Abandoned Wells – At numerous locations throughout RMA, old or deteriorating farm wells and unused on-post wells have been located and cemented closed. This IRA was completed in 1990.
- Groundwater Intercept and Treatment System in the Basin A Neck Area – The Basin A Neck IRA was designed to capture and contain contaminated groundwater migrating from the Basin A area. The IRA consists of extraction wells for removal of groundwater from the aquifer, a slurry wall to minimize migration of contaminated groundwater, a treatment system, and a reinjection system consisting of several recharge trenches. Approximately 12 to 20 gpm (5 to 10 million gallons per year) of groundwater are extracted and treated to CSRGs by GAC at the Basin A Neck IRA treatment system. The contaminants removed from water include solvents and pesticides. Construction of the Basin A Neck system was completed in 1990; treatment of groundwater is ongoing.
- Basin F Liquids, Sludges, and Soil Remediation – This IRA has included transfer of the basin liquids and decontamination water into temporary storage tanks and a lined, covered surface impoundment (Pond A); construction of a 16-acre lined waste storage pile with a leachate collection system; excavation of 600,000 cubic yards of Basin F soil and placement into the wastepile; and incineration of the stored liquids by Submerged Quench Incineration (SQI). This IRA was completed in two phases. The first phase, which involved the containment of the sludges/soil, was completed in 1989. The SQI system, which became operational in May 1993, was shut down in July 1995 following the completion of the treatment of approximately 11 million gallons of waste liquids. The SQI, storage tanks, and pond were closed in accordance with a CDPHE closure plan. The tank farm and pond areas were clean closed to specific closure performance standards for contaminants in the Basin F liquid. The SQI was demolished, and some of the process equipment was salvaged. All field and administrative closure activities were completed by May 30, 1996.
- Building 1727 Sump Liquid – Liquid in the Building 1727 sump was treated by activated alumina and GAC to remove contaminants that included arsenic and DIMP. This IRA eliminated any remaining threat of liquid release from the sump; it was completed in 1989.
- Closure of the Hydrazine Facility – This facility was used as a depot to receive, blend, store, and distribute hydrazine fuels. Wastewater stored at the facility was treated on post at the SQI facility, the structures demolished, and the debris removed. Uncontaminated materials at the site were salvaged for recycling and reuse, and contaminated materials were disposed at an off-post permitted hazardous waste landfill. The area encompassing the former facility was regraded and revegetated following demolition and debris removal. This IRA was completed in 1992.
- Fugitive Dust Control – In 1991, the Army completed the reapplication of a dust suppressant (Dusdown 70) in Basin A as part of this IRA. Hydro-seeder trucks were used to spray a nontoxic, water-based dust suppressant.
- Sewer Remediation – As part of this IRA, sanitary sewer manholes were plugged to eliminate the transport of contaminated groundwater that may have entered the sewer system via cracks or loose connections. This IRA was completed in 1992.
- Asbestos Removal – This IRA is part of the Army's ongoing survey of asbestos on post, including removal and disposal activities. The survey and removal of friable asbestos from occupied buildings were completed in December 1989. The Asbestos IRA activities continue as part of the final structures remediation.
- Remediation of Other Contamination Sources – Under this IRA, the following contamination sources have or are being minimized or eliminated:
  - Motor Pool – A groundwater extraction system was constructed to remove trichloroethylene (TCE) in groundwater in the Motor Pool area. Because the low levels of TCE present in this water can be

effectively treated by GAC, the water is piped to the ICS for treatment. The amount of water extracted from the Motor Pool area is approximately 100 gpm. A soil vapor extraction (SVE) system was also constructed to draw vapors containing volatile contaminants from the soil. Extracted vapors are sent first to a separation tank to remove the water vapor and then to a treatment system where the volatile contaminants are treated. Soil vapor extraction was conducted at the Motor Pool area between July and December 1991 to remediate TCE-contaminated soil. Two vapor extraction wells as well as four clusters of soil gas monitoring wells were installed. The Motor Pool groundwater extraction system is currently operational.

- Rail Yard – This IRA was conducted to assess a potential DBCP problem in this area and introduce cleanup measures if necessary. It was decided that groundwater removal would be necessary, but that adequate treatment could be provided at the ICS at the western boundary of RMA. The Rail Yard IRA extraction system consists of a row of five wells that extract approximately 230 gpm of groundwater containing low levels of DBCP. The water is piped to the ICS where DBCP is removed by GAC. Two additional wells further downgradient act as a backup system. Treatment is currently ongoing.
- Lime Settling Basins – Workers constructed a soil cover over the Lime Settling Basins area to isolate the basins from the ground surface and minimize the amount of rainwater seeping into the basins. The construction of the cover was completed in 1993.
- South Tank Farm Plume – The South Tank Farm consists of 11 tanks used for storage of alcohol, BCHPD bottoms, DCPD, D-D soil fumigant, and sulfuric acid. Records indicate benzene was also used or stored in this area. The South Tank Farm Plume, located between South Plants and the South Lakes area, consists of two separate groundwater plumes extending toward the lakes, one of which consists of light nonaqueous phase liquids (LNAPLs). The IRA alternative consisted of continued groundwater monitoring to verify that no additional action was necessary due to the natural degradation of the contaminants. Alternative assessment activities were completed in 1994.

  In 1991, an SVE field demonstration, which included collection and analysis of soil, LNAPL, SVE offgas, and soil gas samples, was designed for specific application to the South Tank Farm Plume. The resulting data were used to evaluate the performance, effectiveness, and operating parameters for an SVE system in the area of the plume. Based on the results of the demonstration, it would take more than 10 years for the SVE process to remove the majority of the mass of contaminants that would remain after LNAPL recovery was no longer feasible.
- Army Trenches – Soil samples collected from representative trenches showed elevated concentrations of ICP metals and relatively low concentrations of arsenic, mercury, and many organic contaminants, including members of all the analyte groups except pesticide-related organophosphorous compounds and organonitrogen compounds. A large variety of tentatively identified compounds were also detected in the trench soil. High concentrations of some organic contaminants exist in groundwater in portions of this area. The IRA alternative consisted of continued groundwater monitoring in this area. Alternative assessment activities were completed in 1994.
- Shell Trenches – Under this IRA, the trenches were covered with a soil cover and revegetated. A slurry wall that surrounds the trench area was constructed to reduce the lateral movement of contaminants away from the trenches. Construction of this IRA was completed in 1991.

• CERCLA Hazardous Wastes – The initial action was pretreatment of CERCLA liquid wastes. This IRA was later expanded to include identification, storage, and disposal of a variety of CERCLA wastes. The initial action and expanded elements are as follows:

  - Wastewater Treatment Plant – A wastewater treatment plant was constructed by 1992 under the first phase of the CERCLA Liquid Waste IRA. This facility is currently used to treat wastewater generated from laboratory operations, field sampling, decontamination, and other sources such as equipment washing. Several treatment technologies are used at the CERCLA Wastewater Treatment Plant including activated GAC, advanced oxidation using ultraviolet light, air stripping, chemical precipitation, and activated alumina adsorption. It is expected that this facility will be used to treat similar wastewater streams during remediation.

- Waste Management – This element identified both off- and on-post landfilling as options to dispose hazardous waste that has been or will be placed in storage areas at RMA and that has not been addressed in another IRA. Waste streams currently being managed include RI/FS wastes; IRA wastes; miscellaneous wastes from vehicles, grounds, and building maintenance; and items found on post.
- Polychlorinated Biphenyls (PCBs) – The purpose of this element was to inventory and sample PCB-contaminated equipment followed by remediation off post. This IRA included characterization of spill sites (i.e., soil and structures) associated with PCB contamination and is ongoing. PCB contamination not addressed in this IRA will be addressed as part of the final remedy.
- Waste Storage – This element included analysis of an on-post facility for temporary management of solids that are bulk hazardous wastes. These wastes primarily consist of contaminated soil and building debris. Analysis resulted in the decision to dispose wastes in the on-post **hazardous waste landfill** when it becomes available.

• Chemical Process-Related Activities – Agent-related and nonagent-related process equipment and piping located in North Plants and South Plants is being sampled, decontaminated, and **dismantled** under this IRA. Although much of the equipment in these areas has already been removed and recycled, process-related equipment not remediated as part of this IRA will be disposed in the new on-post hazardous waste landfill. Asbestos-removal activities as required for equipment removal will continue as part of the final response action at RMA.

A summary of the actions undertaken in each IRA, including the status of the IRA, is presented in Table 2.4-1, and the locations at which the actions were taken are presented in Figure 2.4-1. The procedure for IRA implementation is set forth in Section XXII of the FFA. The typical IRA process that applies to most RMA IRAs is outlined in Figure 2.4-2. For a variety of technical reasons, a slightly different process was used for the following IRAs: Improvements of the North Boundary Containment System and Evaluation of all Existing Boundary Containment Systems; Closure of Abandoned Wells; Basin F Liquids, Sludges, and Soil Remediation; and Fugitive Dust Control (PMRMA 1988). The environmental media potentially affected by the implementation of the various IRAs are listed in Table 2.4-2. Reports generated for these IRAs (Technical Plans, Alternatives Assessment Reports, Decision Documents, Implementation Documents, and Operational Reports) can be accessed through the JARDF.

In addition, two other response actions were undertaken at RMA: waste disposal operations at the deep injection well and the construction of the Klein treatment plant. The deep injection well was drilled 12,045 ft deep into Precambrian rocks beneath Basin F as a solution to RMA's chemical waste disposal problem. As described in Section 2.2, 165 million gallons of waste were disposed in this well, but operations were suspended and the well plugged when it was suspected that the injection of the wastes was causing an unusual series of earthquakes. The Klein treatment plant (located in Section 33) was constructed in the mid-1980s to treat off-post groundwater to the west of RMA that was primarily contaminated by chlorinated solvents. (It was subsequently determined that this contamination originated primarily from non-RMA sources.)

2.5 History of Enforcement Activities

2.5.1 CERCLA Enforcement Activities

On December 6, 1982, the EPA, Army, Shell, and Colorado Department of Health (now CDPHE) entered into a Memorandum of Agreement outlining joint participation in the Army's study of decontamination at RMA. Although the Parties followed the process outlined in the Memorandum of Agreement until 1986, they also pursued litigation with respect to issues relating to legal authority over RMA remediation efforts, payment of natural resource damages (NRDs), and reimbursement of costs expended for cleanup activities (response costs).

United States v. Shell Oil Company, Civil Action No. 83-C-2379

On December 9, 1983, the United States filed this action in federal court to recover NRDs caused by the release of Shell's contaminants at RMA and to recover from Shell a portion of the costs expended by the United States for RMA cleanup efforts.

This case was consolidated with the state's case against the United States and Shell (discussed below) by the Court on March 26, 1985. On November 15, 1985, the Court ruled that the United States and Shell were liable parties at RMA, subject to certain defenses. The Parties filed a joint stipulation setting forth the factual bases for the United States' and Shell's liability on November 18, 1985.

On February 1, 1988, the United States and Shell lodged a proposed consent decree with the Court to resolve the litigation between those two parties. The proposed consent decree set forth the process to be utilized to select and implement cleanup decisions for RMA, subject to public comments. The United States and Shell moved for entry of a modified consent decree on June 7, 1988, following the receipt of public comments. This version of the modified consent decree was never entered by the Court.

In February 1989, the Army and Shell, along with EPA, USFWS, ATSDR, and U.S. Department of Justice, executed the FFA, an interagency agreement and administrative order on consent that embodied the terms of the modified consent decree. The state did not agree with parts of the FFA and did not become a signatory. The state has remained actively involved in RMA remediation efforts and participated in informal dispute under the FFA. The United States and Shell also executed a Settlement Agreement that set out a process to deal with financial issues between them, such as the allocation and payment of response costs or NRDs.

Under the Settlement Agreement, the United States and Shell share "allocable costs" relating to RMA remediation to different degrees based on the cumulative total of those costs. Allocable costs are defined in the Settlement Agreement. For the first $500 million of allocable costs, the United States and Shell are equally responsible. For the next $200 million, the United States is responsible for 65 percent of allocable costs and Shell is responsible for 35 percent of those costs. For allocable costs over $700 million, the United States is responsible for 80 percent of allocable costs and Shell is responsible for 20 percent of those costs. The United States and Shell are also separately responsible for all costs with respect to Army-only or Shell-only response actions, respectively, which are described in exhibits to the Settlement Agreement. This case was resolved by entry of a modified proposed consent decree on February 12, 1993.

EPA, Army, Department of Interior, and Shell have established a process for resolving disputes that arise at RMA concerning CERCLA cleanup actions. This dispute resolution process is set forth in the FFA (EPA et al. 1989). The state of Colorado became a party to the FFA dispute resolution process on June 13, 1995, when it signed, along with the above entities, the Agreement for a Conceptual Remedy for the Cleanup of the Rocky Mountain Arsenal (Conceptual Remedy). The only provisions of the FFA that shall be binding upon the state are those relating to dispute resolution.

The state declares its intention to utilize the FFA dispute-resolution process in a good-faith effort to resolve all issues informally. For any issues not subject to dispute resolution under the FFA, and for those issues over which the state has independent authority pursuant to United States v. State of Colorado and the Colorado Department of Health, Civil Action No. 89-C-1646, 990 F. 2d 1565 (10th Cir. 1993), cert. denied 114 S. Ct. 922 (1994), the state reserves any rights and authorities it may have.

State of Colorado v. United States and Shell Oil Company, Civil Action No. 83-C-2386

On December 9, 1983, the state of Colorado filed an action in federal court seeking NRDs from the Army and Shell under CERCLA for injury to the state's natural resources. On November 25, 1985, the state added a claim against the Army and Shell for response costs the state had expended at RMA pursuant to CERCLA.

On March 14, 1989, pursuant to a partial settlement of the state's response cost claim, the Army and Shell each agreed to pay the state $1 million to cover state costs at RMA through December 31, 1988.

The state then requested reimbursement for costs it had incurred from January 1, 1989 to June 30, 1992. The Court ruled on several legal issues relating to these response costs on November 17, 1994. (State of Colorado v. United States and Shell Oil Company, 867 F. Supp. 948 [D. Colo. 1994].) The Court found that the state's costs expended to enforce its hazardous waste laws could be reimbursed to the state under CERCLA if the cost met the CERCLA definition of response costs. The Court also held that the Army and Shell were responsible for interest from the date response costs were incurred because the state had previously demanded payment. The Court also held that the Army and Shell were responsible for interest on response costs incurred after February 7, 1989, the date that the state made a specific dollar amount demand for response costs, at the time these costs were incurred. Interest for response costs incurred before February 7, 1989 was held to begin to accrue on February 7, 1989.

On January 31, 1995, the Parties entered into a partial settlement under which the Army and Shell paid the state $4.8 million for response costs from January 1, 1989 through June 30, 1992.

On February 9, 1995, the Court placed the NRD portion of the state's case against the United States and Shell on administrative closure pending remedial selection. However, the portion of this litigation with respect to subsequent response costs remains open. In September 1995, the state made a demand for payment of response costs to the Army and Shell for the period of July 1, 1992 to June 30, 1994.

2.5.2 State Enforcement Activities

State of Colorado v. Department of the Army, Civil Action No. 86-C-2524

In 1974, the Colorado Department of Health (now CDPHE) detected DIMP and DCPD in the groundwater aquifer north of RMA. On April 7, 1975, CDPHE issued three administrative orders to the Army and/or Shell with respect to this contamination. These orders cited violations of the Colorado Water Quality Control Act and directed Shell and/or the Army to immediately stop the off-post discharge of DIMP and DCPD in surface and subsurface water.

On October 1, 1986, CDPHE issued a final modified closure plan for Basin F pursuant to the Colorado Hazardous Waste Management Act (CHWMA) and its implementing regulations. CHWMA is the state-delegated RCRA program. The closure plan became effective on October 2, 1986. On November 14, 1986, the state filed an action against the Army in state court. On December 15, 1986, the case was removed to the U. S. District Court for Colorado. The state's original complaint alleged violations of the CHWMA groundwater monitoring regulations.

On October 14, 1987, the Army notified CDPHE, based on EPA' s listing of RMA (excluding Basin F) and the proposed listing of Basin F on the NPL on July 22, 1987, Basin F and the RMA were no longer subject to CHWMA jurisdiction. The Army stated its intent to implement a cleanup for Basin F pursuant to its authority under CERCLA.

On December 4, 1987, the state was granted leave to amend its complaint to add claims alleging a failure to close Basin F in accordance with the closure plan issued under CHWMA and alleging the Army's failure to pay fees due under CHWMA.

On February 24, 1989, the Court, in a memorandum opinion denying the United States' motion to dismiss the state's complaint, stated that CERCLA was intended to operate independently of and in addition to RCRA and held that CHWMA enforcement was not precluded by CERCLA in the circumstances then presented (State of Colorado v. Department of the Army, 707 F. Supp. 1562, 1569-70 [D. Colo. 1989]). The Court further ruled that the state's CHWMA regulations pertaining to groundwater monitoring and closure of hazardous waste units were within the waiver of federal sovereign immunity in Resource Conservation and Recovery Act (RCRA). Based, in part, on

EPA's subsequent listing of Basin F on the NPL, the United States filed a motion for reconsideration of the Court's February 24th order on March 6, 1989. The Court did not rule on this motion. The remaining aspects of the case were dismissed without prejudice on September 4, 1991 as a result of subsequent developments in other RMA cases.

United States v. State of Colorado and the Colorado Department of Health, Civil Action No. 89-C-1646

Following inspections of the Basin F site in May and June of 1989, CDPHE issued a compliance order against the Army, citing 42 violations of CHWMA and its implementing regulations regarding hazardous waste management. The compliance order was amended twice. A final amended compliance order was issued on September 1, 1989, with a stated effective date of September 22, 1989.

On September 22, 1989, the United States filed suit in federal court, United States v. State of Colorado and the Colorado Department of Health, Civil Action No. 89-C-1646, seeking a judgment that CDPHE had no authority to enforce the final amended compliance order and that the United States was not liable for civil penalties under RCRA or CHWMA.

On August 14, 1991, the Court ruled in the United States' favor and enjoined the state from taking any action to enforce the final amended compliance order or to impose civil penalties against the United States. The state appealed this ruling in regards to its enforcement authority to the Tenth Circuit Court of Appeals on October 11, 1991.

On April 6, 1993, the Tenth Circuit ruled that RMA is a facility subject to interim status requirements pursuant to CHWMA and its implementing regulations and that the state has the authority to enforce its federally-delegated hazardous waste program at RMA.

On June 30, 1993, the Tenth Circuit issued an amended opinion and denied the United States' petition for rehearing. (United States v. State of Colorado and the Colorado Department of Health, 990 F. 2d 1565 [10th Cir. 1993].) The amended opinion acknowledges that "final disposition of the solids remaining under the Basin F cap and in the wastepile will be determined as part of the remedial action for which a final record of decision will be issued." The opinion also reiterates that the state has authority to enforce CHWMA at RMA by holding that "the Army is obligated to comply with RCRA/CHWMA regulations applicable to interim status facilities pending closure of Basin F pursuant to an approved closure plan" (Id. at 1512 n. 11, 1582 n. 22). On July 8, 1993, the mandate was issued for the Tenth Circuit decision and the case was remanded to the District court.

On November 17, 1993, the United States petitioned the Supreme Court of the United States to review the decision of the Tenth Circuit. The Supreme Court denied the United States' petition on January 24, 1994 (114 S. Ct. 922 [1994]).

On June 30, 1994, the United States and the state of Colorado entered into a consent decree resolving remaining litigation issues. The consent decree required the Army to submit closure plans for Basin F and the Basin F Wastepile for CDPHE approval.

United States v. Colorado Water Quality Control Commission, Civil Action No. 94-C-491

On December 27, 1993, the Colorado Water Quality Control Commission, after a public hearing, issued a Notice of Final Adoption, setting a groundwater standard for DIMP at 8 parts per billion (ppb). The United States filed a lawsuit in federal court on March 2, 1994 challenging the state's DIMP standard. On May 5, 1995, the Court granted the state's motion to dismiss the complaint. The Court relied on the abstention doctrine, under which federal courts decline to review matters concerning state agency action where such review would interfere with state programs pertaining to matters of local concern. On May 18, 1995, the United States filed a motion for amendment and reconsideration of the May 5th decision. The Court has not ruled on this motion.

2.5.3 Conceptual Remedy

As required by CERCLA, and in accordance with the FFA, the Army's selection of a preferred alternative was based on the RI, the Exposure Assessment and Integrated Endangerment Assessment/Risk Characterization, FS, and other scientific and technical information. As part of the remedial process, the Parties engaged in an extensive series of meetings over a 6-month period regarding the remediation of RMA. Interested citizens and representatives of city and county agencies, collectively called the Stakeholders, also participated in discussions about potential remedial approaches. These stakeholder meetings, along with information obtained in the previously described process, provided the basis for negotiations among the Parties that culminated in the Conceptual Remedy, which was signed by the Parties on June 13, 1995. The Detailed Analysis of Alternatives report incorporates the elements of the Conceptual Remedy and became the basis for the Proposed Plan for the Rocky Mountain Arsenal On-Post Operable Unit (Foster Wheeler Environmental 1995b). The Proposed Plan was submitted for public comment on October 16, 1995, and was the subject of a public meeting on November 18, 1995.

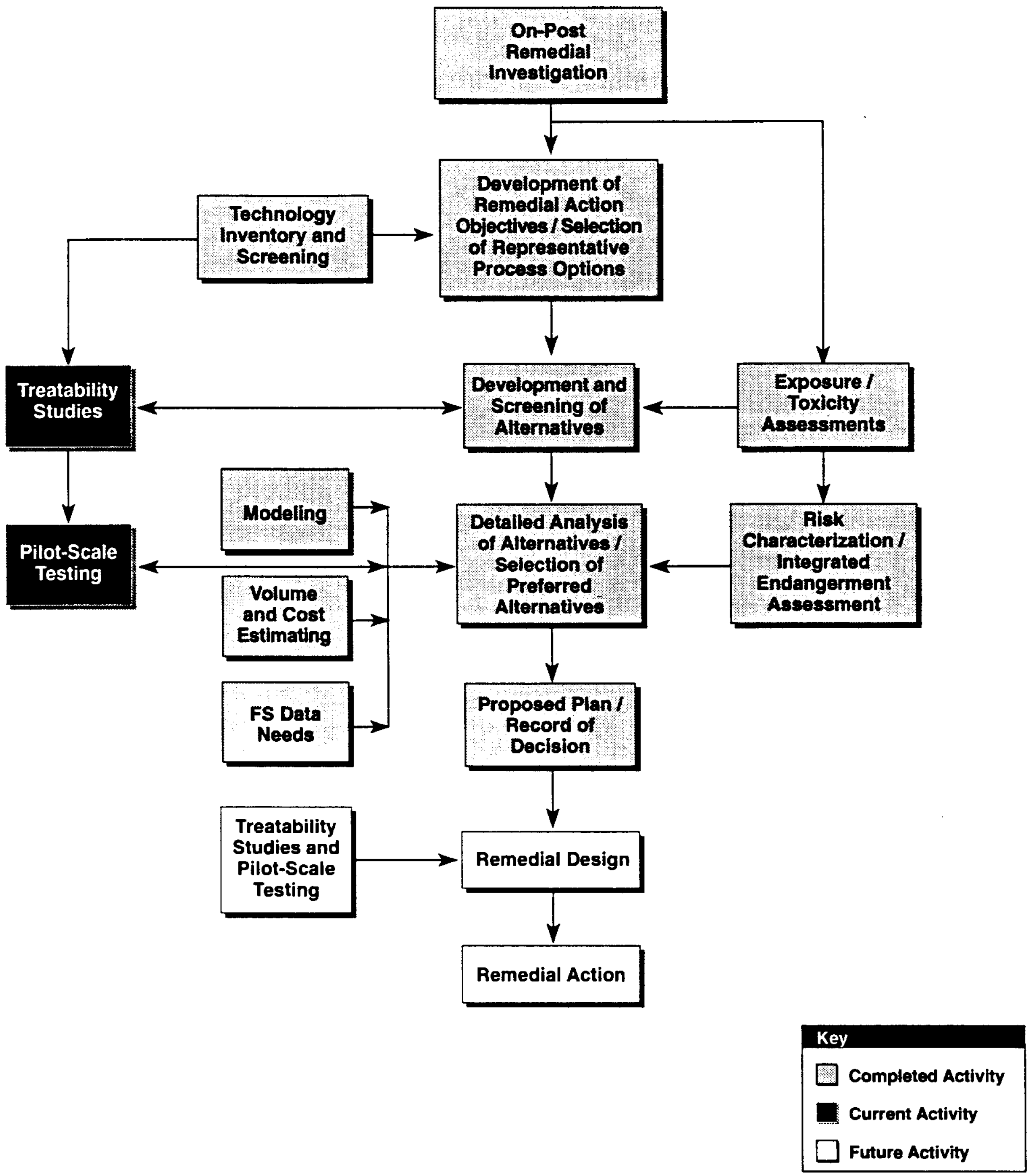
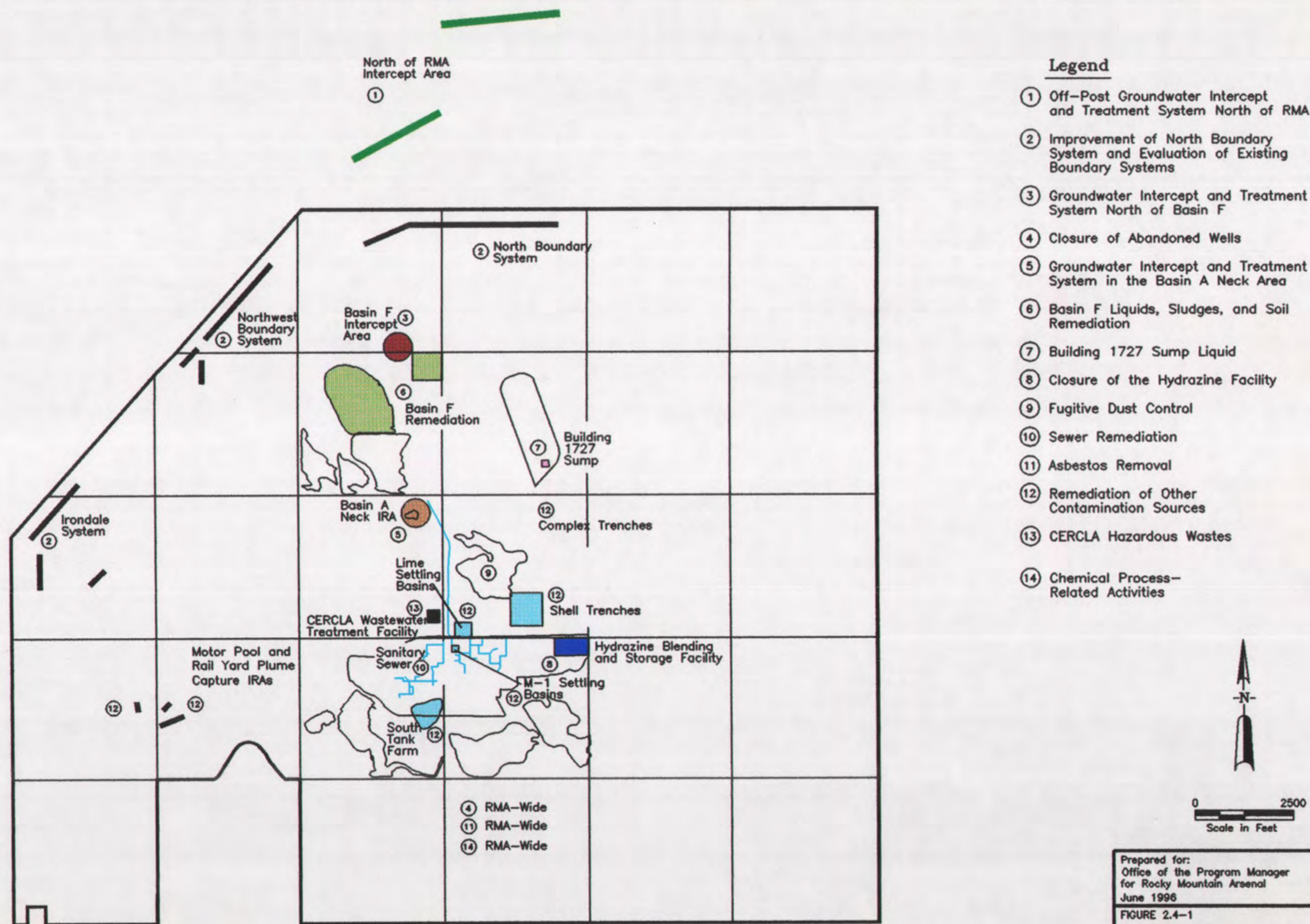


Figure 2.3-1

Remedial Investigation / Endangerment Assessment / Feasibility Study Flow Diagram

Rocky Mountain Arsenal
Prepared by Foster Wheeler Environmental Corporation



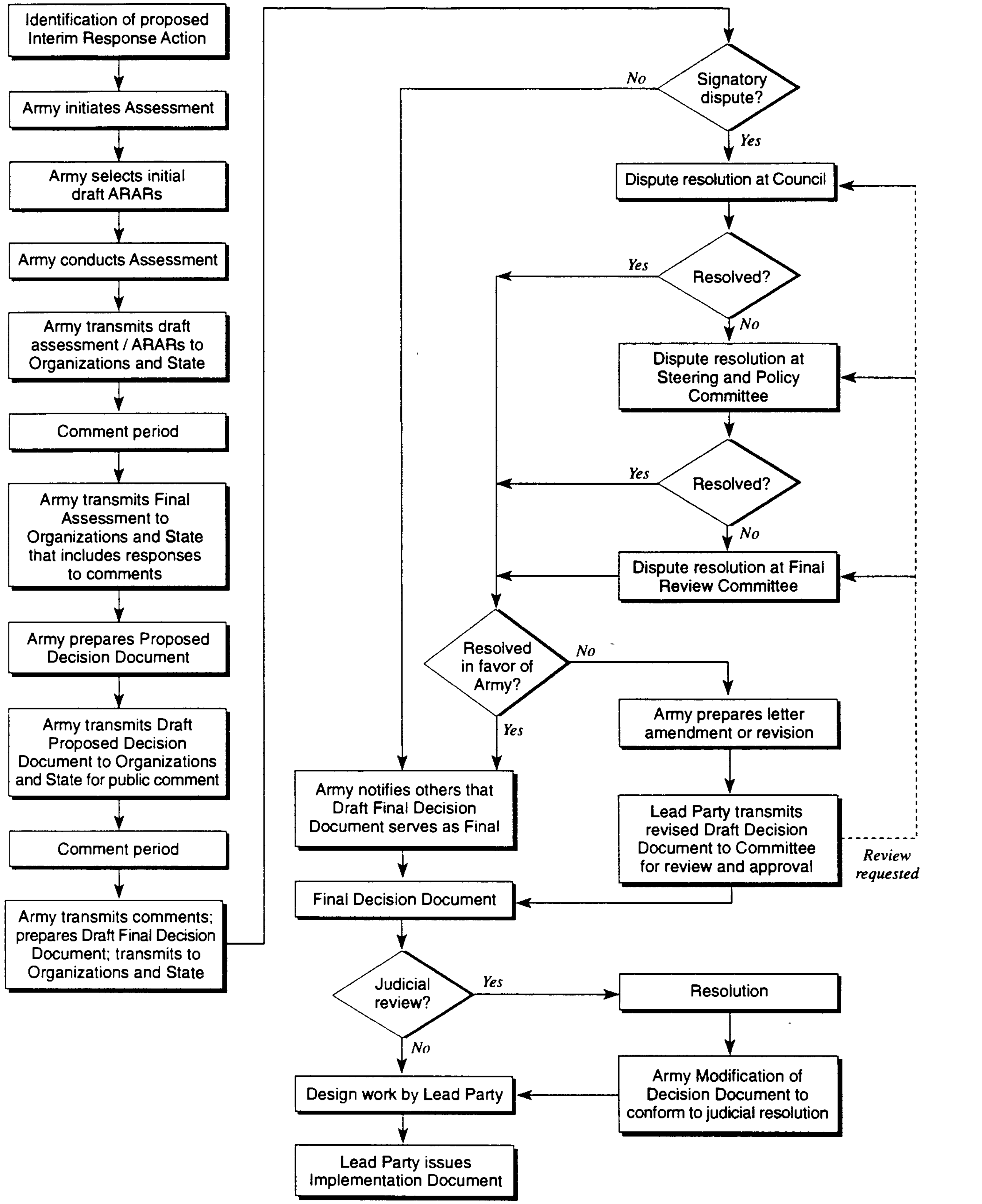
Prepared for:
Office of the Program Manager
for Rocky Mountain Arsenal
June 1996

FIGURE 2.4-1

RMA Interim Response Action Locations

Prepared by:
Foster Wheeler Environmental Corporation

Checked by SA | Drawn by TH/JLS | Date 6/06/96 | File Name: F:\PROJECTS\RMA\F2_4-1.DWG



Source: PMRMA (1988)

Figure 2.4-2

Typical RMA Interim Response Action Process

Rocky Mountain Arsenal
Prepared by Foster Wheeler Environmental Corporation

Table 2.3-1 Inception and Completion Dates for Major RMA Documents

Document	Start Date	Finish Date[1]
Remedial Investigation	October 1984	January 1992
Human Health Exposure Assessment	October 1986	September 1990
Human Health Exposure Assessment Addendum	August 1990	December 1992
Integrated Endangerment Assessment/Risk Characterization		
Human Health Risk Characterization	May 1990	September 1992
Ecological Risk Characterization	October 1987	July 1994
Development and Screening of Alternatives	February 1989	December 1992
Detailed Analysis of Alternatives	January 1993	October 1995
Proposed Plan	July 1995	October 1995

1 Finish date indicates the date the final version of the document was submitted to the administrative record for public review.

Table 2.4-1 Summary of Past and Ongoing Response Actions

Response Action	Objective	Status/Completion[1]
Interim Response Actions		
1. Groundwater Intercept and Treatment System North of RMA	Capture and treat contaminated groundwater plumes north of RMA.	Construction completed 1993; treatment is ongoing.
2. Improvement of the North Boundary Containment and Treatment System and Evaluation of Existing Boundary Systems	Evaluate and improve, as necessary, the operation of the boundary containment and treatment systems.	Construction completed 1993; treatment is ongoing.
3. Groundwater Intercept and Treatment System North of Basin F	Capture and treat contaminated groundwater north of the Basin F area closer to its source.	Construction completed 1990; treatment is ongoing.
4. Closure of Abandoned Wells	Identify, locate, examine, and properly close old or unused wells at RMA to prevent vertical migration of contamination between aquifers.	Completed 1990.
5. Groundwater Intercept and Treatment System in the Basin A Neck Area	Capture and treat shallow contaminated groundwater from Basin A closer to the source area.	Construction completed 1990; treatment is ongoing.
6. Basin F Liquids, Sludges, and Soil Remediation	Construct wastepile and cap that minimize the potential for infiltration of contaminants to groundwater and the potential for volatile emissions; reduce the potential impact of Basin F on wildlife; and incinerate Basin F liquids.	Containment of sludges/soil completed in 1989; incineration of liquids completed 1995.
7. Building 1727 Sump Liquid	Treat contaminated liquid in the sump.	Completed 1989.
8. Closure of the Hydrazine Facility	Treat the wastewater stored at this facility and demolish the aboveground structures.	Completed 1992.
9. Fugitive Dust Control	Minimize the amount of windblown contaminated dust.	Application completed 1991; reapplication as required by final response action.
10. Sewer Remediation	Plug the RMA sanitary sewers so that they cannot transport contaminated groundwater.	Completed 1992.
11. Asbestos Removal	Remove and dispose of friable asbestos in RMA structures where any potential for human exposure exists.	Action is ongoing as part of ROD implementation.
12. Remediation of Other Contamination Sources • Motor Pool • Rail Yard • Lime Settling Basins • South Tank Farm Plume • Army Trenches • Shell Trenches	Minimize or eliminate releases from selected contamination sources.	Action is ongoing as part of ROD implementation.

Table 2.4-1 Summary of Past and Ongoing Response Actions

Response Action	Objective	Status/Completion[1]
13. CERCLA Hazardous Wastes • Wastewater Treatment Facility • Waste Management • Polychlorinated Biphenyls • Waste Storage	Construct and operate a facility to treat wastewater resulting from response actions; identify disposal options for hazardous wastes; inventory, sample, and remediate PCB-contaminated structures and soil; analyze temporary management of bulk hazardous wastes.	Construction of treatment plant completed 1992; liquid treatment and waste management is ongoing; PCB remediation is ongoing as part of ROD implementation; waste storage analysis completed.
14. Chemical Process-Related Activities • Agent Equipment and Tanks • Nonagent Equipment and Tanks • Underground Storage Tanks	Remove and dispose of contaminated process-related equipment from manufacturing areas.	Action is ongoing as part of ROD implementation.
Other Response Actions		
1. Klein Treatment Plant	Construct and operate a facility to treat chlorinated-solvent contaminated groundwater extracted by SACWSD wells west of RMA.	Construction of treatment plant completed 1989; water treatment is ongoing.
2. Deep Injection Well Closure	Properly seal and abandon deep injection well adjacent to Basin F.	Completed in 1985.

1 All ongoing actions are incorporated as part of the final response action.

Table 2.4-2 Media Potentially Impacted by Past and Ongoing Response Actions

Response Action	Soil	Water	Structures	Air	Biota
Interim Response Actions					
Groundwater Intercept and Treatment System North of RMA		X			
Improvement of the North Boundary System and Evaluation of all Existing Boundary Systems		X			
Groundwater Intercept and Treatment System North of Basin F		X		X	
Closure of Abandoned Wells at RMA		X			
Groundwater Intercept and Treatment System in the Basin A Neck Area		X		X	
Basin F Liquids, Sludges, and Soil Remediation	X	X	X	X	X
Building 1727 Sump Liquid	X	X	X		
Closure of the Hydrazine Facility			X	X	
Fugitive Dust Control	X	X	X	X	X
Sewer Remediation	X	X		X	
Asbestos Removal			X	X	
Remediation of Other Contamination Sources					
• Motor Pool	X	X			
• Rail Yard	X	X			
• Lime Settling Basins	X	X			X
• South Tank Farm Plume	X	X			X
• Army Trenches	X	X			X
• Shell Trenches	X	X			X
CERCLA Hazardous Wastes					
• Wastewater Treatment Facility		X			
• Waste Management		X			
• Polychlorinated Biphenyls	X		X		
• Waste Storage	X		X		X
Chemical Process-Related Activities					
• Agent Equipment and Tanks			X	X	X
• Nonagent Equipment and Tanks			X	X	X
• Underground Storage Tanks			X	X	X
Other Response Actions					
Klein Treatment Plant		X			
Deep Injection Well Closure		X			

3.0 Highlights of Community Participation

The Department of Defense has long recognized that successful environmental restoration projects require the input of interested community residents. To that end, the Army began developing its Community Involvement Program in 1984 as the first environmental investigations were initiated. The Community Involvement Program has one primary objective: inform and involve the public with regard to site studies, proposed technologies, and ongoing remediation projects. A comprehensive Community Relations Plan was first developed in May 1990 to provide a road map for public involvement, which was further revised in May 1995. The Army has accomplished the public involvement objectives by conducting one-on-one sessions and informal group meetings, soliciting input using surveys and questionnaires, and pursuing phone contacts to identify interested citizens and organizations, assess public perceptions of the issues, and determine appropriate mechanisms for engaging in two-way communication. In addition, the Army has made available to the public the comprehensive documentation generated during the remediation process at the JARDF and eight area libraries (Table 3.0-1).

Educational outreach efforts included developing several publications that describe current investigations and available remedial technologies, making literature regarding the on-post remediation available to the public, and conducting more than 20 open houses and public meetings. In 1990, a joint Public Affairs Office (PAO) Subcommittee of the RMA Committee was formed to pool the skills and resources of public information specialists from all the Parties. The majority of fact sheets and training materials were developed by this subcommittee.

An example of a current publication is "Update," which has been distributed to approximately 125,000 households within a 10-mile radius of the installation on a quarterly basis since 1990. The focus of Update is to highlight a single, significant issue of the remediation during the preceding quarter. Past Update topics have included the various technologies considered to manage the Basin F liquid, the building of the SQI, the test-burn results of the SQI, and the release of the Proposed Plan for the On-Post Operable Unit. Along with lead stories on similar topics, the publication has also described opportunities for public involvement, including the schedules for public meetings, workshops, and tours. The Army has also published a tri-fold brochure, called "RMA Public Outreach," focusing on public outreach programs since 1994. Various topics discussed in this quarterly pamphlet include RMA technical information and history, wildlife viewing tour schedules, educational programs, and recycling programs.

Since 1988 all the Parties have made extensive efforts to ensure that the public is kept informed on all aspects of the cleanup program. More than 100 fact sheets about topics ranging from historical information to site remediation have been developed and made available to the public. All educational materials were developed and coordinated with all the Parties. In addition, ATSDR has provided public health information and support, including health consultation related to the Basin F IRA, a Public Health Assessment of RMA, and other health-related studies.

The Army held one of its largest public open houses in January 1994, following the release and distribution of the draft Detailed Analysis of Alternatives report for the On-Post Operable Unit. The purpose of the event was to provide the public one-on-one experience with federal, state, and local professionals who could explain in simple terms the views of their organizations regarding the various aspects of the remediation. It was vital to the success of the open house that the organizations, although not in total agreement with the technologies being proposed for the final remedy, were available to present their respective opinions.

Regulatory agencies represented at the event were EPA, CDPHE, and Tri-County Health Department. The two responsible parties, the Army and Shell, were also present. Members of USFWS were also available to express their opinions on the various proposed remedies from the standpoint of habitat preservation. Each organization created displays that described the organization's position and staffed these displays with experts available to answer questions from the public. Videos were shown that detailed, in easy-to-understand terms, the various technologies outlined in the draft Detailed Analysis of Alternatives report.

As part of the open house, the Army offered site tours of RMA to the 1,000 citizens who attended. The tours, which were accompanied by technical experts who explained the ongoing remedial operations, provided visitors with a better understanding of the size of the installation and the degree of contamination at various locations as well as its potential as a national wildlife refuge. The Army and USFWS cooperate in implementing and supporting community involvement activities regarding wildlife/habitat during remediation. Remediation activities will take into account RMA's end use as a national wildlife refuge, which fulfills the provision of the FFA that states it is a goal of the Organizations to make significant portions of the site available for beneficial public use. In October 1992, in conjunction with the future goal of beneficial public use and in recognition of the unique urban wildlife resources provided by RMA, President George Bush signed the Rocky Mountain Arsenal National Wildlife Refuge Act, making RMA a national wildlife refuge following EPA certification that required response actions have been appropriately completed.

Prior to April 1994, various public meetings and workshops were coordinated with interested citizens through a Technical Review Committee (TRC), which was established under FFA and CERCLA guidelines. The committee, established at RMA in 1989, was comprised of representatives from local health and regulatory agencies, community residents, and the local government. In November 1993, the TRC opened its meetings to the public.

In April 1994, the Department of Defense directed military installations involved in environmental remediation to transition the TRCs into Restoration Advisory Boards (RABs). The RAB at RMA serves as a forum to exchange information and establish open dialog among the communities, regulatory agencies, the Army, and Shell. In less than 1 year, the RAB modified how public input was obtained and incorporated into the CERCLA process for selecting a remedy for RMA. For example, one of the primary changes included making the JARDF more user-friendly. Millions of pages of documents relating to RMA history, mission, remediation, and wildlife were made available to the public via a computerized optical disk system. Citizens may access volumes of research material on literally any subject relating to RMA simply by keying in a word or series of words. The system then allows users to select a specific document or page of a document for further review. The JARDF allows users to photocopy up to 100 pages of RMA-related material at no charge.

The Site-Specific Advisory Board (SSAB) of RMA was formed with the assistance of EPA and CDPHE in 1994. Although the RAB is the officially recognized citizen advisory board for RMA, the SSAB serves as another forum for community concerns. Many of the members serving on the SSAB also serve on the RAB. More information on the SSAB can be obtained from CDPHE at (303) 692-3327.

A Technical Assistance Grant (TAG) was awarded to Citizens Against Contamination (CAC) by EPA in 1990. CAC was formed in 1985 and has been monitoring all aspects of the remediation at RMA and has provided a crucial role for public participation in the decision-making process. The TAG has provided funds to CAC so that an outside consultant could be hired to assist with the interpretation of technical information. In 1995, an additional $50,000 grant was awarded to CAC for continued technical assistance.

Members of the public and local authorities participated in an extensive series of meetings during 1994–95 regarding the remediation of RMA. These meetings provided the basis for negotiations among the Parties that led to the Conceptual Remedy in June 1995 and the Detailed Analysis of Alternatives report and Proposed Plan in October 1995.

The Proposed Plan was released for public review on October 16, 1995. On November 18, 1995 the Parties held a public meeting, attended by approximately 50 members of the public, to obtain public comment on the Proposed Plan. As a result of requests at this meeting, the period for submitting written comments on the plan was extended 1 month, concluding on January 19, 1996.

The Army also regularly issues press releases and provides access to hotlines that relate up-to-date information about remedial operations, and publishes brochures on selected topics, environment/wildlife tours, and school programs. Army representatives and public outreach specialists from EPA, USFWS, Shell, and CDPHE also visit area libraries, schools, and grocery stores and distribute flyers and brochures regarding the public meetings, the remediation process, and recreational activities available at RMA. The PAO Subcommittee has also established an active speaker's bureau program that serves as a focal point to communicate with civic organizations. RMA has also established an Internet World Wide Web home page (http://www.pmrma-www.army.mil).

Table 3.0-1 Area Libraries Holding RMA Documentation

Library	Address	Telephone Number
RMA Joint Administrative Record Document Facility[1]	Building 135, Room 16 72nd Avenue and Quebec Street Commerce City, CO 80022	(303) 289-0362
Adams County Library Brighton Branch	575 S. Eighth Avenue Brighton, CO 80601	(303) 659-2572
Aurora Public Library	14949 East Alameda Drive Aurora, CO 80012	(303) 340-2290
Commerce City Public Library	7185 Monaco Street Commerce City, CO 80022	(303) 287-0063
Denver Public Library	10 West 14th Avenue Parkway Denver, CO 80204	(303) 640-6200
EPA Library	999 18th Street, Suite 500 Denver, CO 80202	(303) 312-6937
Lakewood Public Library	10200 West 20th Avenue Lakewood, CO 80215	(303) 232-9507
Montbello Public Library	12955 Albrook Drive Denver, CO 80239	(303) 373-0767
Park Hill Library[2]	4705 Montview Denver, CO 80207	(303) 331-4063

1 The entire administrative record is accessible through the JARDF.

2 Only the Proposed Plan, Detailed Analysis of Alternatives report, and ROD can be found at Park Hill Library.

4.0 Scope and Role of the On-Post Operable Unit

The On-Post Operable Unit is one of two operable units at RMA (Figure 1.0-1). The On-Post Operable Unit addresses contamination within the fenced 27 square miles of RMA proper. The contaminated areas include approximately 3,000 acres of soil, 15 groundwater plumes, and 798 remaining structures. The most highly contaminated sites are located at South Plants (Central Processing Area, Hex Pit, Buried M-1 Pits, Chemical Sewers), Basins A and F, Lime Basins, and the Army and Shell disposal trenches. The primary contaminants at these sites are pesticides, solvents, heavy metals, and agent byproducts, which are found in soil and/or groundwater. The soil in these areas poses a principal threat to human and ecological **receptors**. The potential **exposure pathways** through which a threat would be posed to humans are identified in Section 6.1 and for wildlife in Section 6.2.

At RMA, groundwater contamination is moving principally to the north and northwest, but it is intercepted before it flows off post by the boundary groundwater treatment systems west, northwest, and north of the major source areas. At these systems, the groundwater is treated to established CSRGs (see Section 9). Ongoing monitoring of n-nitrosodimethylamine (NDMA) will be used in support of design refinement for the groundwater treatment systems. Possible ingestion or dermal contact with the groundwater is not a threat to human health on post because the use of groundwater for domestic purposes is restricted by the FFA. Nonpotable uses of on-post groundwater were not anticipated and risk was therefore not considered in the human health risk characterization portion of the Integrated Endangerment Assessment/Risk Characterization for such uses. A risk evaluation would be performed prior to any future nonpotable use to ensure that such use would be protective of human health and the environment.

The purpose of the on-post remedial action is to prevent current or future excessive exposure to contaminated soil or structures, to reduce contaminant migration into the groundwater, and to treat contaminated groundwater at the boundary to meet remediation goals. Remedial measures for on-post groundwater will augment the soil remedy and facilitate long-term remediation of groundwater. In addition, it addresses the arrangement for provision of potable water to the South Adams County Water and Sanitation District (SACWSD). The selected remedy described in this ROD will permanently address the threats to human health and the environment by using a combination of containment (as a principal element) and treatment technologies to reduce the toxicity, mobility, or volume of contaminants in groundwater, structures, or soil; comply with applicable or relevant and appropriate requirements (ARARs); and be cost effective.

The Off-Post Operable Unit addresses contamination in the groundwater north and northwest of RMA. The area impacted by this contamination is referred to as the Off-Post Study Area (see Figure 1.0-1). The final ROD for the Off-Post Operable Unit was issued in December 1995, the major components of which are summarized in Table 4.0-1.

The selected remedy for the On-Post Operable Unit, integrated with the IRAs and the selected remedy for the Off-Post Operable Unit, will comprehensively address all contamination at RMA. The ROD for the On-Post Operable Unit will be the final response action at RMA.

Table 4.0-1 Description of the Remedy for the Off-Post Operable Unit

Component	Description
1	Continued operation of the Off-Post Groundwater Intercept and Treatment System.
2	Natural attenuation of inorganic chloride and sulfate concentrations to meet remediation goals for groundwater in a manner consistent with the on-post remedial action.
3	Continued operation of the NWBCS, NBCS, and ICS as specified in Section 7.2 of the ROD for the On-Post Operable Unit.
4	Improvements to the NBCS, ICS, NWBCS, and the Off-Post Groundwater Intercept and Treatment System as necessary.
5	Long-term groundwater monitoring (including monitoring after groundwater treatment has ceased) to ensure continued compliance with the CSRGs.
6	Five-year site reviews.
7	Exposure control/provision of alternate water as detailed in the ROD for the Off-Post Operable Unit.
8	Institutional controls, including deed restrictions on Shell-owned property, to prevent the use of groundwater exceeding remediation goals.
9	Closure of poorly constructed wells within the Off-Post Study Area that could be acting as migration pathways for contaminants found in the Arapahoe aquifer.
10	Continuation of monitoring and completion of an assessment by the Army and Shell of the NDMA plume by June 13, 1996 using a 20 ppt method detection limit.
11	Preparation of a study that supports design refinement for achieving NDMA remediation goals at the RMA boundary. The study will use a 7.0 ppt preliminary remediation goal or a certified analytical detection level readily available at a certified commercial laboratory (currently 33 ppt).
12	Tilling and revegetation of approximately 160 acres in the southeast portion of Section 14 and the southwest portion of Section 13 by the Army and Shell.
13	Treatment of any contaminated extracted groundwater prior to discharge or reinjection so that it meets the CSRGs that meet or exceed the water quality standards established in the CBSGs and CBSMs.

5.0 Summary of Site Characteristics

This section provides a general overview of site characteristics at RMA. More detailed information regarding the environmental setting, nature and extent of the contamination, contaminant fate and transport, and other special investigations associated with the RI Program can be found in the Remedial Investigation Summary Report and references therein.

The Army initiated the RI Program in 1984 to define the nature and extent of contamination in soil, water, structures, air, and biota at RMA to a degree sufficient to permit an assessment of contaminant migration and exposure to human and ecological receptors and selection of viable remediation options for RMA.

5.1 Sources of Contamination

Contaminants were introduced into the RMA environment beginning in the early 1940s by disposal of liquid waste in open basins, solid waste burial in trenches, accidental spills of feedstock and product chemicals, leakage from sewer and process water systems, emissions from air stacks, and use of commercial chemical products during normal facility operation. The most highly contaminated sites are located at South Plants, Basins A and F, and the Army and Shell disposal trenches in Section 36. Other contaminated sites include storage areas, maintenance areas, and sewer lines. Over time contaminants have migrated from the soil and sediments to groundwater at RMA.

5.2 Nature of Contamination

More than 600 chemicals have been associated with activities at RMA since it was first established. However, on the basis of risk and frequency of use, the RI focused on about 70 chemicals. Of these, the principal contaminants are organochlorine pesticides (OCPs), metals (including arsenic and mercury), agent-degradation products and manufacturing byproducts (e.g., DIMP), DBCP, and chlorinated and aromatic solvents. Contamination in soil, sediment, and groundwater includes relatively mobile and soluble compounds (e.g., solvents) and less soluble contaminants, principally OCPs and arsenic. This range of contaminants exhibits a great variability in environmental mobility and persistence. OCPs are less mobile than the other contaminants present and are more persistent, tending to associate with soil and sediment and to **biomagnify** in the food chain. Conversely, a solvent or DIMP migrates more readily into the groundwater and can spread more rapidly in groundwater plumes. However, the relative contributions of various sources to groundwater plumes are often difficult to ascertain as contaminants within a groundwater plume can rarely be unequivocally associated with a specific source.

5.3 Contaminant Migration Pathways

Chemicals have historically migrated from source areas through the unsaturated zone, unconfined and confined flow systems, surface water, and wind-borne pathways. These pathways are briefly described as follows:

- **Unsaturated Zone** – This is the usual pathway by which contaminants enter the aquifer. Contaminants migrate through the unsaturated zone to the aquifer most readily when it is thin and/or highly permeable.

The unsaturated zone is relatively thin beneath Basin A, the Lime Settling Basins, the Section 36 disposal trenches, and the north-central portion of South Plants.

- Unconfined Flow System – This is a major groundwater **migration pathway** that has transported contamination in shallow groundwater to the north and west from source areas.
- Confined Flow System – This pathway generally consists of fine-grained discontinuous, permeable sand lenses and lignites, separated by low-permeability siltstones and claystones, of the Denver Formation. Detections of contaminants in this pathway generally correspond with contaminant plumes in the overlying UFS, but the contamination is much less widespread and at much lower concentrations. In many cases, detections are suspected to be related to faulty well installation rather than actual migration into this zone. Transport of contaminants along this pathway is much slower than in the UFS.
- Surface Water – Historically, this was a major contaminant transport pathway, contributing to the spread of contaminants in basins, ditches, lakes, ponds, and land at RMA. Use of the disposal ditches has been discontinued. Runoff from major storm events or snow melt is expected to transport low concentrations of contaminants present in surficial soil, although the efficiency of this mechanism is limited for most areas.
- Windblown – Windblown transport of residual contamination from various sources is responsible for broad areas of low-level surficial soil contamination within RMA boundaries adjacent to the major source areas.

In the past, human and ecological receptors 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 ecological receptors from the most toxic sources. However, some of the major sources continue to pose a risk to ecological receptors and to humans (although access restrictions and health and safety practices prevent site workers and visitors from coming into contact with these sources).

5.4 Extent of Contamination

One hundred eighty-one sites with varying degrees of contamination, ranging from areas of several hundred acres with multiple contaminant detections at concentrations up to a few parts per hundred to isolated detections of single analytes at a few parts per billion, were delineated during the RI and subsequent studies. During the FS, these sites were combined into groups of sites containing similar contaminant types and distributions, as shown in Figure 5.4-1. In addition, areas of RMA potentially containing Army chemical agent or **unexploded ordnance** (UXO) were delineated, as shown in Figure 5.4-2. Summary discussions of the contaminant concentrations and distributions, along with analytical results in tabular format, can be found in the Remedial Investigation Summary Report and subsequent studies referenced in the Detailed Analysis of Alternatives report.

Contamination was detected in soil, ditches, stream and lakebed sediments, sewers, groundwater, surface water, biota, structures, and, to a much lesser extent, air. Less extensive and less concentrated contamination occurs only sporadically within the relatively uncontaminated buffer zone along the boundaries. The most highly contaminated sites (those showing the highest concentrations and/or the greatest variety of contaminants) are concentrated in the central six sections (square miles) of RMA (Sections 1, 2, 25, 26, 35, and 36) within which the manufacturing and waste disposal areas are located.

A number of sites at RMA that posed a potential risk to human health and the environment have been initially addressed by the implementation of IRAs. Additional actions at these sites and the other contaminated sites that remain will be undertaken as specified in this ROD, thereby reducing the risks to human health and the environment. Current conditions for air, wildlife, water, structures, and soil are described below.

Air

The Army is currently monitoring the ambient air at strategic locations at RMA. No ambient air contamination related to RMA has been consistently detected, and air quality at RMA is generally better than that of the surrounding Denver metropolitan area.

Wildlife

Elevated contaminant concentrations have been detected in some wildlife at RMA. Adverse impacts, including death, have been identified for individuals of species feeding or residing in certain highly contaminated areas at RMA. USFWS, through the ongoing biomonitoring program, is studying the wildlife populations at RMA for health effects by analyzing tissue samples, conducting bioassays, and recording animal observations such as reproduction, survival, and mortality. The Parties, represented by the Biological Assessment Subcommittee (BAS), are working together with USFWS to ensure that the study of potential effects is designed to consider actual exposures for the individuals sampled. The potential for additional unacceptable levels of exposure to biota on RMA is being evaluated for support of design refinement by Phase I of the **Supplemental Field Study (SFS)** (see Section 6.2.4.3).

Groundwater

The regional groundwater flow direction at RMA is northwest toward the South Platte River. High groundwater flow volumes and velocities at RMA are associated with thick, permeable sand and gravel deposits of the Platte River Valley, which occur along the Western Tier (e.g., Sections 4, 9, and 33) of RMA, and with similar deposits along First Creek. The saturated portion of these alluvial sediments is generally thicker and coarser grained than alluvial sediments in the central portion of RMA. Groundwater flow velocities and volume in the central portion of RMA are one or more orders of magnitude less than in the Western Tier or First Creek areas because groundwater in the central portion flows through predominantly thin, fine-grained alluvium and low-permeability bedrock. Superimposed on the regional groundwater flow system is a large groundwater mound centered over a bedrock topographic high beneath the South Plants. Groundwater in this area flows radially away from the South Plants mound and eventually flows towards the Western Tier or the northern boundary.

Because RMA is located in a semiarid environment, the amount of annual groundwater recharge from precipitation is low (precipitation is approximately 15 inches per year). Sources of manmade recharge have historically contributed to the groundwater mound in South Plants. These manmade sources include leaking potable and process water systems (used for fire protection), sanitary and storm sewer systems, infiltration of steam plant cooling water discharged to ditches, and infiltration of precipitation that ponds in depressions and ditches adjacent to buildings and roadways. The amount of recharge from these manmade sources is decreasing and eventually will be eliminated when remediation activities are completed. The sanitary and chemical sewers systems were closed in 1992 and the steam plant in South Plants is no longer in operation. Since that time, measurements indicate that groundwater elevations in South Plants have decreased several feet. It is currently believed that the decrease in water levels is the result, in part, of the reduction in manmade recharge; however, some of the decreases in water levels may be due to drought. In the long term, water levels in the mound area are expected to decrease as a result of eliminating manmade recharge.

To develop and evaluate remedial alternatives, the 15 groundwater contaminant plumes identified at RMA were grouped into 5 plume groups, primarily based on location (Figure 5.4-3). The five plume groups are as follows:

- North Boundary Plume Group
- Northwest Boundary Plume Group
- Western Plume Group
- Basin A Plume Group
- South Plants Plume Group

The North Boundary Plume Group includes the Basins C and F Plume and the North Plants Plume (Figure 5.4-3). The NBCS extracts and treats these plumes as they approach the northern boundary of RMA. The Basins C and F Plume flows primarily within alluvial-filled paleochannels and to a lesser extent through weathered bedrock. The North Plants Plume flows primarily within sandy alluvial material. The primary contaminants in the Basins C and F Plume are chloroform, benzene, atrazine, dieldrin, DIMP, TCE, DBCP, and DDT. The plume also has high levels of inorganics such as fluoride, chloride, and sulfate. The primary contaminant in the North Plants Plume is DIMP. Sulfate is present at high concentrations (chiefly due to natural sources) in the First Creek aquifer. Concentration ranges for these primary contaminants are presented in Table 5.4-1.

The Northwest Boundary Plume Group includes the Basin A Neck Plume and the Sand Creek Lateral Plumes. The existing NWBCS (Figure 5.4-3) was installed to intercept and treat these plumes at the RMA boundary. The Basin A Neck Plume extends from Basin A in Section 36 to the northwest boundary of RMA. The Sand Creek Lateral Plumes appear to originate in the vicinity of the Sand Creek Lateral in the western portion of Section 35 and merge with the Basin A Neck Plume. The primary organic contaminants in these plumes are dieldrin, chloroform, and DIMP. The Basin A Neck Plume also has high levels of chloride, fluoride, and sulfate. However, dieldrin is the only compound that is present at levels requiring treatment at the boundary. Contaminant concentration ranges for the primary contaminants in this plume group are presented in Table 5.4-2.

The Western, Motor Pool, and Rail Yard Plumes are collectively defined as the Western Plume Group. The Motor Pool and Rail Yard Plumes are treated by the ICS and those portions of the Western Plume that extend off post (downgradient) are extracted by the SACWSD water supply wells and treated at the Klein treatment plant. The plumes occur primarily within thick alluvial-terrace deposits. The primary contaminants in these plumes are TCE in the Motor Pool Plume; 1,1-dichloroethylene, 1,1,1-trichloroethane, and TCE in the Western Plume; and DBCP in the Rail Yard Plume. The concentrations of these primary contaminants are shown in Table 5.4-3.

The Basin A Plume Group includes the Basin A Plume, the South Plants North Plume, and the Section 36 Bedrock Ridge Plumes. Contaminated groundwater flow in the South Plants North and Basin A Plumes occurs principally within saturated alluvium, with lesser flow through the underlying weathered bedrock. However, in the Section 36 Bedrock Ridge area, the water table generally lies below the alluvium and groundwater flows predominantly within weathered bedrock. The major contaminants detected in all the Basin A Plume Group are chloroform, methylene chloride, DIMP, TCE, DBCP, and benzene. Additionally, aldrin, dieldrin, and chlordane are also major contaminants in the South Plants North and Basin A Plumes. The concentrations of these contaminants are presented in Table 5.4-4.

The South Plants Plume Group includes the South Plants Southeast, Southwest, North Source, and the South Tank Farm Plumes. Groundwater in these plumes flows principally within the weathered, upper portion of the Denver Formation. Small portions of the South Plants North Source and South Plants Southeast Plumes also flow within areas of thin, saturated alluvium. Continued monitoring of groundwater adjacent to Lake Ladora and Lower Derby Lake will make it possible to assess migration of contaminants toward the lakes. The primary contaminant in the South Tank Farm Plume is benzene. The major contaminants in the other plumes in the South Plants Plume Group include chloroform, carbon tetrachloride, TCE, tetrachloroethylene, benzene, aldrin, dieldrin, and DBCP. Contaminant concentrations for these contaminants are presented in Table 5.4-5.

Structures

The structures medium encompasses a wide variety of structural types and materials including all aboveground structures, buildings, foundations, basements, tanks (including underground storage tanks), process and nonprocess equipment (including bone yards), aboveground chemical and nonchemical pipelines, asbestos-containing material (ACM), equipment and materials contaminated with PCBs, and other miscellaneous manmade objects placed at RMA since it was acquired by the Army in May 1942. The structures medium also includes a few houses and barns constructed before 1942 that still exist at RMA.

During the FS, the **use history** information was used to categorize structures in terms of their potential for contamination. Detailed use histories of structures at RMA were gathered based on plant operational records, official Army and Shell histories, and depositions from operational personnel. The histories of each structure were summarized in the Task 24 Structures Survey Report (Ebasco 1988). For example, the history of a structure involved with chemical production would include the chemicals produced, the years of operation, and any spills, exposures, or accidents that occurred there. Similarly, the history of a structure used for nonproduction activities would include the type of use, such as staff housing or administration, and any chemical spills or accidents that may have occurred there.

There are 798 structures currently standing at RMA. In order to efficiently evaluate cleanup alternatives, structures with similar use histories and potential for contamination were placed in one of four groups. One of the four groups is identified as "Future Use," meaning that the use history indicates the structures are uncontaminated, and they have some usefulness at the conclusion of remedial activities. The other three groups are identified as "No Future Use," meaning that they are not needed following remediation and that their use history indicates the structures may be contaminated. Many of these structures must be removed to access the underlying contaminated soil. These three groups are further distinguished by the relative severity of the potential contamination associated with their use histories. The four structures medium groups, and the number of structures included in the groups, are as follows:

- Future Use, No Potential Exposure (Future Use Group) – 48 structures
- No Future Use, Significant Contamination History (Significant Contamination History Group) – 49 structures
- No Future Use, Other Contamination History (Other Contamination History Group) – 631 structures
- No Future Use, Agent History (Agent History Group) – 70 structures

Tables 5.4-6 through 5.4-9 present an inventory of the structures included in each medium group. Refinement of the Future Use structures inventory will be completed during remedial design.

Soil

The soil medium consists of unsaturated soil, bedrock, fill material, process water lines, chemical and sanitary sewer lines, lake sediments, and soil/waste/debris mixtures. The term "soil," used for convenience in this document, refers to any of these materials. A total of 178 potentially contaminated soil sites were investigated during the RI, and three sites were added during the FS as a result of additional IRA and RI investigative efforts. Of the 181 sites investigated, 114 were determined to require further evaluation in the FS based on the site evaluation criteria (SEC) as described in Section 7.1.3, on potential agent or UXO presence, or on the potential risk to biota as described in Section 6.2. These 114 sites are organized into four exceedance categories as follows:

- Potential UXO Presence – Potential presence of UXO identified as the only risk
- Potential Agent Presence – Potential presence of Army chemical agent identified as the only risk

- Biota Risk – Potential risk only to biota based on the evaluations presented in the Integrated Endangerment Assessment/Risk Characterization report
- Human Health Exceedance – Exceedance of human health SEC, although portions of these sites may also potentially contain UXO, potentially contain agent, and/or pose potential risks to biota

The sites were further organized into 15 medium groups, which are groups of sites within each exceedance category that are similar in site type and contamination patterns (e.g., sanitary landfills with metallic debris and rubbish). Eight of these medium groups were divided into subgroups based on chemical or physical variation between the sites within a group.

The site characteristics that were used to develop medium groups and subgroups fall into nine general criteria, which are described as follows:

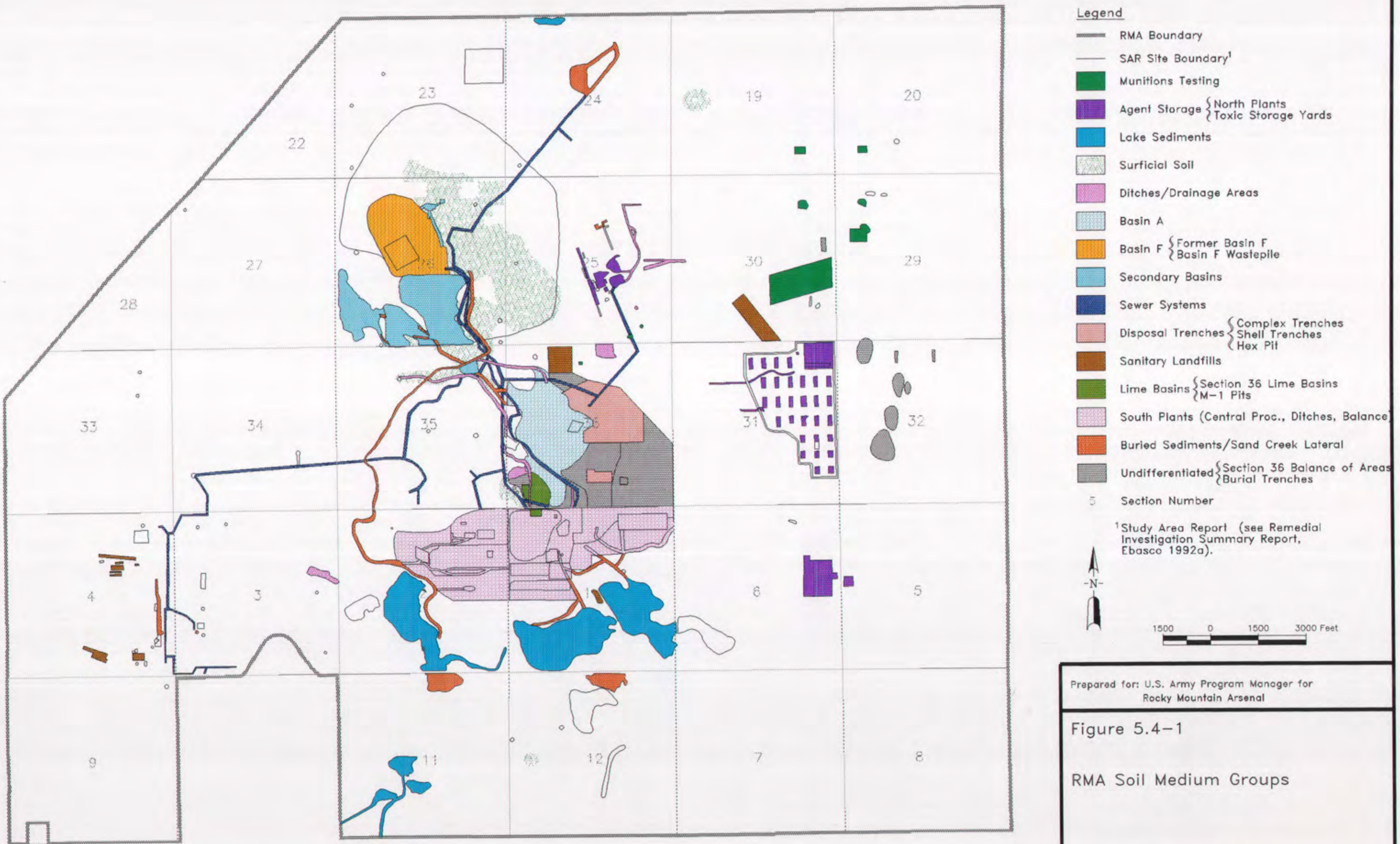
- Depth of Contaminated Soil – This criterion is evaluated because the depth of contamination may limit the suitability of particular remedial technologies. For example, technologies such as **surface heating** are effective only for volatile contaminants at shallow depths.
- Driver Contaminants – The types of contaminants that comprise the exceedance volumes influence the evaluation of alternatives. One treatment technology may provide effective remediation for all contaminants detected at the site. In some cases, however, a primary remedial technology is developed for the most prevalent contaminant(s) and a secondary treatment system or systems are used for the remainder of the contamination.
- Depth to Groundwater – Thickness of the unsaturated zone varies across RMA, and treatment technologies may require a minimum thickness for installation and function of the system. For example, **in situ vitrification** and **RF heating** require a minimum unsaturated soil thickness to operate.
- Major Soil Type – The total of 10 soil units that have been identified at RMA were divided into four soil types based on texture, clay content, and soil permeability for the purpose of evaluating subgroups. Soil types may increase or reduce treatment effectiveness. For example, **soil venting** is more effective on a sandy loam than on a clay loam due to the increased porosity and permeability of a sandy unit.
- Soil/Groundwater Interactions – Soil/groundwater interactions are evaluated at each site to assess the potential impacts of soil alternatives on groundwater alternatives.
- IRAs – Sites at which IRAs have been or are being performed (see Section 2.4) may not need further remediation if the IRA is determined to provide long-term protection of human health and the environment.
- Site Configuration – Site shapes vary and are categorized as either square to oblate or extremely narrow. The shape of a site can affect the selection of an alternative. For example, extremely narrow sites, such as ditches, are not favorable locations for access controls like **habitat modifications**.
- Agent/UXO Presence – Agent and/or UXO along with human health **contaminants of concern (COCs)** or contaminants that pose potential risk to biota may be present at some of the sites. Sites are identified that potentially contain agent and/or UXO based on historical usage of the site as presented in the Remedial Investigation Summary Report. Additional FS data-collection programs have been performed to further define the extent of agent contamination.
- Site Type/Usage – Each site was evaluated for site type or usage and eight categories were developed in the Remedial Investigation Summary Report. The site type/usage categories include surface soil/windblown; ordnance testing and disposal; spills/isolated; lake sediments, ditches, and ponds; basins or lagoons; buildings, equipment, and storage; sewer systems; and buried waste.

The exceedance categories, medium groups, and subgroups that were developed based on these criteria are listed in Table 5.4-10; the medium group and subgroup characteristics are described in Table 5.4-11. The contaminant concentrations (range and average) detected for each medium group and subgroup within the soil exceedance volumes defined by the SEC are listed in Table 5.4-12. The exceedance volumes represent only those parts of a site that exceed the SEC; therefore, the listed ranges and average concentrations are higher than the data for each site as a whole (see Section 6).

5.5 Potential Human and Environmental Exposure

Contaminant sources and pathways are identified to allow an assessment, described in Section 6, of the potential for exposure and risk to human health or the environment. In summary, most of the potential human health risks are caused by four chemicals, aldrin, dieldrin, DBCP, and arsenic. The highest estimated risks are limited to the central portions of RMA, coinciding with the former location of chemical processing and disposal areas (e.g., South Plants, the disposal trenches and basins). The primary routes for potential exposure are consumption, dermal contact, and inhalation. Some of the sites pose a risk to wildlife and could pose a risk to site workers and visitors. However, in these heavily contaminated areas, public access is carefully restricted and workers follow prudent health and safety procedures. IRAs have reduced some of the potential risks associated with these sites; however, risks still remain and the reduction of those risks to acceptable levels (see Section 6) is addressed by this ROD.

Under current conditions, biota are the primary receptors of RMA contamination in surficial soil, 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 eliminate wildlife from contaminated areas. Most of the potential biota risks are caused by pesticides and metals. The primary route for biota exposure is ingestion. Consumption of contaminated prey is a concern at higher trophic levels due to contaminants such as OCPs, which are known to bioaccumulate and biomagnify in the food chain.



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

Figure 5.4-1

RMA Soil Medium Groups

Foster Wheeler Environmental Corporation
June 1996

File Name: C:\SOILS\ROD\MEDGRP
Date 6/06/96
Drawn by XG
Checked by SA

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

Figure 5.4-2

Potential Agent/UXO Presence Areas

Foster Wheeler Environmental Corporation
June 1996

File Name: C:\SOILS\ROD\AGT-UXO
Date 6/06/96
Drawn by XG
Checked by SA

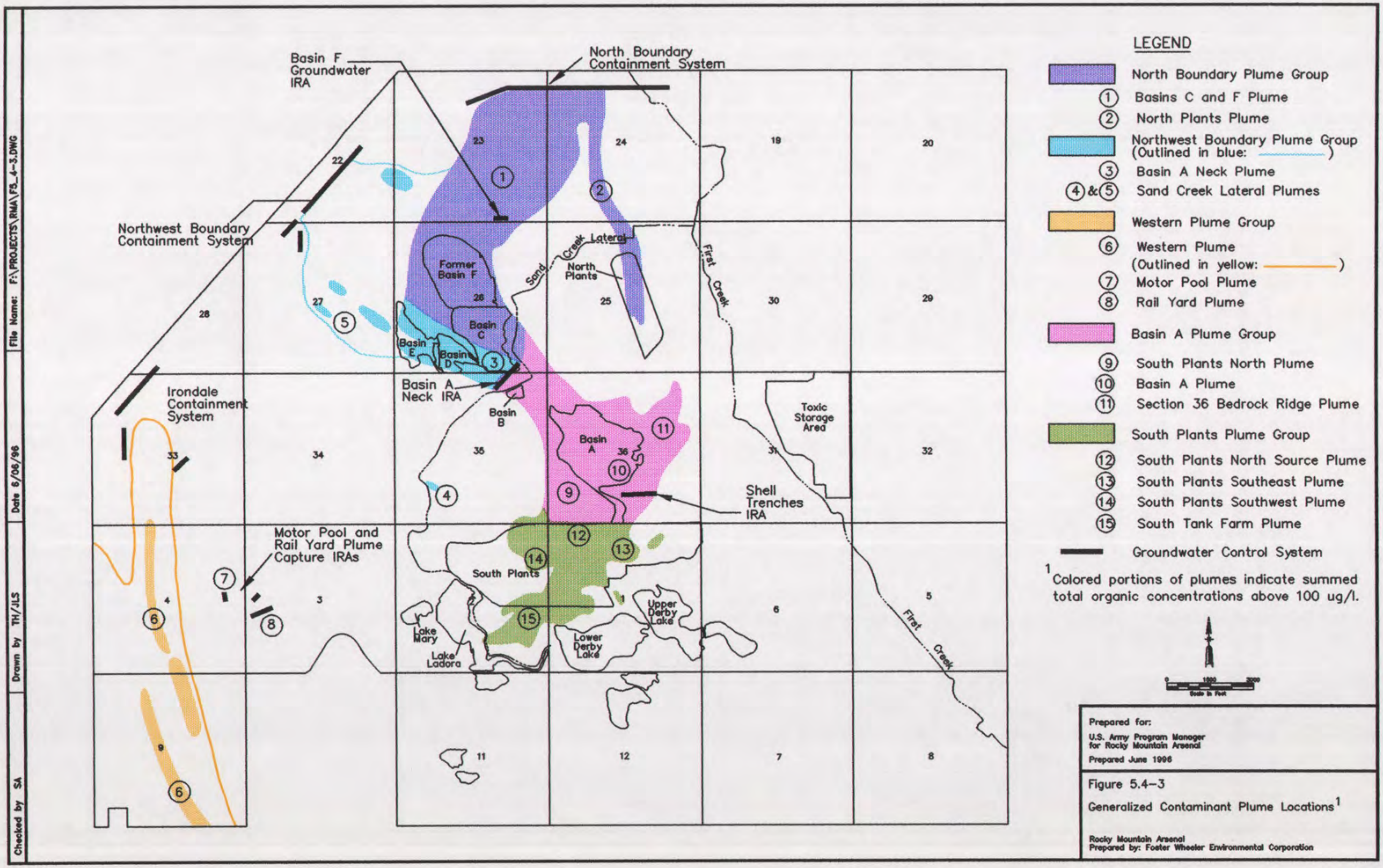


Figure 5.4-3
Generalized Contaminant Plume Locations[1]

Table 5.4-1 Primary Contaminant Concentrations in the North Boundary Plume Group[1,2]

Analyte	Minimum Concentration (µg/l)	Maximum Concentration (µg/l)	TSGM[3] (µg/l)
North Plants Plume			
DIMP	<0.39	3,900	44
Sulfate	8,600	1,800,000	600,000
Basins C and F Plume			
Chloroform	<0.5	85,000	8.5
Trichlorethylene	<0.5	790	1.6
Benzene	<0.5	460	1.8
Dieldrin	<0.05	440	0.46
DIMP	<0.2	64,000	210
DDT	<0.049	27	0.11
Atrazine	<0.51	1,800	5.4
DBCP	<0.06	71	0.21
Chloride	7,200	32,000,0000	1,000,000
Fluoride	180	500,000	4,100
Sulfate	<180	10,000,000	660,000

1 The reported concentrations are based on data from first quarter 1989 through second quarter 1994.

2 Concentrations are reported with two significant figures.

3 The two-step geometric mean (TSGM) was used to calculate plume concentration averages. In the first step, the geometric mean of all samples for each individual well was calculated, and in the second step, the geometric mean for all wells within the identified plume was calculated.

Table 5.4-2 Primary Contaminant Concentrations in the Northwest Boundary Plume Group[1,2] **Page 1 of 1**

Analyte	Minimum Concentration (µg/l)	Maximum Concentration (µg/l)	TSGM[3] (µg/l)
Basin A Neck Plume			
Chloroform	<0.5	30	3.4
Dieldrin	<0.05	3.5	0.14
DIMP	<0.39	5,900	66
Chloride	30,000	1,900,000	670,000
Fluoride	1,100	6,200	2,600
Sulfate	190,000	2,400,000	630,000
Sand Creek Lateral Section 35 Plume			
Chloroform	<0.5	4.5	0.96
Dieldrin	<0.05	0.10	0.032
Sand Creek Lateral Section 27 Plume			
Chloroform	18	22	20
Dieldrin	0.50	2.6	1.1
DIMP	0.81	3.2	1.8

1 The reported concentrations are based on data from first quarter 1989 through second quarter 1994.
2 Concentrations are reported with two significant figures.
3 The two-step geometric mean (TSGM) was used to calculate plume concentration averages. In the first step, the geometric mean of all samples for each individual well was calculated, and in the second step, the geometric mean for all wells within the identified plume was calculated.

Table 5.4-3 Primary Contaminant Concentrations in the Western Plume Group[1,2] Page 1 of 1

Analyte	Minimum Concentration (µg/l)	Maximum Concentration (µg/l)	TSGM[3] (µg/l)	TSGM[3,4]
Western Plume				
1,1,1-Trichloroethane	<0.76	100	4.0	4.3
1,1-Dichloroethylene	<1.7	48	3.6	3.7
TCE	<0.56	55	5.8	4.0
Motor Pool Plume				
TCE	<0.49	180	3.0	1.1
Rail Yard Plume				
DBCP	1.1	29	13	1.0

1 The reported concentrations are based on data from first quarter 1989 through second quarter 1994.
2 Concentrations are reported with two significant figures.
3 The two-step geometric mean (TSGM) was used to calculate plume concentration averages. In the first step, the geometric mean of all samples for each individual well was calculated, and in the second step, the geometric mean for all wells within the identified plume was calculated.
4 These data were estimated using third quarter 1994 through fourth quarter 1995 data.

Table 5.4-4 Primary Contaminant Concentrations in the Basin A Plume Group[1, 2]

Analyte	Minimum Concentration (µg/l)	Maximum Concentration (µg/l)	TSGM[3] (µg/l)
Basin A Plume			
Chloroform	<0.5	100,000	180
TCE	<0.56	8,200	26
Methylene chloride	<2.5	910,000	50
Benzene	<1.1	39,000	52
DIMP	<0.2	29,000	60
Aldrin	<0.05	9.5	0.080
Dieldrin	<0.05	19	0.17
Chlordane	<0.095	120	0.11
DBCP	<0.13	10,000	9.7
Section 36 Bedrock Ridge Plume			
Chloroform	<0.5	23,000	56
TCE	2.2	3,000	98
Tetrachloroethylene	1.1	14,000	370
Methylene chloride	<1.0	910,000	50
Benzene	<1.0	890	5.8
DBCP	<0.13	120	0.24
South Plants North Plume			
Chloroform	<0.5	2,900,000	180
TCE	<0.56	6,200	6.2
Methylene chloride	<2.5	34,000	39
Benzene	<1.1	100,000	24
Aldrin	<0.05	300	0.21
Dieldrin	<0.046	65	0.20
Chlordane	<0.095	460	0.56
DBCP	<0.13	480	0.90

1 The reported concentrations are based on data from first quarter 1989 through second quarter 1994.
2 Concentrations are reported with two significant figures.
3 The two-step geometric mean (TSGM) was used to calculate plume concentration averages. In the first step, the geometric mean of all samples for each individual well was calculated, and in the second step, the geometric mean for all wells within the identified plume was calculated.

Table 5.4-5 Primary Contaminant Concentrations in the South Plants Plume Group[1,2]

Analyte	Minimum Concentration (µg/l)	Maximum Concentration (µg/l)	TSGM[3] (µg/l)
South Tank Farm Plume			
Benzene	<1.0	1,500,000	1,200
South Plants Southwest Plume			
Chloroform	14	420	71
Carbon Tetrachloride	<0.99	200	9.0
TCE	<0.56	8.6	2.1
Tetrachloroethylene	<0.75	23.7	4.6
Benzene	<1.1	220	1.6
Dieldrin	0.092	15	0.27
DBCP	<0.13	0.93	0.11
South Plants Southeast Plume			
Chloroform	400	45,000	2,500
Carbon Tetrachloride	30	1,500	140
TCE	2.5	710	22
Tetrachloroethyene	<0.75	440	17
Benzene	9.9	8,100	230
Aldrin	<0.05	310	0.17
Dieldrin	<0.05	32	0.23
DBCP	<0.195	1,900	22
South Plants North Source			
Chloroform	1.6	500,000	1,400
TCE	<1.31	1,500	18
Tetrachloroethylene	<0.75	950	60
Methylene chloride	<2.5	3,800	14
Benzene	2.2	82,000	390
Aldrin	<0.083	71	0.44
Dieldrin	<0.05	110	0.35
Chlordane	<0.095	29	0.21
DBCP	<0.13	3,200	4.7

1 The reported concentrations are based on data from first quarter 1989 through second quarter 1994.
2 Concentrations are reported with two significant figures.
3 The two-step geometric mean (TSGM) was used to calculate plume concentration averages. In the first step, the geometric mean of all samples for each individual well was calculated, and in the second step, the geometric mean for all wells within the identified plume was calculated.

Table 5.4-6 Inventory of Future Use, No Potential Exposure Medium Group

Place #	Structure Number	Description of Structure	Bank Volume (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
1	0105	Bus Shelter			33		Short-Term			Not in T-24	
2	0111	RMA Administration, Hqs, Offices	770	39,000	35						
3	0112	Communication Headquarters	290	2,300	35				Cleanup		
4	0120	Facilities Maintenance Headquarters		15,380	35		Long-Term			Not in T-24	
5	0121	Change House		5,000	35		Long-Term			Not in T-24	
6	0124	Maintenance Garage		6,900	35		Long-Term			Not in T-24	
7	0128	Mission Support Contractor		13,200	35		Long-Term			Not in T-24	
8	0129	Administrative Record Facility		38,400	35				Cleanup	Not in T-24	
9	0130	Chemistry Laboratory		17,500	35		Long-Term		Cleanup	Not in T-24	
10	0133	Sewage Lift Station			35		Long-Term			Not in T-24	
11	0135	Guardhouse			04					Not in T-24	
12	0143	West Gate Guardhouse	23	180	04						
13	0145	South Gate Guardhouse	46	170	11						
14	0211	Gas Meter House	21	240	02		Long-Term		Cleanup		
15	0312	Fire Station Headquarters	860	12,000	36		Long-Term				
16	0361	Primary Electrical Substation	54	380	02				Cleanup and Beyond		
17	0369	Lower Derby Valve Gate	20	49	01		Long-Term		Cleanup		
18	0370	Restroom			02		Long-Term			Not in T-24	
19	0371	Water Pumping Station	820	1,800	02		Long-Term		Cleanup		
20	0372	Million Gallon Reservoir (Potable)	530	21,000	02						
21	0383	Community Club	340	6,100	02		Short-Term				
22	0385	Water Pump Station	14	140	04		Long-Term		Cleanup		
23	0386	Water Pump Station	14	140	04		Long-Term		Cleanup		
24	0387	Water Pump Station	14	140	04		Long-Term		Cleanup		
25	0551	Elevated Storage Tank, South Plants	620		01				Cleanup		Tanks/Pipes
26	0552	Valve Pit	55	310	01				Cleanup		
27	0618	Warehouse	5,300	110,000	03		Short-Term		Cleanup		
28	0619	Warehouse	5,200	110,000	03		Long-Term		Cleanup		
29	0702	Bald Eagle Observation Structure			05		Long-Term			Not in T-24	
30	NN0501	Abandoned School-fdn & wall	45	1,300	05		Long-Term				
31	NN0903	VORTAC Station	110	1,000	09						
32	SS 0370	Substation-1T-150'W of C			03		Long-Term				

Table 5.4-6 Inventory of Future Use, No Potential Exposure Medium Group

Place #	Structure Number	Description of Structure	Bank Volume (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
33	SS 0371	Substation-10T-N of 371			02		Long-Term				
34	SS 0385	Substation-3T-N of 385			04		Long-Term				
35	SS 0386	Substation-3T-N of 386			04		Long-Term				
36	SS 0387	Substation-3T-W of 387			04		Long-Term				
37	SS 0619	Substation-4T-N of 619			03		Short-Term				
38	Z-28	Trailer			23				Cleanup	Not in T-24	
39	Z-3	Trailer			35				Cleanup	Not in T-24	
40	Z-38	Trailer			04				Cleanup	Not in T-24	
41	Z-39	Trailer			04				Cleanup	Not in T-24	
42	Z-40	Trailer			25				Cleanup	Not in T-24	
43	Z-41	Trailer			25				Cleanup	Not in T-24	
44	Z-42	Trailer			25				Cleanup	Not in T-24	
45	Z-58	Trailer			35				Cleanup	Not in T-24	
46	Z-68	Trailer			35				Cleanup	Not in T-24	
47	Z-69	Trailer			35				Cleanup	Not in T-24	
48	Z-70	Trailer			04				Cleanup	Not in T-24	

[1] These buildings may be reevaluated for potential historic preservation or future use. The Rocky Mountain Arsenal National Wildlife Refuge Act states that "transfer shall be made without cost to the Secretary of the Interior and shall include such improvements on property as the Secretary of the Interior may request in writing for refuge management purposes."

Table 5.4-7 Inventory of No Future Use, Significant Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Volume (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
1	0242	Chlorine Production/US Mint Storage	3,100	42,000	02						
2	0243	Chlorine Production Compressor Bldg	1,000	9,200	02						
3	0247	Salt Storage Building & foundation	1,100	58,000	02						
4	0251	Chlorine Evaporator/Storage	1,100	23,000	02						
5	0342	Warehouse/M74 I. B. Storage	1,000	13,000	02						
6	0411	SM & SD Manufacturing/Storage	1,500	16,000	01						
7	0411A	Steam Meter House	6	72	01						
8	0424A	Mustard Scrubber-foundation	10	720	01						
9	0424C	Aldrin Filter Building-foundation	16	750	01						
10	0451	Warehouse/Production Filling	900	11,000	01	Leased					
11	0471	TC Reactor/Pesticide Production	580	5,100	01	Leased					
12	0473	TC Drum Loading/Pesticide Packaging	86	1,900	01	Leased					
13	0475	Railroad Car Warmer Shed	180	980	01	Leased					
14	0502	West Chemical Metering Pump	41	700	01	Owned					
15	0503	East Chemical Metering Pump	37	290	01	Owned					
16	0505	DET Pretreatment Feed Pump House	30	510	01	Owned					
17	0507	DET Separator Pumphouse	41	520	01	Owned					
18	0515	CP/DDT/Pesticide Production	1,600	15,000	01	Leased					
19	0515A	Nudrin/Endrin Storage	202	1,900	01	Owned					
20	0521	Acetylene Compressor/Pesticide Mfg.	220	1,100	01	Leased					
21	0521A	Refrigeration/DCPD Cracking	36	320	01	Owned					
22	0523	AT Mfg. Bldg./Igniter Tube Filling	300	4,000	01						
23	0523C	Arsenic Trioxide Dry Storage Silo	71	210	01	Leased					
24	0523D	Arsenic Trioxide Dry Storage Silo	96	360	01	Leased					
25	0523E	Arsenic Trioxide Dry Storage Silo	96	360	01	Leased					
26	0523F	Arsenic Trioxide Dry Storage Silo	96	360	01	Leased					
27	0523G	Arsenic Trioxide Dry Storage Silo	96	360	01	Leased					
28	0525	Product Development Lab/Nudrin Mfg.	380	8,100	01	Leased					
29	0526	Pesticide Filter-foundation	26	900	01						
30	0532	Pesticide Storage/Warehouse	1,100	12,000	01	Leased					
31	0533	Flammable Materials Storehouse	19	130	01	Leased					
32	0534	Pumphouse/Storage	330	930	01	Leased					

Table 5.4-7 Inventory of No Future Use, Significant Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Volume (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
33	0534A	Drum Storage/Field Shop/Office	250	2,700	01	Owned					
34	0534B	Planavin Manufacture	470	13,000	01	Owned					
35	0542	Drummed Product Storage/Gen.Storage	1,000	11,000	01						
36	0544	Heavy Equipment Maintenance Shop	180	3,300	01						
37	0561	BCH Unit Control House	170	1,600	01	Owned					
38	0571	Vent Gas Burner	140	520	01	Owned					
39	0571B	Tank Room/HCCPD Drum Storage	130	2,600	01	Owned					
40	0616	Warehouse	910	11,000	03		Short-Term				
41	0624	Repair/Salvage/Surplus Facility	850	24,000	04				Cleanup		
42	0627	Vehicle Maintenance Shop	620	16,000	04		Short-Term		Cleanup		
43	0631	Railcar Maintenance/Roundhouse	350	4,500	04				Cleanup		
44	0643	Flammable Materials Storehouse	55	400	03						
45	0646	Rodent Control Building-foundation	5	840	04						
46	0724	Incinerator/Electostatic Preciptator	460	2,600	01	Owned					
47	0741	Refrigeration Building	880	6,300	01						
48	0834	Incinerator	120	3,800	36						
49	0884	Igloo Storage	210	1,600	06						

[1] These buildings may be reevaluated for potential historic preservation or future use. The Rocky Mountain Arsenal National Wildlife Refuge Act states that "transfer shall be made without cost to the Secretary of the Interior and shall include such improvements on property as the Secretary of the Interior may request in writing for refuge management purposes."

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
1	0112A	Emergency Generator Plant	35	240	35				Cleanup		
2	0112B	BBQ-N of 112	2	16	35						
3	0114	Security Incinerator	8	34	35						
4	0116	Bus Stop Shelter	4	140	01						
5	0132	Shell/MKE Field Headquarters			35				Cleanup	Not in T-24	
6	0136	Garage-to 134-foundation	3	130	35						
7	0137	Garage-to 131-foundation	3	130	35						
8	0148	Storage/Pass Office-NW of 166	1	410	34						
9	0169B	Gas Station House-fdn-S of 150	4	100	34						
10	0176	5-Unit Garage & Unused Apt-foundation	24	1,500	03						
11	0213	Calibration Facility/X Ray Lab	680	4,600	02						
12	0241	Administration/Lab/Change House	290	3,000	02						
13	0244	3 Liquid Chlorine Tank Saddles	30	200	02						
14	0245	Substation Building	23	210	02						
15	0246	HCl Production Facility	56	1,600	02						
16	0248	Brine Treatment Plant-foundation	180	4,200	02						
17	0249	Brine Storage & Pump House-foundation	260	9,300	02						
18	0252	Cell Liquor Storage-foundation	29	2,900	02						
19	0253	50% NaOH Storage-foundation	36	4,500	02						
20	0254	Caustic Fusion Plant/Drum Storage	1,200	16,000	02	Leased					
21	0255	Fuel Oil Pump Station & 2 tank pads	23	300	02	Leased					
22	0256	Fuel Oil Tank-SE corner of 254	6	65	02						
23	0282	Guard Station-foundation-NW of NN0102	7	64	01						
24	0286	Guard Station-SE of 557-foundation	6	64	01						
25	0287	Guard Tower-foundation	6	64	01						
26	0291	Guard Station-foundatn-735'W of 362	6	64	02						
27	0295	Guard Tower-SE of 112-foundation	6	64	02						
28	0296	Guard Tower-foundation	6	64	02						
29	0307	Potable Water Valve & Meter Pit	11	130	36				Cleanup and Beyond		
30	0309	Maintainence/Storage-S of 545	10	420	01						
31	0311	Sterns-Rogers Office/Sample Storage	350	4,400	02				Cleanup		
32	0313A	Sewage Pump Station	3	38	01						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
33	0314	Fixed Laundry Service Building	770	8,600	01						
34	0315A	Steam Meter Pit-W of 315	7	100	01				Cleanup		
35	0316	Plants Dispensary/Clinic	240	3,200	01	Leased					
36	0316	Wood Shed-W of 727	2	100	01	Leased					
37	0316A	Morrison-Knudsen/Change House	340	5,100	01	Owned					
38	0317A	Pipe Shop/Grease Pit	48	2,600	01						
39	0318				35				Cleanup	Not in T-24	
40	0321	Boiler Plant-Central Gas Heat Plant	6,000	56,000	02				Cleanup		
41	0321C	Pumphouse	37	580	02				Cleanup		
42	0321D	Fuel Oil Pumphouse	38	480	02				Cleanup		
43	0322	Coal Sampling Building	30	340	02						
44	0322A	Tractor Storage Shed	34	410	02						
45	0323	Ash (Coal) Storage Silo-Hopper	350	500	02						
46	0324	Coal Hopper Structure	6	160	02						
47	0325	Electrical Power Plant	3,100	12,000	02						
48	0326	Power Plant Pumphouse & Spray Pond	720	15,000	02						
49	0327	Cafeteria-foundation	29	1,600	02						
50	0328	Goop Mixing and Filling Building	2,300	16,000	02						
51	0328A	Toilet House	15	130	02						
52	0329	Gasoline Pump Building	46	400	02						
53	0331	Phosgene Filling Warehouse	1,000	12,000	02				Cleanup		
54	0332	Warehouse	1,000	12,000	02				Cleanup		
55	0333	Warehouse	980	11,000	02				Cleanup		
56	0334	Warehouse	980	11,000	02				Cleanup		
57	0335	Warehouse	990	11,000	02				Cleanup		
58	0336	General Purpose Warehouse	990	11,000	02				Cleanup		
59	0337	Locker Room/Change House	57	590	02						
60	0338	Storage Magazine	12	54	02						
61	0339	Storage Magazine	14	54	02						
62	0340	Magazine	14	54	02						
63	0341	Change House	1,000	12,000	02						
64	0341A	Condensate Pump House	15	160	02				Cleanup		

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
65	0341B	Sewage Lift Station-covered pit	8	71	02						
66	0343	Manuf. Bldg.-PreClustering Warehous	1,000	11,000	02						
67	0343A	Flammable Materials Storehouse	29	240	02						
68	0344	Mfg Assembly/Warehouse	1,200	11,000	02						
69	0345	Mfg Assembly/Storage/Warehouse	1,000	11,000	02						
70	0346	Warehouse	920	11,000	02				Cleanup		
71	0347	Warehouse/Chemical Storage	1,900	27,000	02	Leased			Cleanup		
72	0351	Change House	920	9,000	02						
73	0352	Open Storage-foundation	250	12,000	02						
74	0352A	Quonset Storage	19	970	02						
75	0353	Open Storage-foundation	760	13,000	02						
76	0354	Warehouse	1,000	12,000	02						
77	0355	Warehouse	1,000	13,000	02						
78	0356	Warehouse	1,000	13,000	02						
79	0362	Warehouse	4,000	59,000	02				Cleanup		
80	0364	Sewage Lift Station-SE of 354	21	85	02						
81	0365	Explosive Blending Building	490	3,200	02						
82	0368	Swimming Pool & Filter House	640	1,900	02						
83	0372A	Chlorinator Station	56	380	02		Long-Term		Cleanup		
84	0373	Officer's Quarters	130	1,100	02		Long-Term				
85	0373B	Garage-to 373	42	720	02						
86	0374	Water Treatment Plant-W o'Lr Derby-fdn	110	890	02						
87	0378	Chlorinating Station (on airport)	16	150	10				Cleanup		
88	0379	Chlorinating Station	20	210	03				Cleanup		
89	0381				02				Cleanup	Not in T-24	
90	0382	Chlorinating Station	7	56	03						
91	0383A	Officer's Club Storage	16	82	02						
92	0391	Sewage Disposal & Treatment Plant	88	1,100	24						
93	0392	Sewage Lift Station	46	260	34				Cleanup		
94	0393	Sewage Lift Station	46	260	34				Cleanup		
95	0394	West Gate Sewage Treatment Plant	3	140	33						
96	0395	Toxic Yard Sewage Plant-NW of 867B	7	88	06						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
97	0409	Condensate Pump House	4	130	01						
98	0413	WP Storage/SM Storage	670	5,500	01						
99	0413A	Phossy Water Tank-W of 413	120		01						Tanks/Pipes
100	0415	Caustic Makeup Tank-foundation	79	290	01						
101	0432	Sand Blasting Pad/Change House-fdn	180	9,200	01	Leased					
102	0434	West Gas Holder	730		01	Leased					Tanks/Pipes
103	0435	East Gas Holder	720		01	Leased					
104	0459	Acetylene Generator Building	229	3,200	01	Owned					
105	0459A	Lime Slurry Pumphouse	24	81	01	Owned					
106	0459B	Lime Slurry Pumphouse	36	170	01	Owned					
107	0459C	Small Building-N of 459	6	140	01						
108	0461	Tank Farm Pumphouse	51	430	01	Leased					
109	0464	Sample Building	2	55	01						
110	0471B	Electrical Vault	9	160	01	Owned					
111	0471C	TC Refrigeration	66	730	01	Owned					
112	0472	TC Refrigeration	110	1,200	01	Leased					
113	0472A	Lunchroom/Maintainence Equipmt Stor	24	320	01	Owned					
114	0474	Electrical Control House	16	80	01	Leased					
115	0504	DET Emergency Diesel Generator	31	330	01	Owned					
116	0506	DET Control House	68	830	01	Owned					
117	0508	DET Copper Sulfate Treatment	160	4,700	01	Owned					
118	0509	DET Methyl Cl Compressor/Liquifier	69	430	01	Owned					
119	0510	Methyl Isocyanate Refrigeration	28	300	01	Owned					
120	0511	Chlorinated Paraffin Mfg./Storage	2,500	23,000	01	Leased					
121	0511A	Chlorinated Paraffin/Change House	160	1,700	01	Leased					
122	0512A	Flammable Solvent Storage Shed	7	250	01	Owned					
123	0514C	Pump House	1	96	01	Owned					
124	0514D	Refrigeration Compressor	13	200	01	Owned					
125	0514E	Monomethylamine Dilution Control	4	92	01	Owned					
126	0516B	Misc Electrical Equipment Storage	34	210	01	Owned					
127	0518A	Emergency Fire Protection Generator	22	290	01	Owned			Cleanup		
128	0519	Hydrogen Peroxide Storage	82	290	01	Owned					

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
129	0519A	Hydrogen Peroxide Pumphouse	4	160	01	Owned					
130	0520	Sample Pump/pH Probes Storehouse	1	36	01	Owned					
131	0521B	Compressor House/Maintainence	93	670	01	Owned					
132	0521C	Lunchroom/Field Foreman Office	41	640	01	Owned					
133	0522	WP Cup Filling/Acetylene Mfg	890	9,400	01						
134	0522A	Phossy Water Tank	17	112	01						Tanks/Pipes
135	0522B	Change House/Administration Bldg	420	5,100	01						
136	0523A	WP Storage Tank House	140	1,500	01						
137	0524	WP Filling Building-fndatn	27	1,400	01						
138	0525A	Refrig Compressor/Electrical Vault	31	440	01	Owned					
139	0527	Change House/Quonset Hut	16	1,000	01						
140	0529	NaOH Make Up/Azodrin Support Struct	87	750	01	Leased					
141	0531	Warehouse	970	11,000	01	Leased					
142	0534C	Emergency Generator/Electric Vault	27	210	01	Owned					
143	0534D	Emergency Generator	46	440	01	Owned					
144	0538A	Compressor Building	67	690	01						
145	0539	Electrical Substation Builiding	17	430	01						
146	0541A	Magazine	9	88	01						
147	0543	Maintainence Shops/Instrument Lab	2,000	25,000	01				Cleanup		
148	0543A	Steam Meter Pit	12	93	01				Cleanup		
149	0543B	Facilities Engineers	590	8,700	01				Cleanup		
150	0545	Paint Shop	22	800	01						
151	0546	Sewage Lift Station	12	72	01						
152	0548	Water Pumping Station	370	2,300	01						
153	0549	Reservoir and Cooling Tower	630	4,500	01						
154	0550	Lift Station	6	280	01						
155	0553	Vault	8	64	01						
156	0555	Guardhouse/Gas Mask Training(TW-14)	5	210	01						
157	0557	Salvage Yard Storage/Maintenance	51	1,000	01	Owned					
158	0561A	Acetylene Compressor-foundation	400	5,000	01						
159	0571A	Electrical Vault	21	85	01	Owned					
160	0605	Flammable Materials Storehouse	2	170	03						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
161	0606	Flammable Materials Storehouse-fdn	1	170	03						
162	0607	Flammable Materials Storehouse	2	210	03						
163	0608	Flammable Materials Storehouse	2	210	03						
164	0611	Data Processing Building	440	4,600	04		Short-Term				
165	0612	Courier Building	240	5,100	04		Short-Term				
166	0613	Management Information Systems	480	6,500	04		Short-Term				
167	0614	Warehouse	920	11,000	03						
168	0615	Warehouse	920	11,000	03						
169	0617	Warehouse	920	11,000	03						
170	0621	Property Disposal/Salvage Ofice	890	19,000	04				Cleanup		
171	0621A	Truck Scale Platform	56	740	04				Cleanup		
172	0622	Paint Shop/General Storage	160	1,700	04						
173	0623	Carpenter Shop/Hobby Shop/Auto Shop	230	4,200	04						
174	0625	Warehouse	870	11,000	04				Cleanup		
175	0626	Machine and Welding Shop-foundation	100	6,000	04						
176	0626C	Heavy Equipment Shop-foundation	10	580	04						
177	0627B	Flammable Materials Storehouse	5	240	04						
178	0629	Service Station	44	290	04						
179	0629E	Service Station Shelter	35	25	04						
180	0630	Gas Meter House	37	240	03				Cleanup		
181	0631A	Flammable Materials Storehouse	5	240	04						
182	0632	Gas-Fired Heating Plant	420	1,400	04		Short-Term		Cleanup		
183	0633	Cafeteria/Bug Lab/Movie Theatre	130	2,500	04						
184	0633A	Laboratory/Storehouse	56	680	04						
185	0633B	Hazardous Materials Storage	140	640	04				Cleanup		
186	0634	Flammable Materials Storehouse	58	400	04				Cleanup		
187	0635	Admin Offices-Rocky Mtn Railcar	48	590	03						
188	0639	Lumber Storage	94	4,500	04						
189	0641	Warehouse-foundation	95	900	03						
190	0644	NCO Quarters-foundation	17	1,400	03						
191	0644A	Garage/Storage-foundation	1	40	03						
192	0647A	Motor Pool Dispatch Office	35	1,000	04						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
193	0647B	Motor Pool Vehicle Storage	100	9,600	04		Short-Term				
194	0647C	Motor Pool Vehicle Storage	29	3,000	04		Short-Term				
195	0647D	Motor Pool Vehicle Storage	29	3,000	04		Short-Term				
196	0648	Road Oil Pump and Boiler House	56	350	04						
197	0670				03				Cleanup	Not in T-24	
198	0673	Railcar Scale House	2	88	03				Cleanup		
199	0679	Warehouse/Can Scouring-foundation	62	780	10						
200	0680	Radio Range B-foundation	2	49	09						
201	0684	Guard Tower-E of 644, N of 675-fndn	6	64	03						
202	0685	Guard Tower-SE of 673-foundation	6	64	03						
203	0688	Guard Tower-E of 615-foundation	6	64	03						
204	0727	Facilities Maintenance	98	3,600	01	Owned			Cleanup		•
205	0729	General Purpose Warehouse	1,600	23,000	01	Leased			Cleanup		
206	0731	Reserve Center/Office/Change House	770	12,000	01						
207	0732	Army Reserve Warehouse/M19 Bomb Rew	3,900	47,000	01						
208	0733A	Magazine	34	400	01						
209	0733B	Magazine	34	400	01						
210	0733C	Magazine	34	400	01						
211	0733D	Magazine	58	400	01						
212	0733E	General Purpose Magazine	65	400	01						
213	0733F	General Purpose Magazine	69	400	01						
214	0735	Foamite/Oil Product Storage	37	440	01						
215	0743	RMA Laboratory/Change House/Office	360	5,400	01						
216	0743A	Chemical Sewer Lift Station	4	36	01						
217	0744	Gasoline/Benzol Pumphouse	78	760	01						
218	0745	Fire Fighting Manifolds for 745ABC	21	24	01						
219	0746	Gasoline Unloading Rack	2	1	01	Leased					
220	0748	Flammable Materials Storehouse	49	400	01						
221	0751	Paint and Process Shop	640	5,500	01						
222	0752	Carpenter Shop/Storage	610	4,900	01						
223	0752A	Lumber Storage	110	1,000	01						
224	0753	Steam Fitter Maintenance/Storage	52	1,000	01						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
225	0754	Lumber Storage	49	840	01						
226	0765	Potable Water Purificaton			01				Cleanup	Not in T-24	
227	0784	Guard Station-SE of 742-foundation	6	64	01						
228	0787	Warehouse	480	9,600	06		Long-Term		Cleanup Use		
229	0801	Radio Relay Station-N of 1726	12	180	25				Cleanup		
230	0808	No Bdry Groundwater Treatment Plant	650	3,900	23				Cleanup Use		
231	0809	Irondale Groundwater Treatment Sys.	320	3,000	33				Cleanup		
232	0810	NW Bndry Groundwater Treatment Bldg	490	3,100	27				Cleanup		
233	0825	Basin A Neck Treatment Bldg.			35				Cleanup	Not in T-24	
234	0831	Technical Escort/Officer's Quarters	120	1,100	35				Cleanup		
235	0831A	Garage/Storage Shed	27	360	35				Cleanup		
236	0833	Lumber Storage Shed	82	580	35						
237	0836	Air Force Seismic Monitoring	590	7,100	24						
238	0840	Air Monitoring Station			25				Cleanup	Not in T-24	
239	0841	CO Public Service Co Meter House	82	200	12				Cleanup and Beyond		
240	0851	Pistol Range House	6	250	19						
241	0853	Observation Pit/Mortar Range	94	2,000	30		Long-Term				
242	0854	Concrete Wall	12	200	26						
243	0863	Target Range House	5	260	12						
244	0864	General Storehouse	10	400	06						
245	0865	Warehouse	41	1,000	06						
246	0866	Toxic Yard Office & Change House	140	2,400	06				Cleanup		
247	0867A	Toxic Yard Metal and Wood Shop	67	1,600	06						
248	0867B	Flammable Materials Storehouse	13	190	06						
249	0871A	Magazine	66	600	06		Long-Term				
250	0871B	Magazine	66	600	06		Long-Term				
251	0871C	Magazine	66	600	06						
252	0871D	Magazine	86	800	06						
253	0872A	Magazine	86	800	06						
254	0872B	Magazine	86	800	06						
255	0872C	Magazine	86	800	06						
256	0872D	Magazine	86	800	06						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
257	0873A	Magazine	86	800	06						
258	0873B	Magazine	86	800	06						
259	0873C	Magazine	86	800	06						
260	0874A	Magazine	86	800	06						
261	0874B	Magazine	86	800	06						
262	0874C	Magazine	86	800	06						
263	0874D	Magazine	86	800	06						
264	1403	2-HF Storage Tanks & Unloading Dock	83		25						Tanks/Pipes
265	1404	Carbon Tetrachloride Storage Tank	83		25						Tanks/Pipes
266	1405	Hydrochloride Acid Storage Tanks	83		25						Tanks/Pipes
267	1502	Unloading Dock-Isopropanol Storage	83		25						Tanks/Pipes
268	1504A	Monitoring Shed	7	220	25						
269	1505A	Sentry Station	2	85	25						
270	1507	Methanol Storage Tank	83		25						Tanks/Pipes
271	1508	TBA Storage Tank	84		25						Tanks/Pipes
272	1509	Isopropanol Dehydration Unit	76	400	25			Treaty			
273	1510	Fuel Oil Tank	1,200		25						Tanks/Pipes
274	1510A	Fire Apparatus Buildng/Foam Storage	16	130	25						
275	1512	Sentry Station/Gate House	18	130	25			Treaty			
276	1611A	Sentry Station	4	84	25						
277	1618	General Storehouse-N of North Plant	36	1,000	25						
278	1619	Administration Building-N o'N Plant	8	320	25						
279	1622	General Storehouse-N of North Plant	34	970	25						
280	1701	Warehouse	2,300	26,000	25			Treaty	Cleanup		
281	1704	Compressed Air Plant	1,400	9,100	25			Treaty			
282	1705	Instruction Building/Cafeteria	250	4,000	25			Treaty			
283	1706	Sentry Station/Gatehouse	44	360	25		Long-Term	Treaty			
284	1707	Cooling Tower	560	2,800	25			Treaty			
285	1710	Clinic and Administration Building	920	15,000	25				Cleanup		
286	1711	Gas Meter House	6	170	25				Cleanup		
287	1712	Gas Heating Plant	320	2,300	25						
288	1713	Standby Generator Plant	100	2,500	25			Treaty	Cleanup		

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
289	1715				25				Cleanup	Not in T-24	
290	1717	Chlorinating Station	11	120	25				Cleanup		
291	1718	Valve Pit & Chlorinating Station	24	260	25				Cleanup		
292	1719	Electrical Distribution System	13	130	25				Cleanup		
293	1726	Elevated Process Water Tank, North Plants	270		25		Short-Term		Cleanup		Tanks/Pipes
294	1728	Potable Water Tank	69		25						Tanks/Pipes
295	1730	Guardhouse	13	110	31						
296	1734	Change House	48	470	31		Long-Term				
297	NN0101	Valve Gate-W side of Upper Derby	20	49	01		Long-Term				
298	NN0102	Foundation-N of 534B	19	750	01						
299	NN0103	Bathroom-N of 533	3	120	01						
300	NN0104	Flare Tower-N of 571B, NW of 571	17	660	01	Owned					
301	NN0105	Gas Meter House-SW of 508	5	200	01						
302	NN0106	Fertil & Waste Loadng Fac-N of 728	78	99	01						
303	NN0107	Metal Shed-W of 733B	1	310	01						
304	NN0108	Metal Shed-W of 733C	1	310	01						
305	NN0109	Guard Station-NE of 732	1	64	01						
306	NN0110	Metal Shed-S of 521B	3	80	01						
307	NN0111	Three Metal Incinerator-NW of 541	150	440	01	Owned					
308	NN0112	Stack Observation Station-E of 527	12	280	01						
309	NN0113	2 Metal Sheds-S of 474 SS	27	250	01						
310	NN0114	Wooden Hut-SW of 461	2	22	01						
311	NN0115	Flare Tower-N of Lime Pond	17	660	01	Owned					
312	NN0116	Long Metal Shed-S of 544	47	6,000	01						
313	NN0117	2 Sheds-SW of 557	4	130	01						
314	NN0201	Concrete Silo-NW of 254	350	1,300	02						
315	NN0202	Brick Structure-E of SS 361	15	140	02						
316	NN0204	Coal Hopper foundation-N of 334	38	1,100	02						
317	NN0205	Brick Valve House-S of 321B	27	150	02						
318	NN0300				03				Cleanup	Not in T-24	
319	NN0301	Metal Shed-N of 618	1	410	03						
320	NN0302	Metal Shed-N of 618	1	410	03						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
321	NN0303	Metal Shed-N of 619	1	2,400	03						
322	NN0304	Metal Shed-N of 619	1	1,900	03						
323	NN0601	Loading Dock-W of 866	150	11,000	06						
324	NN0602	Long Metal Shed-W of 865	1	3,500	06						
325	NN0603	Metal Shed-E of 867A	1	510	06						
326	NN0902	Survey Tower-N of Post Office	1	140	09				Cleanup		
327	NN1208	Brick Structure-900'SW of 846	9	81	12						
328	NN1209	Concrete Bunker-1100'S of 846	14	68	12						
329	NN1210	Concrete Bunker-1250'S of 846	10	56	12						
330	NN1211	Concrete Bunker-1300'S of 846	14	68	12						
331	NN1212	Concrete Bunker-1350'S of 846	6	64	12						
332	NN1213	AMSA/OMS Maintenance Shop-N of 841	780	10,000	12						
333	NN2001	Antenna Installation-1/2 mi N o'9th	17	44	20						
334	NN2002	Tank Pad-N of 9th, 2/3 mi E of F St	14	380	20				Cleanup		
335	NN22	36 GW Wells-NW Boundary Treatment			22						
336	NN23	36 GW Wells-N Boundary Treatment			23						
337	NN2301	Abandoned Water Purification Plant	60	1,600	23						
338	NN24	56 GW Wells-N Boundary Treatment			24						
339	NN2401	Concrete Structure-E of Bog	3	25	24						
340	NN2402	Wooden Shed-N of Trickling Filters	7	170	24						
341	NN2403	2 Trickling Filters-S of 391	1,800	17,000	24						
342	NN2404	Imhoff Tank-S of 391	410	2,800	24						
343	NN2405	Antenna Installation-N of 836	12	44	24						
344	NN2501	Shed-NW of 1618	8	300	25						
345	NN2502	Gas Pump & Pad-NE of 1618	32	950	25						
346	NN2503	Pumping Station-S of 1510	4	72	25						
347	NN2601	Decon Pad/Tank-NE of Basin F	58	2,300	26						
348	NN2602	Valve gate-N end of Reservoir C	19	56	26						
349	NN28	2 GW Wells-Irondale Treatment			28						
350	NN3001	Metal Shed-E of 853	1	580	30						
351	NN3002	Metal Shed-E of 853	1	580	30						
352	NN3101	Metal Shed-N of 1734	1	80	31						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
353	NN3102	3 Sets Shed Siding-1100'SE of 1735	2,400	59,000	31						
354	NN3103	Storage Bldg-Toxic Storage Yard	1	1,500	31						
355	NN3104	Shack-W of Berms-Toxic Storage Yard	1	70	31						
356	NN3105	Shed-NW End of Berms-Toxic Storg Yd	1	110	31						
357	NN3106	Shed-NE End Berms-Toxic Storage Yd	2	4,000	31						
358	NN3107	Antenna Station-Toxic Storage Yard	4	32	31						
359	NN3108	Shed-SW End of 1st Berm-Toxic Yard	1	110	31						
360	NN3109	Shed-SE End of 1st Berm-Toxic Yard	2	4,000	31						
361	NN33	45 GW Wells-Irondale Treatment			33						
362	NN3501	3 Communications Antenna Pits	6	48	35						
363	NN3601	Incinerator-500'NE of 834	30	350	36						
364	NN3602	Incinerator-1000'SE of 834	6	100	36						
365	NN3603	Metal Shed-NW of 725	4	140	36						
366	NN3604	Metal Shed-SW of 725	6	200	36						
367	NN3605	Metal Shed-SE of 725	2	200	36						
368	NNT0101	Vertical Tank-TF0101	21		01						Tanks/Pipes
369	NNT0103	Vertical Tank-TF0106	1		01						Tanks/Pipes
370	NNT0105	Horizontal Tank-TF0108	1		01						Tanks/Pipes
371	NNT0106	Vertical Tank-TF0109	2		01						Tanks/Pipes
372	NNT0107	Horizontal Tank-E of 471C	1		01						Tanks/Pipes
373	NNT0110	Horizontal Tank-E of 536	1		01						Tanks/Pipes
374	NNT0111	Vertical Tank-TF0105	5		01						Tanks/Pipes
375	NNT0201	Undrground Oil Tank w/DCPD-W of 321	1		02						Tanks/Pipes
376	PR01	Pipe Runs in Section 1	2,000		01						Tanks/Pipes
377	PR02	Pipe Runs in Section 2	520		02						Tanks/Pipes
378	PR04	Pipe Runs in Section 4	100		04						Tanks/Pipes
379	PR25	Pipe Runs in Section 25	820		25						Tanks/Pipes
380	PR36	Pipe Runs in Section 36	470		36						Tanks/Pipes
381	SS 0100	Substation-1T-30'N of 866			06						
382	SS 0101	Substation-2T-200'NE of 866			06						
383	SS 0102	Substation-1T-500'W of 867A			06						
384	SS 0103	Substation-1T-700'W of 865			06						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
385	SS 0104	Substation-1T-400'N of 872A			06						
386	SS 0105	Substation-1T-NE of 867A			06						
387	SS 0111	Substation-2T-N side 111			35						
388	SS 0112	Substation-1T-150'S of 112			02		Short-Term				
389	SS 0121	Substation-1T-NW corner of section			03						
390	SS 0141	Substation-3T-E of 141			04						
391	SS 0176	Substation-1T-W of Staff Quarters			03						
392	SS 0213	Substation-3T-SE of 213			02		Short-Term				
393	SS 0232	Substation-3T-SW of 254			02						
394	SS 0243	Substation-1T-W of 243			02						
395	SS 0245	Substation-3T-S of 245			02						
396	SS 0311	Substation-1T-S of 311			02						
397	SS 0312	Substation-1T-S of 312			01						
398	SS 0312A	Substation-1T-NE of 312			36						
399	SS 0313	Substation-3T-W of 313			01						
400	SS 0313-2	Substation-3T-W of 313			01						
401	SS 0314	Substation-3T-NW of 314			01						
402	SS 0315	Substation-3T-SW of 315			01						
403	SS 0316	Substation-1T-S of 316			01						
404	SS 0316A	Substation-3T-S of 316A			01						
405	SS 0317	Substation-1T-NW of 433			01						
406	SS 0321	Substation-6T-S of 321			02						
407	SS 0321A	Substation-3T-SW of 242			02						
408	SS 0321B	Substation-1T-SE of 242			02						
409	SS 0325	Substation-14T-between 325 & 311			02						
410	SS 0327	Substation-3T-W of 332			02						
411	SS 0328	Substation-3T-N of 328			02						
412	SS 0330	Substation-1T-SW of 337			02						
413	SS 0335	Substation-3T-S of 336			02						
414	SS 0342	Substation-3T-ENE of 342			02						
415	SS 0344	Substation-5T-E of 344			02						
416	SS 0355	Substation-3T-E of 356			02						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
417	SS 0361	Primary Substation-68T-SE of 112			02						
418	SS 0362	Substation-3T-N of 362			02						
419	SS 0363	Substation-3T-N of 362			02						
420	SS 0365	Substation-3T-N of 365			02						
421	SS 0368	Substation-1T-1/4 mi SSE of 351			01						
422	SS 0371A	Substation-1T-S of 372			02		Short-Term				
423	SS 0371B	Substation-1T-N of SS 371			02		Short-Term				
424	SS 0378	Substation-1T-N of 378			03		Short-Term				
425	SS 0379	Substation-1T-SE of 379			03		Short-Term				
426	SS 0383	Substation-3T-E of 383			02		Short-Term				
427	SS 0391	Substation-3T-SE of 391			24						
428	SS 0392	Substation-2T-W of 392			34		Short-Term				
429	SS 0393	Substation-2T-S of 393			34		Short-Term				
430	SS 0411	Substation-3T-NE of 411			01						
431	SS 0422	Substation-3T-W of 422			01						
432	SS 0451	Substation-1T-SE of 413			01						
433	SS 0461	Substation-2T-S of 459			01						
434	SS 0464	Substation-2T-SE of 464			01						
435	SS 0474	Substation-7T-W of 472			01						
436	SS 0510	Substation-3T-SE of 510			01						
437	SS 0512	Substation-3T-NW of 517			01						
438	SS 0514	Substation-3T-200'E of 561			01						
439	SS 0515	Substation-6T-NW of 515			01						
440	SS 0516	Substation-3T-W of 519			01						
441	SS 0517	Substation-2T-NW of 517			01						
442	SS 0517A	Substation-3T-N of 512			01						
443	SS 0517B	Substation-3T-SW corner of 517			01						
444	SS 0521	Substation-3T-SW of 521			01						
445	SS 0523	Substation-3T-S of 803			26						
446	SS 0525A	Substation-1T-SW of 525			01						
447	SS 0527	Substation-1T-S of 527			01						
448	SS 0528	Substation-1T-S of 529			01						

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
449	SS 0529	Substation-3T-S of 540			01						
450	SS 0531	Substation-1T-W of 531			01						
451	SS 0534	Substation-3T-200'N of 534A			01						
452	SS 0539	Substation-2T-SE of 537			01						
453	SS 0541	Substation-3T-W of 541			01						
454	SS 0543	Substation-5T-W of 543			01						
455	SS 0548	Substation-1T-N of 548			01						
456	SS 0548A	Substation-1T-101'W of 548			01						
457	SS 0556	Substation-1T-N of 541			01						
458	SS 0571	Substation-3T-75'W of 504A			01						
459	SS 0575	Substation-1T-N of 504			01						
460	SS 0575A	Substation-1T-N of 505			01						
461	SS 0611	Substation-3T-S of 611			04		Short-Term				
462	SS 0612	Substation-1T-E of 612			04		Short-Term				
463	SS 0613	Substation-3T-NW of 613			04		Short-Term				
464	SS 0614	Substation-1T-W of 614			03						
465	SS 0616	Substation-3T-N of 614			03						
466	SS 0618	Substation-3T-N of 618			03						
467	SS 0618-2	Substation-1T-W of 618			03						
468	SS 0622	Substation-1T-NE of 621			04						
469	SS 0624	Substation-3T-E of 624			04						
470	SS 0625	Substation-1T-E of 624			04						
471	SS 0627	Substation-3T-E of 627			04		Short-Term				
472	SS 0627A	Substation-1T-E of SS 627			04		Short-Term				
473	SS 0629	Substation-3T-NE of 629			04						
474	SS 0631	Substation-3T-N of 631			04						
475	SS 0632	Substation-1T-NE of 632			04		Short-Term				
476	SS 0633	Substation-3T-S of 633			04						
477	SS 0634	Substation-3T-SE of 634			04						
478	SS 0635	Substation-1T-W of 635			03						
479	SS 0647	Substation-1T-E of 647A			03						
480	SS 0673	Substation-1T-1200'NNE of 619			03		Short-Term				

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
481	SS 0725	Substation-3T-S of SS 726			36						
482	SS 0726	Substation-3T-200'S of 725			36						
483	SS 0727	Substation-1T-W side of 727			01						
484	SS 0728	Substation-3T-E of 728			01						
485	SS 0729	Substation-6T-E of 729			01						
486	SS 0732	Substation-6T-S of 732			01						
487	SS 0742	Substation-6T-N of 742			01						
488	SS 0747	Substation-1T-75'S of 729			01						
489	SS 0755	Substation-3T-S of 868C			01						
490	SS 0756	Substation-1T-W of 868C			01						
491	SS 0757	Substation-1T-S of 463D			01						
492	SS 0780	Substation-1T-N of T 1505			01						
493	SS 0781	Substation-1T-NE of T 1507			01						
494	SS 0782	Substation-1T-N of 732			01						
495	SS 0791-2	Substation-1T-E of 145			11						
496	SS 0806D	Substation-1T-SE of 806			26						
497	SS 0806G	Substation-1T-0.25 mi SW of 9 & D			26						
498	SS 0808ABC	Substation-3T-NE of 808			23						
499	SS 0808D	Substation-1T-0.3 mi SW of 808			23						
500	SS 0808E	Substation-1T-0.2 mi SW of 808			23						
501	SS 0808F	Substation-1T-427'SSE of 808			24						
502	SS 0808G	Substation-1T-800'SE of 808			24						
503	SS 0808H	Substation-1T-0.36 mi ESE of 808			24						
504	SS 0808I	Substation-1T-0.49 mi ESE of 808			24						
505	SS 0808K	Substation-1T-0.68 mi ESE of 808			24						
506	SS 0808L	Substation-1T-0.65 mi E of 808			24						
507	SS 0809	Substation-3T-S of 809			33						
508	SS 0809A	Substation-3T-300'SW of 809			33						
509	SS 0809B	Substation-3T-200'W of 809			33						
510	SS 0809C	Substation-3T-400'N of 809			33						
511	SS 0809D	Substation-3T-700'NE of 809			33						
512	SS 0809E	Substation-3T-500'E of 809			33						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
513	SS 0809F	Substation-3T-0.2 mi S of 809			33						
514	SS 0831	Substation-3T-200'S of 8th & D St			35						
515	SS 0831E	Substation-1T-538'SSE of 8th & D St			36						
516	SS 0832	Substation-1T-300'E of 159			34						
517	SS 0836	Substation-3T-S of 836			24						
518	SS 1402	Substation-3T-150'W of 1601/1701			25						
519	SS 1403	Substation-3T-S of 1701			25						
520	SS 1404	Substation-3T-130'S of 1501			25						
521	SS 1501	Substation-7T-SE of 1501			25						
522	SS 1505	Substation-3T-E of 1505			25						
523	SS 1506	Substation-2T-NW corner of 1506			25						
524	SS 1510	Substation-2T-150'W of 1601			25						
525	SS 1601-1	Substation-1T-E of 1601			25						
526	SS 1601-2	Substation-1T-E of 1601			25						
527	SS 1602	Substation-2T-100'SE of 1606			25						
528	SS 1603	Substation-3T-100'NE of 1602			25						
529	SS 1605	Substation-1T-between 1605 & 1608			25						
530	SS 1606-1	Substation-3T-100'E of 1606			25						
531	SS 1606-2	Substation-1T-100'NE of 1606			25						
532	SS 1607	Substation-3T-100'E of 1607			25						
533	SS 1609	Substation-1T-150'NE of 1609			25						
534	SS 1611	Substation-1T-E of 1611			25						
535	SS 1611AB	Substation-2T-S of 1611			25						
536	SS 1614	Substation-2T-NE o'1615			25						
537	SS 1616	Substation-2T-NE of 1616			25						
538	SS 1701	Substation-3T-100'E of 1701			25						
539	SS 1702	Substation-2T-W of 1702			25						
540	SS 1703	Substation-1T-S of 1703			25						
541	SS 1704-1	Substation-3T-E of 1704			25						
542	SS 1704-2	Substation-2T-E of 1704			25						
543	SS 1704-3	Substation-3T-E of 1704			25		Long-Term				
544	SS 1706	Substation-1T-N of 1706			25						

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
545	SS 1707	Substation-1T-S of 1704			25						
546	SS 1710	Substation-3T-100'E of 1710			25						
547	SS 1711	Substation-3T-100'E of 1706			25						
548	SS 1724	Substation-3T-200'N of 1706			25						
549	SS 1730	Substation-2T-NW of 1730			31						
550	SS 1731	Substation-1T-200'NW of 1730			31						
551	SS 1732	Substation-1T-NW corner of section			31						
552	SS 1735	Substation-3T-E of 1736			31						
553	SS 1736	Substation-2T-200'S of 1736			31						
554	SS 6C	Substation-1T-SW corner of section			02						
555	SS 7215	Substation-1T-fenced railcar area			36						
556	SS 7C	Substation-1T-112'ESE 7th & C			02						
557	SS AL338	Substation-1T-SE corner of section			31						
558	SS AWL021	Substation-1T-S of pool rd			02						
559	SS CPR 1	Rectifier-1R-130'SSE of 254			02						
560	SS CPR 10	Rectifier-1R-S of 742A			01						
561	SS CPR 2	Rectifier-1R-W of 313			01						
562	SS CPR 3	Rectifier-1R-146'W of 326			02						
563	SS CPR 4	Rectifier-1R-E of 352A			02						
564	SS CPR 5	Rectifier-1R-with SS 514			01						
565	SS CPR 6	Rectifier-1R-with SS 515			01						
566	SS CPR 7	Rectifier-1R-NE of SS 411			01						
567	SS CPR 8	Rectifier-1R-W of 433			01						
568	SS CPR 9	Rectifier-1R-W of 542			01						
569	SS F182	Substation-1T-500'W of T 1512			36						
570	SS FL842	Substation-1T-N of 1618			25						
571	SS GA	Substation-1T-0.1 mi N of 732			36						
572	SS H-1	Substation-2T-SE of 319			01						
573	SS LDLA	Substation-1T-W of Lower Derby			01						
574	SS NN2201	Substation-1T-640'NNW of 810			22						
575	SS NN2202	Substation-1T-960'NNW of 810			22						
576	SS NN2203	Substation-1T-1260'NW of 810			22						

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
577	SS NN2204	Substation-1T-1600'NW of 810			22						
578	SS NN2205	Substation-1T-2050'NW of 810			22						
579	SS NN2206	Substation-1T-2500'NW of 810			22						
580	SS NN2207	Substation-1T-800'WNW of 810			22						
581	SS NN2208	Substation-1T-1100'WNW of 810			22						
582	SS NN2209	Substation-1T-1350'WNW of 810			22						
583	SS NN2210	Substation-1T-1670'WNW of 810			22						
584	SS NN2211	Substation-1T-2370'WNW of 810			22						
585	SS NN2301	Substation-3T-200'N of 808			23						
586	SS NN2501	Substation-1T-SE corner of 1602			25						
587	SS NN2601	Substation-1T-S of 806			26						
588	SS NN2701	Substation-3T-W of 810			27						
589	SS PSCOST	Substation-1T-1/8 mi S of 7th on C			02						
590	SS PT56/57	Substation-2T-NE of 510			01						
591	SS SBA	Substation-3T-SE side of 834			36						
592	SS SWIM	Substation-1T-W of pool/on C			02						
593	SS WR	Substation-1T-600'NE of 732			36						
594	T 0026	Horizontal Tank-TF0107	1		01	Owned					Tanks/Pipes
595	T 0064	Horizontal Tank-TF0107	1		01	Owned					Tanks/Pipes
596	T 0065	Vertical Tank-TF0103	31		01						Tanks/Pipes
597	T 0075	Vertical Tank-TF0103	1		01						Tanks/Pipes
598	T 0076	Vertical Tank-TF0103	1		01						Tanks/Pipes
599	T 0078	Vertical Tank-TF0103	1		01						Tanks/Pipes
600	T 0139	Horizontal Tank-TF0107	1		01						Tanks/Pipes
601	T 0190	Horizontal Tank-TF0107	3		01						Tanks/Pipes
602	T 0289	Air Receiver/Surge Tank-NE of 516	1		01						Tanks/Pipes
603	T 1040	Vertical Tank-TF0107	1		01	Owned					Tanks/Pipes
604	T 1128	Methanol Tank-TF0104	1		01						Tanks/Pipes
605	T 1129	MMAA Tank-TF0104	1		01						Tanks/Pipes
606	T 1132	Trimethylphosphite(TMP) Tank-TF0103	1		01						Tanks/Pipes
607	T 1133	MMA Tank-TF0104	1		01						Tanks/Pipes
608	T 1140	Chloroform Tank-TF0104	1		01						Tanks/Pipes

Table 5.4-8 Inventory of No Future Use, Other Contamination History Medium Group

Place #	Structure Number	Description of Structure	Bank Vol (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
609	T 1146	Dicetene Tank-TF0110	2		01						Tanks/Pipes
610	T 1147	Dicetene Tank-TF0110	2		01						Tanks/Pipes
611	T 1168	Brine Storage Tank-SE corner 528	5		01						Tanks/Pipes
612	T 1178	Acetone Storage Tank-TF0103	1		01						Tanks/Pipes
613	T 1216	Mother Liquor/Dinitro Tank-TF0102	6		01						Tanks/Pipes
614	T 1324	Brine Storage Tank-TF0103	1		01						Tanks/Pipes
615	T 1327	Vertical Tank-TF0103	17		01						Tanks/Pipes
616	T 1340	Crystal, Acetone Tank-TF0102	16		01						Tanks/Pipes
617	T 1392	Vertical Tank-E of 512	5		01						Tanks/Pipes
618	T 1463	Vertical Tank-TF0104	2		01						Tanks/Pipes
619	T 1570	Vertical Tank-TF0105	5		01	Owned					Tanks/Pipes
620	T 1606	Horizontal Tank-TF0109	5		01						Tanks/Pipes
621	T 1973	Vertical Tank-TF0103	2		01						Tanks/Pipes
622	TF0107	Tank Farm-W & S of 514A	110		01						Tanks/Pipes
623	TF2501	Tank Farm-W of 1704	25		25						Tanks/Pipes
624	TW-13	Open Storage-foundation-N of 1611	120	5,800	25						
625	V 1064	Vertical Tank-TF0109	1		01						Tanks/Pipes
626	V 1214	Vertical Tank-TF0106	2		01						Tanks/Pipes
627	V 1220	Vertical Tank-TF0106	6		01						Tanks/Pipes
628	V 1250	Horizontal Tank-TF0104	1		01						Tanks/Pipes
629	V 1253	Horizontal Tank-TF0104	1		01						Tanks/Pipes
630	V 1267	Surge Vessel-TF0105	2		01						Tanks/Pipes
631	V 1270	Horizontal Tank-TF0105	1		01						Tanks/Pipes

[1] These buildings may be reevaluated for potential historic preservation or future use. The Rocky Mountain Arsenal National Wildlife Refuge Act states that "transfer shall be made without cost to the Secretary of the Interior and shall include such improvements on property as the Secretary of the Interior may request in writing for refuge management purposes."

Table 5.4-9 Inventory of No Future Use, Agent History Medium Group

Place #	Structure Number	Description of Structure	Bank Volume (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
1	0313	Laboratory	1,000	10,000	01						
2	0315	Warehouse-Laundry	1,000	10,000	01						
3	0319	Magazine/Flammable Material Storage	52	400	01						
4	0414	Mustard Scrubber Unit-foundation	79	310	01						
5	0416	H/Dichlor Disposal Reactor-foundatn	79	300	01						
6	0417	H/Dichlor Decon Pit-foundation	79	280	01						
7	0422	H Manufacture/Aldrin Production	2,100	23,000	01	Leased					
8	0426	Mustard Disposal Reactor-foundation	59	1,600	01	Leased					
9	0427	Decontamination Pit-fdn	4	80	01	Leased					
10	0428	Incinerator	6	56	01						
11	0429	H Brine Mixing/Pesticide Mfg.	15	560	01						
12	0512	Filling/Pesticide Production	610	3,800	01	Leased		Treaty			
13	0514	Lewisite/HD/Pesticide Production	3,200	27,000	01	Leased		Treaty			
14	0514A	L/M-1 Storage/Dowtherm Boiler	110	1,700	01	Leased		Treaty			
15	0516	Lewisite Distillation/Pest. Prod.	1,400	13,000	01	Leased					
16	0517	Offices/Change House/Laboratory	1,300	18,000	01	Leased					
17	0528	HD Burning/Pesticide Manufacture	380	2,200	01	Leased					
18	0536	Ammo.Dem.Facility/Crude Mustard Sto.	990	4,100	01						
19	0537	Thaw House	2,300	16,000	01			Treaty			
20	0538	Ton Container Reconditioning Plant	1,200	15,000	01			Treaty			
21	0540	Ton Container Renovation Plant	330	4,900	01						
22	0541	Warehouse/WP Filling	770	11,000	01						
23	0725	Bomb Testing Station	99	460	36						
24	0726	Bomb Test Building	40	430	36						
25	0728	HD Filling/Pesticide Storage/Wareh.	1,400	21,000	01				Cleanup		
26	0742	Warehouse	4,800	49,000	01			Treaty	Cleanup		
27	0742A	Tank House	330	1,300	01			Treaty			
28	0785	Warehouse	1,400	29,000	06		Long-Term				
29	0786	Warehouse	480	9,600	06		Long-Term		Cleanup		
30	0788	Warehouse	480	9,600	06		Long-Term		Cleanup		
31	0791	Warehouse	480	9,600	31				Cleanup		
32	0792	Drum Storage Warehouse	440	9,600	31				Cleanup		

Table 5.4-9 Inventory of No Future Use, Agent History Medium Group

Place #	Structure Number	Description of Structure	Bank Volume (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
33	0793	Drum Storage Warehouse	470	9,600	31				Cleanup		
34	0794	Drum Storage Warehouse	520	9,600	31				Cleanup		
35	0795	Drum Storage Warehouse	480	9,600	31				Cleanup		
36	0796	Warehouse	480	9,600	31				Cleanup		
37	0797	Drum Storage Warehouse	480	9,600	31				Cleanup		
38	0798	Drum Storage Warehouse	480	9,600	31				Cleanup		
39	0881	Igloo Storage	210	1,600	06		Long-Term		Cleanup		
40	0882	Igloo Storage	210	1,600	06				Cleanup		
41	0883	Igloo Storage	210	1,600	06						
42	0885	Igloo Storage	210	1,600	06		Long-Term		Cleanup		
43	0886	Igloo Storage	210	1,600	06				Cleanup		
44	1501	GB Manufacturing/Demil. Building	9,000	81,000	25			Treaty			
45	1503A	Scrubber Facility-1503A/B/C=1503	440	580	25			Treaty			
46	1503B	Scrubber Facility-1503=1503A/B/C	88	580	25			Treaty			
47	1503C	Scrubber Facility-1503=1503A/B/C	79	580	25			Treaty			
48	1504	200-ft Steel Stack	630	710	25			Treaty			
49	1506	GB Storage	1,900	9,000	25			Treaty			
50	1601	GB Filling	7,700	69,000	25			Treaty			
51	1601A	Ammunitions Demilitarization Facility	670	2,800	25			Treaty			
52	1602	Paint Storage	620	2,200	25			Treaty			
53	1603A	Scrubber Facility	89	580	25						
54	1603B	Scrubber System-1603=1603A/B	89	580	25						
55	1605	Munitions Storage Igloo	150	1,000	25						
56	1606	Cluster Assembly Buildinge	14,000	60,000	25			Treaty			
57	1607	Warehouse	1,700	26,000	25			Treaty	Cleanup		
58	1608	Munitions Storage Igloo	150	1,000	25						
59	1609	Munitions Storage Igloo	150	1,000	25						
60	1610	Munitions Storage Igloo	150	1,000	25						
61	1611	Demilitarization Facility	3,100	32,000	25						
62	1613	Explosive Unpacking Building	77	750	25			Treaty			
63	1614	Warehouse	260	7,800	25						
64	1615	Warehouse	170	4,000	25			Treaty			

Table 5.4-9 Inventory of No Future Use, Agent History Medium Group

Place #	Structure Number	Description of Structure	Bank Volume (BCY)	Size (SF)	Section	Shell Use	USFWS Use[1]	Treaty	Cleanup Use	Added After Task 24	Pipe Runs & Tanks
65	1616	Warehouse	85	4,000	25			Treaty			
66	1702	Weld Shop	49	2,400	25						
67	1703	Spray Dryer Facility	2,700	28,000	25			Treaty			
68	1727	Industrial Waste Sewer	36	700	25			Treaty			
69	1735	Loading Dock	670	11,000	31						
70	T 0027	Vertical Tank-TF0107	1		01						Tanks/Pipes

[1] These buildings may be reevaluated for potential historic preservation or future use. The Rocky Mountain Arsenal National Wildlife Refuge Act states that "transfer shall be made without cost to the Secretary of the Interior and shall include such improvements on property as the Secretary of the Interior may request in writing for refuge management purposes."

Table 5.4-10 Soil Exceedance Categories, Medium Groups, and Subgroups

Human Health Exceedance Category

- Basin A Medium Group
- Basin F Medium Group
  - Basin F Wastepile Subgroup
  - Former Basin F Subgroup
- Secondary Basins Medium Group
- Sewer Systems Medium Group
  - Chemical Sewers Subgroup
  - Sanitary/Process Water Sewers Subgroup
- Disposal Trenches Medium Group
  - Complex Trenches Subgroup
  - Shell Trenches Subgroup
  - Hex Pit Subgroup
- Sanitary Landfills Medium Group
- Lime Basins Medium Group
  - Section 36 Lime Basins Subgroup
  - Buried M-1 Pits Subgroup
- South Plants Medium Group
  - South Plants Central Processing Area Subgroup
  - South Plants Ditches Subgroup
  - South Plants Balance of Areas Subgroup
- Buried Sediments/Ditches Medium Group
  - Buried Sediments Subgroup
  - Sand Creek Lateral Subgroup
- Undifferentiated Medium Group
  - Section 36 Balance of Areas Subgroup
  - Burial Trenches Subgroup

Biota Exceedance Category

- Surficial Soil Medium Group
- Lake Sediments Medium Group
- Ditches/Drainage Areas Medium Group

Potential Agent Presence Category

- Agent Storage Medium Group
  - North Plants Subgroup
  - Toxic Storage Yards Subgroup

Potential UXO Presence Category

- Munitions Testing Medium Group

Table 5.4-11 Summary of Soil Medium Groups and Subgroups

Medium Groups	Subgroup	Description
Munitions Testing	—	This group is comprised of sites having similar histories and uses. The sites, considered potential HE-filled UXO presence areas and predominantly located in the eastern portions of RMA, were used for testing or destruction of nonchemical munitions. These sites typically contain slag, debris, and potential UXO in the uppermost 1 ft of soil and therefore present physical hazards. The mortar impact area in Section 30 may contain UXO at depths as deep as 6 ft. COC concentrations were not detected above human health SEC at any of the sites.
Agent Storage	North Plants	Sites in this subgroup have potential agent presence but do not contain human health exceedances except as isolated detections. They are located in the North Plants GB manufacturing area. These sites are presumed to contain agent based on use histories and detections of agent breakdown products. Isolated detections of arsenic exceed the human health SEC. Portions of the sites in this subgroup potentially pose risks to biota.
	Toxic Storage Yards	Sites in this subgroup (including the New and Old Toxic Storage Yards) are located in the storage areas in the eastern portion of RMA and are considered to potentially contain agent based on use histories and detections of agent breakdown products. However, sampling has not indicated the presence of agent at these sites. The Old Toxic Storage Yards were retained as sites presumed to contain agent. Isolated detections of chloroacetic acid and arsenic exceed the human health SEC.
Lake Sediments	—	Sites within this medium group include sediments from lakes located in the southern portion of RMA and sediments from the North Bog. They were grouped together based on the potential risk they present to ecological receptors. Contamination has resulted from the influx of suspended solid- or dissolved-phase contaminants transported to the lakes by surface water or groundwater. Isolated exceedances of human health SEC include chlordane and chromium and acute exceedances of aldrin and dieldrin. Water is not currently allowed to pond in Upper Derby Lake, and portions of Upper Derby Lake contain soil that poses a potential risk to biota.
Surficial Soil	—	This medium group consists of areas of shallow soil contamination (including Basin F Exterior) posing risk to biota that are not included as sites in other medium groups/subgroups. Portions of this group contain OCPs above human health SEC. This group also contains the pistol and rifle ranges.
Ditches/Drainage Areas	—	Exceedance sites within this medium group have various disposal and release histories and contain low levels of contaminants, primarily OCPs, that pose risks to biota.

Table 5.4-11 Summary of Soil Medium Groups and Subgroups

Medium Groups	Subgroup	Description
Basin A	—	This medium group is comprised of two sites within the Basin A high-water line. Basin A contains soil and sediment that were contaminated by organic and inorganic chemicals from manufacturing wastewater discharged to the basin. The medium group is also characterized by the potential presence of agent and agent-filled UXO. Agent was detected in the southern portion of Basin A. COCs detected above the human health SEC include primarily OCPs; soil near the center of the basin exceeds the principal threat criteria.
Basin F	Basin F Wastepile	This subgroup consists of the Basin F Wastepile that was formed as a result of the Basin F IRA. The IRA has included incineration of Basin F liquids in the SQI, excavation of Basin F soil from below the original asphalt liner and the final grading, capping, and revegetation of the excavated area. The Basin F Wastepile consists of excavated sediment and soil that are contaminated with organic compounds, arsenic, and metals at concentrations exceeding human health SEC and principal threat criteria. The total concentrations of organics are inferred to be on the order of 1,000 to 10,000 ppm. This material also contains elevated levels of salts due to the high chloride content in the wastewater stored in the former Basin F.
	Former Basin F	The former Basin F site consists of the former basin area, including the area beneath the Basin F Wastepile. Basin F received wastewaters through the chemical sewer system, and the site is expected to contain somewhat elevated levels of salts due to the high chloride content in the wastewater. COCs remaining in the soil exceeding human health SEC include OCPs and chloroacetic acid; large portions of the former basin exceed principal threat criteria. The Basin F IRA included the installation of a soil cover.
Secondary Basins	—	Sites within this subgroup consist of four liquid disposal basins (Basins B, C, D, and E) that collected overflow water from Basin A and the former deep disposal well. These sites are expected to contain somewhat elevated levels of salts that are a result of the storage of wastewater with high chloride content. COCs detected in the soil above human health SEC include OCPs, although the majority of contamination potentially poses risks to biota only.
Sewer Systems	Sanitary/ Process Sewers	Sites within this subgroup consist of sanitary and process water sewers. Soil around these sewer lines does not exceed human health SEC and does not pose risks to biota based on the depth of the sewer lines; however, these sewer lines potentially serve as conduits for the migration of groundwater contamination.
	Chemical Sewers	Sites within this subgroup consist of chemical sewers. COCs in the soil exceeding human health SEC and principal threat criteria in portions of South Plants include OCPs, volatile organics, and chloroacetic acid. These sewers are further characterized by the potential presence of agent.

Table 5.4-11 Summary of Soil Medium Groups and Subgroups

Medium Groups	Subgroup	Description
Disposal Trenches	Complex Trenches	This subgroup is characterized by trenches or pits that were filled with trash and manufacturing/military wastes. Wastes are suspected to consist of drums of solid and liquid material, wood, glass, metal, laboratory and manufacturing equipment, and miscellaneous material. This subgroup is further characterized by the potential presence of agent and agent-filled UXO.
	Shell Trenches	This subgroup is characterized by trenches or pits that were filled with trash and manufacturing/military wastes in the area of the Shell Trenches. Wastes are suspected to consist of drums of solid and liquid material. IRA activities at this site have consisted of the placement of a soil cap across the entire site and a vertical barrier surrounding the site.
	Hex Pit	This site was historically used for disposal of hex bottoms, a tarry, chlorinated wastestream resulting from the production of HCCPD. The soil at this site is contaminated with these resinous materials. This material was buried in thin-gauge caustic barrels and in bulk.
Sanitary Landfills	—	This medium group consists of sanitary landfills and inferred trenches that are predominantly located in the eastern and western portion of RMA. These sites contain trash and rubbish, but are not anticipated to contain drums of hazardous material, agent, or UXO.
Lime Basins	Section 36 Lime Basins	The Section 36 Lime Basins, used for the neutralization of process wastes related to agent production, are characterized by soil/sludge mixtures with high pH levels and the potential presence of agent. COCs in the soil/sludge exceeding human health SEC include primarily OCPs; low-level inorganic contamination is also present. IRA activities at this site involved placing a soil cover across the entire site.
	M-1 Pits	The Buried M-1 Pits, used for the neutralization of process wastes related to agent production, are characterized by soil/sludge mixtures with high pH levels and the potential presence of agent. COCs in the soil/sludge exceeding human health SEC and principal threat criteria primarily consist of arsenic and mercury. This subgroup is distinguished by percentage levels of arsenic and mercury.

Medium Groups	Subgroup	Description
South Plants	South Plants Central Processing Area	This subgroup consists of the main processing area within the South Plants. Contamination has resulted from manufacture, storage, and disposal of chemicals and from the demilitarization of agent-filled ordnance. A wide range of COCs in the soil exceeding human health SEC and principal threat criteria include volatiles, OCPs, and arsenic. The soil in this area potentially contains agent.
	South Plants Ditches	This subgroup consists of the drainage ditches within South Plants. Contamination has resulted from manufacture, storage, and disposal of chemicals and from the demilitarization of agent-filled ordnance. COCs in the soil exceeding human health SEC and principal threat criteria include primarily OCPs. Also, contaminated soil in these ditches potentially poses risk to biota.
	South Plants Balance of Areas	The remainder of the sites within South Plants were placed in this subgroup. Contamination at these sites has resulted from manufacture, storage, and disposal of chemicals and from the demilitarization of agent-filled ordnance, and from windblown dispersion of contaminants from the Central Processing Area. COCs in the soil exceeding the human health SEC and principal threat criteria primarily consist of OCPs and ICP metals. Most of the contaminated soil in the balance of South Plants potentially poses risks to biota. This subgroup is also characterized by the potential presence of high explosives-filled UXO and agent.
Buried Sediments/ Ditches	Buried Sediments	This subgroup consists of two sites that contain contaminated sediments that were dredged from the adjacent lakes (Lake Ladora and Derby lakes), deposited in unlined ditches at their current locations, and covered with clean soil. COCs exceeding human health SEC include OCPs.
	Sand Creek Lateral	This subgroup consists of the northern and southern segments of the Sand Creek Lateral that transported runoff from the South Plants Central Processing Area during storm events and snowmelt, and of the drainage ditches used to transport water to and from the Secondary Basins and to drain the South Plants and North Plants process areas. COCs in the soil exceeding Human Health SEC primarily consist of OCPs.
Undifferentiated	Section 36 Balance of Areas	Sites within this subgroup are located in the southern area of Section 36. They do not have unique site-type characteristics or contamination patterns. COCs in the soil exceeding human health SEC include OCPs and chloroacetic acid. This subgroup is also characterized by the potential presence of agent and agent-filled UXO.
	Burial Trenches	Sites within this subgroup consist of trenches that are located in Sections 30 and 32 related to munitions testing and disposal. COCs in the soil exceeding human health SEC include chromium and lead. The sites are also characterized by the potential presence of HE-filled UXO.

Table 5.4-12 Summary of Contaminant Concentrations Within the Soil Exceedance Volumes

Medium Group/ Subgroup	Contaminants of Concern	Range of Concentrations Within Exceedance Volume[1] (ppm)	Average Concentration Within Exceedance Volume[1] (ppm)	Exceedance Depth (ft)[2]
North Plants				
Human Health	Arsenic	312–10,000	2,800	1
Biota	Dieldrin	0.01–2.9	0.13	1
	Endrin	0.003–0.09	0.01	
	Arsenic	2.8–260	41	
	Mercury	0.05–2.9	0.32	
Toxic Storage Yards				
Human Health	Chloroacetic	80–134	115	6
	Acid	270–4,000	1,600	
	Arsenic			
Biota	Arsenic	BCRL–140	3.6	1
	Mercury	BCRL–30	0.15	
Lake Sediments				
Human Health	Aldrin	BCRL–31	11.8	3
	Dieldrin	BCRL–3.4	0.7	
	Chlordane	BCRL–57	1.8	
Biota	Aldrin	BCRL–2.7	0.060	1
	Dieldrin	BCRL–2.9	0.069	
	Chlordane	BCRL–9.3	0.056	
	DDE	BCRL–1.3	0.018	
	DDT	BCRL–3.0	0.35	
	Mercury	BCRL–18	0.43	
	Arsenic	BCRL–16	0.69	
Surficial Soil				
Human Health	Aldrin	0.048–390	17	1
	Dieldrin	0.001–560	27	
	Lead (firing ranges)	Not Available	Not Available	
Biota	Aldrin	BCRL–3.0	0.016	1
	Dieldrin	BCRL–3.5	0.057	
	Endrin	BCRL–13	0.039	

Table 5.4-12 Summary of Contaminant Concentrations Within the Soil Exceedance Volumes

Medium Group/ Subgroup	Contaminants of Concern	Range of Concentrations Within Exceedance Volume[1] (ppm)	Average Concentration Within Exceedance Volume[1] (ppm)	Exceedance Depth (ft)[2]
Ditches/Drainage Area				
Biota	Aldrin	BCRL–0.094	0.005	1
	Dieldrin	BCRL–2.2	0.27	
	Endrin	BCRL–2	0.053	
	DDE	BCRL–0.78	0.027	
	DDT	BCRL–0.32	0.01	
	Arsenic	BCRL–50	6.6	
	Mercury	BCRL–1.9	0.16	
Basin A				
Human Health	Aldrin	BCRL–720	42	8
	Dieldrin	BCRL–2,600	150	
	Endrin	BCRL–3,200	110	
	Isodrin	BCRL–160	9	
	Chlordane	BCRL–2,900	100	
	Arsenic	BCRL–28,000	350	
	Chromium	BCRL–98	13	
	DDT	BCRL–105	3	
	DDE	BCRL–21	1.4	
	Mercury	BCRL–11,000	140	
Biota	Aldrin	BCRL–1.9	0.04	1
	Dieldrin	BCRL–3.6	0.53	
	Endrin	BCRL–3.0	0.10	
	Arsenic	BCRL–230	25	
	Mercury	BCRL–54	0.67	
	DDT	BCRL–0.73	0.01	
	DDE	BCRL–0.71	0.01	
Basin F Wastepile				
Human Health[3]	Aldrin	0.1–3,100	Not Available	NA
	Dieldrin	0.1–700	Not Available	
	Endrin	9.2–900	Not Available	
	Isodrin	3.16–3,000	Not Available	
	Chloroacetic	110–760	Not Available	
	Acid	3,4–110	Not Available	
	1,2-	1,500–2,000	Not Available	
	Dichloroethane			
	DCPD			

Table 5.4-12 Summary of Contaminant Concentrations Within the Soil Exceedance Volumes

Medium Group/ Subgroup	Contaminants of Concern	Range of Concentrations Within Exceedance Volume[1] (ppm)	Average Concentration Within Exceedance Volume[1] (ppm)	Exceedance Depth (ft)[2]
Former Basin F				
Human Health	Aldrin	BCRL–2,900	260	10
	Dieldrin	BCRL–1,100	130	
	Endrin	BCRL–710	47	
	Isodrin	BCRL–10,000	360	
	Chloroacetic	BCRL–7,000	960	
	Acid	BCRL–20,000	670	
	DCPD			
Secondary Basins				
Human Health	Aldrin	BCRL–180	21.6	1
	Dieldrin	BCRL–120	28.2	
	Chlordane	BCRL–3.0	0.68	
	Endrin	BCRL–8.4	2.1	
	Chromium[4]	BCRL–120	–	
	Arsenic	BCRL–140	9.8	
	Mercury	BCRL–1.6	0.17	
Biota	Aldrin	BCRL–2.7	0.08	1
	Dieldrin	BCRL–3.4	0.69	
	Endrin	BCRL–0.57	0.07	
	DDE	BCRL–1.0	0.006	
	Arsenic	BCRL–56	10	
	Mercury	BCRL–0.23	0.086	
Chemical Sewers				
Human Health	Aldrin	BCRL–20,000	Not Available	10
	Dieldrin	BCRL–200	Not Available	
	Isodrin	BCRL–1,000	Not Available	
	DDT	BCRL–500	Not Available	
	Chloroacetic	BCRL–230	Not Available	
	Acid	BCRL–32,000	Not Available	
	DBCP	BCRL–4,000	Not Available	
	HCCPD	BCRL–200	Not Available	
	Carbon	BCRL–400	Not Available	
	Tetrachloride	BCRL–740	Not Available	
	Chloroform			
	Arsenic			

Table 5.4-12 Summary of Contaminant Concentrations Within the Soil Exceedance Volumes

Medium Group/ Subgroup	Contaminants of Concern	Range of Concentrations Within Exceedance Volume[1] (ppm)	Average Concentration Within Exceedance Volume[1] (ppm)	Exceedance Depth (ft)[2]
Complex Trenches[5]				
Human Health	Aldrin	BCRL–40	Not Available	14
	Isodrin	BCRL–27	Not Available	
	Chlordane	BCRL–150	Not Available	
	DBCP	BCRL–6.7	Not Available	
	Chromium	BCRL–5,200	Not Available	
	Lead	BCRL–10,000	Not Available	
	Mercury	BCRL–860	Not Available	
	Arsenic	BCRL–4,500	Not Available	
Biota	Aldrin	BCRL–0.19	Not Available	1
	Dieldrin	BCRL–3	Not Available	
	Endrin	BCRL–4.7	Not Available	
	DDE	BCRL–2.9	Not Available	
	DDT	BCRL–0.18	Not Available	
	Arsenic	BCRL–98	Not Available	
	Mercury	BCRL–70	Not Available	
Shell Trenches[5]				
Human Health	Aldrin	BCRL–1,000	Not Available	10
	Dieldrin	BCRL–500	Not Available	
	Endrin	BCRL–400	Not Available	
	Isodrin	BCRL–1,000	Not Available	
	Chlordane	BCRL–70	Not Available	
	DBCP	BCRL–700	Not Available	
	HCCPD	BCRL–40,000	Not Available	
Hex Pit[5]				
Human Health	Aldrin	BCRL–1,000	Not Available	10
	Dieldrin	BCRL–500	Not Available	
	Endrin	BCRL–400	Not Available	
	Isodrin	BCRL–1,000	Not Available	
	Chlordane	BCRL–70	Not Available	
	HCCPD	BCRL–40,000	Not Available	

Table 5.4-12 Summary of Contaminant Concentrations Within the Soil Exceedance Volumes

Medium Group/ Subgroup	Contaminants of Concern	Range of Concentrations Within Exceedance Volume[1] (ppm)	Average Concentration Within Exceedance Volume[1] (ppm)	Exceedance Depth (ft)[2]
Sanitary Landfills				
Human Health	Aldrin	BCRL–420	2.5	12
	Dieldrin	BCRL–300	3.0	
	Endrin	BCRL–38	0.31	
	Isodrin	BCRL–27	0.16	
	Chlordane	BCRL–3.1	0.02	
	DDT	BCRL–61	0.44	
	Chromium	BCRL–1,800	18	
	Lead	BCRL–8,600	65	
	Cadmium	BCRL–1,100	5.8	
Biota	Aldrin	BCRL–3.2	0.09	1
	Dieldrin	BCRL–2.6	0.17	
	DDE	BCRL–5.6	0.19	
	DDT	BCRL–61	1.3	
	Endrin	BCRL–20	0.39	
	Arsenic	BCRL–120	5.5	
	Mercury	BCRL–3.5	0.11	
Section 36 Lime Basins				
Human Health	Aldrin	BCRL–1,700	190	10
	Dieldrin	BCRL–780	90	
	Endrin	BCRL–400	41	
	Isodrin	BCRL–400	48	
	Chlordane	BCRL–240	25	
	DDE	BCRL–13	1.9	
	DDT	BCRL–2.6	0.06	
	Arsenic	BCRL–900	100	
	Mercury	BCRL–56	5.4	
Buried M-1 Pits				
Human Health	Aldrin	BCRL–27	0.55	10
	Dieldrin	BCRL–36	0.82	
	Isodrin	BCRL–7.1	0.099	
	HCCPD	BCRL–1,300	44	
	DCPD	BCRL–7,800	195	
	Cadmium	BCRL–2,400	320	
	Arsenic	27–100,000	17,000	
	Mercury	1.3–83,000	4,300	

Table 5.4-12 Summary of Contaminant Concentrations Within the Soil Exceedance Volumes

Medium Group/ Subgroup	Contaminants of Concern	Range of Concentrations Within Exceedance Volume[1] (ppm)	Average Concentration Within Exceedance Volume[1] (ppm)	Exceedance Depth (ft)[2]
South Plants Central Processing Area				
Human Health	Aldrin	BCRL–15,000	580	10
	Dieldrin	BCRL–6,300	210	
	Endrin	BCRL–3,700	67	
	Isodrin	BCRL–300	19	
	Chlordane	BCRL–1,500	15	
	Chloroacetic	BCRL–350	13	
	Acid	BCRL–300	7.5	
	DDT	BCRL–5,300	28	
	HCCPD	BCRL–14,000	275	
	DBCP	BCRL–140	1.9	
	Carbon	BCRL–40,000	580	
	Tetrachloride	BCRL–970	6.7	
	Chloroform	BCRL–14,000	230	
	DCPD	BCRL–540	5.1	
	Arsenic	BCRL–280	20	
	Cadmium	BCRL–7,100	310	
	Chromium	BCRL–17,000	300	
	Lead			
	Mercury			
Biota	Aldrin	BCRL–3.4	0.19	1
	Dieldrin	BCRL–3.4	0.73	
	Endrin	BCRL–1.2	0.029	
	DDE	BCRL–1.6	0.023	
	DDT	BCRL–8.6	0.03	
	Arsenic	BCRL–289	11	
	Mercury	BCRL–56	2.04	
South Plants Ditches				
Human Health	Aldrin	0.60–4,400	270	5
	Dieldrin	0.71–805	58	
	Isodrin	BCRL–23	2.3	
	Chlordane	BCRL–6.3	0.4	
	Chromium	BCRL–62	12	
	Endrin	BCRL–3.4	0.17	
	DDE	BCRL–2.1	0.20	
	DDT	BCRL–10	0.4	
	Arsenic	BCRL–6.1	0.42	
	Mercury	BCRL–15	0.30	
Biota	Aldrin	BCRL–2.3	0.11	1
	Dieldrin	BCRL–2.7	0.69	
	Endrin	BCRL–0.31	0.038	
	DDE	BCRL–3.2	0.12	
	DDT	BCRL–0.81	0.047	
	Mercury	BCRL–2.5	0.10	

Table 5.4-12 Summary of Contaminant Concentrations Within the Soil Exceedance Volumes

Medium Group/ Subgroup	Contaminants of Concern	Range of Concentrations Within Exceedance Volume[1] (ppm)	Average Concentration Within Exceedance Volume[1] (ppm)	Exceedance Depth (ft)[2]
South Plants Balance of Areas				
Human Health	Aldrin	BCRL–6,900	14	10
	Dieldrin	0.67–1,500	33	
	Endrin	BCRL–46	1.6	
	Isodrin	BCRL–390	18	
	Chlordane	BCRL–370	4.2	
	DDE	BCRL–9.7	0.53	
	DDT	BCRL–140	1.4	
	HCCPD	BCRL–2,000	23	
	Chromium	BCRL–2,200	62	
	Lead	BCRL–4,900	340	
	Mercury	BCRL–8,600	500	
Biota	Aldrin	BCRL–3.5	0.037	1
	Dieldrin	BCRL–3.6	0.32	
	Endrin	BCRL–1.17	0.011	
	DDE	BCRL–1.02	0.006	
	DDT	BCRL–1.7	0.15	
	Arsenic	BCRL–180	0.73	
	Mercury	BCRL–41	0.065	
Buried Sediments				
Human Health	Dieldrin	26.1–53	40	10
	Chlordane	BCRL–8.9	0.8	
Sand Creek Lateral				
Human Health	Aldrin	BCRL–400	27.8	2
	Dieldrin	BCRL–140	18.5	
	Isodrin	BCRL–4.0	0.24	
	Chlordane	BCRL–9.7	0.42	
	Chloroacetic Acid	230	Not Applicable	
	Chromium	BRCL–490	180	
	Lead	BCRL–2,000	800	
	DDE	BCRL–4.7	0.04	
	DDT	BCRL–6.0	1.0	
Biota	Aldrin	BCRL–3.7	0.30	1
	Dieldrin	BCRL–3.6	0.44	
	Endrin	BCRL–3.8	0.087	
	DDE	BCRL–4.7	0.095	
	DDT	BCRL–6.0	0.10	
	Arsenic	BCRL–190	5.8	
	Mercury	BCRL–2.3	0.13	

Table 5.4-12 Summary of Contaminant Concentrations Within the Soil Exceedance Volumes

Medium Group/ Subgroup	Contaminants of Concern	Range of Concentrations Within Exceedance Volume[1] (ppm)	Average Concentration Within Exceedance Volume[1] (ppm)	Exceedance Depth (ft)[2]
Section 36 Balance of Areas				
Human Health	Aldrin	BCRL–120	11	10
	Dieldrin	BCRL–140	24	
	Endrin	BCRL–46	5.3	
	Isodrin	BCRL–37	1.6	
	Chlordane	BCRL–140	2.2	
	Chloroacetic	BCRL–320	52	
	Acid	BCRL–1.8	0.10	
	DDE	BCRL–23	0.20	
	DDT	BCRL–16	2.4	
	Arsenic	BCRL–50	0.46	
	Mercury			
Biota	Aldrin	BCRL–2.2	0.061	1
	Dieldrin	BCRL–3.5	0.010	
	Endrin	BCRL–3.1	0.12	
	Chlordane	BCRL–11	0.84	
	DDE	BCRL–1.6	0.010	
	DDT	BCRL–8.6	0.028	
	Arsenic	BCRL–39	3.85	
	Mercury	BCRL–56	0.5	
Burial Trenches				
Human Health	Chromium	BCRL–39	20	10
	Lead	BCRL–3,400	190	

1 Concentrations listed are based on the samples present within the respective exceedance volumes only. For modeled sites, the range and average represent estimated contaminant concentrations for the modeled exceedance volume. See Section 7.1.4 for more discussion on soil contaminant modeling.
2 Human health exceedance depths represent the maximum depth of any detected human health exceedances.
3 Concentrations inferred from remedial investigations sampling at Former Basin F prior to interim response action.
4 Present above human health SEC in one sample in NCSA-4a.
5 Concentrations for these sites represent samples taken throughout the site. Limited information is available for soil concentrations within the disposal trenches proper.

6.0 Summary of Site Risks

A risk assessment is a scientific procedure used to estimate the potential adverse effects on human health and the environment from exposure to chemicals. At a CERCLA site, a baseline risk assessment is prepared and serves as the basis for evaluating risks posed from contamination if no remedial actions are taken. The resulting level of risk is called the baseline risk, i.e., an estimate of risk that might exist if no remediation or institutional controls were applied at a site. At RMA, a risk assessment called the Integrated Endangerment Assessment/Risk Characterization (IEA/RC) was performed and used as the baseline risk assessment. In this instance, the IEA/RC defined baseline to include the completion of the soil-related IRAs (e.g., Basin F, Lime Basins) and enforcement of the FFA's use restrictions. The FFA prohibits residential development; potable use of groundwater and surface water; agricultural activities for the purpose of raising livestock, crops, or vegetables; and the consumption of fish and game taken from RMA. Therefore, these uses were not considered during the IEA/RC. The relevant IRAs (Table 2.4-1) were implemented in accordance with the FFA to prioritize the selection of some of the more highly contaminated sites for remedial action and reduce or eliminate the risk for exposure to contaminated soil prior to the selection of the final remedial action. The risk assessment methodology used during the IEA/RC was initiated prior to the publication of EPA risk assessment guidance (OERR-EPA 1989). However, this methodology does incorporate the exposure assumptions and toxicity assessment methods specified in EPA guidance and fulfills EPA's requirement of estimating risk based on a reasonable maximum exposure (RME).

The IEA/RC was the result of a progressive series of endangerment assessment analyses initiated by the Biota RI (ESE 1989), the Human Health Exposure Assessment (HHEA), and the HHEA Addendum. These initial evaluations served as screening assessments for the protection of human health and preliminary estimations of biota risk, and provided the basic building blocks of the IEA/RC report, which is divided into two evaluations, the Human Health Risk Characterization (HHRC) and the Ecological Risk Characterization (ERC). Both of these evaluations are summarized in the final report.

The general methodology of the risk assessment process involves the following steps: identify the COCs, perform the exposure and toxicity assessments, and perform the risk characterization. The more than 50,000 groundwater, surface water, sediment, soil, air, and biota samples collected during the past decade were used to evaluate which chemicals were of concern to human health and the environment and to develop the risk assessment.

6.1 Human Health Risk Characterization

Soil at RMA is the primary medium by which humans can be exposed to contamination on post, due to land-use restrictions and/or limitations on the uses of other environmental media specified in the FFA and the Rocky

Mountain Arsenal National Wildlife Refuge Act of 1992. Remedial measures for on-post groundwater will augment the soil remedy and facilitate long-term remediation of groundwater. Risk-based criteria for groundwater established by the ROD for the Off-Post Operable Unit are used for the on-post boundary treatment systems.

The objectives of the HHRC were to develop risk-based soil criteria protective of people who might visit or work at RMA, evaluate the uncertainty associated with these criteria, characterize the potential risks to these people, and evaluate where these risks exist at RMA to guide the remedial decisions. Two types of health effects were evaluated, potential cancer (carcinogenic) risks and potential health effects other than cancer. The context for interpreting cancer risk estimates is provided by EPA in CERCLA regulations and guidance: Acceptable exposure levels for a carcinogenic compound are those levels that result in an increased cancer risk between 1 in 10,000 (or 1×10^{-4}) and 1 in 1,000,000 (or 1×10^{-6}). These estimated carcinogenic risks are usually termed "excess lifetime cancer risks," which means there is an increased chance of an individual developing cancer over 30 years of exposure over a 70-year life span to the carcinogenic chemicals in "excess" of the normal cancer rate. (The normal cancer rate determined by the American Cancer Society is about one in three persons.)

Noncancer (noncarcinogenic) risk estimates are expressed in terms of a hazard index (HI) for **chronic, subchronic,** and **acute exposure durations**. A concern for adverse health effects may occur when an HI value, the sum of chemical-specific hazard quotients (HQs), exceeds 1.0. However, the value of any given HI does not provide an estimate of the probability of any adverse effects that may occur (unlike a cancer risk estimate). An HI of 1.0 represents the highest level of chronic exposure that is unlikely to result in adverse effects. For values of HI greater than 1.0, the potential for adverse effects to occur increases as the HI value increases.

6.1.1 Identification of Contaminants of Concern

Contaminants in the RI and Endangerment Assessment programs were selected as target analytes if they satisfied all of the following criteria:

- Quantities handled or disposed at RMA
- Acute toxicity and carcinogenic potential
- Persistence in the environment
- Identification as a breakdown product from Army surety agents
- The presence of the chemical in other monitoring or investigatory programs ongoing at RMA

A total of 64 contaminants were identified as target analytes from a list of more than 650 chemical constituents. These target contaminants were subsequently evaluated in the HHEA report. The HHEA served as a basis for identifying COCs that would become the focus of a more detailed evaluation of risk during the IEA/RC.

Based on the evaluation conducted during the HHEA, 27 soil COCs were ultimately selected for evaluation in the HHRC (Table 6.1-1). These chemicals, which are expected to contribute the majority of projected risks at RMA, were identified based on pre-established selection criteria as follows:

1. Include all COCs designated as Category A (Exposure Index >10) in the HHEA.
2. Include all COCs with carcinogenic weight of evidence classifications designations A or B.
3. Include all COCs with carcinogenic weight of evidence classification designation C and potency factors.
4. Consider treatability to exclude chemicals from the COC list.
5. Consider isolated detections to exclude chemicals.
6. Include all COCs listed on the Land Ban Disposal Restriction List.
7. Include all COCs with RCRA soil criteria.
8. Consider the state's request to include DIMP and isopropylmethyl phosphonate (IMPA). (DIMP and IMPA are predominantly groundwater contaminants and were therefore not included on the final COC list.)
9. Group by chemical class to reduce COCs.
10. Consider frequency of detection.
11. Consider essential nutrients.
12. Consider concentration and toxicity.
13. Consider historical information.
14. Consider special exposure routes.
15. Consider Army agent degradation products.
16. Consider co-occurrence with other COCs to exclude chemicals.
17. Consider bioconcentration, mobility, and persistence.
18. Consider detections in laboratory blanks in comparison to concentrations detected on site. (Fluoroacetic acid, which was considered a COC in drafts of the IEA/RC report, was removed as a COC in this analysis because on-post detections of this chemical were similar in concentration to detections in laboratory blanks.)

6.1.2 Exposure Assessment

The objective of the human health exposure assessment is to estimate the type and magnitude of exposure to COCs by human populations through the characterization of the exposure setting (i.e., potential land uses) and current and future potentially exposed populations, identification of exposure pathways, and estimation of the exposure point concentrations.

6.1.2.1 Characterization of Exposure Setting and Potentially Exposed Populations

The identification of potentially exposed populations at RMA required consideration of potential site land uses. The FFA indicates the Parties' goal that significant portions of RMA will be available for open space for public benefit, including, but not limited to, wildlife habitat(s) and park(s). By the enactment of the Rocky Mountain

Arsenal National Wildlife Refuge Act of 1992, future land-use options will involve an open space scenario dominated by the formation of a nature preserve and wildlife refuge that includes parks and recreational areas.

Given the land-use projections identified above, two land-use options were identified that formed the basis for defining target receptor populations: open space, which includes nature preserve, wildlife refuge, and recreational park scenarios, and economic development, which includes commercial and industrial scenarios. Following passage of the Rocky Mountain Arsenal National Wildlife Refuge Act, economic development would only apply in limited areas along the western boundary of RMA. Based on the open space land-use projection, three receptor populations were evaluated in the HHRC, biological workers, regulated/casual visitors, and recreational visitors. Based on the economic development land-use projection, two worker populations, industrial and commercial workers, were selected for evaluation. Figure 6.1-1 is a diagram showing the land-use scenarios and the potentially exposed populations associated with them. For both open space and economic development land-use options, risks were calculated assuming that exposure would occur at a given site or, in the case of the boring-by-boring analysis, at an individual soil boring.

6.1.2.2 Identification of Exposure Pathways

An exposure pathway describes the course a chemical or physical agent takes from the contaminant source to the exposed receptor. A complete exposure pathway includes a source area, a means of transport in the environment, an exposure point, and a receptor. At RMA, direct and indirect exposure pathways were evaluated. The direct pathways included ingesting contaminated soil (ingestion), coming into contact with contaminated soil (dermal absorption), or breathing contaminated dust particles (inhalation). The indirect pathways included inhalation of contaminated vapors in open areas (e.g., during work performed outdoors) and enclosed spaces (e.g., in basements). Dermal contact with metals in soil was not evaluated for any receptor population due to negligible contaminant absorption through this exposure pathway.

The five potentially exposed populations/subpopulations and their respective current and future exposure pathways included the following:

- Biological Worker, e.g., a wildlife biologist working on the refuge – All direct pathways and open space vapor inhalation
- Regulated/Casual Visitor, e.g., someone (adult or child) visiting the wildlife refuge – All direct pathways and open space vapor inhalation
- Recreational Visitor, e.g., someone (adult or child) jogging or playing on areas of the wildlife refuge – All direct pathways and open space vapor inhalation
- Commercial Worker, e.g., a person working inside a building on the wildlife refuge – All direct pathway and enclosed space vapor inhalation
- Industrial Worker, e.g., a person working outside and potentially exposed to soil – All direct and indirect pathways

Figure 6.1-2 depicts the potential exposure pathways for each human receptor population and Table 6.1-2 lists the soil horizons (soil depth interval) for each exposure pathway evaluated.

6.1.2.3 Estimation of Exposure Point Concentrations

The chemical concentration to which an individual could be exposed is known as the exposure point concentration. To characterize potential chronic (long-term risk, i.e., 7 to 70 years) human health risks at RMA, both location-specific (i.e., 178 discrete sites on RMA) and sample-specific (boring-by-boring) risks were quantified. The complete data set used for the estimation of these exposure point concentrations was issued on computer diskettes and distributed with the IEA/RC report.

Human health risks were estimated for the location-specific analysis using representative contaminant concentrations calculated for each of the 178 sites evaluated in the HHRC. The concentration term used to estimate exposure was calculated by several different methods to give a range of potential risks. A mean exposure concentration term ($C_{rep,mean}$) was calculated as the simple arithmetic mean of the samples as representative of a potential average exposure for each of the 178 locations. (This method is no longer recommended by EPA.) The 95 percent upper confidence limit (95% UCL) on the site sample arithmetic mean ($C_{rep,upper}$) was calculated to establish the RME risks. The 95% UCL was calculated in accordance with EPA guidance (OSWER-EPA 1992) and this represents EPA's preferred method to calculate concentration terms.

For the location-specific analysis, concentrations based on **composited samples** (i.e., samples collected from borings from the 0-ft to 1-ft interval mixed with samples from a deeper interval). These concentrations were estimated by doubling the concentration detected in the 0-ft to 1-ft interval, using the conservative assumption of 50 percent dilution by clean soil collected from the deeper samples. Concentrations reported for samples that were not composited (i.e., samples collected from the 0-ft to 1-ft interval and analyzed without the addition of deeper soil) were not doubled because these concentrations were not potentially diluted by deeper, clean soil.

For the boring-by-boring analysis, potential risks were evaluated using the maximum contaminant concentration (C_{max}) at a given boring for a specific depth interval or at a given surficial soil sample location. Surficial soil sample results were included in the boring-by-boring analysis to supplement results from the deeper sample intervals. The objective of the surficial soil sampling program was to identify any contamination that may have occurred as a result of windblown contamination from source areas using composited samples from randomly selected sample locations at the 0-inch to 2-inch depth interval. Because the samples were composited from within this one interval, the effects of dilution caused by mixing soil from deeper intervals was avoided. The inclusion of these results in the boring-by-boring analysis are intended to offer insight into the variability of contamination at RMA and facilitate the identification of contaminant hot spots. The use of analytical results from composited samples may have reduced the overall conservatism of the boring-by-boring analysis, which assumes that cumulative chronic exposures would occur at any individual boring location and at the specific depths where the maximum concentration occurred. However, the surficial soil results do supplement the subsurface boring evaluation, and may be more relevant to the evaluation of direct contact exposure risks for some receptors (e.g., visitor populations) than corresponding results for deeper soil intervals.

6.1.2.4 Exposure Parameters

Exposure parameters are combined with chemical-specific exposure point concentrations and toxicity data to characterize each of the five potential routes of human exposure to COCs at RMA. Some exposure parameters, such as body weight and frequency of exposure, are applicable to all exposure pathways. Other parameters, however, such as soil ingestion rate and molecular diffusivity, are used only for specific exposure routes. The probabilistic analysis developed for the IEA/RC assumes chronic exposures (greater than 7 years). However, potential risks associated with shorter-term exposures (i.e., acute exposures occurring on a single day or subchronic exposures lasting more than 1 day but less than 7 years) were calculated during the HHEA using deterministic methods (i.e., using fixed exposure parameters).

The exposure parameters used in this evaluation are fixed or probabilistic (Tables 6.1-3 through 6.1-5). Probabilistic parameters are characterized by a distribution of values, while the fixed parameters are represented by a single value. Probability distributions and the fixed numerical estimates are defined based on an extensive literature search and data review. A detailed description of the individual exposure parameters and the development of their specific distributions is contained in Appendix B of the IEA/RC report. The deterministic exposure parameters used for the development of the acute and subchronic **preliminary pollutant limit values** (PPLVs) are presented in Tables 6.1-6 and 6.1-7, respectively. A detailed description of these parameters is provided in the HHEA Addendum report.

6.1.3 Toxicity Assessment

The objective of the toxicity assessment is to derive toxicological criteria that can be used in the calculation of potential risk from exposure to COCs in terms of carcinogenic and noncarcinogenic effects.

Carcinogenic effects result, or are suspected to result, in the development of different types of cancer. EPA assumes a nonthreshold mechanism for carcinogens; accordingly, any amount of exposure to a carcinogenic chemical is assumed to have a potential for producing a carcinogenic response in the exposed individual. EPA has a carcinogenic-classification system that uses weight of evidence to classify the likelihood that a chemical is a human carcinogen. The classifications are as follows:

- A Human Carcinogen
- B1 Probable human carcinogen; limited human data are available

B2 Probably human carcinogen; sufficient evidence in animals and inadequate or no evidence in humans

C Possible human carcinogen

D Not classified as to human carcinogen

E Evidence of noncarcinogenicity for humans

Carcinogenic toxicity values used in the HHRC were developed by the EPA Cancer Assessment Group and obtained from EPA-derived sources that include the Integrated Risk Information System database and the Health Effects Summary Table. These values are based on cancer slope factors. Slope factors are chemical-specific, experimentally derived potency values that are used to calculate the risk of cancer resulting from exposure to carcinogenic chemicals. A higher value implies a more potent carcinogen. Slope factors and carcinogenic doses based on a 1×10^{-6} excess cancer risk for the COCs are summarized in Table 6.1-8 for both oral and inhalation routes.

Noncarcinogenic effects, or any health impact other than cancer, may result from short-term (i.e., acute and subchronic), or long-term (chronic) exposures. For most noncarcinogenic effects, protective mechanisms within an individual are assumed to exist that must be overcome before there is an adverse effect. The level above which effects may occur is called a threshold level. In developing dose-response values for noncarcinogenic effects, i.e., the reference dose (RfD), EPA's goal is to identify the highest no observed adverse effect level (NOAEL), the upper bound of the tolerance range (generally regarded as safe), or the lowest observed adverse effect level (LOAEL) from well-designed human or animal studies. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. To account for uncertainty associated with the toxicity studies, uncertainty factors (UFs) are incorporated to adjust this level. The RfDs for COCs at RMA are summarized in Table 6.1-9 for both the oral and inhalation exposure routes for chronic exposures. (Acute and subchronic exposures from RMA media were evaluated in the HHEA Addendum report.)

The chronic reference doses listed in Table 6.1-9 pertain to lifetime or other long-term exposures (i.e., 7 years to lifetime). However, for noncarcinogenic chemicals, chronic exposure is not a prerequisite for toxicity to be manifested; even a single exposure or shorter-duration exposure may be sufficient to produce adverse effects. More recently, EPA has begun developing acute and subchronic reference doses, which are useful for characterizing potential noncarcinogenic effects associated with shorter-term exposures (i.e., acute and subchronic). Acute and subchronic reference doses are used to evaluate the potential noncarcinogenic effects of exposure periods lasting 1 day or more than 1 day but less than 7 years.

Development of acute and subchronic reference doses parallels the development of chronic reference doses; the distinction is one of exposure duration. If acute or subchronic data are not available and a chronic RfD derived from chronic data exists, the chronic RfD is adopted as the acute or subchronic RfD. There is no application of an uncertainty factor to account for differences in exposure duration in this instance. The critical toxicity factors (D_T values) used for the acute and subchronic PPLVs are listed in Table 6.1-10.

Toxicity profiles for each of the COCs were published in the HHEA. Toxicity profiles for each RMA target contaminant were generated from current toxicological literature and include considerations of dose, routes of exposure, types of adverse effects manifested, transport, and fate and a quantitative evaluation of a D_T value. Each profile is composed of seven sections that address the following elements:

- Summary
- Chemical and physical properties
- Transport and fate
- Health effects
- Toxicity to wildlife and domestic animals
- Regulations and standards
- D_T value

The toxicity factors contained in the toxicity profiles were revised if current values contained in the Integrated Risk Information System or the Health Effects Summary Table differed from those contained in the HHEA toxicity profile. Tables 6.1-8 and 6.1-9 list the toxicity factors used in the IEA/RC.

6.1.4 Risk Characterization

PPLVs, which are risk-based concentrations of chemicals in soil that are considered protective of human health given a defined set of exposure and toxicity assumptions, were used to estimate risks to human health. For noncarcinogens, PPLVs are defined as soil concentrations unlikely to pose adverse health effects. For carcinogens, PPLVs are defined as soil concentrations protective of human health at a specified cancer risk level. PPLVs are a function of media intake rates, exposure frequencies and durations, partition coefficients, physiological parameters (e.g., breathing rates, body rates, skin surface areas), pharmacokinetic parameters (e.g., contaminant absorption fractions), and toxicity data.

6.1.4.1 Calculation of PPLVs

Probabilistic PPLVs were computed for each of the five potentially exposed populations via the direct and indirect exposure pathways. In addition, because exposure to contaminants may occur from a number of exposure routes, cumulative direct and indirect PPLVs were also calculated over all the single pathways. Acute/subchronic deterministic and chronic probabilistic approaches differ in their use of exposure assumptions. The exposure parameters used in the estimation of probabilistic PPLVs are characterized by a distribution of values or ranges of exposures potentially occurring within the population. It is assumed that some individuals have a high level of exposure and others have a lower level. The exposure parameters used in the estimation of deterministic PPLVs (i.e., nonprobabilistic) are the fixed numerical estimates that correspond to a reasonable maximally exposed individual (RME). EPA defines the RME as the highest exposure that is reasonably expected to occur at a site and in practice is estimated by combining upper bound fixed values for some but not all exposure parameters.

During the HHRC, both 5th and 50th percentile cumulative direct PPLVs (Tables 6.1-11 and 6.1-12, respectively) were calculated for each of the five receptor populations. The 5th percentile defines the RME PPLV (i.e., there is 95 percent confidence that the PPLV will be protective at the specified risk level), and the 50th percentile represents the median PPLV estimate (i.e., there is 50 percent confidence that the PPLV will not exceed the specified risk level). The remediation decisions are based on the 5th percentile PPLV, which corresponds to a reasonable maximum exposure (and risk) evaluation. The lowest (more protective) cumulative direct PPLVs were generally derived for the biological worker. The only exceptions are related to the PPLVs calculated for certain volatile organic compounds (i.e., benzene, carbon tetrachloride, chloroacetic acid, chlorobenzene, and toluene); for these compounds, the lowest PPLVs were derived for the industrial worker.

The single-pathway PPLVs used to derive the cumulative PPLVs are summarized in Tables 6.1-13 through 6.1-17. As shown in these tables, the majority of the cumulative direct PPLVs were derived based on a carcinogenic endpoint. The dermal absorption pathway accounts for the majority of the cumulative risk for most of the organic COCs. The only exceptions are aldrin, dieldrin, DDE, endrin, isodrin, chlordane, DDT, and DCPD, for which soil ingestion is the driver exposure pathway, and DCPD and HCCPD, for which soil particulate inhalation is the driver exposure pathway for some populations/subpopulations.

For aldrin, soil ingestion is the driver exposure pathway for the biological worker, recreational visitor, regulated/casual visitor, and commercial worker subpopulations. For dieldrin, soil ingestion is the driver exposure pathway for the biological worker, regulated/casual visitor, and commercial worker subpopulations. For DDE, endrin, and isodrin, soil ingestion is the driver exposure pathway for the biological worker and commercial worker subpopulations. For chlordane, DDT, and DCPD, soil ingestion is the driver exposure pathway for the commercial worker subpopulation.

For DCPD, inhalation is the driver exposure pathway for all populations/subpopulations except the commercial worker, for which ingestion is the driver exposure pathway. For HCCPD, inhalation is the driver exposure pathway for all populations except the recreational visitor, for which dermal exposure is the driver exposure pathway.

Soil ingestion and particulate inhalation are the driver pathways for metals. (As explained in Section 6.1.2.2, dermal absorption was not quantified for metals.) Soil ingestion represents the driver pathway for arsenic, lead, and mercury, and particulate inhalation represents the driver pathway for cadmium and chromium.

6.1.4.2 Determination of Carcinogenic and Noncarcinogenic Risks

Once PPLVs were calculated, they were combined with exposure point concentrations to calculate excess lifetime carcinogenic risks and noncarcinogenic HIs. As noted in Section 6.1, these excess lifetime cancer risks are probabilities that are generally expressed in scientific notation (e.g., 1×10^{-6}). An excess lifetime cancer risk of 1×10^{-6} indicates that, as a plausible upper bound, an individual has a 1 in 1 million chance of developing cancer as a result of site-related exposure to a carcinogen over 30 years of exposure over a 70-year life span under the specific exposure conditions at a site.

Potential concern for noncarcinogenic effects of a single contaminant in a single medium is expressed as the HQ (or the ratio of the estimated intake derived from the contaminant concentration in a given medium to the contaminant's RfD). By adding the HQs for all contaminants within a medium or across all media to which a given population may reasonably be exposed, the HI can be generated. The HI provides a useful reference point for gauging the potential significance of multiple contaminant exposures within a single medium or across media.

For carcinogens, cumulative risks (representing all exposure pathways and COCs) were compared to an acceptable risk range that is no greater than 1×10^{-6} to 1×10^{-4}. For carcinogens causing health effects in addition to cancer and for noncarcinogens, potential adverse health effects were identified where HI values exceeded 1.0, below which is considered the safe, or benchmark, level. As stated by EPA (OSWER-EPA 1991b), where the cumulative site risk to an individual based on the RME for both current and future land-use scenarios is less than 1×10^{-4}, and the HQ is less than 1.0, action generally is not warranted; however, when risk reduction is warranted, the remediation goals should be towards 1×10^{-6} risk-based concentrations.

Location-Specific Risks and HIs

RME risks were calculated for each of the 178 sites using $C_{rep,upper}$ concentrations and PPLVs. During the HHRC, site risks were calculated for Horizon 0 (0-ft to 1-ft depth interval), Horizon 1 (0-ft to 10-ft depth interval), and Horizon 2 (>10 ft to groundwater). Because Horizon 0 results were not graphically displayed in the IEA/RC report, this section mainly focuses on the results for that horizon. More information on site risks for Horizons 1 and 2, as well as results for surficial soil (0 inches to 2 inches), can be found in the IEA/RC report.

PPLVs were derived for each of the five potentially exposed populations/subpopulations evaluated in the risk characterization. Table 6.1-18 lists the number of site $C_{rep,upper}$ values exceeding the corresponding PPLV for

Horizon 0. As shown in this table, only five carcinogenic contaminants have $C_{rep,upper}$ estimates exceeding a 1 x 10^{-4} cancer risk PPLV: aldrin, chlordane, dieldrin, arsenic, and DBCP. For noncarcinogens, only chloroacetic acid, endrin, isodrin, and chromium have $C_{rep,upper}$ values exceeding the corresponding PPLV (assuming an HI of 1.0 as the target criterion).

The results of the HHRC indicate that site-specific cancer risks and HIs were highest in Horizons 0 and 1 for the biological worker (open space option) and industrial worker (economic development land-use option). Given these findings, and the fact that the biological worker exposure setting is most reflective of anticipated future land uses at RMA, the following summary is based on results obtained for the biological worker. These results indicate that potential cancer risks are highest in the following areas, which are generally located in the central portions of RMA:

- Chemical Sewers (site SP10)
- Lime Basins, including sites SP1E (Buried M-1 Pits) and NC1B (Section 36 Lime Basins)
- South Plants, with sites SP3A (ditch), SP1A (Central Processing Area), and SP3B (concrete salt storage pad) exhibiting the highest risks
- Former Basin F (site NC3)
- Sanitary/Process Water Sewers (site NC8A)
- Basin A (site NC1A)
- Shell Trenches (site C1A)

The generalized locations of these sites are depicted on Figure 6.1-3. Exceedances of 1 x 10^{-4} cancer risk levels are limited to the sites listed above (the Basin F Wastepile was not evaluated separately, but would fall into this category) (Figure 6.1-4). The results for noncarcinogenic endpoints (HIs) exhibit similar trends; however, more sites exceed an HI of 1.0 than those identified above (e.g., one sanitary landfill and additional sites in South Plants [Figure 6.1-5]).

Summary of Principal Chemical Risk Drivers

Figures 6.1-6 and 6.1-7 summarize cancer risks and HIs associated with the $C_{rep,\ upper}$ concentrations for Horizon 0. As shown in these figures, the number of exceedances shown for the biological worker at Horizon 0 is larger than for any of the other populations; however, the cumulative direct PPLVs (summarized in Table 6.1-11) are generally lower (and are thus drivers) for the biological worker. As indicated in Section 3 of the IEA/RC report, Horizon 1 C_{rep} concentrations show slightly higher cancer risks and HIs than for Horizon 0, probably because the indirect soil vapor inhalation pathways were not evaluated for shallow depth intervals. As is also indicated in the IEA/RC report, Horizon 2 C_{rep} concentrations revealed far lower cancer risks and HIs (relative to results for Horizons 0 and 1). No site exceedances of a 10^{-4} cancer risk level were identified for either the biological or industrial workers. Only 2.2 percent (four sites) of Horizon 2 site cancer risks calculated for the industrial worker exceed 10^{-6}; similar trends are exhibited for HI endpoints.

For cancer risk endpoints, DBCP, aldrin, arsenic, and dieldrin are the primary contributors to the total estimated risks for the biological worker at Horizon 1. It should be noted, however, that the apparent major contribution of DBCP stems in large part from the elevated observation at the Chemical Sewers (site SP10), where the DBCP cancer risk was 7.6×10^{-3} and the HI was 0.016. The influence of arsenic on total cancer risks for Buried M-1 Pits (site SP1E) and some North Plants agent storage sites (sites NP5 and NP6) is expected as arsenic is a component of the agent compounds that were stored or disposed in these areas. For noncarcinogenic risk endpoints, DBCP, aldrin, and arsenic account for the majority of the total estimated HIs.

No cancer risk estimates exceed 10^{-4} at Horizon 2. However, for those sites with Horizon 2 cancer risks exceeding 10^{-6}, chloroform and benzene are the major contributors to the total estimated risks. For those sites with HIs exceeding 1.0, DBCP, DCPD and HCCPD account for the majority of the total estimated HIs.

Detailed data regarding the contribution of individual chemicals to total site risks and HIs are provided in the additivity reports, which can be accessed using the HHRC software provided in Appendix D of the IEA/RC report.

Summary of Pathway Risk Drivers

Carcinogenic and noncarcinogenic risks estimated for the biological worker and other open space land-use option receptors were attributed primarily to the direct soil exposure pathways (soil ingestion and dermal absorption; see Tables 6.1-13 through 6.1-17). In contrast to trends identified for the biological worker, the soil vapor inhalation pathway was the dominant exposure pathway for the driver COCs identified for industrial (and commercial) workers.

A sensitivity analysis was conducted for the HHRC to rank the influence of several distributed input parameters on the variability of the cumulative direct PPLVs for aldrin, dieldrin, DBCP, arsenic, and chlordane. These chemicals were chosen because of their strong contributions to overall risk at RMA. The sensitivity analysis considered both biological and industrial worker receptors (representing open space and economic development land-use options, respectively) for both cancer risk and HI endpoints. Standardized regression coefficients and full-model partial correlation coefficients were computed for each input parameter to provide two separate measures of a parameter's influence on the variability of the direct exposure pathway PPLVs.

The eight distributed input parameters used for the direct PPLV calculations included the following:

TE	Exposure duration (years) (for carcinogens only)
DW	Annual frequency of exposure (days/year)

TM	Daily exposure rate (hours/day)
RAF_{dermal}	Relative absorption factor for dermal absorption (unitless)
$RAF_{ingestion}$	Relative absorption factor for ingestion (unitless)
CSS	Dust loading factor ($\mu g/m^3$)
SC	Skin soil covering (mg/cm^3)
SI	Soil ingestion (mg/day)

The results of this analysis indicate that variability in exposure duration is consistently the dominant contributor to variability in the direct carcinogenic PPLV, followed by soil ingestion. Soil ingestion is also a dominant contributor to variability in the direct noncarcinogenic PPLV. Other influential parameters include RAF_{dermal}, $RAF_{ingestion}$, and soil covering.

Risks for the boring-by-boring analysis were characterized using the following sampling data:

- Surficial soil results (samples collected from a 0- to 2-inch soil-depth interval in areas outside of designated sites)
- Boring-by-boring results (maximum contaminant concentrations detected in each soil-depth interval for individual borings located within designated sites)

Surficial Soil Results

Figure 6.1-8 shows the incremental cancer risks estimated for the biological worker using surficial soil (0-inch to 2-inch depth interval) results. This map indicates only three surficial soil locations with incremental cancer risks exceeding 10^{-4}: one occurs east of Basin C, one occurs in Basin A, and one occurs in the southern area of Section 36. Similar trends are apparent for HIs; of the 493 non-zero observations, only three surficial soil locations have incremental HIs exceeding 1.0. The surficial soil results supplement the subsurface boring evaluation discussed below, and may be more relevant to the evaluation of direct contact exposure risks for open space land-use option receptors than corresponding results for deeper soil intervals (in particular, the recreational and regulated/casual visitor subpopulations).

Boring-Specific Risks and HIs

The findings of the boring-specific evaluation for Horizons 0 and 1 basically parallel those described for the site analysis summarized above in that exceedances of a 1 x 10^{-4} cancer risk level (Figures 6.1-9 and 6.1-10) or an HI of 1.0 (Figures 6.1-11 and 6.1-12) at individual borings are generally limited to the following areas located in the central portions of RMA: South Plants, Sewer Systems, Lime Basins, Former Basin F, Basin A, and the Complex Trenches located in Section 36. Isolated exceedances of a 1 x 10^{-4} cancer risk were also identified at borings located in Basin C, Sand Creek Lateral, the North Plants Agent Storage Areas, and the sanitary landfill near the Rail Yard (located in the western portion of RMA). The boring-specific HI results exhibit similar trends.

Figures 6.1-13 and 6.1-14 show the composite of carcinogenic and noncarcinogenic chronic risk exceedances, as well as acute risk exceedances.

For all receptors evaluated in the HHRC, the major contaminants contributing to potential cancer risks were aldrin, DBCP, arsenic, and dieldrin. For noncancer risk endpoints, DBCP, aldrin, and arsenic account for the majority of the total estimated HIs.

Acute and Subchronic Risk Evaluation

In the probabilistic evaluation, PPLVs were calculated to be protective of chronic (long-term) exposures. However, it is possible that exposures to COCs at RMA could be short term, such as exposures occurring only on a single day (acute), or exposures lasting more than 1 day but less than 7 years (subchronic). These PPLVs, originally calculated for the HHEA Addendum, are summarized in Tables 6.1-19 and 6.1-20. The cumulative direct acute and subchronic PPLVs are protective of exposure via three pathways, soil ingestion, particulate inhalation, and dermal contact with soil. The PPLVs presented in these tables are the same as those originally calculated, with two exceptions: PPLVs for aldrin and dieldrin were recalculated during the HHRC to reflect updated toxicity criteria and the dermal relative absorption factor (all receptor scenarios) and soil covering factor (visitor populations only) were revised.

In general, and particularly for the biological and industrial worker populations, the acute and subchronic PPLVs shown in Tables 6.1-19 and 6.1-20 are higher than the corresponding chronic noncarcinogenic 5th percentile PPLVs (Tables 6.1-13 through 6.1-17). This finding is expected because the body can generally tolerate a higher contaminant dose over a short (e.g., acute) duration than over a long (chronic) duration for a given dose rate. However, for the recreational and regulated/casual visitor exposure settings, acute/subchronic PPLVs for some chemicals are lower than corresponding chronic noncarcinogenic 5th percentile PPLVs. Figure 6.1-15 shows sample locations exceeding an HI of 1.0 for all COCs having acute PPLV values.

6.2 Ecological Risk Characterization

Ecological risk characterization focuses on chemicals that, because of their toxicity, may adversely affect biota populations, individuals of threatened or endangered species, or the species diversity in a community. For these effects to occur, toxic chemicals must be present in the environment, potential biota receptors must be present and they must be engaged in activities that would expose them to chemicals that are not only present, but bioavailable (Figure 6.2-1). The sections below summarize the steps of the ERC at RMA, which are similar to the HHRC steps.

6.2.1 Identification of Contaminants of Concern

Fourteen chemicals detected on RMA were selected as of concern to biota: aldrin, dieldrin, chlordane, endrin, DDT, dichlorodiphenyldichloroethene (DDE), mercury, arsenic, cadmium, chlorophenylmethylsulfide (CPMS), chlorophenylmethylsulfone ($CPMSO_2$), copper, DBCP, and DCPD. The biota COCs were selected on the basis of criteria (toxicity, persistence, amount used or produced at RMA, and areal extent of contamination) developed collectively by the Army, EPA, USFWS, and Shell to focus on the potential main risk drivers.

Of the 14 biota COCs considered in the ERC, six (aldrin, dieldrin, endrin, DDT, DDE, and mercury) are known to biomagnify substantially, and seven do not biomagnify substantially or at all (arsenic, cadmium, CPMS, $CPMSO_2$, copper, DBCP, and DCPD). Chlordane can biomagnify (usually in the form of its metabolites), but was not treated quantitatively as such because no tissue sample data were available for this chemical. Biomagnification means that each successive organism in the food chain (e.g., from plant to insect, mouse, and hawk) will have a higher concentration of the chemical in its body tissue.

6.2.2 Exposure Assessment

Numerous ecological studies have been performed at RMA, particularly by USFWS in the 1960s, the Army in the 1970s to mid-1980s, and by Shell, USFWS, and the Army in the late 1980s and 1990s to identify the ecological receptors that may be exposed to the biota COCs and to determine the effects of this exposure. Using the data from these studies, several food webs were constructed to represent the biota food chains present at RMA. For the purposes of the IEA/RC, a food web is a collection of food chains that all culminate in a single top predator. Five such food webs were evaluated for RMA, each headed by different predators:

- Bald eagle
- American kestrel
- Great horned owl
- Great blue heron
- Shorebird

The following types of biota were selected to represent the various feeding levels (trophic boxes) in these RMA food webs and were evaluated from past varied studies where tissues were collected for analysis of COC concentrations:

- Earthworms
- Insects (represented by grasshoppers and ground beetles)
- Small birds (represented by vesper sparrows, western meadowlarks, and mourning doves)
- Small mammals (represented by deer mice and 13-lined ground squirrels)
- Medium mammals (represented by desert cottontails and black-tailed prairie dogs)
- Water birds (represented by mallards, blue-winged teal, and American coots)

- Shorebirds (represented by killdeer)
- Large fish (represented by northern pike and largemouth bass)
- Small fish (represented by channel catfish, black/brown bullheads, and bluegills)
- Aquatic invertebrates
- Plankton
- Terrestrial and aquatic plants

The data on tissue concentrations of contaminants were used to both document the nature and extent of contamination in biota and to provide tissue data that could be used in the ERC process described in Section 6.2.4. The exposure assessment included the estimation of exposure area soil concentrations; the estimation of species- and chemical-specific biomagnification factors (BMFs) based on bioaccumulation factors (BAFs) that describe the amount of COC transfer from food to consumers; and the identification of dietary items, fraction of items consumed, and feed rates. Exposure area soil concentrations were calculated based on an area-wide average (i.e., an arithmetic mean) concentration, an "area" being defined as an organism's estimated foraging or exposure area. The area-averaged concentration was computed from spatially interpolated soil concentrations in the 0-ft to 1-ft depth interval (except for the prairie dog's exposure area, which incorporated a vertical average for the 0-ft to 20-ft depth interval). The interpolated soil concentrations were calculated on a square grid with 100-ft spacing using surrounding actual soil sample concentration data and the inverse distance-squared algorithm. Before the soil data were interpolated, values that were below certified reporting limits (BCRL) were replaced with estimated values based on nearby detections when the surrounding data were sufficient using the inverse distance-squared algorithm. Because the spatial interpolation of BCRL data proceeded iteratively, a previously estimated BCRL value may have been included with nearby detections to estimate a replacement value for a BCRL at a different location (see Appendix C of the IEA/RC report for a detailed description of the spatial interpolation of BCRL data). Specifically, exposure area soil concentrations were estimated in three steps: spatial interpolation of BCRL data, interpolation of soil concentrations onto an RMA-wide grid, and averaging of interpolated data within an exposure area to compute exposure area soil concentrations. A best estimate of the exposure range of each receptor was obtained from the literature and represented by a circle (to facilitate the modeling of average risk) within which an individual receptor was assumed to be exposed. By centering the exposure range circle for a given receptor on a grid block and averaging the soil values within grid blocks that fell half or more within the circle, an average exposure concentration was estimated. This process was repeated for each grid block over the entire RMA area.

The BMF used at RMA represents a ratio between the concentration of a chemical in biota tissue (generally represented as the "whole-body concentration," which includes the whole animal for small mammals, such as deer mice, and the skinned/eviscerated carcass for medium mammals, such as prairie dogs) and that in soil. Three different methods of calculating the BMF were used in evaluating potential risk at RMA, which yielded differing BMF values for four COC categories (Table 6.2-1). The differences reflect the uncertainties associated with the data as well as the alternate methods used to derive the BMFs. Because the BMFs resulted in varying risk estimations, the SFS (see Section 6.2.4.3) will attempt to resolve uncertainties about the spatial extent of potential excess exposure and resulting subpopulation risk to biota compared to the three ranges of risk derived from the three BMFs.

Once a BMF was developed for a particular chemical/receptor combination, it was multiplied by the estimated exposure soil concentration in each block to obtain an estimated tissue concentration for the ecological receptor centered on that grid block. Data on dietary fractions and feed rates were obtained from the literature and from studies conducted at RMA. Where appropriate, the RMA-specific dietary data were used instead of literature values; however, if RMA data were not available, preference was given to literature dietary information from geographic and habitat types most similar to those at RMA. The exposure assessment parameters (Table 6.2-2) were based on best estimates of averages and were used to calculate potential tissue concentrations and dosages based on ingestion of contaminated soil and prey.

6.2.3 Toxicity Assessment

Literature data on chemical toxicity that include biota COC concentrations associated with some type of adverse health effect were used as numerical thresholds against which risk was evaluated. Reported effects on reproduction were preferred because these have the most obvious connection with detrimental population impacts; however, nonreproductive effects, such as behavioral toxicity, may also be important, but these effects are more difficult to evaluate and quantify. Other such toxicological endpoints were considered from a qualitative perspective. For all of the receptors evaluated, both tissue-based (i.e., maximum allowable tissue concentrations, or MATCs) and dose-based (i.e., toxicity-reference values, or TRVs) threshold values were sought in the literature. Each of the values found in the literature was evaluated as to its appropriateness for use as a threshold value (NOAELs and no observed effects levels, or NOELs, were the preferred endpoints). UFs were applied to the final literature-based pre-UF MATCs and pre-UF TRVs to help ensure adequate protection of biota populations. UFs were developed for the MATC and the TRV (Table 6.2-3) approaches in parallel (i.e., it was decided to apply the same rationale and values for each derivation process).

UFs were developed for four categories as follows:

- Intertaxon variability in toxicological responses to contaminants when extrapolating from the species used in an experimental study to a target species at RMA
- Extrapolation from the duration of an experimental study to the chronic exposure being assessed at RMA

- Extrapolation from a toxicity endpoint in an experimental study to the desired no adverse effects endpoint for the ecological risk assessment at RMA
- Modifying factors to account for additional sources of uncertainty

The final UF, the product of the results of these four categories, is divided into the pre-UF MATC or pre-UF TRV critical value to determine a final MATC or TRV (Table 6.2-4). The total uncertainty (final UF) applied for the derivation of TRVs ranged from 4 to 7,500 and the total uncertainty for MATCs ranged from 1.5 to 375. However, if the final UF exceeded 400, a final UF of 400 was used. The total uncertainty ranges for the main risk driver, aldrin/dieldrin, was much tighter: 4 to 30 for the aldrin/dieldrin TRVs (Table 6.2-5) and 1.5 to 30 for the aldrin/dieldrin MATCs (Table 6.2-6).

The MATCs represent maximum whole-body concentrations of bioaccumulative chemicals that are unlikely to cause harmful effects to specific receptors. The MATCs, expressed as the weight of contaminant per unit of body weight (mg/kg-bw), were derived from literature data on tissue concentrations associated with the presence or absence of observed toxicological effects in biological test species (to produce pre-UF MATCs), and then adjusted with the COC/receptor-specific UF to produce final MATCs.

The final TRVs represent estimates of a daily dose (mg/kg-bw-day) that are likely to be without an appreciable risk of harmful effects to target receptors. The TRVs computed for the IEA/RC follow an approach that is different from that described in the Off-Post Operable Unit Endangerment Assessment/FS for RMA (Harding Lawson Associates 1992); however, both RMA approaches are similar to the methodology used by EPA to compute RfDs for assessing risks to human health.

The final toxicological threshold values, MATCs and TRVs, are compared to the site-specific exposure measurements (i.e., population mean contaminant tissue concentrations and doses) to estimate potential risk to biota populations (Section 6.2.4.1). The toxicological threshold values are intended to be protective of biota populations and individual bald eagles at RMA.

The final tissue- and dose-based threshold values selected for the characterization of risk are shown in Table 6.2-4. When both tissue-based and dose-based threshold values were available, the value with the lower UF was selected. When the uncertainty was equal, the TRV was selected because it avoided the use of a BMF, which introduced uncertainty of its own. Where two values were calculated, the value that is shown in bold face was used to estimate risk.

6.2.4 Risk Characterization

6.2.4.1 Methods

The characterization of potential risk from the biota COCs to terrestrial receptors was performed by integrating the exposure assessment and the toxicity assessment with a Geographic Information System (GIS) to produce a series of maps that display areas of potential risk (i.e., HQs or HIs greater than 1.0).

For the tissue-based approach, estimated tissue concentrations were compared directly with a tissue-based toxicity threshold value to calculate an HQ, which represented an estimate of potential risk in a grid block for the chemical/receptor combination being investigated. This approach is represented by the following equation:

$$HQ = \frac{Tissue\ Concentration}{MATC}$$

Alternatively, if the dose-based approach was used, the dose to the receptor being investigated was estimated and compared to a dose-based toxicity threshold value to calculate an HQ. The dose-based approach is represented by the following equation:

$$HQ = \frac{Dose}{TRV}$$

The HQ equations presented above are a generalized representation of those actually used in the ERC. Appendix C of the IEA/RC report contains a detailed description of the equations used. The risk characterization processes were repeated for all grid blocks and for all chemical/receptor combinations for which biomagnification factors were calculated. There were variations from these approaches for chemicals having no tissue data, for predators that were not sampled for nonbioaccumulative COCs, and for aquatic food chains. These variations are also described in Appendix C of the IEA/RC report.

An HQ greater than 1.0 indicated a potential risk from a particular chemical. The sum of all HQs for a single receptor resulted in an HI, which indicates the potential risk from all biota COCs to that receptor. HQs and HIs were mapped using GIS to show the geographic extent of areas having potential risk (Figures 6.2-2 through 6.2-5).

The degree to which the results of the risk characterization were consistent with the ecological measurement endpoints on observable field effects identified within the ecological database available for RMA was also evaluated. Ecological measurement endpoints were selected at the community, population, and individual levels of ecosystem organization. The community-level measurement endpoints considered were species richness and trophic diversity; these provide information on the assessment endpoint of biological structural diversity of the RMA and regional ecosystem. Population-level measurement endpoints were relative abundance, reproductive success, and morbidity; these provide information on the assessment endpoint of population robustness. Selected biomarkers (i.e., acetylcholinesterase inhibition and eggshell thinning) were examined at the individual level, but evaluated as measurement endpoints for extrapolation to population effects. Endpoints at the individual level are appropriate for evaluating adverse effects on individuals of threatened or endangered species (e.g., bald eagle), which by definition have populations reduced to the level where individuals are important.

6.2.4.2 Results

Quantitative results were calculated for all five of the predators (bald eagle, American kestrel, great horned owl, great blue heron, and shorebird) heading the food webs developed for RMA and for four of the trophic boxes in their food webs (small bird, small mammal, medium mammal, and water bird). Other trophic boxes, including all strictly aquatic organisms in the RMA lakes, were not evaluated quantitatively because toxicity threshold values for these biota COCs/trophic box combinations were not available in the literature. The results of the terrestrial risk characterization are presented primarily in maps, which best show the spatial variability of the estimated potential risk. Figures 6.2-2 and 6.2-3, which illustrate the number of receptors having potential risk, are based on the Shell BMF because Shell BMF results were intermediate between the Army and EPA BMF results. Many other such maps are available in the IEA/RC report (Section 4 and Appendix C.3). In viewing these maps, it should be remembered that a small hot spot (identified by only a few borings) or a large relatively clean area can affect the soil concentrations interpolated for several surrounding grid blocks. These grid blocks in turn can affect the estimated exposure soil concentrations for many grid blocks, particularly for receptors with large exposure ranges such as raptors. Such species are likely to have sizable areas of potential risk because very high contaminant concentrations in hot spots around the manufacturing plants and basins were averaged over large exposure ranges. If the high contaminant concentrations in just these hot spots were reduced, then the areal extent of potential risk, as well as the magnitude of HQs and HIs, would be reduced. Conversely, if large relatively clean areas are included in the estimation of exposure soil concentrations, the effect could be a dilution of concentration attributed to hot spots.

Potential risk varied depending on the BMF used, the chemical or chemical group being considered, and receptor (trophic box) being evaluated. Differences in risk among receptors for a given chemical were partly due to differences in the toxicity threshold values, and especially due to differences in the exposure range size. Figure 6.2-2 shows the number of representative trophic boxes that have HIs greater than 1.0 in various parts of RMA. This figure shows that the areas of potential risk to the greatest number of species tend to be smaller and located toward the center of RMA, even though the specific receptors subject to potential risk in one area may be different from those subject to potential risk elsewhere. Terrestrial areas where all trophic boxes are expected to be at potential risk (based on cumulative risk from all of the COCs combined) are most of the central sections of RMA, including South Plants; Basins A, B, C, D, and F; and the northernmost upland areas adjacent to the South Lakes area. Pesticides (especially aldrin/dieldrin) are the primary biota COCs contributing to biota risk at RMA, as shown in Figure 6.2-3. This figure shows the number of trophic boxes having an HI greater than 1.0 for aldrin/dieldrin, DDT/DDE, and endrin based on soil exposure and the Shell BMF approach. Metals are also significant contributors to biota risk.

The degree to which potential risk predicted by the EPA, Shell, and Army BMFs differed for a single COC/receptor combination based on the TRV (dose-based) approach is shown for aldrin/dieldrin in Figure 6.2-4 for the great horned owl and in Figure 6.2-5 for the small mammal. The effect of the small mammal's much smaller exposure range can be seen by comparing Figure 6.2-4 with Figure 6.2-5. Receptors with larger exposure ranges generally show greater areas of potential risk, and receptors with smaller exposure areas tend to show smaller areas of potential risk that more directly reflect specific areas of higher soil contamination. The areas depicted in the maps do not necessarily denote the extent of magnitude or severity of potential risks to biota, nor do they depict the ecological relevance of the potential risks to local populations. The ecological relevance of the potential risks will be addressed as part of remedial design and incorporate the ongoing USFWS biomonitoring program, as well as the SFS and other evaluations being performed by the BAS (see Section 6.2.4.3). EPA defines ecological relevance generally in terms of "population sustainability and community integrity" for both current and future exposure and risk.

The potential risk to predators at the top of food webs having aquatic food chains is shown in Table 6.2-7. These risks are tabulated because a single risk value was calculated for all the lakes combined. In combining measured tissue concentrations from the various lakes, feeding was assumed to be proportional to the size of the lake. Table 6.2-7 shows that potential risk from aquatic food chains is greatest to the great blue heron.

The results of the quantitative ERC were also compared with the results of evaluating potential ecological effects such as impacts on reproduction, species abundance, and species diversity. No strong trends in any of these data indicated populational effects. However, because sampling was concentrated in contamination areas, average tissue concentrations exceeded the MATC (which represents the tissue-based toxicity threshold value) for dieldrin, mercury (for this COC, the detection limit also exceeded the MATC), and DDE. Likely adverse effects of RMA contamination have been observed in individual animals collected at RMA, but these effects were not apparent in the available data collected for wildlife populations as a whole at RMA. The available data were obtained from studies that had varying purposes and degrees of ability to discern contaminant effects on local populations. It should be noted that the state and EPA disagreed with the ability to draw conclusions on wildlife populations or on the effects of RMA contaminants to individual animals from the available data. In accordance with the Conceptual Remedy, all Parties, through their representatives on the BAS, will continue to evaluate the SFS and USFWS biomonitoring studies and provide information to risk managers on the status and health of biota at RMA in terms of the need to refine design boundaries to include additional locations where biota risks were deemed to be excessive. This process will continue during the remedial design after the ROD is signed (see Section 6.2.4.3).

The potential risk from all COCs combined covered most of RMA for at least one species. However, a number of considerations should be taken into account when evaluating this risk. For example, the risk from mercury is overestimated for RMA because all mercury was assumed to be in its most toxic and bioavailable form, methyl mercury, although this is not the most prevalent form at RMA. Conversely, because chlordane was not quantitatively modeled as a bioaccumulative COC, its risks to biota may be underestimated. For terrestrial and aquatic receptors, there are uncertainties inherent in the toxicity threshold values used and in the estimated tissue concentrations that were compared to these threshold values. The uncertainties in threshold values are mostly reflected in the magnitude of UFs used to derive each TRV or MATC. For terrestrial receptors, uncertainties in estimated tissue concentrations result primarily from uncertainties in the estimates of the exposure soil concentration and the BMF.

The available ecological data used to evaluate ecological effects were also subject to uncertainty resulting from the short-term nature of many of the studies, lack of sufficient precision of the results, and study designs that were not always oriented toward correlating ecological parameters with contaminant concentrations. As noted previously, not all the Parties agreed with the appropriateness of the ecological data used in this comparison.

6.2.4.3 Continuing Biological Studies

Generally, the results of the ERC showed that the areas of highest potential risk are located in the central portions of RMA and are associated with major chemical manufacturing processes or a disposal area that contains the greatest concentration of contaminants. Although the Army, Shell, and EPA approaches all agree regarding excessive risk (i.e., HQ or HI greater than 1.0) to wildlife in the central areas of RMA, they differ in their estimates of areas and magnitudes of potential ecological risk in other parts of RMA. The major variation is due to the use of different BMFs (as calculated by the Army, EPA, and Shell) to estimate exposure. Because of the scientific differences of opinion concerning the best approach to determine field BMFs at RMA, the SFS was established. Phase I of the SFS is designed to determine whether unacceptable levels of exposure (i.e., risk) exist within the Area of Dispute (Figure 6.2-6). The Area of Dispute is defined as the difference in the areas of potential aldrin/dieldrin risk (HQ greater than 1.0, based on MATC) to small mammals based on the Army and EPA approaches and was delineated for the primary purpose of sample collection in Phase I of the SFS. It may or may not reflect the area of uncertainty in terms of excessive risk to biota, although this is also coincidentally the ROD Area of Contamination (AOC) boundary. If Phase I of the SFS indicates that unacceptable risks to biota are likely, the SFS may proceed with Phase II under RMA Council direction to collect additional tissue and soil data to estimate field BMFs for selected species.

The goal of biota remediation is to achieve appropriate remediation such that it is protective of biota health (i.e., sustainability of local subpopulations and individuals of threatened or endangered species). HIs were used in the IEA/RC to provide a semiquantitative characterization of predicted risks to biota at RMA. In general, HIs less than 1.0 denote the absence of excessive risk to biota populations. HIs greater than 1.0 may indicate potential adverse risks to biota populations; the greater the HI, the greater the potential risk.

To demonstrate spatial representation of biota risk, a series of additional risk maps (pre- and post-remediation) are presented for the American kestrel and great horned owl using the Army and EPA BMF approaches (Figures 6.2-7 through 6.2-14). These residual risk maps show locations and relative magnitudes of estimated biota risks due to exposure to the bioaccumulative COCs (excluding mercury) following proposed remediation. Residual risk areas will be evaluated by the BAS as potential locations for additional ecotoxicological studies.

Mean HIs for the American kestrel and great horned owl were estimated within the pre-remediation areas identified as having an HI greater than 1.0 using the Army and EPA BMF approaches based on a semiquantitative analysis of the pre- and post-remediation risk maps (Figure 6.2-7 through 6.2-14). Several general conclusions about the pre- and post-remediation risks to biota and associated uncertainty can be made from this semiquantitative analysis as follows:

- EPA mean HI estimates were an average of about 3 times higher than the Army mean HI estimates based on differences in the BMFs (ranging from about 2 to 4 times higher; American kestrel had the highest difference).
- Pre-remediation mean HIs ranged from about 2 to 120 using Army BMFs and about 7 to 270 using EPA BMFs (bald eagle was the highest in both cases).
- Post-remediation mean HIs ranged from 1 to 7 using Army BMFs and about 4 to 16 using EPA BMFs (bald eagle was the highest in both cases). The residual risk maps show that in general residual risks remain adjacent to the ROD's biota remediation areas (shown as the shaded areas in Figure 6.2-6) and that the highest ranges of residual risk are located adjacent to the southwest section of the green-shaded areas.
- In general, both the Army and EPA methods show at least a 10-fold reduction in risk for all species of concern following remediation of the shaded areas shown in Figure 6.2-6.

While the SFS is being conducted, certain areas of more highly contaminated surficial soil, which represent the areas in which all three BMF approaches yielded HQs greater than 1.0 (using the MATC approach) for aldrin/dieldrin for small mammals, as well as some additional areas north of Former Basin F and areas identified by USFWS as priority areas (i.e., known areas of high contamination and posing a threat to wildlife based on field observations), have been identified as candidates for initial focused remediation and are identified as the green-shaded areas in Figure 6.2-6. The process outlined in the Conceptual Remedy and summarized below permits the further investigation of other identified areas of potential residual risk outside the green-shaded areas in order to more accurately characterize actual biota risk and impacts and to refine design boundaries if warranted. This process includes the following:

- The BAS of technical experts (e.g., ecotoxicologists, biologists, range/reclamation specialists) from the Parties will focus on the planning and conduct of both the USFWS biomonitoring programs and the SFS/risk assessment process. The BAS will provide interpretation of results and recommendations to the Parties' decision makers.
- The ongoing USFWS biomonitoring programs and the SFS/risk assessment process will be used to refine design boundaries for surficial soil and aquatic contamination to be remediated.
  - Phase I and the potential Phase II of the SFS will be used to refine the general areas of surficial soil contamination concern. The field BMFs from Phase II will be used to quantify ecological risks in the Area of Dispute, identify risk-based soil concentrations considered safe for biota, and thus refine the area of excess risks (Figure 6.2-6).
  - Pursuant to the FFA process, USFWS will conduct detailed site-specific exposure studies of contaminant effects and exposure (tissue levels and Army-provided abiotic sampling) on sentinel or indicator species of biota (including the six key species identified in the IEA/RC report as appropriate). These studies will address both the aquatic resources and at least the surficial soil in and around the Area of Dispute. These site-specific studies will be used in refining contamination impact areas in need of further remediation.
  - Results from both the SFS/risk assessment process and the site-specific studies will be considered in risk-management decisions, which may further refine the areas of surficial soil and aquatic contamination to be remediated. (In the event of a conflict between management of RMA as a wildlife refuge and performance of remedial response actions, the Rocky Mountain Arsenal National Wildlife Refuge Act indicates that response actions will take priority.)
- The BAS will serve as a technical resource to the Parties' decision makers by using technical expertise in analyzing, and potentially collecting, data sufficient to support design refinement for surficial soil areas and aquatic resources that will break unacceptable exposure pathways in consideration of minimizing habitat disturbance. Further, it will assess through monitoring the efficacy of remedies in breaking unacceptable pathways to biota. If any additional sites are identified, the remedy will be implemented as follows:
  - It will be staged to allow habitat recovery.
  - It will be performed first on locations selected through a balance of factors such as:
    - The Parties agree an area has a negative impact on or excessive risk to fish or wildlife.
    - The effort will not be negated by recontamination from other remediation activities.
    - The existing fish and wildlife resource value.
  - It will include revegetation of a type specified by USFWS; if the initial revegetation is not successful, the appropriate adjustments will be made and revegetation again implemented.
  - It will provide that the locations and timing of remediation are to be determined with consideration of and in coordination with USFWS refuge management plans and activities.

6.3 Uncertainty Analysis

Several sources of uncertainty must be considered in the evaluation of the HHRC and ERC results. Model parameter distributions were developed based on empirical data, and in instances where empirical data were lacking, best professional judgment was incorporated. In addition, when uncertainty in the empirical data for a given parameter warranted conservative assumptions, these assumptions were incorporated into the exposure and risk estimations.

6.3.1 Human Health Risk Characterization

6.3.1.1 Chemical Database

Contributing to the chemical database uncertainty are the different analytical techniques used by the RI Phase I and Phase II programs for some of the organic chemicals. Phase I employed **gas chromatography/mass spectrometry** (GC/MS), and Phase II employed more precise GC methods. The Phase I techniques made use of higher detection limits; thus, chemicals present at lower levels may not have been detected. In a few cases, Phase I samples required dilution to facilitate analysis, and the dilution may have masked the presence of some compounds by raising the effective detection level. When necessary, an expanded suite of Phase II analyses and/or additional GC/MS analyses were used to ensure that all target analytes were evaluated. Some other limitations associated with the chemical database are soil sample collection, tentatively identified compounds, unidentified compounds, and Army agent contamination. Uncertainties associated with soil sample collection can under- or overestimate risk. Tentatively identified and unidentified compounds were not considered in the risk characterization and the detections of Army chemical agent reported in the chemical database were not quantitatively evaluated. Potential risk may have been underestimated based on the exclusion of agent and tentatively identified compounds from the evaluations.

6.3.1.2 Exposure Point Concentration

Uncertainties associated with the exposure point concentrations include the estimation method used to approximate site concentration values used to calculate risk. In accordance with EPA guidance, representative soil concentrations were estimated using the arithmetic mean ($C_{rep,mean}$). The uncertainty in these estimates was characterized by reporting the 95 percent upper and lower confidence limits (95% UCL and 95% LCL, respectively) on the mean. The 95% UCL ($C_{rep,upper}$) was used to estimate the RME risks. Conservative assumptions were also employed to address potential dilution effects when soil boring samples were composited and to calculate the boring-by-boring risk estimates; the highest detected concentration of the COC was used regardless of the depth of the sample.

6.3.1.3 Land-Use and Exposure Scenarios

Uncertainty exists regarding the likelihood that the land uses evaluated will in fact occur under a future development scenario at RMA. Land use at RMA is currently limited to commercial, industrial, recreational, and open space (i.e., nature preserve/wildlife refuge) uses. The land-use designations were based on information obtained from several governmental agencies overseeing and directing land use within their respective jurisdictions surrounding RMA. The FFA restricts the ownership, use, and transfer of property at

RMA now and into the future. Consistent with the FFA, certain future land uses at RMA are not considered foreseeable, such as residential and agricultural development. It is for this reason that certain pathways of exposure (e.g., potable and agricultural use of groundwater, surface water and sediment exposures, and consumption pathways) were not evaluated at RMA. The uncertainties associated with the human health exposure scenarios evaluated in the IEA/RC as related to land use, target receptors, spatial exposure patterns, and exposure pathways could result in an over- or underestimation of risk.

6.3.1.4 Human Health Toxicity Estimates

The toxicity factors (D_T; the dose-response parameter based on the slope factor or RfD) used in the HHRC were designated as a fixed parameter to maintain consistency with established EPA toxicity factors used in CERCLA risk assessments. However, a large degree of uncertainty is known to be associated with the toxicity factors. This uncertainty could lead to an over- or underestimation of risk. The major sources of uncertainty include the following:

- Extrapolation of toxicity factors from effects observed at high doses administered in a laboratory setting to effects observed at relatively low doses expected from human contact with the chemical in environmental media
- Use of short-term toxicity studies to predict the effects of long-term (chronic) exposures and vice versa
- Use of animals to predict the effects of contaminant exposure on humans where adequate human data are lacking
- Use of toxicity data from laboratory animals (homogeneous populations) and healthy humans to predict the effects observed in a general population, which included individuals having a wide range of sensitivities

As indicated in "Guidelines for Carcinogenic Risk Assessment," the cancer slope factors generated from the linearized multistage extrapolation procedure lead to what is considered a "plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis. Such an estimate, does not necessarily give a realistic prediction of the cancer risk. The true value of the risk is unknown, and may be as low as zero" (EPA 1986). Descriptions of the uncertainties associated with the toxicity factors are contained in Appendix B and Appendix E of the IEA/RC report.

6.3.1.5 Exposure Parameters and PPLVs

The variability and uncertainty in the PPLVs were estimated by developing probabilistic distributions for each of the HHRC model's parameters. The variability in the parameter distribution refers to the real variation in possible parameter values, which may be spatial (e.g., soil density), temporal (e.g., dust loading), physiological (e.g., body weight, skin surface areas) or due to the effects of other factors such as behavior. Uncertainty is that part of the parameter distribution resulting from random sampling variation and other sources of potential error. Uncertainty increases the overall spread of the distribution and may also result in bias, both intentional (e.g., conservative assumptions) and unintentional (unknown). There was substantial uncertainty about the representativeness of data for parameters describing human exposures (e.g., soil intake parameters, time-dependent exposure parameters). In general, however, conservative assumptions were made. Ages and activities associated with the open space visitor land-use options were characterized using available empirical data and professional judgment. Although survey data were used to characterize time and activity patterns for the refuge worker population and biological worker subpopulation in order to improve the confidence in the analysis, the representativeness of the resulting distributions for current and future exposed populations at RMA remains uncertain. The datasets compiled for these populations or subpopulations may under-represent exposures for some portion of the future RMA population and over-represent for some other portion. It is not possible to determine with certainty whether data representativeness in the risk evaluations imparted a conservative or underconservative bias to the results. Summaries of the major uncertainties associated with the PPLV equation parameters are presented in Tables 6.3-1 through 6.3-3.

The variation in the HHRC model parameters is reflected in the spread of the PPLV distribution. Because the uncertainty and/or variability in many key probabilistic parameters is higher for particular chemicals or for exposed populations, the resulting PPLV distributions corresponding to these chemicals and land uses have a wider spread. A detailed description of the PPLV distribution variability is described in Appendix E of the IEA/RC report.

6.3.1.6 Risk Estimates

The PPLV-based risk estimations were based on a target cancer risk of 1 x 10^{-6} or an HQ of 1.0 and exposure point concentrations representing the C_{max}, $C_{rep,mean}$, and $C_{rep,upper}$ (the different risk calculation methods are available via the HHRC model). When the cancer risk estimates are based on the 5th percentile PPLV and the $C_{rep,upper}$, the results can be considered as upper bound estimates of potential risk.

In the IEA/RC, both carcinogenic risks and noncarcinogenic HQs are assumed to be additive, consistent with current risk assessment guidance. There are several limitations associated with this assumption. Due to these limitations, the potential to over- or underestimate risk cannot be firmly established. In summing cancer risks, the underlying assumption is that there is an independence of action (i.e., effect to organ, tissue, etc.) by the chemicals involved and that there are no synergistic or antagonistic chemical interactions. Uncertainty is also associated with summing cancer risks for multiple chemicals that have differing weights of evidence for human carcinogenicity (i.e., Group A versus Group C carcinogens; see Section 6.1.3). Because little or no information on antagonistic or synergistic effects was available for the RMA COCs, noncarcinogenic effects from multiple chemicals were also assumed to be additive. A limitation with the additive approach used for the IEA/RC is that the COC-specific HQs were not segregated by major toxic effect prior to summing to derive the HI;

however, this simplifying step may not have introduced large degrees of uncertainty because most of the noncancer effects were attributed to a single COC (dieldrin).

6.3.2 Ecological Risk Characterization

6.3.2.1 Chemical Database

The same uncertainties associated with the chemical database that were identified for the HHRC apply to the ERC. However, the database used for the ERC also included results associated with biota sample collection and analysis. Despite the relative abundance of site-specific field data to characterize ecological risk at RMA, the need to work with data from sampling programs designed for other purposes (e.g., to establish nature and extent of contamination) may have been less than ideal for the estimation of exposure soil concentrations and BMFs. It is difficult to know if the use of these data resulted in an over- or underestimation of potential risks to biota. The biota species sampled on RMA were chosen from species that best represented the uptake of contaminants from environmental media and the subsequent transfer, via food consumption, through food chains to top predators. Uncertainty is associated with the use of these biota samples to derive RMA-specific BMFs. Some uncertainty is also associated with the more scattered peripheral abiotic sampling where heterogeneous soil contamination occurs, and where detection limits, in some cases, exceeded the risk-based concentrations. These factors, along with lesser sampling density and little collocation of tissue and soil samples, added to the uncertainties associated with the chemical database.

6.3.2.2 Exposure Pathways

Exposure pathways were selected to include the predominant pathways of exposure believed to exist at RMA. Those selected for the food-web model included food consumption, dermal exposure to surface water by organisms, ingestion of water by some terrestrial organisms, and sediment and soil ingestion by some aquatic and terrestrial organisms. Exposure pathways excluded from the food-web model included inhalation of contaminant vapors and particulates and dermal exposure to contaminants from soil contact. These exposure pathways are implicitly contained in the BMF because measured tissue concentrations (from sampled biota species) are the result of cumulative exposure by all pathways. Additional uncertainties related to the exposure pathways are presented in Section 6.3.2.4.

6.3.2.3 Exposure Concentrations

Most of the uncertainty regarding exposure concentrations centers on the estimated exposure area concentrations used to calculate terrestrial risk. Aquatic risk was estimated directly from measured tissue concentrations and therefore was not based on quantitative exposure concentrations in aquatic media. Terrestrial tissue concentrations, dose, and risk are theoretically dependent on exposure soil concentrations (ESCs), i.e., the concentration in soil that is bioavailable and accessed by an individual during exposure activity. The ESC is, for all practical purposes, unverifiable in the field; therefore, it is represented by estimated exposure area soil concentration, i.e., the average soil concentration in a specified depth profile within a circular species-specific exposure area. Two types of uncertainty occur when applying ESC to estimate risk. "Representation uncertainty" refers to the uncertainty in adequately representing spatial and temporal scales of the ESC by exposure area soil concentration, and "estimation uncertainty" refers to the uncertainty in analytically estimating the exposure area soil concentration based on available data. Representation uncertainty explains the difference between true exposure concentration for an individual and the exposure area concentration for a typical (mean) individual. Unfortunately, representation uncertainty is for all practical purposes unquantifiable and irreducible, because the detailed information on individual organisms (and their prey) required for its calculation cannot be practically obtained. Estimation uncertainty explains the differences between the true exposure area soil concentration in a given area or for a given individual, and the estimated exposure area soil concentration based on available sampling and analytical data.

The empirical mathematical constant used to relate exposure area soil concentration to tissue concentration is the BMF. BMF is therefore defined as a correlation based on the variable exposure area soil concentration and not on actual exposure soil concentration. The BMF values determined purely from literature data, rather than site-specific data from RMA, will describe the relationship between tissue concentration and a different dose-based quantity than ESC, and therefore may create more or less bias if used with ESC to predict risk at RMA. Uncertainty is also associated with the BMF based on the use of site-specific information (e.g., RMA-soil and biota data collected at different times and locations and for various purposes). The uncertainty associated with the exposure concentration, including the estimation of BMFs, will be further ascertained by review of the findings gathered from the SFS and the ongoing USFWS biomonitoring studies.

6.3.2.4 Ecological Toxicity Estimates

MATC and TRV uncertainty was incorporated quantitatively by use of UFs as discussed in Section 6.2.3. The UFs were applied to add a margin of safety to the extrapolated toxicity measures. The UF protocol included factors to account for four categories of uncertainty: intertaxon variability, study duration, toxicity effect levels (study endpoints), and other modifying factors (including nine subcategories) that were multiplied to arrive at the total estimated uncertainty.

In addition to the uncertainty incorporated in the UFs are potentially unrecognized or unquantifiable sources of uncertainty. These include the following:

- Representativeness of toxicity endpoint tissue concentration data from one species relative to other species in the trophic box
- Differences in metabolic rate, body size, and physiology between test and target species
- Differences in feeding habits and behavioral patterns in test v. target species
- Differences in the life stage of the organisms tested v. those exposed

- Seasonal differences in response to toxicants (e.g., "fat" versus "lean" times)
- Difficulty in adequately estimating exposure concentrations (including environmental variability in time and space)
- The possibility that exposed organisms may avoid, or be attracted to, contaminated media (e.g., pesticide-debilitated prey) and so may not show effects seen in laboratory tests (Suter 1993)
- Inability to quantify the other stresses that biota may face (e.g., climate, food supplies, background levels of toxicants, habitat disturbance, and other manmade causes)
- The possibility that exposure pathways, in addition to ingestion, are significant
- The fact that there are no standard measures of effect, patterns of dosing, durations of exposure, etc., so comparison across studies/ecosystems is obscured or confounded

6.3.2.5 Risk Estimates

Toxicological effects from multiple chemicals were assumed to be additive, consistent with the risk assessment procedures used for human health. This assumes independence of action, i.e., no net synergistic or antagonistic effects, since these effects are poorly understood with the limited toxicological data available. This practice of additivity without a toxicological basis (i.e., common mechanism of action or target organ effect) is protective but scientifically questionable; however, some means of evaluating the potential cumulative effects of exposure was required and EPA guidance requires such an approach in the absence of site-specific data on additivity. Hence, the individual HQs for each COC were summed to estimate the total risk (HI) for each trophic box. It is difficult to determine whether this procedure over- or underestimated risks to biota. As noted in the IEA/RC report, a range of potential risk was presented for the bioaccumulative COC because three different BMFs were employed. Because of the overall uncertainty associated with each of the parameters incorporated in the food-web model and the toxicity threshold values, it is difficult to state with certainty at this time which of the three BMF approaches best estimated risk to biota at RMA. Additionally, it is possible that actual residual risk to biota of an excessive nature may occur in some cases following remediation based on the uncertainty associated with the food-web risk modeling process and its application to delineated areas proposed for remediation. Again, the uncertainty associated with the risk estimates will be further ascertained by review of the findings gathered from the SFS and the ongoing USFWS biomonitoring studies.

6.3.2.6 Ecological Measurement Endpoints

The presence of potential ecological risk was given further perspective by considering it together with available field data on ecological endpoints. The available data on ecological status and health used to evaluate ecological endpoints are also subject to uncertainty. In this context, uncertainty results from the following:

- The short-term nature of many of the studies relative to the cycles of natural variability
- Estimation of quantitative ecological parameters at levels of precision that may not be biologically and/or statistically significant and/or use of endpoints that may not have been sensitive enough to discern the various potential human health risks to biota

- Study designs that did not precisely and quantitatively correlate ecological parameters with parameters related to contaminant concentrations
- Study designs that did not precisely quantify all parameters that might have positively or negatively affected the ecological data

Appendix E of the IEA/RC report presents a detailed discussion on the assumptions, limitations, and uncertainties associated with each of the uncertainty categories listed above.

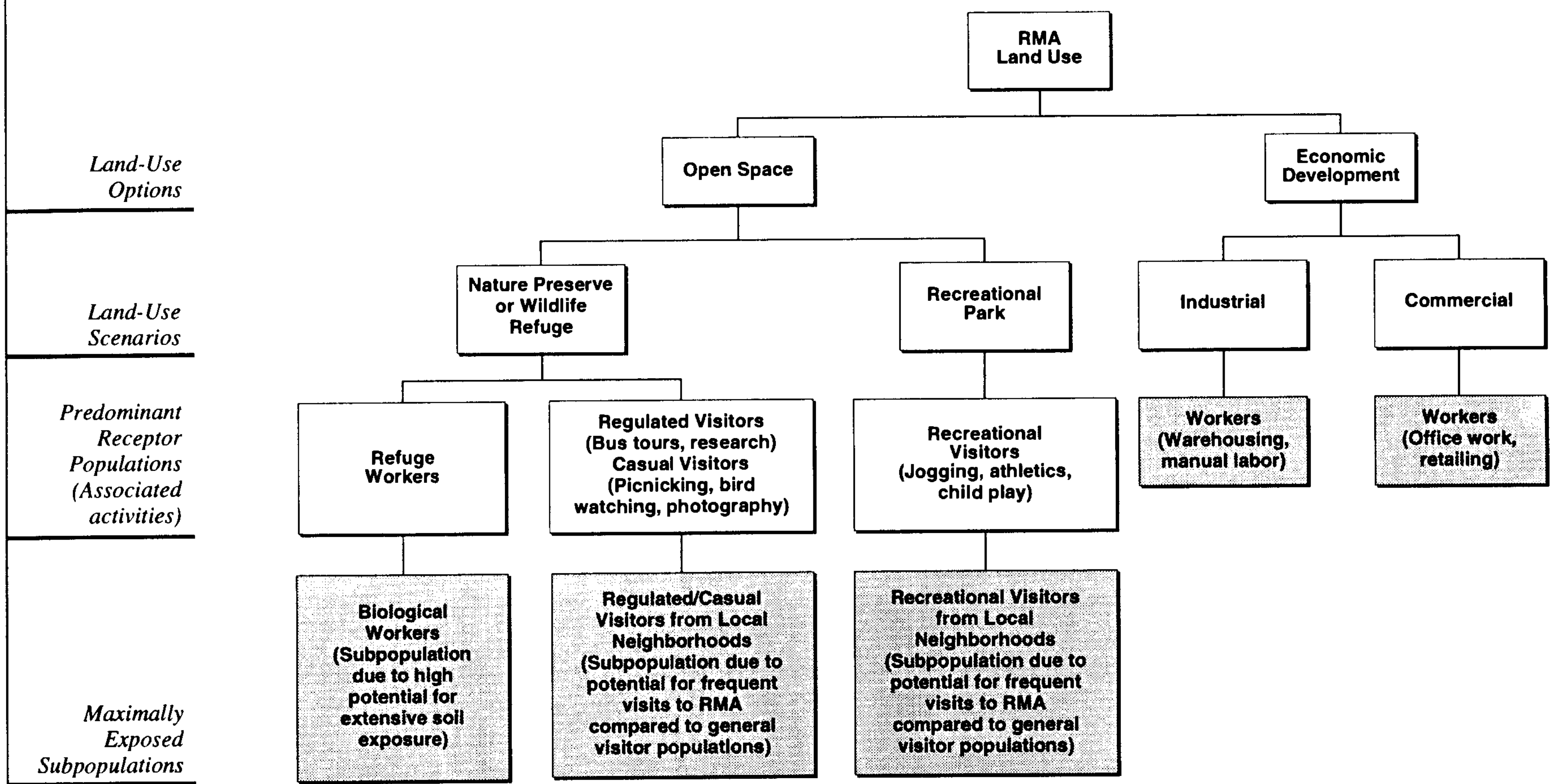
6.4 Conclusions

Both the human health and the ecological risk assessment results are based on probabilistic methodologies. The probabilistic methods account for the variability in literature and field data for the various parameters used to quantify exposure and risk and at least partially reflect the uncertainty associated with these parameters. The use of this methodology and the discussions of uncertainty increases the understanding the risk characterization by clarifying the uncertainties associated with the input values and their implications on estimated risks.

The results of the risk assessment, as presented in the IEA/RC report, indicate that potential risks exist for both human and ecological receptors. The contaminants that are the major contributors to overall potential risks are similar for both receptor groups, i.e., the OCPs. Likewise, the areas that pose the greatest potential risks to both receptor groups are in the central core region of RMA. It is very important to remember that the potential risks presented in this report are based on current and historical contamination evaluated under present or future land-use scenarios. However, data from some of the areas at RMA that have undergone interim remediation (e.g., capping to eliminate possible exposure pathways for receptors) were not revised to reflect the remediation; the actual risks are, therefore, likely to be lower than the risks presented in the IEA/RC report.

Areal extents of biota remediation that are needed to reduce or prevent excessive risks to ecological health are not completely known at present, but will be further refined as part of remedial design and incorporate ongoing ecotoxicological evaluations by the BAS. Recommendations regarding the nature and extent of excessive risks to biota will be presented by the BAS to RMA risk managers for inclusion in soil remedial actions to reduce risks to acceptably healthy levels in accordance with EPA Superfund guidance, the Rocky Mountain Arsenal National Wildlife Refuge Act, and the selected remedy.

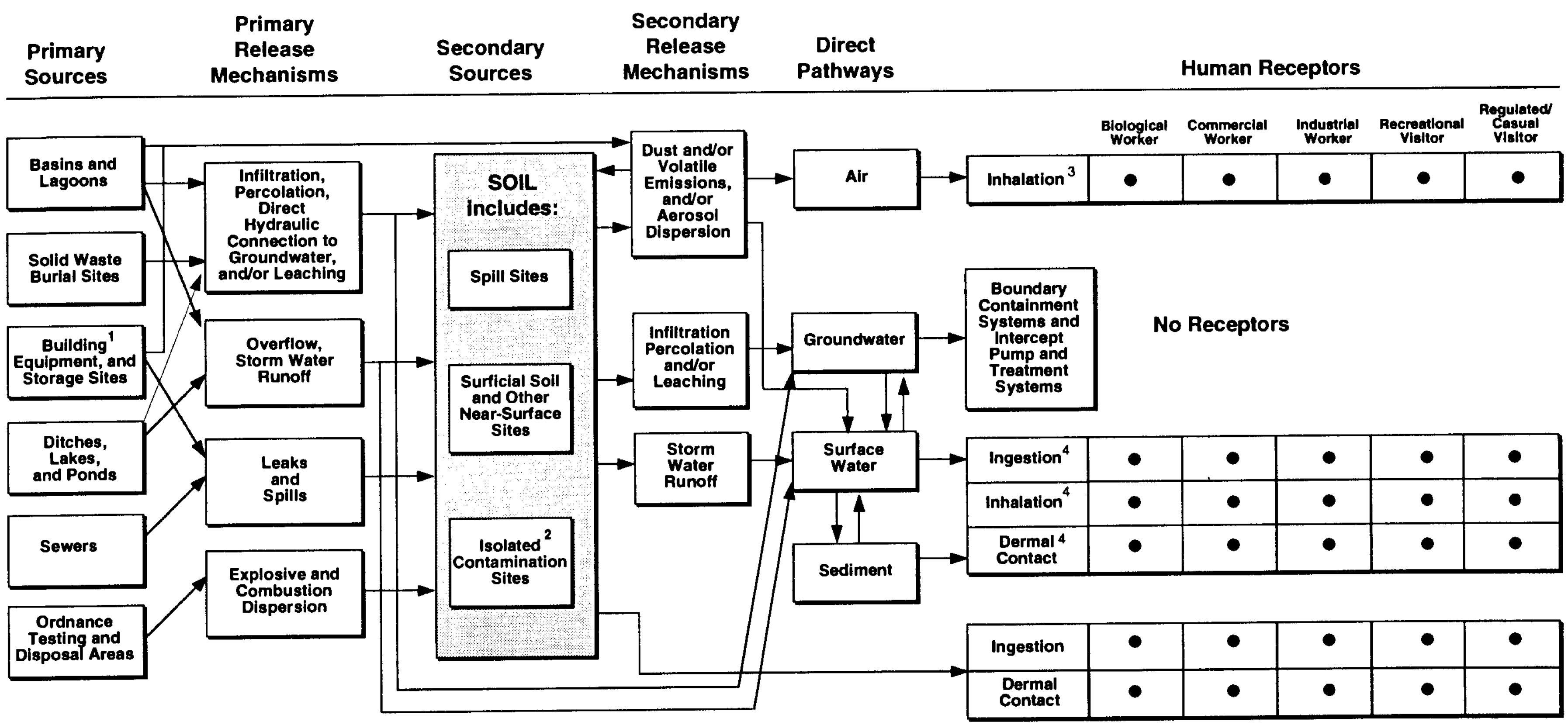
Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment.



1 - Receptor populations/subpopulations shown in shaded boxes were evaluated in this risk assessment

Figure 6.1-1
Projected Land-Use Scenarios for RMA[1]

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corporation

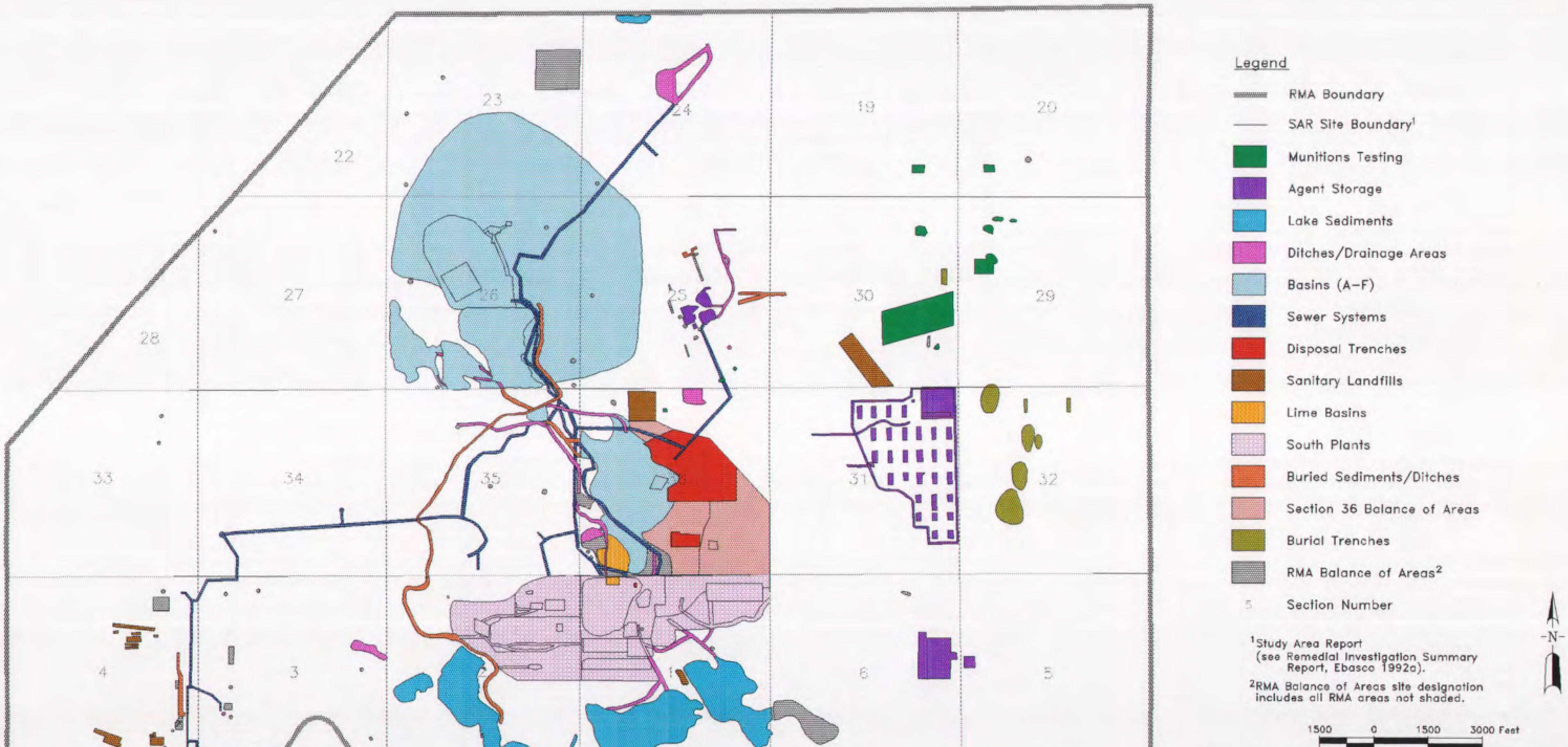


1 - Building, Equipment, and Storage Sites include only the soils present at these sites, not the structures themselves.
2 - Isolated Contamination Sites are not generally considered sources in the sense that they could provide releases to the environment.
3 - Enclosed space vapor inhalation evaluated for commercial and industrial populations only. Open space vapor inhalation evaluated for all populations except commercial workers.
4 - Only ephemeral lake sediments evaluated.

Figure 6.1-2
RMA Site Conceptual Model for Human Receptors

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corporation

RMA ROD 6.96 jb



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

June 1996

Figure 6.1–3

RMA Site Designations used in the HHRC

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corporation

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Date 6/06/96
Drawn by XG
Checked by SA

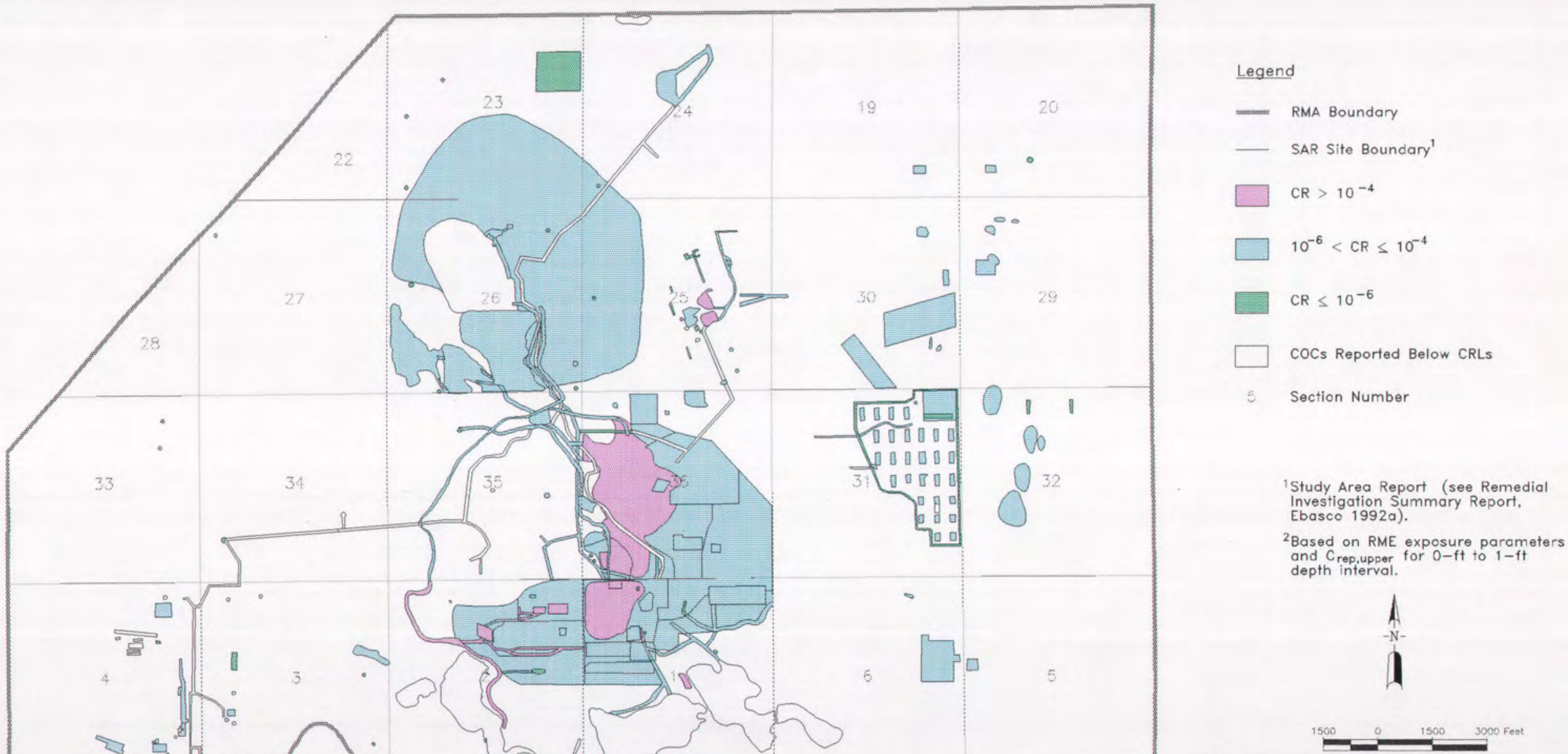

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Figure 6.1-4

Total Site Cancer Risks for Biological Worker,[2] Horizon 0

Foster Wheeler Environmental Corporation
June 1996

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Date 6/06/96
Drawn by XG
Checked by SA

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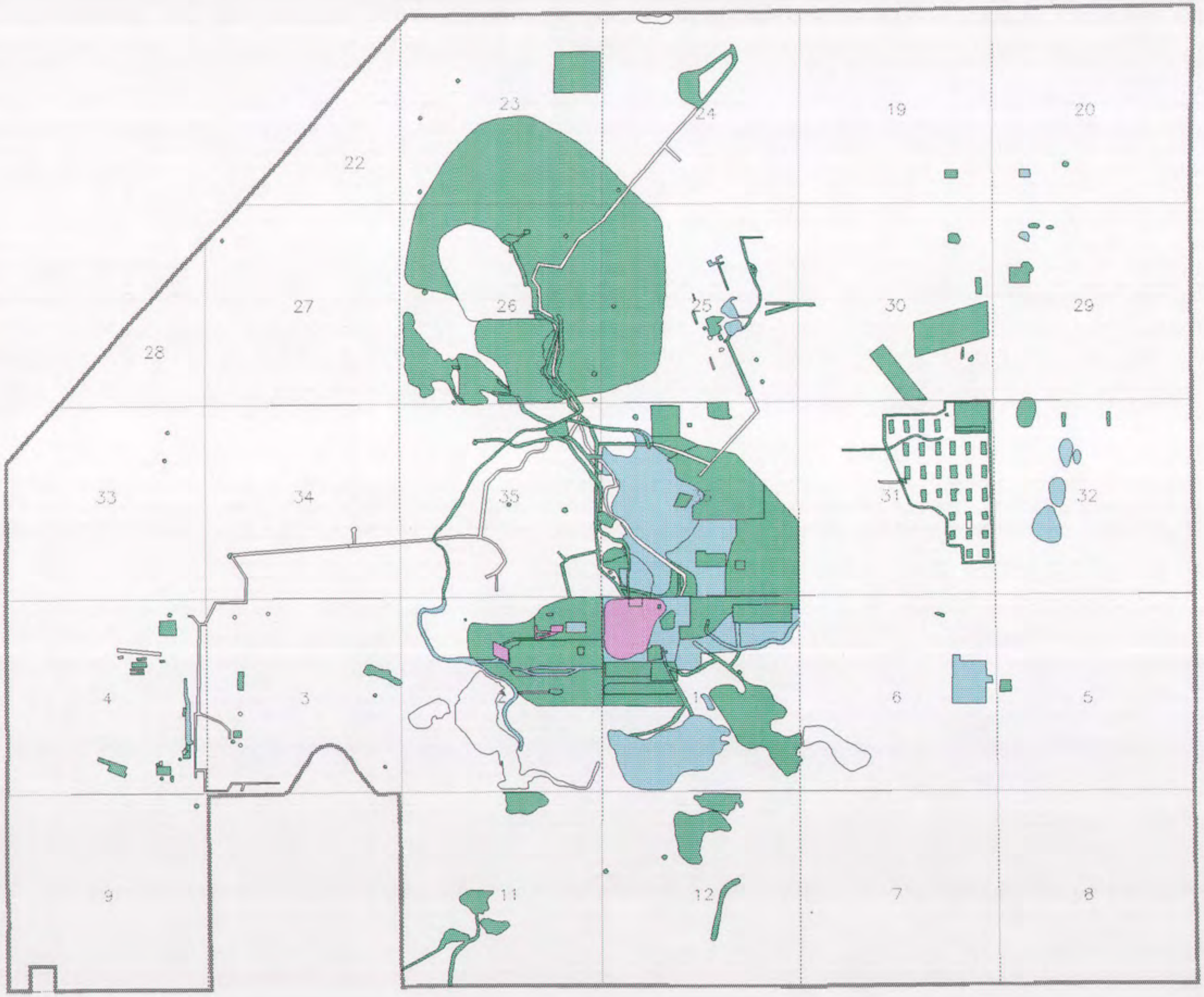


[1] Study Area Report (see Remedial Investigation Summary Report, Ebasco 1992a).

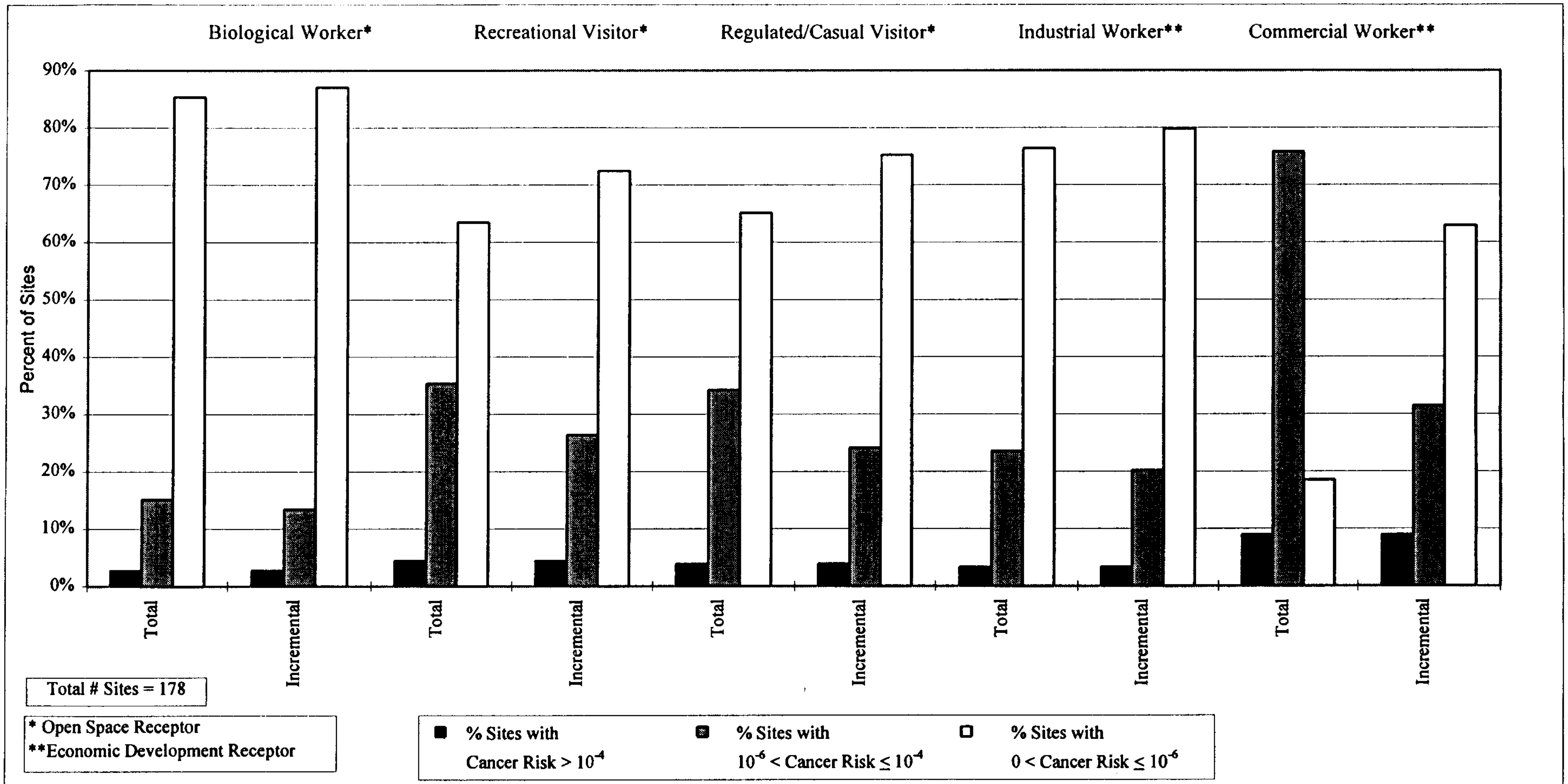
[2] Based on RME exposure parameters and $C_{rep,upper}$ for 0-ft to 1-ft depth interval.

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

Figure 6.1-5

Total Site Hazard Indices for Biological Worker,[2] Horizon 0

Foster Wheeler Environmental Corporation
June 1996



Note: Incremental risk is equal to the total minus the risk attributable to indicator (background) levels of metal COCs.

Figure 6.1-6

Cancer Risk Summary for All Receptors Based on Site-Specific ($C_{rep,\ upper}$) Results, Horizon 0

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corporation

rma\1603G.XLS

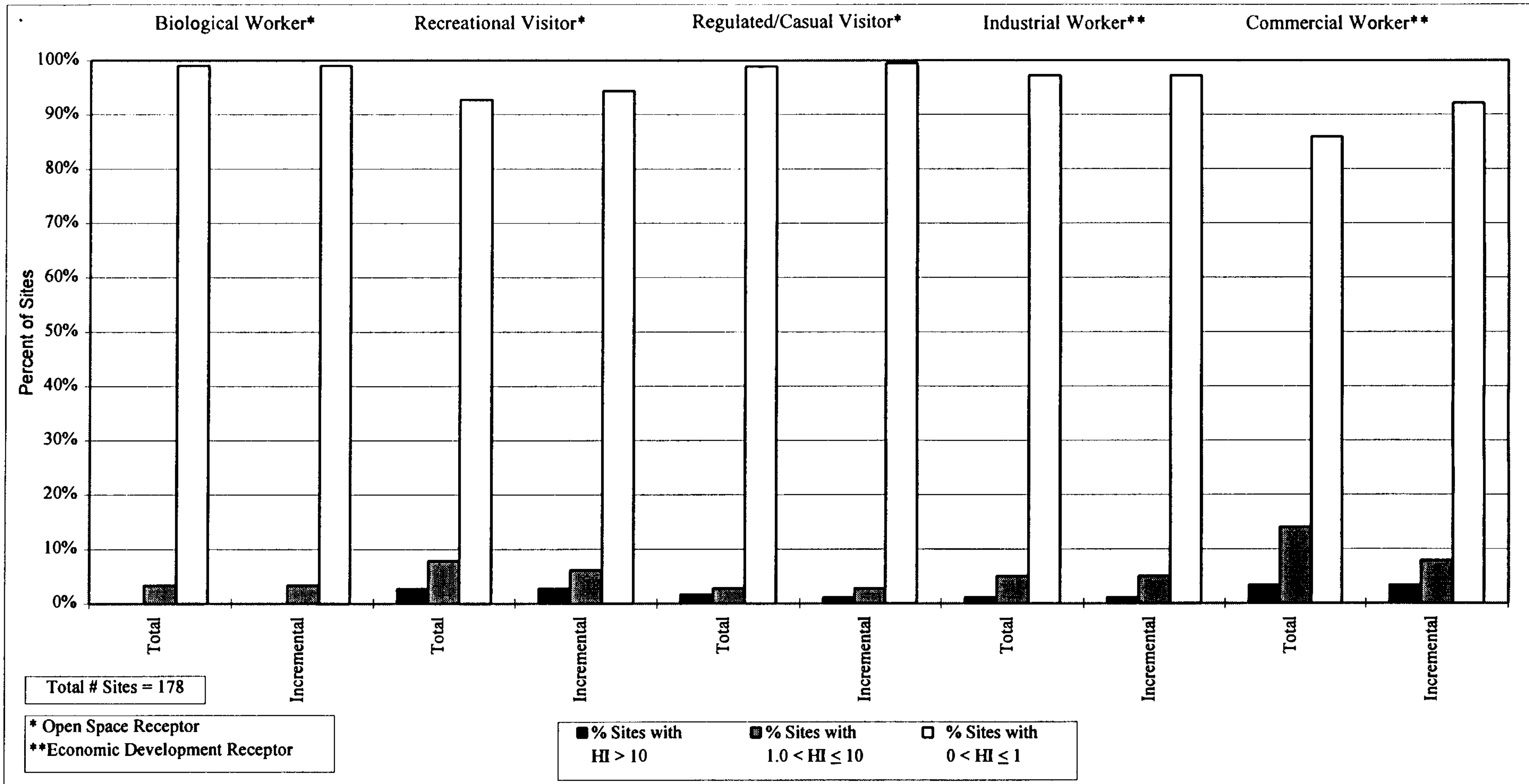
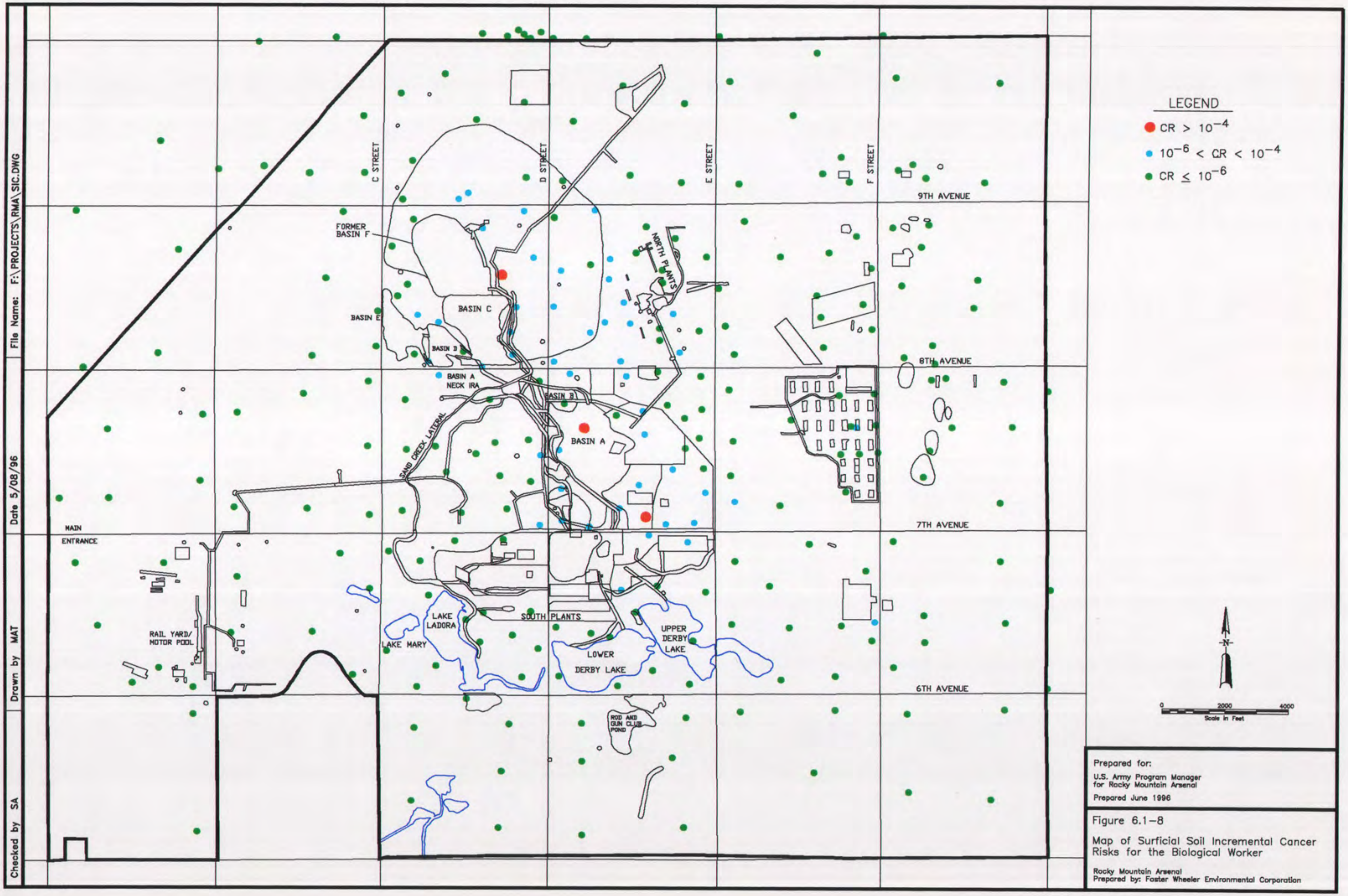


Figure 6.1-7

Hazard Index Summary for All Receptors Based on Site-Specific ($C_{rep,upper}$) Results, Horizon 0

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corporation

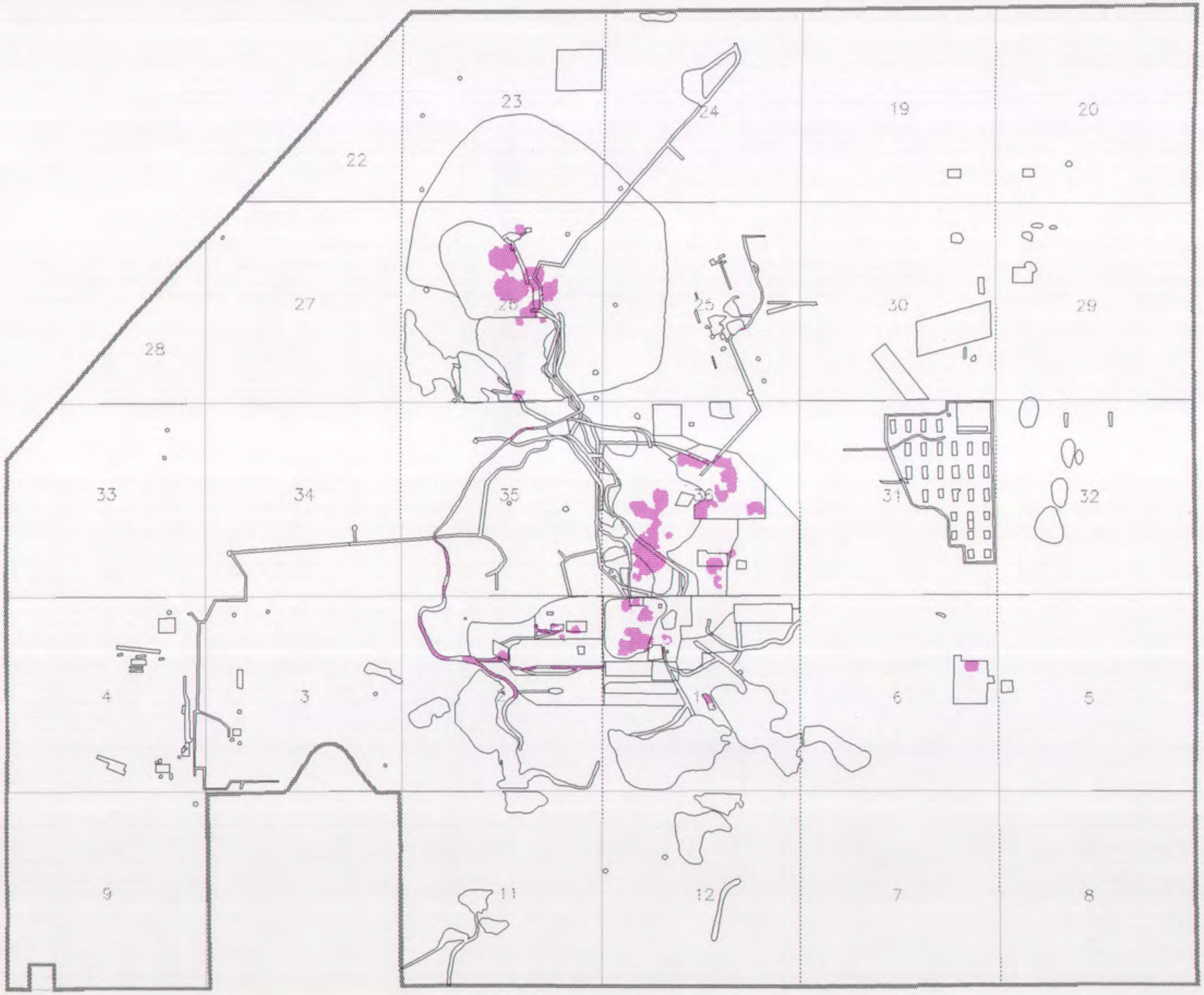


Prepared for:
U.S. Army Program Manager for Rocky Mountain Arsenal
Prepared June 1996

Figure 6.1–8

Map of Surficial Soil Incremental Cancer Risks for the Biological Worker

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corporation



Legend

RMA Boundary

SAR Site Boundary[1]

Human Health Exceedance Area Cancer Risk ≥ 10E−4

5 Section Number

[1]Study Area Report (see Remedial Investigation Summary Report, Ebasco 1992a).

[2]Based on RME exposure parameters and C_{max} on boring by boring basis for 0−ft to 1−ft depth interval.

-N-

1500 0 1500 3000 Feet

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Figure 6.1−9

Human Health Carcinogenic Exceedance Areas,[2] Horizon 0

Foster Wheeler Environmental Corporation
June 1996

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Date 6/06/96

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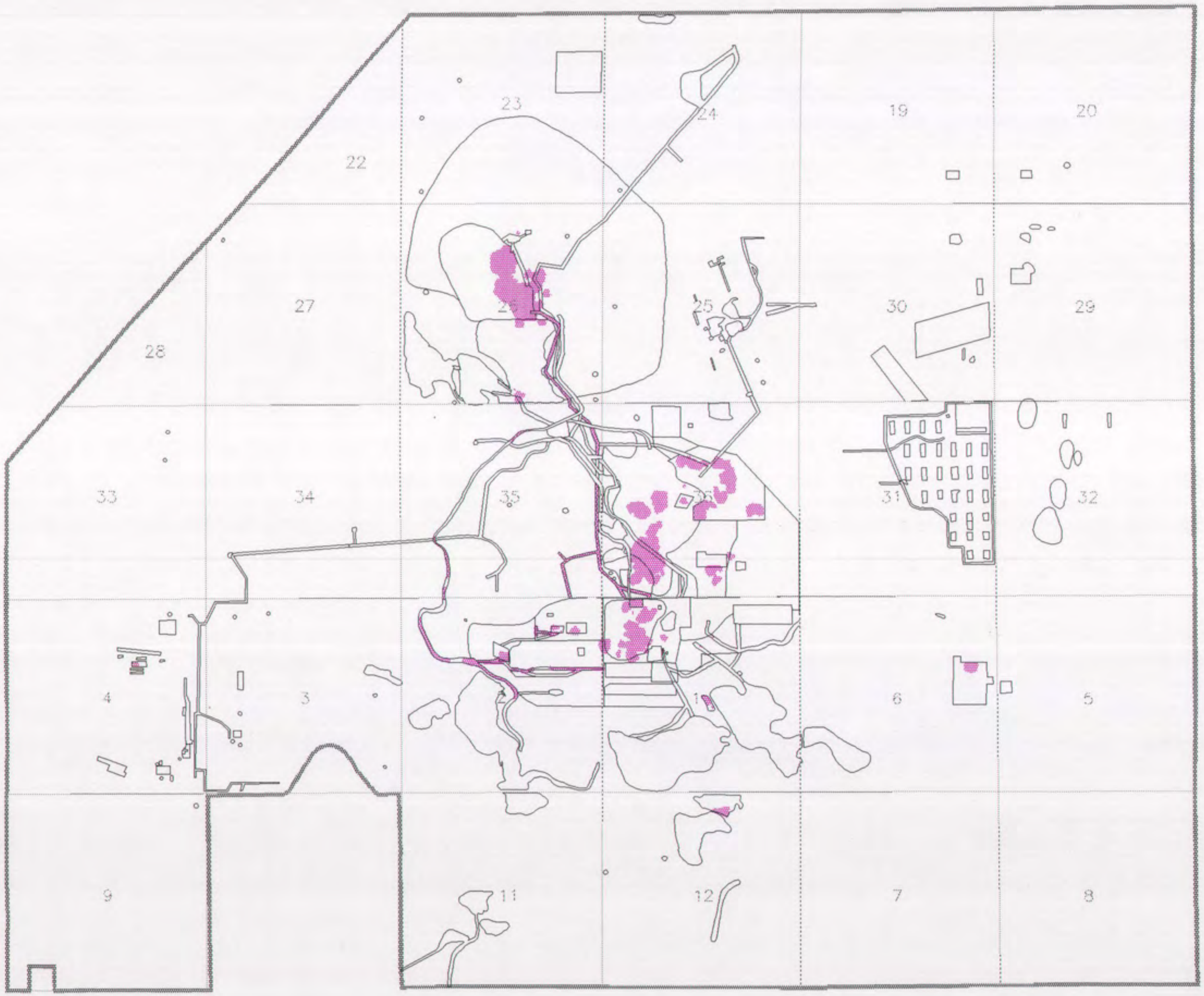
Checked by SA



Legend

RMA Boundary

SAR Site Boundary[1]

Human Health Exceedance Area Cancer Risk ≥ 10E−4

5 Section Number

[1] Study Area Report (see Remedial Investigation Summary Report, Ebasco 1992a).

[2] Based on RME exposure parameters and C_{max} on boring by boring basis for 0–ft to 10–ft depth interval.

-N-

1500 0 1500 3000 Feet

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Figure 6.1–10

Human Health Carcinogenic Exceedance Areas,[2] Horizon 1

Foster Wheeler Environmental Corporation
June 1996

File Name: C:\SOILS\ROD\EI

Date 6/06/96

Drawn by XG

Checked by SA

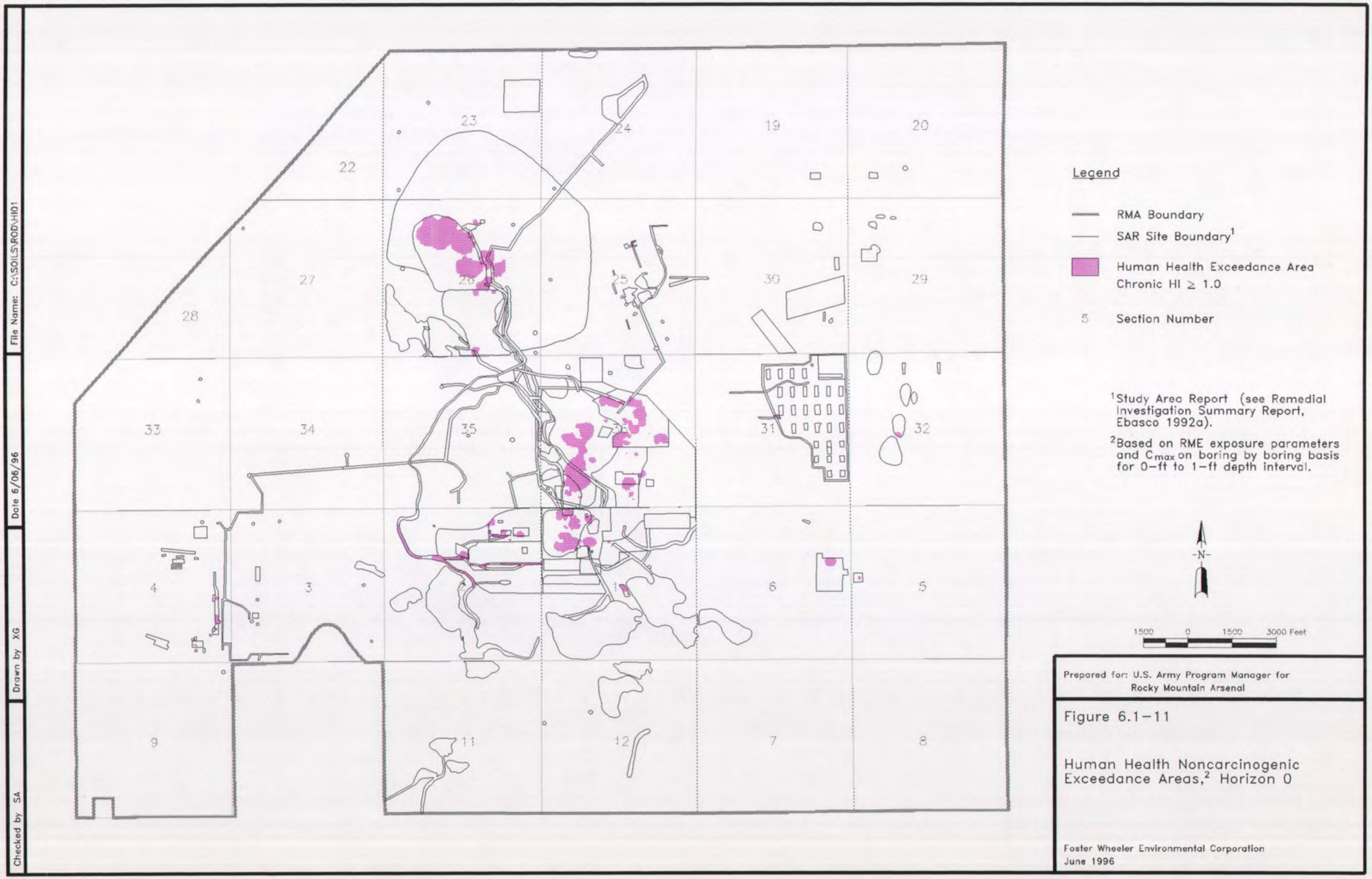

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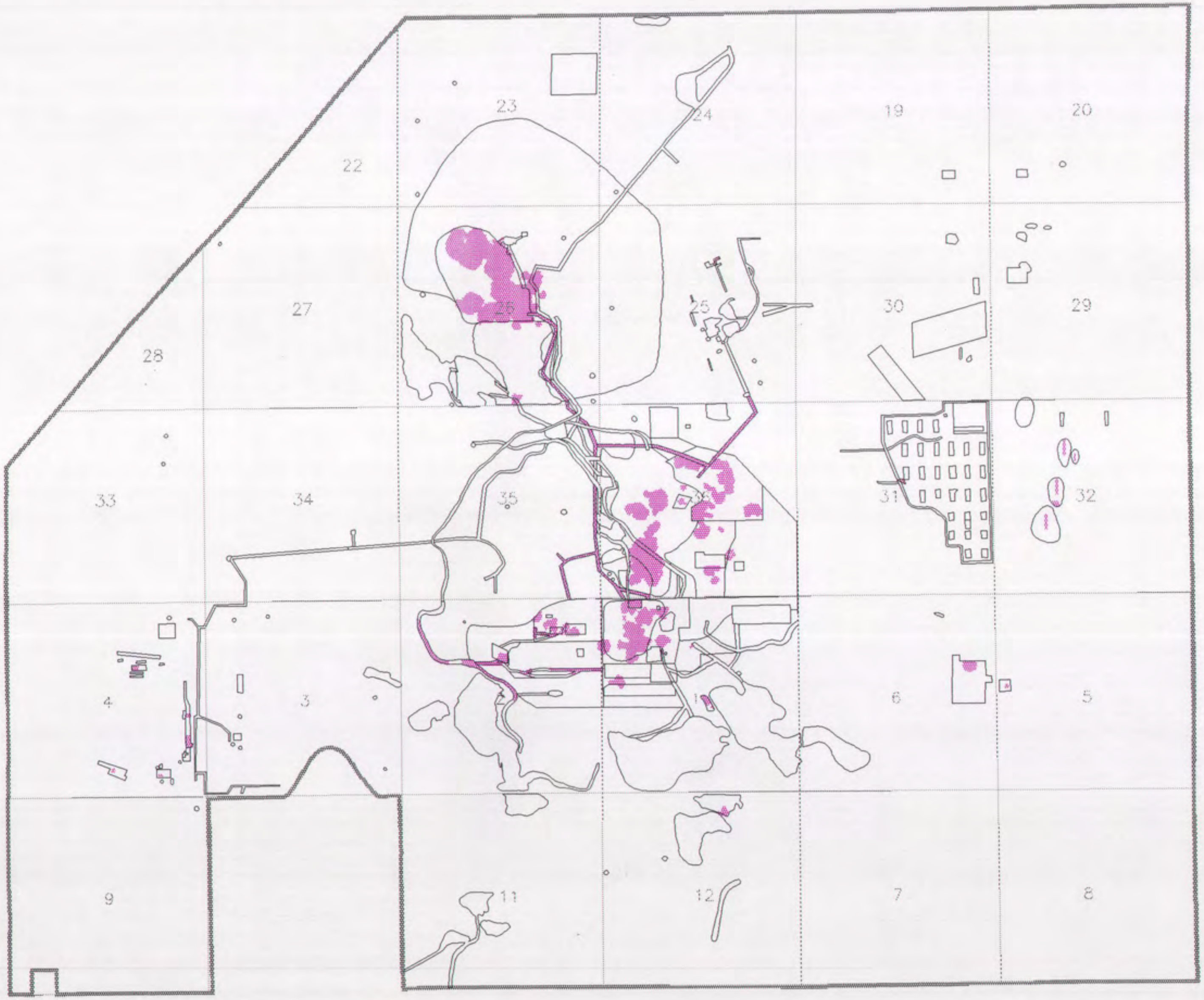
Figure 6.1-11

Human Health Noncarcinogenic Exceedance Areas,[2] Horizon 0

Foster Wheeler Environmental Corporation
June 1996



[1] Study Area Report (see Remedial Investigation Summary Report, Ebasco 1992a).

[2] Based on RME exposure parameters and C_{max} on boring by boring basis for 0-ft to 10-ft depth interval.

File Name: C:\SOILS\ROD\HI | Date 6/06/96 | Drawn by XG | Checked by SA

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Figure 6.1-12

Human Health Noncarcinogenic Exceedance Areas,[2] Horizon 1

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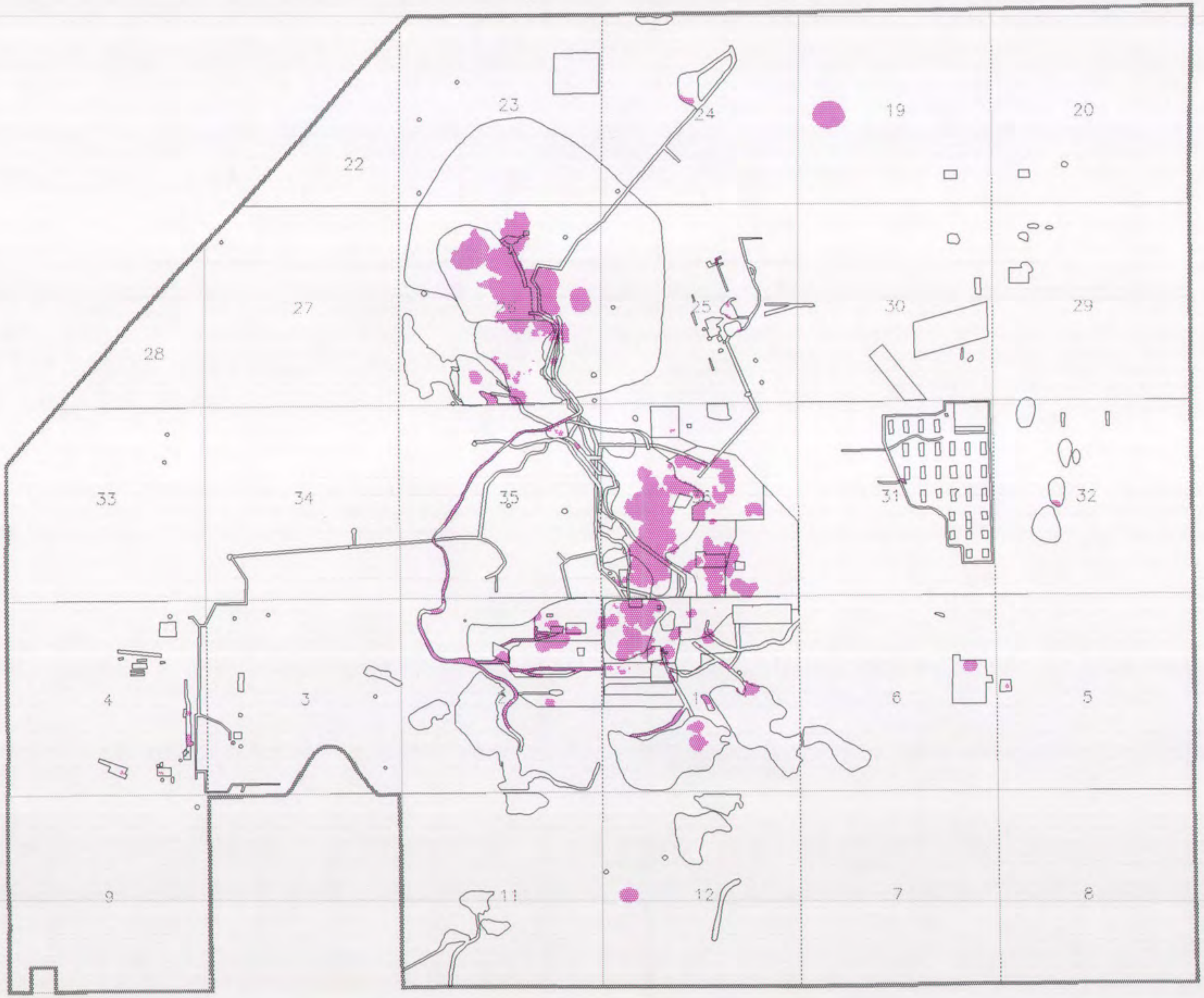

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Date 6/06/96

Drawn by XG

Checked by SA

Legend

- RMA Boundary
- SAR Site Boundary[1]
- Human Health Exceedance Area: Cancer Risk ≥ 10E−4, Chronic HI ≥ 1.0, or Acute HI ≥ 1.0
- 5 Section Number

[1]Study Area Report (see Remedial Investigation Summary Report, Ebasco 1992a).

[2]Based on RME exposure parameters and C_{max} on boring by boring basis for 0−ft to 1−ft depth interval.

-N-

1500 0 1500 3000 Feet

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Figure 6.1−13

Human Health Exceedance Areas,[2] Horizon 0

Foster Wheeler Environmental Corporation
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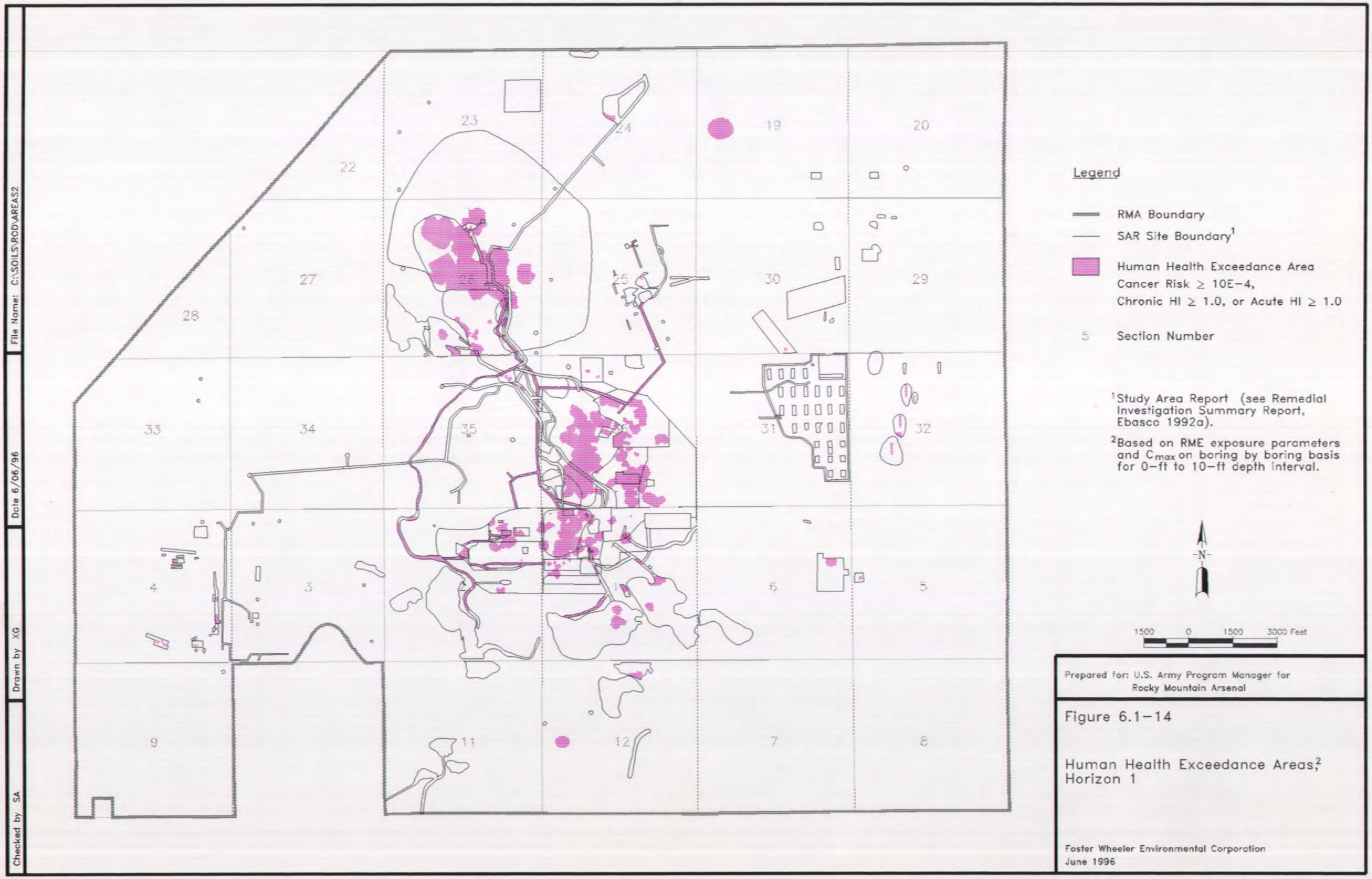

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Figure 6.1−14

Human Health Exceedance Areas,[2] Horizon 1

Foster Wheeler Environmental Corporation
June 1996

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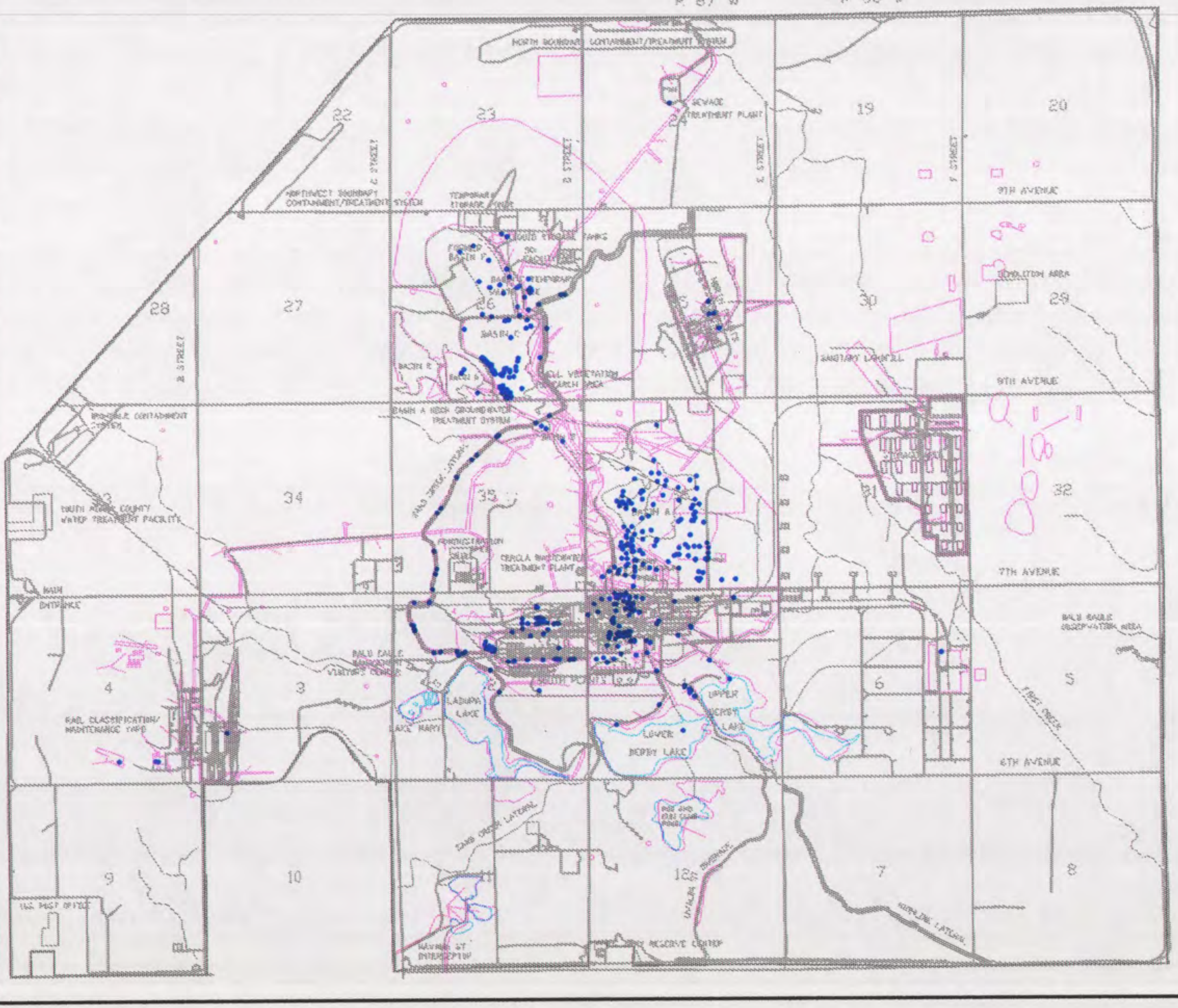

Legend

- SAR Site
- 31 Section Number
- Section Line
- Drainage
- Road
- Railroad
- • Sample Exceeds Acute Criteria HI* ≥ 1.0, 0 – 1 foot depth interval

*Cumulative HI developed using deterministic exposure parameters presented in Table 6.1–6 on environmental soil data, for all COCs with acute PPLV values (Table 6.1–19)

-N-

0 2000 4000
Scale in Feet

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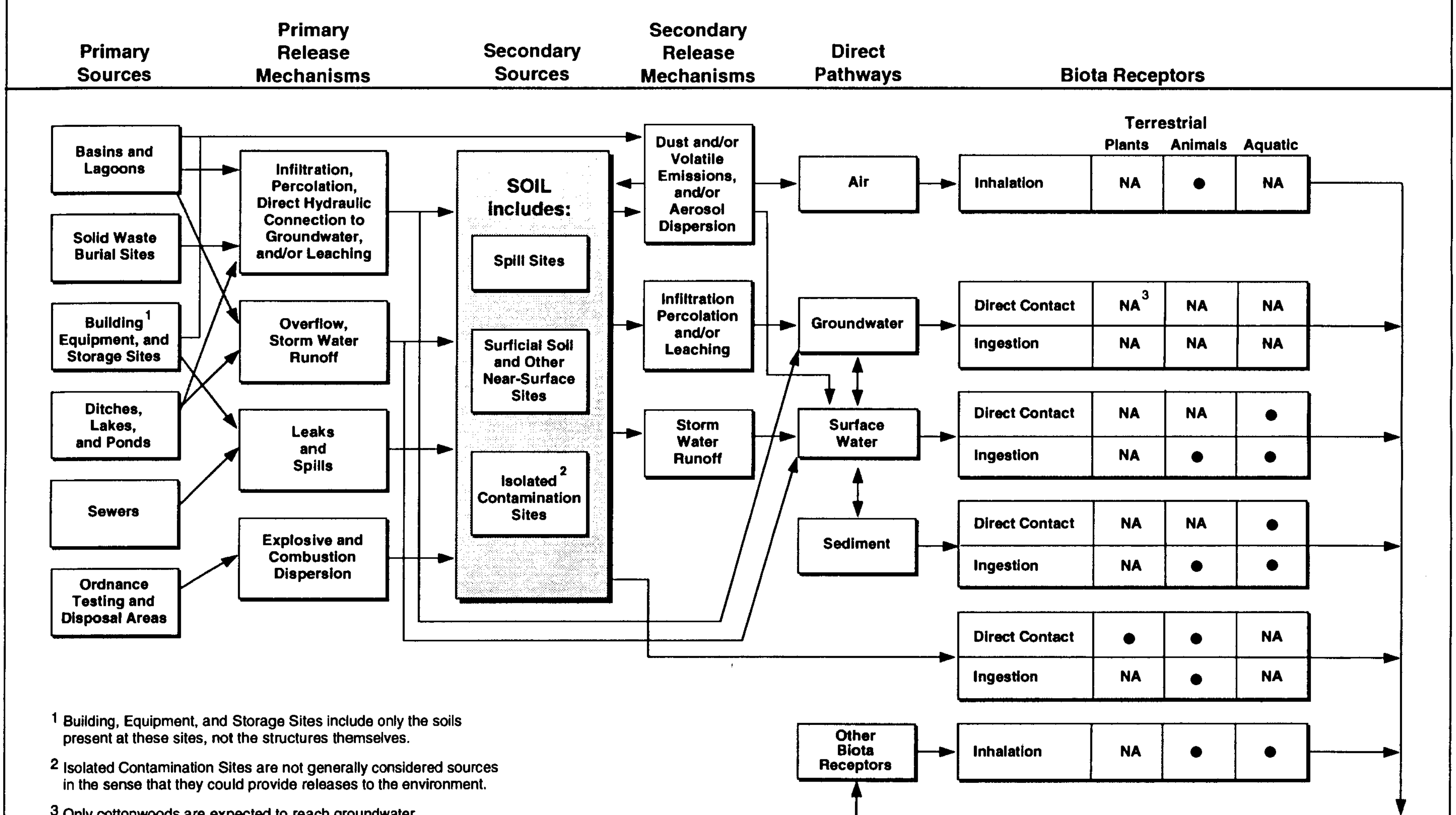
Figure 6.1–15

Acute Exceedance Sample Locations

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.



1 Building, Equipment, and Storage Sites include only the soils present at these sites, not the structures themselves.

2 Isolated Contamination Sites are not generally considered sources in the sense that they could provide releases to the environment.

3 Only cottonwoods are expected to reach groundwater.

NA - Not applicable.

Figure 6.2-1
RMA Site Conceptual Model for Ecological Receptors

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corporation

RMA ROD 6.96 jb

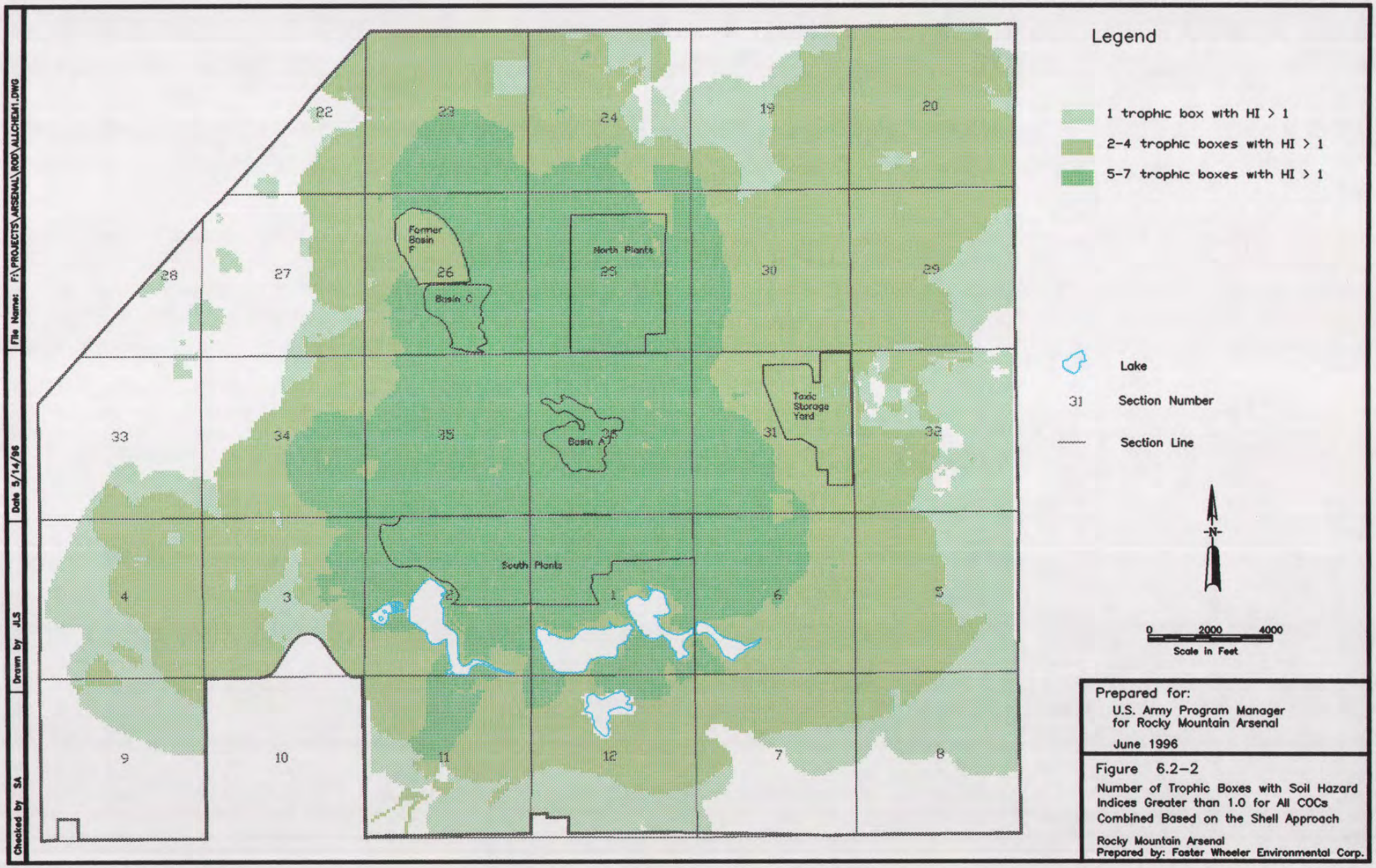


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Figure 6.2–2
Number of Trophic Boxes with Soil Hazard Indices Greater than 1.0 for All COCs Combined Based on the Shell Approach

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

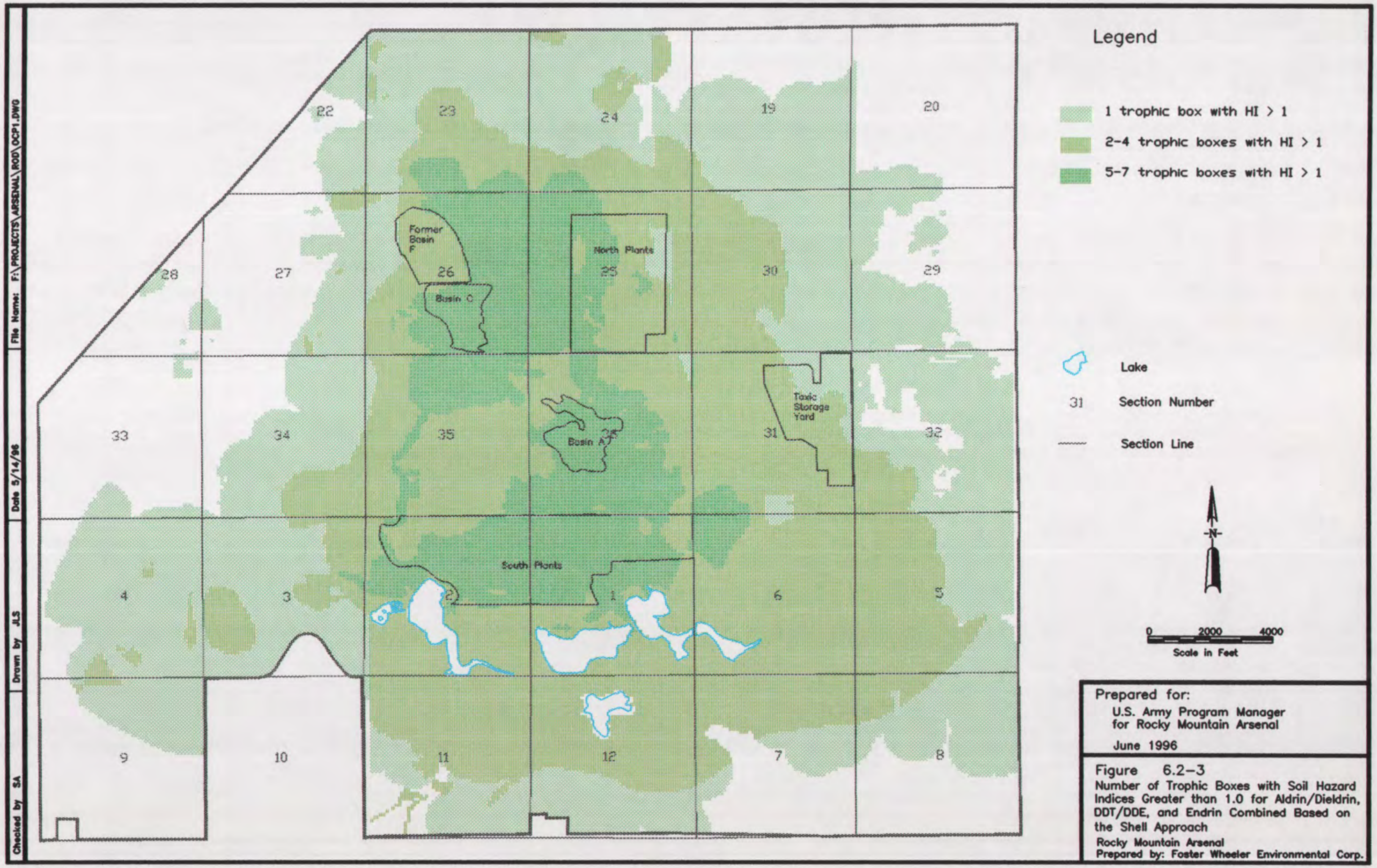
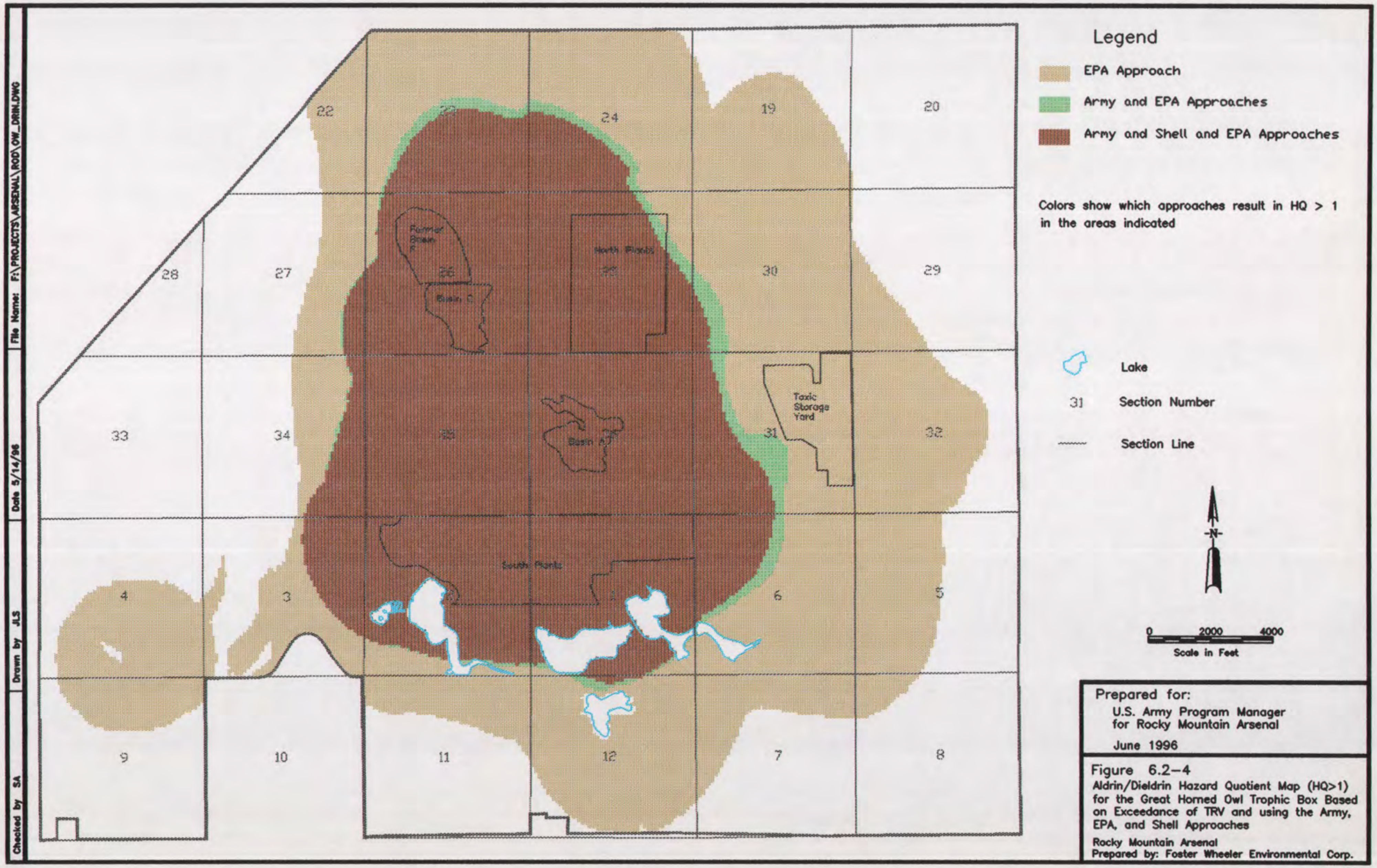


Figure 6.2-3
Number of Trophic Boxes with Soil Hazard Indices Greater than 1.0 for Aldrin/Dieldrin, DDT/DDE, and Endrin Combined Based on the Shell Approach
Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

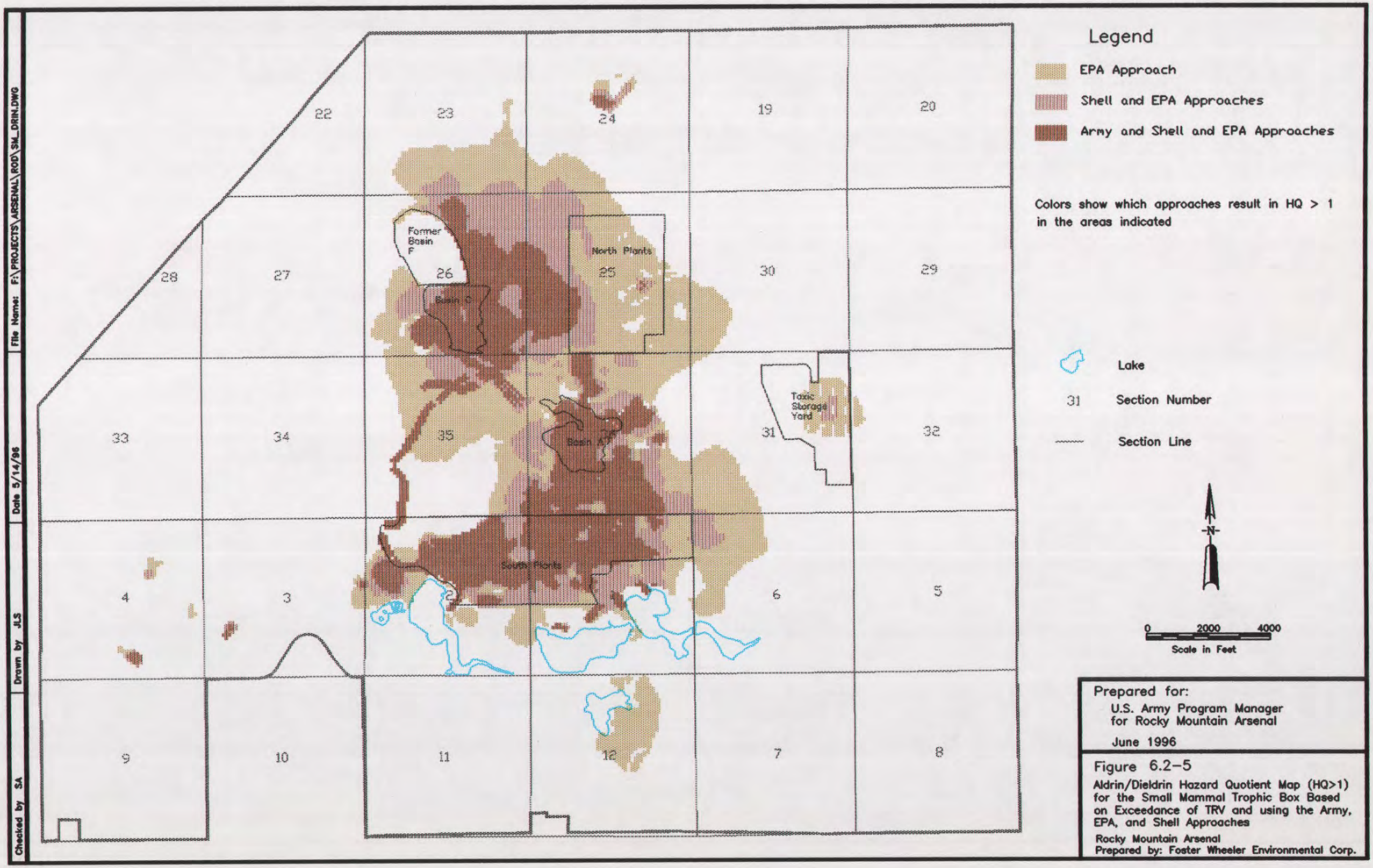


Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

June 1996

Figure 6.2–4
Aldrin/Dieldrin Hazard Quotient Map (HQ>1) for the Great Horned Owl Trophic Box Based on Exceedance of TRV and using the Army, EPA, and Shell Approaches

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.



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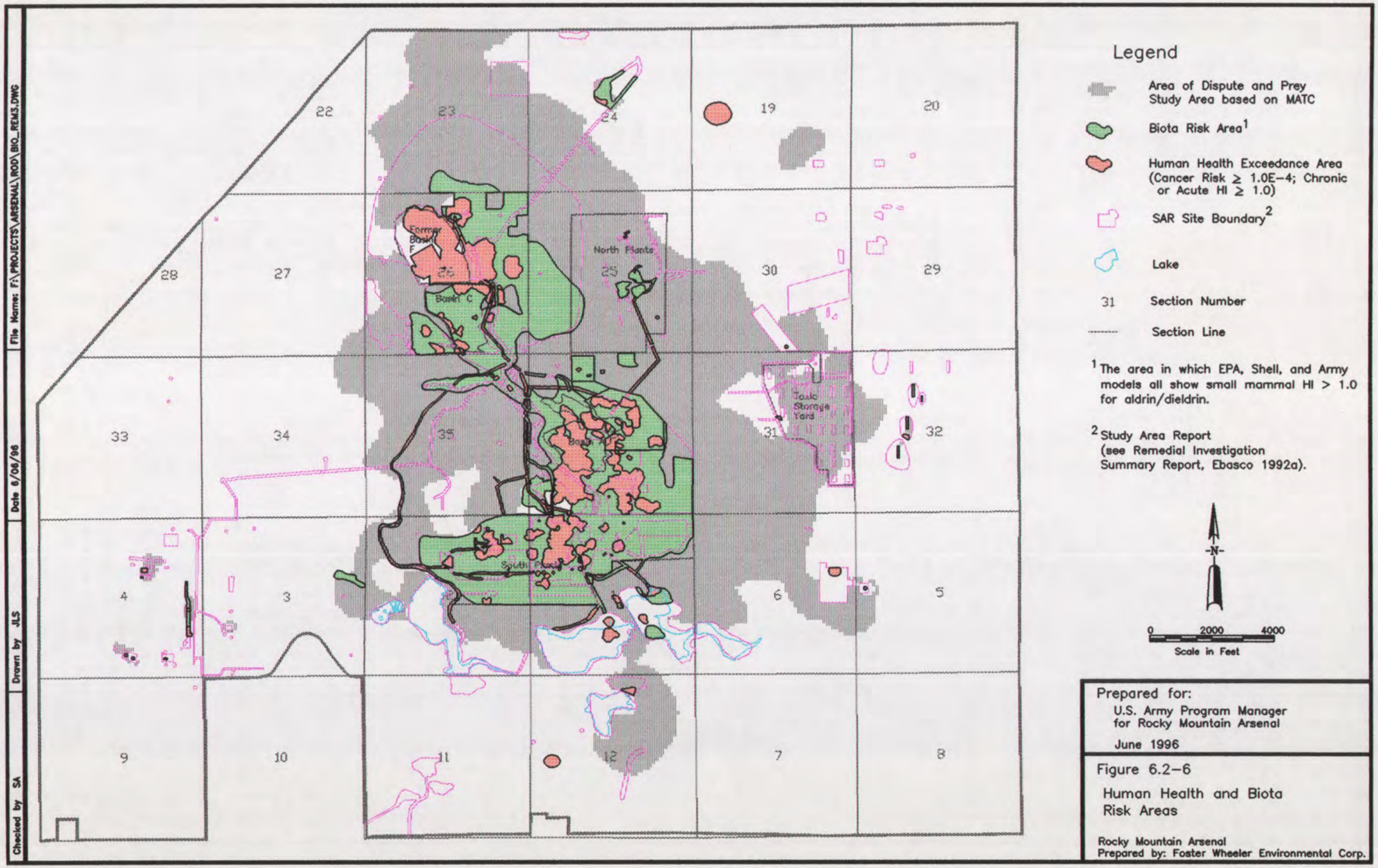
U.S. Army Program Manager
for Rocky Mountain Arsenal
June 1996

Figure 6.2–5
Aldrin/Dieldrin Hazard Quotient Map (HQ>1) for the Small Mammal Trophic Box Based on Exceedance of TRV and using the Army, EPA, and Shell Approaches

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.



Prepared for:
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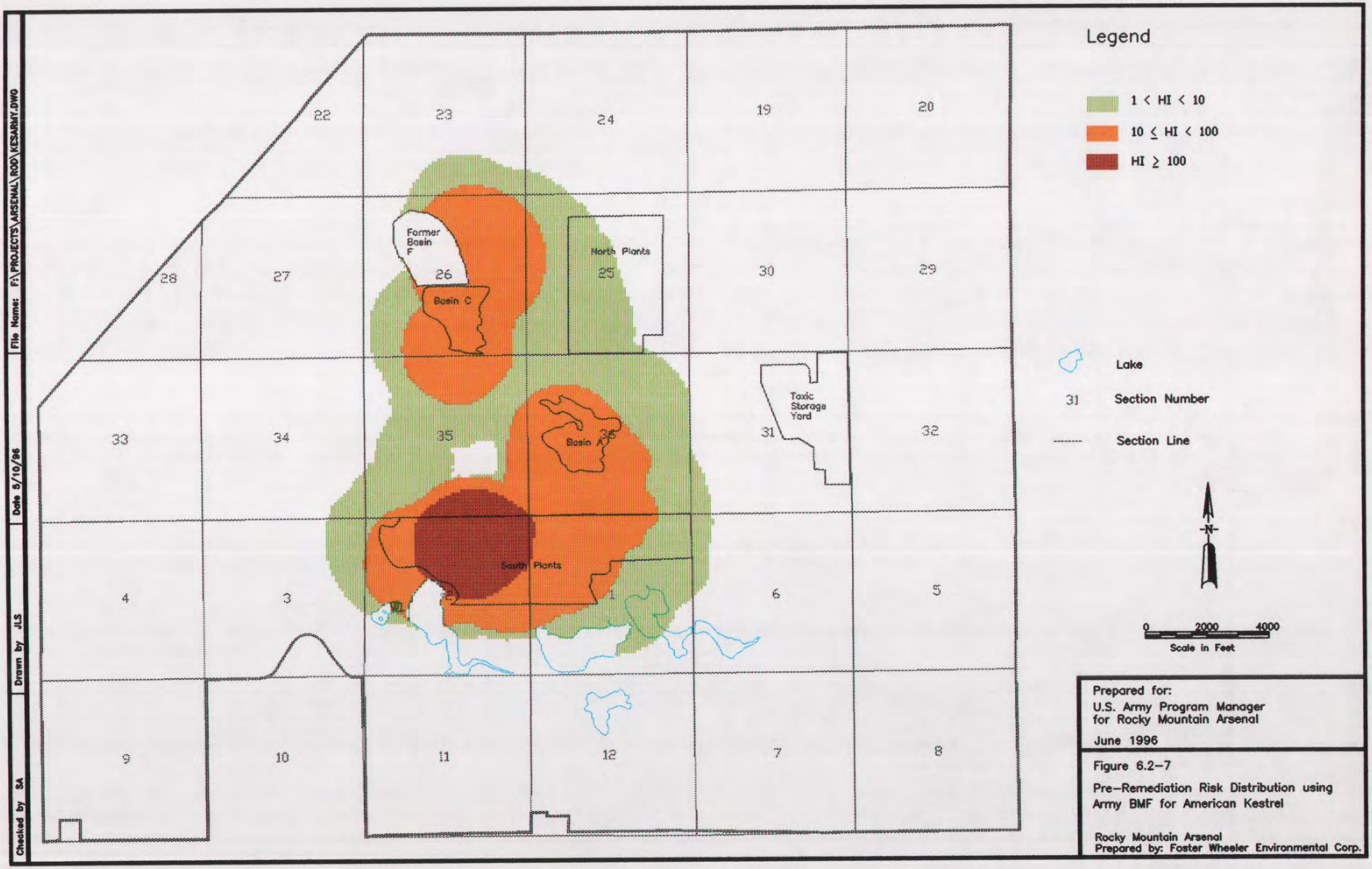
June 1996

Figure 6.2−6
Human Health and Biota Risk Areas

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.



Prepared for:
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for Rocky Mountain Arsenal
June 1996

Figure 6.2–7

Pre–Remediation Risk Distribution using Army BMF for American Kestrel

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

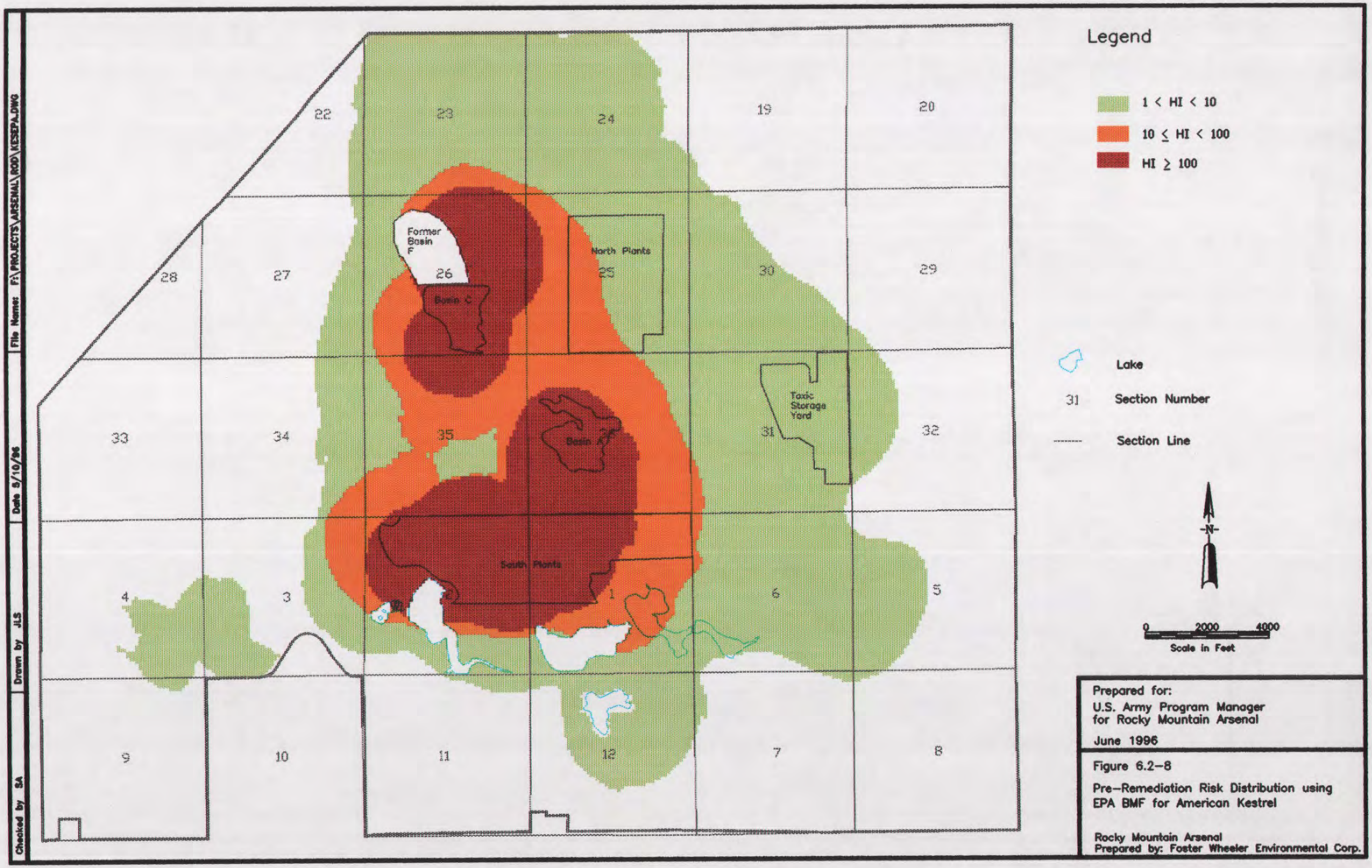
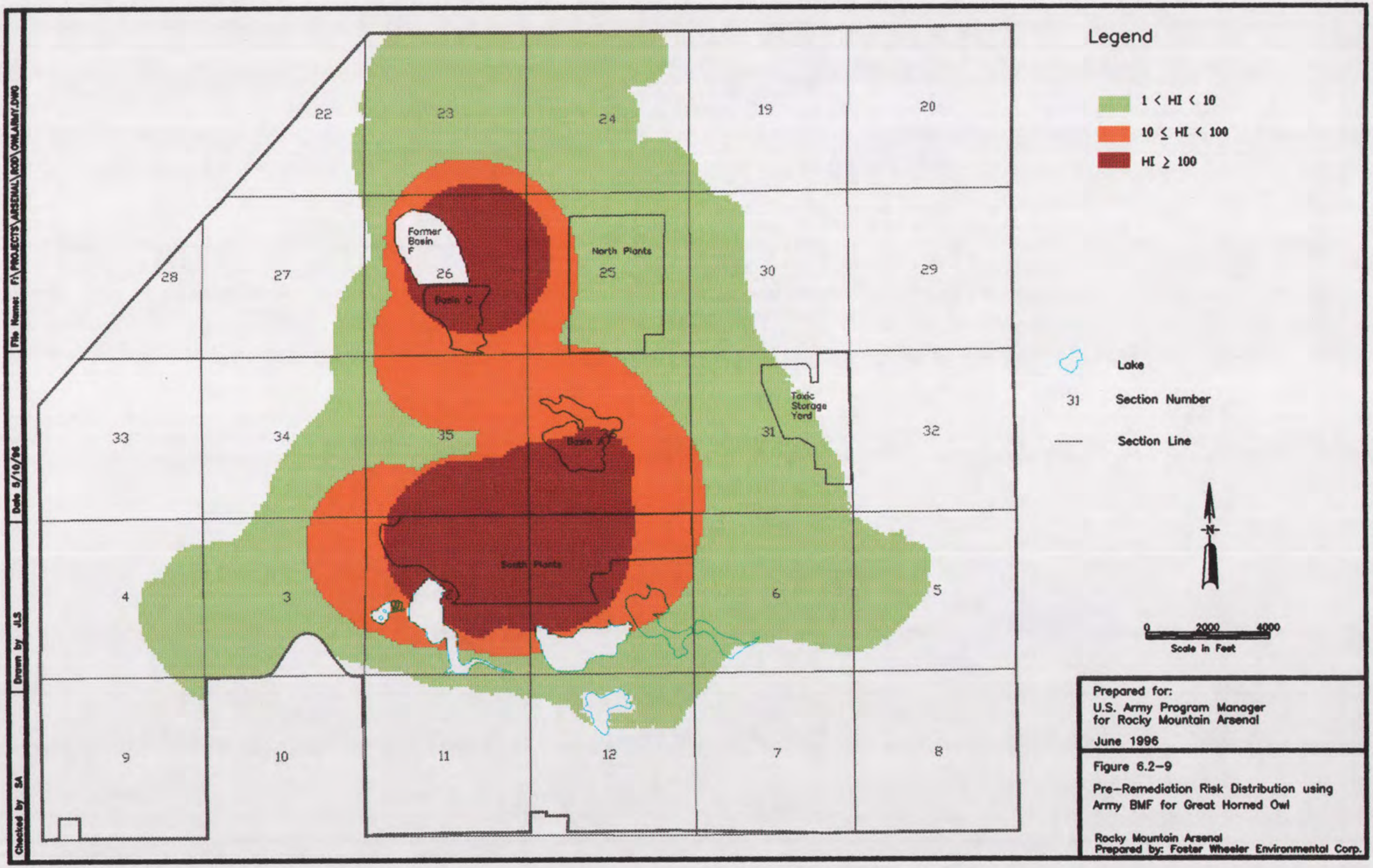


Figure 6.2–8

Pre–Remediation Risk Distribution using EPA BMF for American Kestrel



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June 1996

Figure 6.2-9

Pre-Remediation Risk Distribution using Army BMF for Great Horned Owl

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

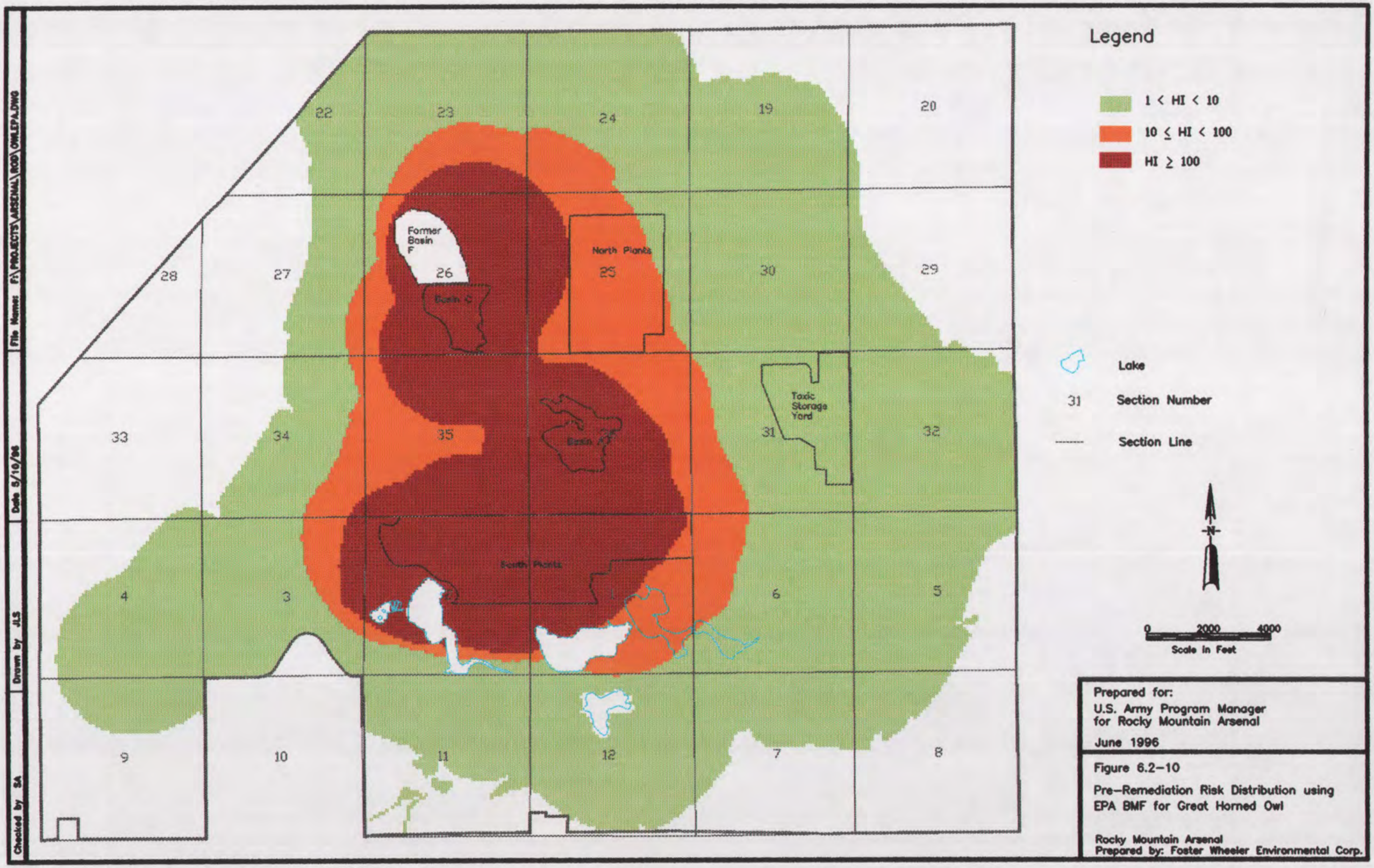

Figure 6.2–10

Pre–Remediation Risk Distribution using EPA BMF for Great Horned Owl

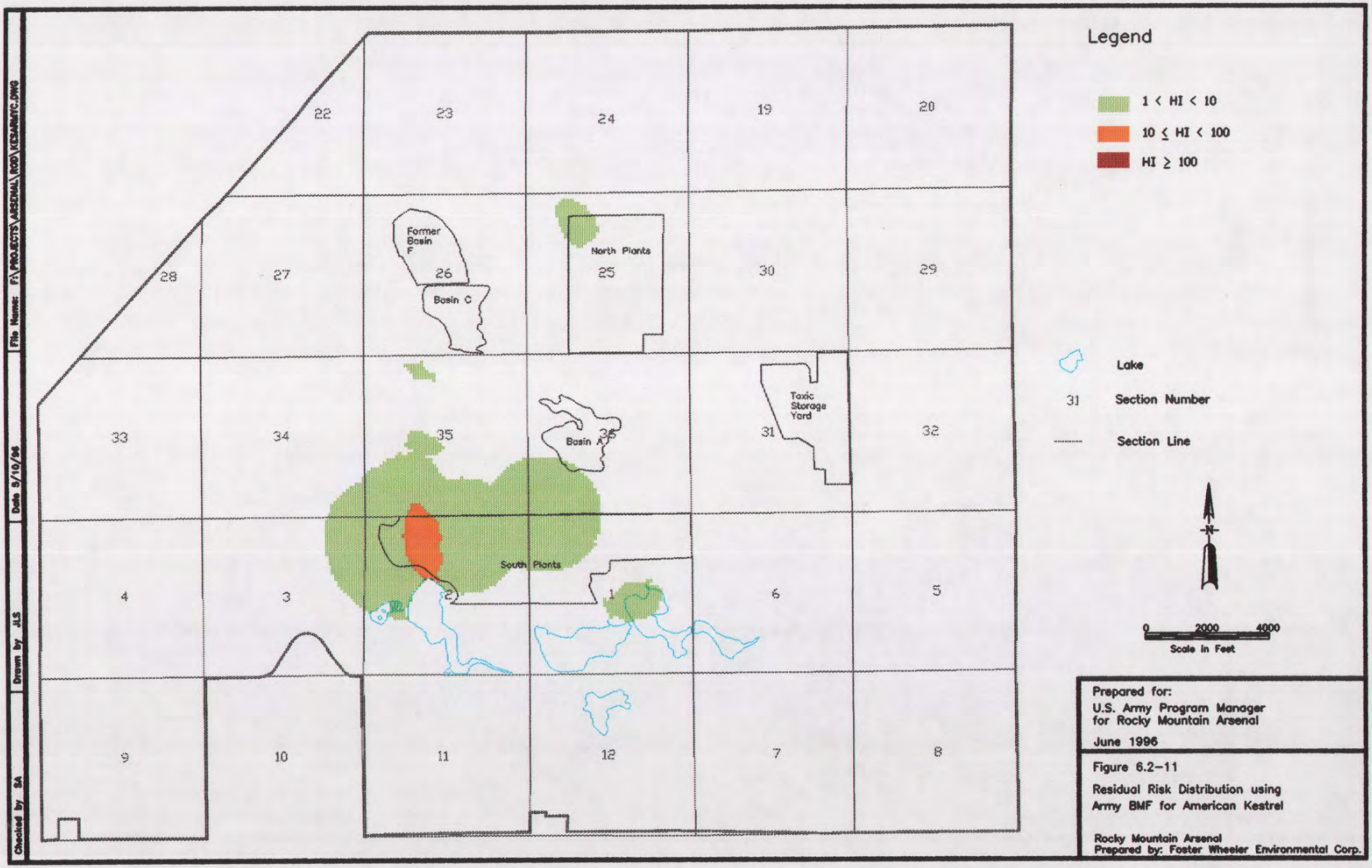

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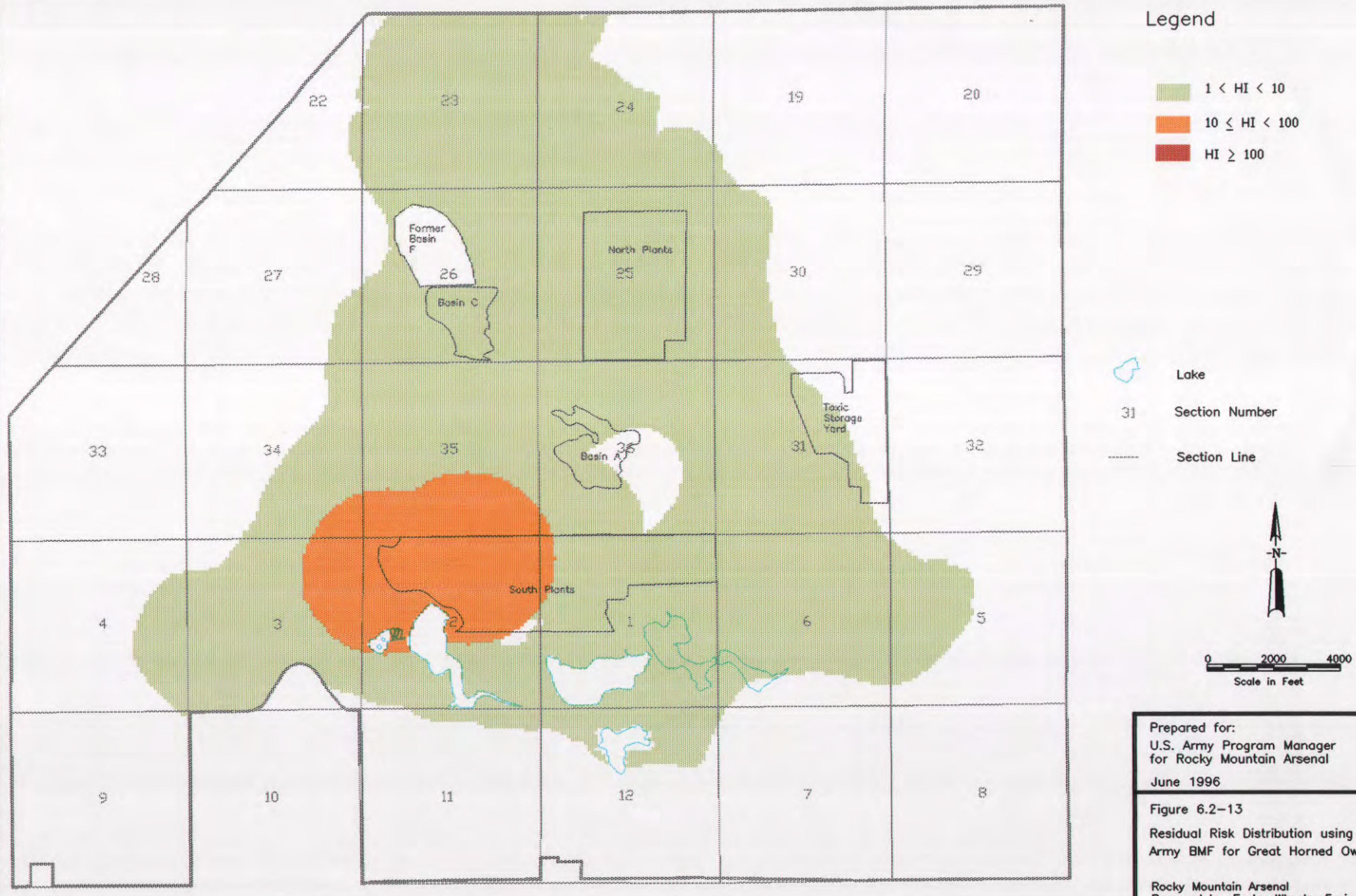
Figure 6.2−11
Residual Risk Distribution using Army BMF for American Kestrel

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

Figure 6.2-12

Residual Risk Distribution using EPA BMF for American Kestrel



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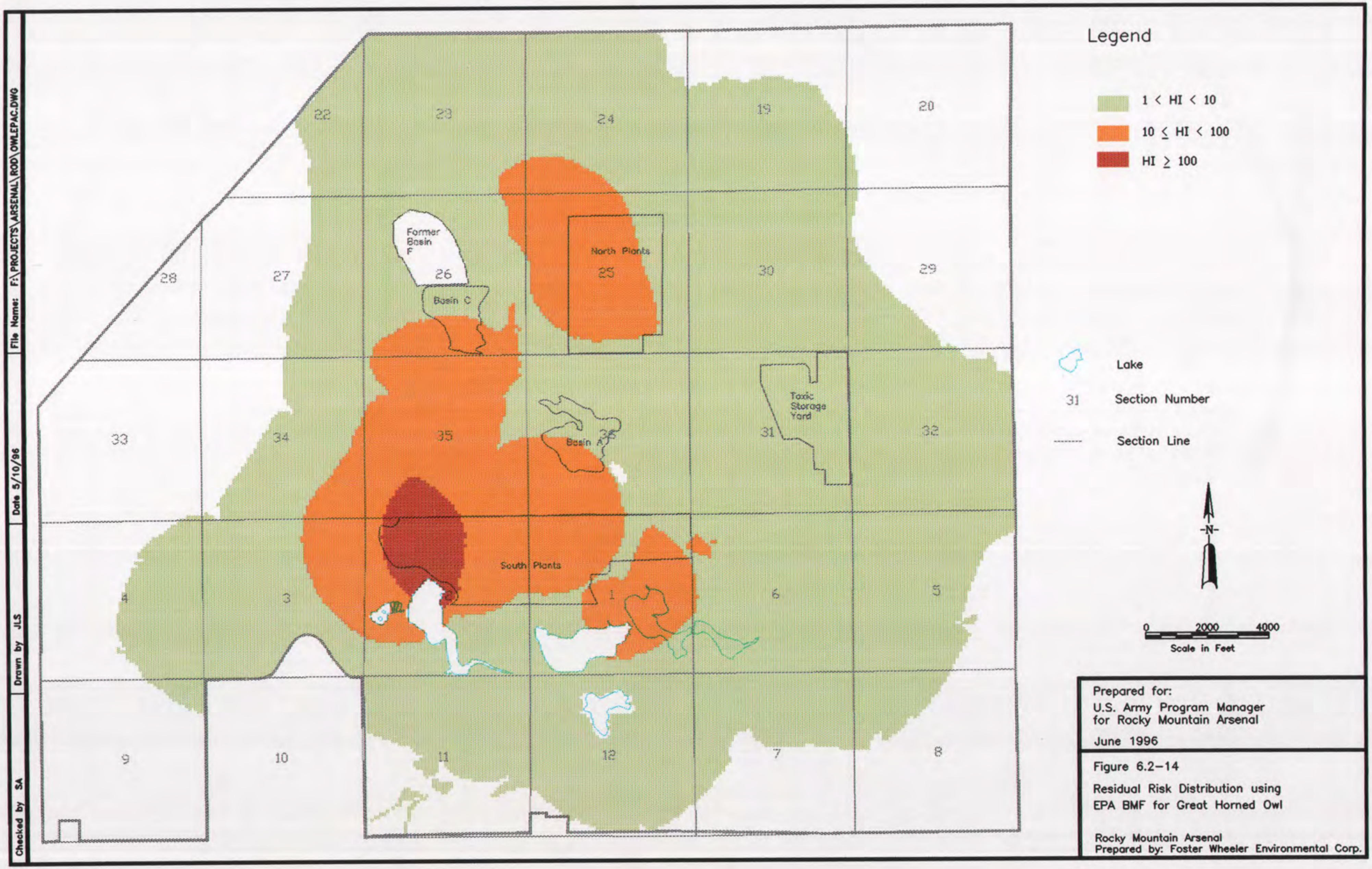
June 1996

Figure 6.2–13

Residual Risk Distribution using
Army BMF for Great Horned Owl

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

File Name: F:\PROJECTS\ARSENAL\ROD\OWLARMYC.DWG | Date 5/10/96 | Drawn by JLS | Checked by SA



Prepared for:
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June 1996

Figure 6.2-14

Residual Risk Distribution using
EPA BMF for Great Horned Owl

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

Table 6.1-1 Chemicals of Concern for the IEA/RC

Aldrin

Arsenic

Benzene

Cadmium

Carbon Tetrachloride

Chlordane

Chloroacetic Acid

Chlorobenzene

Chloroform

Chromium

DBCP

DCPD

DDE

DDT

1,2-Dichlororethane

1,1-Dichloroethylene

Dieldrin

Endrin

HCCPD

Isodrin

Lead

Mercury

Methylene Chloride

1,1,2,2-Tetrachloroethane

Tetrachloroethylene

Toluene

TCE

Table 6.1-2 Soil Horizons and Exposure Pathways Evaluated for the HHRC

		Open Space Option Receptor		Economic Development Option Receptor	
Soil Horizon	Depth Interval	Biological Worker	Local Neighborhood Regulated/Casual and Recreational Visitor	Industrial Worker	Commercial Worker
Surficial Soil	0–2 inches[1]	Dir	Dir	Dir	Dir
Horizon 0	0–1 ft[2]	Dir	Dir	Dir	Dir
Horizon 1	0–10 ft[2]	Dir, Ind (Open Space)	Dir (Open Space)	Dir, Ind (Open and Enc. Space)	Dir, Ind (Enc. Space)
Horizon 2	>10 ft–Groundwater[2]	Ind (Open Space)	Not Evaluated	Ind (Open and Enc. Space)	Ind (Enc. Space)

[1] Risks for this depth horizon were calculated on a boring-by-boring basis using results of surficial soil samples collected in areas peripheral to designated sites. The surficial soil interval (0–2 inches) is not a subset of Horizon 0 (0–1 ft).

[2] Cumulative risks for these soil horizons were calculated on both a site-specific basis (representing both direct and indirect pathway exposures) and a boring-by-boring evaluation (representing direct exposure pathways only).

Dir Denotes direct soil exposure pathway evaluation (soil ingestion, dermal contact, and particulate inhalation). Dermal contact with metals in soil was not evaluated for any receptors due to negligible contaminant absorption from this exposure route.

Ind Denotes indirect vapor inhalation pathway evaluation for open space and/or enclosed space (e.g., enclosed basement structures). Both open and enclosed space soil vapor inhalation exposures were not considered to be significant for shallower depth intervals due to volatilization loss, and therefore were not evaluated for surficial soil and Horizon 0.

Table 6.1-3 Time-Dependent and Other Parameter Values

Parameter	Distribution Family	Mean	Value 50%	95%
Exposure Time (TM) (hours/day)				
Reg/casual visitor	Lognormal	2.47	1.87	6.34
Recreational visitor	Lognormal	1.8	1.38	4.96
Biological worker	Fixed Value	8		
Commercial worker	Normal	7.42	7.42	12.8
Industrial worker	Normal	7.42	7.42	12.8
Exposure Frequency (DW) (days/year)				
Reg/casual visitor	Lognormal	34.9	29.6	76.1
Recreational visitor	Lognormal	63.14	43.3	181
Biological worker	Normal	225	225	242
Commercial worker	Normal	236	236	241
Industrial worker	Normal	236	236	241
Exposure Duration (TE) (years)				
Reg/casual visitor	Lognormal	10.1	5.45	33.8
Recreational visitor	Lognormal	10.1	5.45	33.7
Biological worker	Truncated Normal	7.18	7.18	18.7
Commercial worker	Lognormal	4.38	2.32	14.8
Industrial worker	Lognormal	4.38	2.32	14.8
Basement				
Length (m)	Uniform	10	10	16.3
Width (m)	Uniform	8.5	8.5	13.45
Ventilation Flow Rate (cm^3/sec)	Triangular	617500	617500	1008960
Percent Organic Carbon (fraction) (Aquatic) in Sediments	Lognormal	0.1197716	0.1039339	0.2496338
Percent Organic Carbon (fraction) (Terrestrial) in Sediments	Lognormal	0.0038779	0.003735	0.0058623
Soil Density	Normal	1.45315	1.45315	1.752022
Soil Porosity (fraction)	Normal	0.45164	0.45164	0.5644193
Soil Temperature (celsius)	Fixed Value	9.9		
Soil Moisture (unitless)	Exponential	0.07099	0.04921	0.2126
Respiratory Deposition				
Vapor (fraction)	Fixed Value	1		
Particulate (fraction)	Fixed Value	0.85		

Table 6.1-4 Chemical-Specific Parameter Values

Chemical		Molecular Weight (g/mole)		Molecular Diffusivity (cm^2/sec)		Soil/Water Partition Coefficient (L/kg) Mean	50%	95%		Vapor Pressure (ATM) Mean	50%	95%		Henry's Law Constant (unitless) Mean	50%	95%
Aldrin	F	364.3	F	0.0407	A	298100	151800	1027000	A	5.84E-08	2.78E-08	2.07E-07	D	0.000306	0.0003033	0.0005831
Arsenic	F	74.92	F	NA	A	179.9	55.76	691		NA	NA	NA		NA	NA	NA
Benzene	F	78.11	F	0.0819	A	19034	158.1	461.3	E	0.104	0.107	0.1514207	E	0.00533	0.00533	0.007074
Cadmium	F	112.4	F	NA	A	169.9	59.2	645.2		NA	NA	NA		NA	NA	NA
Carbon Tetrachloride	F	153.8	F	0.0750	A	513	457.1	1007	E	0.124	0.124	0.159	E	0.0237	0.0237	0.0356600
Chlordane	F	409.8	F	0.0404	A	280900	156900	925600	A	1.76E-07	4.14E-08	6.79E-07	A	0.0002760	0.0001186	0.0010061
Chloroacetic Acid	F	94.5	F	NA	A	1.787	1.66	3.125	B	0.0004323	0.0004323	0.0008136	A	1.28E-08	8.36E-09	3.81E-08
Chlorobenzene	F	112.5	F	0.0676	A	611.3	508.9	1378	C	0.0151	0.0151833	0.0166427	E	0.00363	0.00363	0.0044410
Chloroform	F	119.4	F	0.0834	A	86.01	81.29	141.3	E	0.241	0.241	0.3084536	E	0.0031	0.0031	0.0042152
Chromium (VI)	F	52	F	NA	A	20.91	11.16	70.52		NA	NA	NA		NA	NA	NA
DDE	F	318	F	0.00440	A	667800	579500	1392000	E	8.69E-09	8.69E-09	1.07E-08	D	7.35E-04	7.28E-04	1.41E-03
DDT	F	354.5	F	0.0423	A	1425000	653400	5099000	A	4.82E-10	3.41E-10	1.34E-09	D	3.49E-05	3.47E-05	6.03E-05
DBCP	F	236.4	F	0.0600	A	310.2	245.4	756.5	B	0.0053025	0.0053025	0.0099803	A	6.61E-04	6.55E-04	1.27E-03
1,2-Dichloro-ethane	F	98.96	F	0.0856	A	38.45	36.17	64.31	E	0.0825	0.0825	0.122	A	0.0033426	0.0031828	0.0053260
1,1-Dichloro-ethylene	F	96.95	F	0.0744	A	63.13	59.57	104.4	A	0.763	0.763	0.8791	A	0.01598	0.01485	0.02792
DCPD	F	132.2	F	0.0562	A	274300	153300	904200	B	0.009292	0.009292	0.0174892	A	0.0539400	0.0330400	0.168400
Dieldrin	F	380.9	F	0.0416	A	64170	42190	190300	A	3.44E-09	1.38E-09	1.27E-08	D	3.51E-05	3.48E-05	6.85E-05
Endrin	F	380.9	F	0.0416	A	201600	140100	569900	D	2.50E-09	2.48E-09	4.62E-09	D	4.71E-06	4.67E-06	8.81E-06
HCCPD	F	273	F	0.0522	A	274300	153300	904200	E	0.000107	0.000107	0.0001481	A	0.0225900	0.021068	0.0389100

Table 6.1-4 Chemical-Specific Parameter Values

Chemical		Molecular Weight (g/mole)		Molecular Diffusivity (cm^2/sec)		Soil/Water Partition Coefficient (L/kg) Mean	50%	95%		Vapor Pressure (ATM) Mean	50%	95%		Henry's Law Constant (unitless) Mean	50%	95%
Isodrin	F	364.9	F	0.407	A	298100	151800	1027000	A	5.84E-08	2.78E-08	2.07E-07	D	0.000306	0.000304	0.000583
Lead	F	207.2	F	NA	A	6386000	3371	2012000		NA	NA	NA		NA	NA	NA
Mercury	F	200.6	F	NA	A	149.1	115.3	375.8		NA	NA	NA		NA	NA	NA
Methylene Chloride	F	84.94	F	0.0958	A	14.97	14.13	24.75	C	0.3347	0.327	0.5479	E	0.00236	0.00236	0.0035476
1,1,2,2-Tetra-chloroethane	F	167.9	F	0.0958	A	14.97	14.13	24.75	C	0.00725	0.00725	0.0100956	E	0.000415	0.000415	0.0005565
Tetrachloro-ethylene	F	165.9	F	0.00798	A	577.8	457.1	1409	E	0.0207	0.0207	0.0282022	D	0.0185	0.0184	0.0334
Toluene	F	92.13	F	0.0736	A	494.5	417.4	1088	C	0.0323333	0.0328564	0.0399016	C	0.00625	0.0063042	0.0068655
TCE	F	131.4		0.0749	A	455.9	317.4	1287	E	0.0826	0.0826	0.1.27	C	0.0092333	0.0093961	0.0125647

Table 6.1-4 Chemical-Specific Parameter Values

Chemical		RAF Dermal (RfD) Mean	50%	95%		RAF Dermal (CPF) Mean	50%	95%		RAF Oral (RfD) Mean	50%	95%		RAF Oral (CPF) Mean	50%	95%
Aldrin	B	0.00291	0.00291	0.00497	B	0.00291	0.00291	0.00497	B	0.45	0.45	0.63	B	0.45	0.45	0.63
Arsenic		NA	NA	NA		NA	NA	NA	B	0.71	0.71	0.971	B	0.71	0.71	0.971
Benzene	B	0.775	0.775	0.9775	B	0.775	0.775	0.9775	B	0.805	0.805	0.9805	B	0.805	0.805	0.9805
Cadmium		NA	NA	NA		NA	NA	NA	F	1	1	1		NA	NA	NA
Carbon Tetrachloride	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.84	0.84	0.984
Chlordane	B	0.023	0.023	0.041	B	0.023	0.023	0.041	B	0.805	0.805	0.9805	B	0.805	0.805	0.9805
Chloroacetic Acid	B	0.845	0.845	0.9845		NA	NA	NA	B	0.84	0.84	0.984		NA	NA	NA
Chlorobenzene	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984		NA	NA	NA
Chloroform	B	0.75	0.75	0.93	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.74	0.74	0.92
Chromium (VI)		NA	NA	NA		NA	NA	NA	F	1	1	1	F	1	1	1
DDE	B	0.022	0.022	0.04	B	0.022	0.022	0.04	B	0.805	0.805	0.9805	B	0.805	0.805	0.9805
DDT	B	0.022	0.022	0.04	B	0.022	0.022	0.04	B	0.805	0.805	0.9805	B	0.805	0.805	0.9805
DBCP	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	NA	NA	NA	B	0.84	0.84	0.984
1,2-Dichloro-ethane	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	NA	NA	NA	B	0.84	0.84	0.984
1,1-Dichloro-ethylene	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.84	0.84	0.984
DCPD	B	0.022	0.022	0.04		NA	NA	NA	B	0.805	0.805	0.9805		NA	NA	NA
Dieldrin	B	0.0056	0.0056	0.00956	B	0.0056	0.0056	0.00956	B	0.8	0.8	0.98	B	0.8	0.8	0.98
Endrin	B	0.022	0.022	0.04		NA	NA	NA	B	0.805	0.805	0.9805		NA	NA	NA
HCCPD	B	0.058	0.058	0.076		NA	NA	NA	B	0.805	0.805	0.9805		NA	NA	NA
Isodrin	B	0.022	0.022	0.04		NA	NA	NA	B	0.805	0.805	0.9805		NA	NA	NA
Lead		NA	NA	NA		NA	NA	NA	B	0.65	0.65	0.964		NA	NA	NA
Mercury		NA	NA	NA		NA	NA	NA	B	0.545	0.545	0.9545		NA	NA	NA

Table 6.1-4 Chemical-Specific Parameter Values

Chemical		RAF Dermal (RfD) Mean	50%	95%		RAF Dermal (CPF) Mean	50%	95%		RAF Oral (RfD) Mean	50%	95%		RAF Oral (CPF) Mean	50%	95%
Methylene Chloride	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.84	0.84	0.984
1,1,2,2-Tetra-chloroethane	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.84	0.84	0.984
Tetrachloro-ethylene	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.84	0.84	0.984
Toluene	B	0.91	0.91	0.991		NA	NA	NA	B	0.88	0.88	0.988		NA	NA	NA
TCE	B	0.845	0.845	0.9845	B	0.74	0.74	0.92	B	0.84	0.84	0.984	B	0.73	0.73	0.91

(A) Lognormal Distribution
(B) Uniform Distribution
(C) Triangular Distribution
(D) Uniform-Triangular Distribution
(E) Normal Distribution
(F) Fixed
(G) The cancer potency factor relative absorption factor differs from the reference dose relative absorption factor.

NA Not Applicable

Table 6.1-5 Summary of Data Sources for PPLV Direct and Indirect Equation Parameters

Parameter	Data Source (s)
Basement Parameters	
Area	Professional Judgment
Volume	Professional Judgment
Volume/Area Ratio	Professional Judgment
Depth	Professional Judgment
Ventilation Rate	Commerce City and Denver 1988 Uniform Building Codes Handbook
Time for Air Exchange	Computed as function of ventilation and basement volume
Body Weight	OHEA-EPA 1989 —Exposure Factors Handbook
Breathing Rate (BR, DINH, RB)	Professional Judgment (EPA 1985)
Density of Arsenal Soils	RMA-Specific —Walsh 1988 —SCS 1987
Dust Loading Factor (CSS)	General Literature RMA-Specific —Comprehensive Monitoring Program
Henry's Law Constant	General Literature
Molecular Weight	General Literature
Percent Organic in Aquatic Sediments	RMA-Specific —Walsh 1988
Fraction Organic Carbon in Soils	RMA-Specific —Walsh 1988

Table 6.1-5 Summary of Data Sources for PPLV Direct and Indirect Equation Parameters

Parameter	Data Source (s)
Refuge Worker Time-Dependent Variables	RMA-Specific (Shell 1991) —Shell/Army Refuge Worker Survey
Relative Absorption Factor (RAF)	
Dermal	General Literature OHEA-EPA 1991 —Interim Guidance for Dermal Exposure Assessment
Oral	General Literature
Respiratory Disposition	General Literature EPA 1982 —Air Quality Criteria for Particulate Matter and Sulfur Oxides (Denver specific data)
Soil Covering	General Literature Professional Judgment OHEA-EPA 1991 —Interim Guidance for Dermal Exposure Assessment
Soil Ingestion	General Literature Professional Judgment OSWER-EPA 1991a —Risk Assessment Guidance (OSWER Directive)
Soil Moisture Content	RMA-Specific —Comprehensive Monitoring Program —Remedial Investigation for RMA
Soil Temperature	Regional Annual Average Temperature
Soil to Water Partition Coefficient (K_{oc}) Normalized to Organic Carbon	General Literature

Table 6.1-5 Summary of Data Sources for PPLV Direct and Indirect Equation Parameters

Parameter	Data Source (s)
Skin Surface Area (SX)	Professional Judgment EPA 1985
Total Soil Porosity	Calculated from soil and particle density
Vapor Pressure	General Literature

Table 6.1-6 RME Estimates For Acute Exposure

Parameter Name	Regulated/Casual Visitors		Recreational Visitors		Commercial Workers	Industrial Workers
Soil Ingestion	2-1/2 yr	250 mg/day	2-1/2 yr	250 mg/day	100 mg/day	100 mg/day
Breathing Rate	2-1/2 yr	4.2 l/min	2-1/2 yr	8.3 l/min	4.8 m^3/day	20 m^3/day
Dust Load Factor		0.042 mg/m^3		0.042 mg/m^3	0.021 mg/m^3	0.042 mg/m^3
Pulmonary Retention		0.75		0.75	0.75	0.75
Pulmonary Absorption		1 (100 percent)		1 (100 percent)	1 (100 percent)	1 (100 percent)
Daily Exposure Period		8 hours		8 hours	8 hours	8 hours
Annual Exposure Frequency		NA	NA	NA	NA	NA
Lifetime Exposure Duration		NA	NA	NA	NA	NA
Skin Surface Area	2-1/2 yr	2,100 cm^2	2-1/2 yr	2,100 cm^2	1,120 cm^2	3,200 cm^2
Soil Covering		0.51 mg/cm^2		0.51 mg/cm^2	0.11 mg/cm^2	1.5 mg/cm^2
Soil Matrix Factor		1.0		1.0	1.0	1.0
Dermal Absorption		0.01 (metals)	0.01 (metals)		0.01 (metals)	0.01 (metals)
		0.10 (organics)	0.10 (organics)		0.10 (organics)	0.10 (organics)
Body Weight		Child: 10th percentile(M&F)[1]	Child: 10th percentile(M&F)[1]		Adult: 70 kg	Adult: 70 kg

NA Not Applicable.
[1] Determined from the average of the male and female 10th percentile bodyweights as summarized in OHEA-EPA (1989).

Table 6.1-7 RME Estimates For Subchronic Exposure

Parameter Name	Regulated/Casual Visitors		Recreational Visitors		Commercial Workers	Industrial Workers
Soil Ingestion	2-1/2 yr	250 mg/day	2-1/2 yr	250 mg/day		
	6 yr	250 mg/day	6 yr	250 mg/day	100 mg/day	100 mg/day
Breathing Rate	2-1/2 yr	4.2 l/min	2-1/2 yr	8.3 l/min		
	6 yr	13.3 l/min	6 yr	20.3 l/min	4.8 m^3/day	20 m^3/day
Dust Load Factor		0.042 mg/m^3		0.042 mg/m^3	0.021 mg/m^3	0.042 mg/m^3
Pulmonary Retention		0.75		0.75	0.75	0.75
Pulmonary Absorption		1 (100 percent)		1 (100 percent)	1 (100 percent)	1 (100 percent)
Daily Exposure Period		8 hours		8 hours	8 hours	8 hours
Annual Exposure Frequency		108 day/year		108 days/year	253 days/year	253 days/year
Lifetime Exposure Duration		7 years		7 years	7 years	7 years
Q-Factor		7 years		7 years	7 years	7 years
Skin Surface Area	2-1/2 yr	2,100 cm^2	2-1/2 yr	2,100 cm^2	1,120 cm^2	3,200 cm^2
	6 yr	2,500 cm^2	6 yr	2,500 cm^2		
Soil Covering		0.51 mg/cm^2		0.51 mg/cm^2	0.11 mg/cm^2	1.5 mg/cm^2
Soil Matrix Factor		1.0		1.0	1.0	1.0
Dermal Absorption		0.01 (metals) 0.10 (organics)		0.01 (metals) 0.10 (organics)	0.01 (metals) 0.10 (organics)	0.01 (metals) 0.10 (organics)
Body Weight		Child: 10th percentile(M&F)[1]		Child: 10th percentile(M&F)[1]	Adult: 70 kg	Adult: 70 kg

NA Not Applicable.
[1] Determined from the average of the male and female 10th percentile bodyweights as summarized in OHEA-EPA (1989).

Table 6.1-8 Carcinogenic Dose-Response Data

Chemical	Weight of Evidence Classification[1]	Exposure Route	Cancer Slope Factor (mg/kg/day)	Carcinogenic Dose for 10^{-6} risk (mg/kg-day)
Aldrin	B2	Oral	1.7E+01	5.90E-08
		Inhalation	1.7E+01	5.90E-08
Arsenic	A	Oral	1.75E+00	5.70E-07
		Inhalation	1.5E+01	6.70E-08
Benzene	A	Oral	2.90E-02	3.40E-05
		Inhalation	2.90E-02	3.40E-05
Cadmium	B1	Oral	NA[2]	NA
		Inhalation	6.30E+00	1.60E-07
Carbon Tetrachloride	B2	Oral	1.30E-01	7.70E-06
		Inhalation	5.25E-02	1.90E-05
Chlordane	B2	Oral	1.30E+00	7.70E-07
		Inhalation	1.30E+00	7.70E-07
Chloroacetic Acid	NE[3]	Oral	NA	NA
		Inhalation	NA	NA
Chlorobenzene	D			
Chloroform	B2	Oral	6.10E-03	1.60E-04
		Inhalation	8.00E-02	1.20E-05
Chromium (VI)	A	Oral	NA	NA
		Inhalation	4.20E+01	2.40E-08
DBCP	B2	Oral	1.40E+00	7.10E-07
		Inhalation	2.40E-03	4.20E-04
DCPD	NE	Oral	NA	NA
		Inhalation	NA	NA
DDE	B2	Oral	3.40E-01	2.90E-06
		Inhalation	3.40E-01[4]	2.90E-06
DDT	B2	Oral	3.40E-01	2.90E-06
		Inhalation	3.40E-01	2.90E-06
1,2-Dichloroethane	B2	Oral	9.10E-02	1.10E-05
		Inhalation	9.10E-02	1.10E-05
1,1-Dichloroethylene	C	Oral	6.00E-01	1.70E-06
		Inhalation	1.80E-01	5.70E-06
Dieldrin	B2	Oral	1.60E+01	6.20E-08
		Inhalation	1.60E+01	6.20E-08
Endrin	D			
HCCPD	D			
Isodrin	NE	Oral	NA	NA
		Inhalation	NA	NA
Lead	B2	Oral	NA	NA
		Inhalation	NA	NA
Mercury	D			
Methylene Chloride	B2	Oral	7.50E-03	1.30E-04
		Inhalation	1.60E-03	6.10E-04
1,1,2,2-Tetrachloroethane	C	Oral	2.00E-01	5.00E-06
		Inhalation	2.00E-01	5.00E-06
Tetrachloroethylene	B2	Oral	5.10E-02	2.00E-05
		Inhalation	1.80E-03	5.50E-04

Table 6.1-8 Carcinogenic Dose-Response Data

Chemical	Weight of Evidence Classification[1]	Exposure Route	Cancer Slope Factor (mg/kg/day)	Carcinogenic Dose for 10^{-6} risk (mg/kg-day)
Toluene	D			
TCE	B2	Oral	1.10E-02	9.10E-05
		Inhalation	5.90E-03	1.70E-04

1 A = Human carcinogen.
B1/B2 = Probable human carcinogen.
B1 = Indicates limited human data are available.
B2 = Indicates sufficient evidence in animals and inadequate or no evidence in humans.
C = Possible human carcinogen.
D = Not classifiable as a carcinogen.

2 NA denotes Not Applicable.

3 NE denotes no Weight of Evidence Classification Assigned.

4 Inhalation cancer slope factor for DDE not available. Value shown is direct extrapolation from oral pathway.

Table 6.1-9 Chronic Noncarcinogenic Dose-Response Data

Chemical	Route of Exposure	Chronic RfD (mg/kg-day)
Aldrin	Oral	3.00E-05
	Inhalation	3.00E-05[1]
Arsenic	Oral	3.00E-04
	Inhalation	3.00E-04[1]
Benzene	Oral	NA[2]
	Inhalation	NA
Cadmium	Oral, water	5.00E-04
	Oral, food	1.00E-03
Carbon Tetrachloride	Oral	7.00E-04
	NA	7.00E-04[1]
Chlordane	Oral	6.00E-05
	Inhalation	6.00E-05[1]
Chloroacetic Acid	Oral	2.00E-03
	Inhalation	2.00E-03[1]
Chlorobenzene	Oral	2.00E-02
	Inhalation	5.00E-03
Chloroform	Oral	1.00E-02
	Inhalation	1.00E-02[1]
Chromium (VI)	Oral	5.00E-03
	Inhalation	6.00E-07
DBCP	Oral	2.00E-04
	Inhalation	6.00E-05[3]
DCPD	Oral	3.00E-02
	Inhalation	6.00E-05
DDE	Oral	NA
	Inhalation	NA
DDT	Oral	5.00E-04
	Inhalation	5.00E-04[1]
1,2-Dichloroethane	Oral	NA
	Inhalation	NA
1,1-Dichloroethylene	Oral	9.00E-03
	Inhalation	9.00E-03[1]
Dieldrin	Oral	5.00E-05
	Inhalation	5.00E-05 [1]
Endrin	Oral	3.00E-04
	Inhalation	3.00E-04[1]
HCCPD	Oral	7.00E-03
	Inhalation	2.00E-05
Isodrin	Oral	7.00E-05
	Inhalation	7.00E-05

Table 6.1-9 Chronic Noncarcinogenic Dose-Response Data

Chemical	Route of Exposure	Chronic RfD (mg/kg-day)
Lead	Oral	1.40E-03
	Inhalation	4.30E-04
Mercury	Oral	3.00E-04
	Inhalation	9.00E-05 [3]
Methylene Chloride	Oral	6.00E-02
	Inhalation	8.60E-01
1,1,2,2-Tetrachloroethane	Oral	NA
	Inhalation	NA
Tetrachloroethylene	Oral	1.00E-02
	Inhalation	1.00E-02 [1]
Toluene	Oral	2.00E-01
	Inhalation	1.10E-01 [3]
TCE	Oral	NA
	Inhalation	NA

1 Inhalation RfD for chemical not available. Value shown is direct extrapolation from oral pathway.
2 NA denotes Not Available.
3 Inhalation RfD extrapolated from RfC, assuming inhalation of 20 cubic meters/day and body weight of 70 kg.

Contaminant	Acute D_TING (mg/kg-day)	Acute D_TINH (mg/kg-day)	Subchronic D_TING (mg/kg-day)	Subchronic D_TINH (mg/kg-day)
Aldrin	1.0E-04	1.0E-04	1.0E-04	1.0E-04
Arsenic	8.0E-03	2.9E-04	1.0E-03	2.9E-04
Atrazine	1.0E-02	1.0E-02	5.0E-03	5.0E-03
Benzene	NA	NA	NA	NA
Benzothiazole	NA	NA	NA	NA
BCHPD	NA	NA	NA	NA
Cadmium	4.0E-03	1.4E-01	5.0E-04	5.0E-04
Carbon tetrachloride	4.0E-01	1.8E-01	7.0E-03	2.7E-02
Chlordane	6.0E-03	6.0E-03	6.0E-05	1.4E-04
Chloroacetic acid	NA	NA	2.0E-02	2.0E-02
Chlorobenzene	2.0E-01	2.0E-01	2.0E-01	5.0E-02
Chloroform	1.8E-01	4.3E-01	1.0E-02	6.8E-03
CPMS	NA	NA	NA	NA
Chlorophenylmethyl sulfoxide	NA	NA	NA	NA
$CPMSO_2$	NA	NA	NA	NA
Chromium VI	1.0E-01	1.0E-01	2.0E-02	5.7E-06
Copper	NA	NA	NA	NA
DBCP	5.0E-03	5.0E-03	NA	NA
DDE	NA	NA	NA	NA
DDT	5.0E-04	5.0E-04	5.0E-04	5.0E-04
1,1-Dichloroethane	NA	NA	1.0E+00	1.0E+00
1,2-Dichlorethane	NA	NA	NA	NA
1,1-Dichlorethylene	2.0E+00	1.0E+00	9.0E-03	2.3E-02
1,2-Dichloroethylene	NA	NA	1.0E-01	1.0E-01
DCPD	NA	NA	3.0E-01	6.0E-04
Dieldrin	1.0E-04	1.0E-04	1.0E-04	1.0E-04
DIMP	8.0E-01	8.0E-01	8.0E-01	8.0E-01
Dimethyl disulfide	NA	NA	NA	NA
Dimethylmethyl phosphonate	NA	NA	NA	NA

Table 6.1-10 D_T Values For Acute and Subchronic Exposure

Contaminant	Acute D_TING (mg/kg-day)	Acute D_TINH (mg/kg-day)	Subchronic D_TING (mg/kg-day)	Subchronic D_TINH (mg/kg-day)
Dithiane	NA	NA	NA	NA
Endrin	2.0E-03	2.0E-03	5.0E-04	5.0E-04
Ethylbenzene	3.0E+00	3.0E+00	1.0E+00	2.8E-01
Fluoroacetic acid	NA	NA	NA	NA
HCCPD	NA	NA	7.0E-02	2.0E-04
Isodrin	NA	NA	NA	NA
Isopropylmethyl phosphonic acid	NA	NA	NA	NA
Isopropylmethyl phosphonate	NA	NA	NA	NA
Lead	NA	NA	NA	NA
Lewisite	NA	NA	NA	NA
Lewisite oxide	NA	NA	NA	NA
Malathion	2.0E-02	2.0E-02	2.0E-02	2.0E-02
Mercury(inorganic)	2.0E-01	2.0E-01	3.0E-04	8.5E-05
Methylene chloride	1.0E+00	4.9E+00	6.0E-02	8.5E-01
Methyl isobutyl ketone	NA	NA	5.0E-01	2.0E-01
NDMA	NA	NA	NA	NA
1,4-Oxathiane	NA	NA	NA	NA
Parathion	NA	NA	6.0E-03	6.0E-03
Sarin	NA	NA	NA	5.7E-07
Sulfur mustard	NA	NA	NA	NA
Supona	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	NA	NA	NA	NA
Tetrachloroethylene	2.0E-01	1.9E+00	1.0E-01	1.7E-01
Thiodiglycol	NA	NA	NA	NA
Toluene	2.0E+00	4.3E+00	2.0E+00	5.7E-01
1,1,1-Trichloroethane	1.0E+01	4.0E-01	9.0E-01	2.8E+00
1,1,2-Trichloroethane	6.0E-02	4.0E-02	4.0E-02	4.0E-02
TCE	2.4E+00	4.3E-01	2.5E+00	2.5E+00
Vapona	NA	NA	NA	NA

Table 6.1-10 D_T Values For Acute and Subchronic Exposure

Contaminant	Acute D_TING (mg/kg-day)	Acute D_TINH (mg/kg-day)	Subchronic D_TING (mg/kg-day)	Subchronic D_TINH (mg/kg-day)
M-xylene	4.0E+00	4.0E+00	4.0E+00	1.0E+00
O,p-Xylene	4.0E+00	4.0E+00	4.0E+00	8.5E-02
Zinc	NA	NA	2.0E-01	2.0E-01

NA Dose-response data not available from EPA.
D_TING Allowable dose for ingestion
D_TING Allowable dose for inhalation

Table 6.1-11 Summary of Chronic Cumulative Direct Soil PPLVs for the 5th Percentile[1,2]

Chemical	Receptor-Specific Soil PPLVs (Units: mg/kg)				
	Open Space Populations			Economic Development Populations	
	Biological Worker	Regulated/ Casual Visitor	Recreational Visitor	Industrial Worker	Commercial Worker
Aldrin	**7.16E-01**	1.16E+01	3.29E+00	3.02E+00	4.71E+00
Benzene	1.18E+01	5.76E+01	1.30E+01	**1.04E+01**	2.26E+02
Carbon Tetrachloride	2.51E+00	1.32E+01	2.69E+00	**2.33E+00**	5.14E+01
Chlordane	**3.72E+00**	5.39E+01	1.09E+01	7.58E+00	2.66E+01
Chloroacetic Acid*	1.01E+02	8.13E+02	2.34E+02	**7.71E+01**	1.88E+03
Chlorobenzene*	9.66E+02	6.95E+03	2.55E+03	**8.45E+02**	1.68E+04
Chloroform	**4.82E+01**	3.23E+02	8.91E+01	4.84E+01	1.11E+03
DDE	**1.25E+01**	1.77E+02	3.05E+01	1.87E+01	1.26E+02
DDT	**1.35E+01**	1.51E+02	3.60E+01	3.61E+01	9.58E+01
DBCP	**2.01E-01**	1.17E+00	2.52E-01	2.36E-01	4.51E+00
1,2-Dichloroethane	**3.23E+00**	1.74E+01	3.75E+00	3.39E+00	7.07E+01
1,1-Dichloroethylene	**5.16E-01**	2.82E+00	7.33E-01	5.21E-01	1.02E+01
DCPD*	**3.69E+03**	6.11E+04	2.91E+04	6.65E+03	5.83E+04
Dieldrin	**4.14E-01**	6.45E+00	1.96E+00	1.40E+00	2.54E+00
Endrin*	**2.32E+02**	2.99E+03	8.65E+02	3.18E+02	1.12E+03
HCCPD*	**1.06E+03**	1.47E+04	6.16E+03	1.78E+03	1.67E+04
Isodrin*	**5.24E+01**	6.43E+02	2.15E+02	7.39E+01	2.51E+02
Methylene Chloride	**3.53E+01**	2.06E+02	4.58E+01	4.43E+01	7.78E+02
1,1,2,2-Tetrachloroethane	**1.45E+00**	1.94E+00	9.61E+00	1.49E+00	3.31E+01
Tetrachloroethylene	**5.43E+00**	3.57E+01	6.26E+00	5.87E+00	1.30E+02
Toluene*	9.46E+03	6.48E+04	2.11E+04	**7.22E+03**	1.38E+05
TCE	**2.84E+01**	1.78E+02	3.98E+01	2.90E+01	6.27E+02
Metals (Indicator Level[3])					
Arsenic (IL = 10 ppm, >driving PPLV)	**4.17E+00**	7.91E+01	3.68E+01	2.60E+01	2.60E+01
Cadmium (IL = 2.0 ppm)	**5.01E+01**	8.55E+02	2.17E+02	2.12E+02	1.87E+03
Chromium (IL = 40 ppm, >driving PPLV)	**7.52E+00**	1.29E+02	3.28E+01	3.23E+01	2.36E+02
Lead* (IL = 40 ppm)	**2.17E+03**	4.77E+04	2.65E+04	4.46E+03	7.06E+03
Mercury* (IL = 0.1 ppm)	**5.74E+02**	9.85E+03	5.49E+03	1.24E+03	1.35E+03

* Denotes a noncarcinogen. No asterisk denotes PPLV based on carcinogenic slope factors for both oral and inhalation pathways.

1 Cumulative direct PPLVs represent a cancer risk level of 10^{-6} for carcinogens; the PPLV at a 10^{-4} cancer risk is 100 times higher than the values shown in this table. Values in bold face represent the driver PPLVs for the corresponding receptor population.

2 Summaries of dominant exposure pathways comprising the cumulative (5th percentile) direct PPLV are provided in Appendix Section B.4.1 of the IEA/RC report for each receptor population evaluated (Appendix Tables B.4.1-1 through B.4.1-5). As shown in these tables, the majority of PPLVs listed above reflect the carcinogenic endpoint. Also, for most chemicals, dermal absorption was the driver exposure pathway. The only exceptions were certain OCPs (aldrin, DDE, endrin, and isodrin), for which soil ingestion was the driver pathway, and metals, for which ingestion or inhalation pathways were drivers.

3 Indicator level is the assumed background concentration for the inorganic COCs.

Table 6.1-12 Summary of Chronic Cumulative Direct Soil PPLVs for the 50th Percentile[1] Page 1 of 1

	Receptor-Specific Soil PPLVs (Units: mg/kg)				
	Open Space Populations			Economic Development Populations	
Chemical	Biological Worker	Regulated/ Casual Visitor	Recreational Visitor	Industrial Worker	Commercial Worker
Aldrin	**4.27E+00**	1.10E+02	9.43E+01	1.52E+01	3.89E+01
Benzene	**3.43E+01**	6.21E+02	3.26E+02	1.04E+02	1.53E+03
Carbon Tetrachloride	**7.69E+00**	1.28E+02	6.75E+01	1.94E+01	3.05E+02
Chlordane	**1.97E+01**	3.30E+02	2.35E+02	5.03E+01	2.53E+02
Chloroacetic Acid*	2.19E+02	2.84E+03	1.31E+03	**1.67E+02**	2.60E+03
Chlorobenzene*	2.19E+03	2.88E+04	1.28E+04	**1.61E+03**	2.50E+04
Chloroform	**1.91E+02**	3.08E+03	1.66E+03	4.58E+02	7.48E+03
DDE	**7.13E+01**	1.28E+03	8.10E+02	1.95E+02	8.22E+02
DDT	**6.49E+01**	1.29E+03	1.01E+03	2.20E+02	9.01E+02
DBCP	**7.24E-01**	1.24E+01	6.21E+00	1.89E+00	2.89E+01
1,2-Dichloroethane	**1.07E+01**	1.88E+02	9.14E+01	2.99E+01	3.99E+02
1,1-Dichloroethylene	**1.57E+00**	2.94E+01	1.52E+01	4.53E+00	6.83E+01
DCPD*	**8.12E+03**	2.17E+05	2.09E+05	1.66E+04	1.33E+05
Dieldrin	**2.45E+00**	5.73E+01	4.81E+01	8.42E+00	2.27E+01
Endrin*	**6.42E+02**	1.28E+04	6.72E+03	6.81E+02	3.41E+03
HCCPD*	**2.22E+03**	6.12E+04	4.05E+04	6.80E+03	3.32E+04
Isodrin*	**1.48E+02**	2.67E+03	1.56E+03	1.55E+02	7.76E+02
Methylene Chloride	**1.27E+02**	2.04E+03	1.19E+03	3.51E+02	5.32E+03
1,1,2,2-Tetrachloroethane	**5.16E+00**	9.04E+01	4.55E+01	1.32E+01	1.97E+02
Tetrachloroethylene	**1.92E+01**	3.64E+02	1.86E+02	5.33E+01	7.51E+02
Toluene*	2.04E+04	1.74E+05	9.02E+04	**1.46E+04**	1.76E+05
TCE	**1.03E+02**	1.84E+03	8.83E+02	2.79E+02	4.62E+03
Metals (Indicator Level[2])					
Arsenic (IL = 10 ppm, >driving PPLV)	**2.64E+01**	9.38E+02	9.02E+02	1.38E+02	2.44E+02
Cadmium (IL = 2.0 ppm)	**3.10E+02**	1.24E+04	1.36E+04	2.34E+03	2.19E+04
Chromium (IL = 40 ppm, >driving PPLV)	**4.72E+01**	1.89E+03	2.16E+03	3.56E+02	4.21E+03
Lead* (IL = 40 ppm)	**7.22 E+03**	2.37E+05	2.18E+05	1.68E+04	2.40E+04
Mercury* (IL = 0.1 ppm)	**1.80E+03**	6.82E+04	6.81E+04	4.35E+03	5.96E+03

* Denotes a noncarcinogen. No asterisk denotes PPLV based on carcinogenic slope factors for both oral and inhalation pathways.

1 Cumulative direct PPLVs represent a cancer risk level of 10^{-6} for carcinogens; the PPLV at a 10^{-4} cancer risk is 100 times higher than the values shown in this table. Values in bold face represent the driver PPLVs for corresponding receptor population.

2 Indicator level is the assumed background concentration for the inorganic COCs.

Table 6.1-13 Summary of 5th Percentile Direct Single-Pathway PPLVS for the Biological Worker[1]

Chemical Name	Soil Ingestion SPPLV	Soil Inhalation SPPLV	Dermal Absorption SPPLV	Cumulative Direct PPLV-CARC[2]	Cumulative Direct PPLV-NONCARC[2]
Aldrin	**7.64E-01**	9.56E+01	1.30E+01	7.16E-01	7.12E+01
Benzene	1.29E+02	1.02E+04	**1.30E+01**	1.18E+01	NA
Carbon Tetrachloride	8.14E+01	1.20E+04	**2.59E+00**	2.51E+00	3.63E+01
Chlordane	2.71E+01	7.18E+02	**4.34E+00**	3.72E+00	5.51E+01
Chloroacetic Acid	3.98E+03	3.74E+05	**1.04E+02**	NA	1.01E+02
Chlorobenzene	4.12E+04	9.36E+05	**9.91E+02**	NA	9.66E+02
Chloroform	4.58E+03	1.12E+04	**4.90E+01**	4.82E+01	4.41E+02
DDE	**1.96E+01**	1.88E+03	3.53E+01	1.25E+01	NA
DDT	3.02E+01	1.84E+03	**2.47E+01**	1.35E+01	4.09E+02
DBCP	2.96E+00	1.27E+05	**2.16E-01**	2.01E-01	9.75E+00
1,2-Dichloroethane	1.13E+02	6.97E+03	**3.32E+00**	3.23E+00	NA
1,1-Dichloroethylene	1.84E+01	3.61E+03	**5.31E-01**	5.16E-01	4.52E+02
Dicyclopentadiene	3.72E+04	**4.24E+03**	1.20E+05	NA	3.69E+03
Dieldrin	**5.90E-01**	4.02E+01	1.43E+00	4.14E-01	5.77E+01
Endrin	**2.43E+02**	3.76E+04	6.47E+03	NA	2.32E+02
Hexachlorocyclopentadiene	9.74E+03	**1.41E+03**	7.48E+03	NA	1.06E+03
Isodrin	**1.02E+02**	4.42E+03	1.10E+02	NA	5.24E+01
Methylene Chloride	9.51E+02	3.95E+05	**3.66E+01**	3.53E+01	3.11E+03
1,1,2,2-Tetrachloroethane	2.30E+01	1.51E+03	**1.55E+00**	1.45E+00	NA
Tetrachloroethylene	6.05E+02	5.13E+05	**5.48E+00**	5.43E+00	5.47E+02
Toluene	4.69E+05	1.00E+06	**9.75E+03**	NA	9.46E+03
Trichloroethylene	1.41E+03	1.08E+05	**2.90E+01**	2.84E+01	NA
Arsenic	**4.36E+00**	9.56E+01	0.00E+00	4.17E+00	4.76E+02
Cadmium	3.47E+04	**5.01E+01**	0.00E+00	5.01E+01	5.29E+02
Chromium	3.47E+05	**7.52E+00**	0.00E+00	7.52E+00	3.87E+01
Lead	**2.22E+03**	9.28E+04	0.00E+00	NA	2.17E+03
Mercury	**6.24E+02**	7.17E+03	0.00E+00	NA	5.74E+02

[1] Values reported as mg/kg. Values are 5th percentile PPLVs, based on a 10^{-6} risk level for carcinogens, and an HI of 1.0 for noncarcinogens. Values in bold face represent the driver exposure pathway.

[2] Where a chemical is both a carcinogen (CARC) and noncarcinogen (NONCARC), the single-pathway PPLVs summarized represent the carcinogenic endpoint.

Table 6.1-14 Summary of 5th Percentile Direct Single-Pathway PPLVS for the Recreational Visitor[1]

Chemical Name	Soil Ingestion SPPLV	Soil Inhalation SPPLV	Dermal Absorption SPPLV	Cumulative Direct PPLV-CARC[2]	Cumulative Direct PPLV-NONCARC[2]
Aldrin	**6.36E+00**	4.79E+02	6.93E+00	3.29E+00	4.63E+02
Benzene	5.74E+03	8.62E+04	**1.30E+01**	1.30E+01	NA
Carbon Tetrachloride	3.29E+03	1.91E+05	**2.69E+00**	2.69E+00	8.65E+01
Chlordane	5.14E+01	5.67E+02	**1.41E+01**	1.09E+01	1.59E+02
Chloroacetic Acid	5.30E+04	1.00E+06	**2.35E+02**	NA	2.34E+02
Chlorobenzene	6.36E+05	1.00E+06	**2.56E+03**	NA	2.55E+03
Chloroform	8.26E+04	1.21E+05	**8.39E+01**	8.91E+01	1.17E+03
DDE	4.48E+02	7.35E+03	**3.29E+01**	3.05E+01	NA
DDT	7.98E+02	1.93E+04	**3.78E+01**	3.60E+01	1.62E+03
DBCP	1.50E+02	1.00E+06	**2.52E-01**	2.52E-01	2.32E+01
1,2-Dichloroethane	5.57E+03	1.11E+05	**3.75E+00**	3.75E+00	NA
1,1-Dichloroethylene	5.05E+01	5.65E+03	**7.44E-01**	7.33E-01	1.06E+03
Dicyclopentadiene	3.85E+05	**4.49E+04**	1.05E+05	NA	2.91E+04
Dieldrin	3.48E+01	6.24E+02	**2.08E+00**	1.96E+00	4.70E+02
Endrin	9.83E+03	1.43E+05	**9.55E+02**	NA	8.65E+02
Hexachlorocyclopentadiene	7.88E+04	1.50E+04	**1.21E+04**	NA	6.16E+03
Isodrin	2.02E+03	1.07E+05	**2.41E+02**	NA	2.15E+02
Methylene Chloride	2.17E+04	1.00E+06	**4.59E+01**	4.58E+01	7.30E+03
1,1,2,2-Tetrachloroethane	2.70E+03	5.03E+04	**1.94E+00**	9.61E+00	NA
Tetrachloroethylene	9.93E+03	1.00E+06	**6.27E+00**	6.26E+00	1.28E+03
Toluene	1.00E+06	1.00E+06	**2.21E+04**	NA	2.11E+04
Trichloroethylene	2.06E+04	4.31E+05	**3.99E+01**	3.98E+01	NA
Arsenic	**6.16E+01**	9.15E+01	00.0E+00	3.68E+01	5.84E+03
Cadmium	3.96E+04	**2.19E+02**	00.0E+00	2.17E+02	6.53E+03
Chromium	3.96E+05	**3.28E+01**	00.0E+00	3.28E+01	3.55E+02
Lead	**2.75E+04**	7.08E+05	00.0E+00	NA	2.65E+04
Mercury	**5.91E+03**	7.70E+04	00.0E+00	NA	5.49E+03

1 Values reported as mg/kg. Values are 5th percentile PPLVs, based on a 10^{-6} risk level for carcinogens, and an HI of 1.0 for noncarcinogens. Values in bold face represent the driver exposure pathway.

2 Where a chemical is both a carcinogen (CARC) and noncarcinogen (NONCARC), the single-pathway PPLVs summarized represent the carcinogenic endpoint.

Table 6.1-15 Summary of 5th Percentile Direct Single-Pathway PPLVS for the Regulated/Casual Visitor[1]

Chemical Name	Soil Ingestion SPPLV	Soil Inhalation SPPLV	Dermal Absorption SPPLV	Cumulative Direct PPLV-CARC[2]	Cumulative Direct PPLV-NONCARC[2]
Aldrin	**2.32E+01**	3.68E+02	2.48E+01	1.16E+01	1.09E+03
Benzene	4.05E+03	1.36E+05	**5.85E+01**	5.76E+01	NA
Carbon Tetrachloride	1.17E+03	9.73E+04	**1.34E+01**	1.32E+01	2.86E+02
Chlordane	2.91E+02	5.99E+03	**6.69E+01**	5.39E+01	5.82E+02
Chloroacetic Acid	5.62E+04	1.00E+06	**8.25E+02**	NA	8.13E+02
Chlorobenzene	7.37E+05	1.00E+06	**7.07E+03**	NA	6.95E+03
Chloroform	2.34E+04	7.49E+04	**3.29E+02**	3.23E+02	4.41E+03
DDE	3.66E+02	1.16E+04	**3.52E+02**	1.77E+02	NA
DDT	1.11E+03	1.56E+04	**1.77E+02**	1.51E+02	5.89E+03
DBCP	7.20E+01	1.00E+06	**1.19E+00**	1.17E+00	7.76E+01
1,2-Dichloroethane	1.24E+03	4.40E+04	**1.77E+01**	1.74E+01	NA
1,1-Dichloroethylene	2.05E+02	2.28E+04	**2.86E+00**	2.82E+00	3.49E+03
Dicyclopentadiene	1.00E+06	**7.81E+04**	3.91E+05	NA	6.11E+04
Dieldrin	**9.24E+00**	3.17E+02	2.28E+01	6.45E+00	9.39E+02
Endrin	1.15E+04	3.43E+05	**4.09E+03**	NA	2.99E+03
Hexachlorocyclopentadiene	2.48E+05	**2.24E+04**	5.18E+04	NA	1.47E+04
Isodrin	3.04E+03	3.27E+05	**8.17E+02**	NA	6.43E+02
Methylene Chloride	1.33E+04	1.00E+06	**2.09E+02**	2.06E+02	2.37E+04
1,1,2,2-Tetrachloroethane	5.74E+02	2.00E+04	**9.78E+00**	1.94E+00	NA
Tetrachloroethylene	2.52E+03	1.00E+06	**3.62E+01**	3.57E+01	3.82E+03
Toluene	1.00E+06	1.00E+06	**7.44E+04**	NA	6.48E+04
Trichloroethylene	1.25E+04	6.80E+05	**1.80E+02**	1.78E+02	NA
Arsenic	**1.03E+02**	3.43E+02	0.00E+00	7.91E+01	9.97E+03
Cadmium	2.90E+04	**8.80E+02**	0.00E+00	8.55E+02	1.30E+04
Chromium	1.00E+06	**1.29E+02**	0.00E+00	1.29E+02	7.38E+02
Lead	**5.01E+04**	1.00E+06	0.00E+00	NA	4.77E+04
Mercury	**1.05E+04**	1.58E+05	0.00E+00	NA	9.85E+03

1 Values reported as mg/kg. Values are 5th percentile PPLVs, based on a 10^{-6} risk level for carcinogens, and an HI of 1.0 for noncarcinogens. Values in bold face represent the driver exposure pathway.

2 Where a chemical is both a carcinogen (CARC) and noncarcinogen (NONCARC), the single-pathway PPLVs summarized represent the carcinogenic endpoint.

Table 6.1-16 Summary of 5th Percentile Direct Single-Pathway PPLVS for the Industrial Worker[1]

Chemical Name	Soil Ingestion SPPLV	Soil Inhalation SPPLV	Dermal Absorption SPPLV	Cumulative Direct PPLV-CARC[2]	Cumulative Direct PPLV-NONCARC[2]
Aldrin	9.96E+00	1.29E+02	**4.50E+00**	3.02E+00	1.19E+02
Benzene	3.25E+03	7.59E+04	**1.04E+01**	1.04E+01	NA
Carbon Tetrachloride	8.19E+02	2.18E+04	**2.33E+00**	2.33E+00	2.96E+01
Chlordane	1.04E+02	3.06E+03	**8.20E+00**	7.58E+00	6.23E+01
Chloroacetic Acid	5.99E+04	6.82E+005	**7.72E+01**	NA	7.71E+01
Chlorobenzene	5.77E+04	1.00E+06	**8.58E+02**	NA	8.45E+02
Chloroform	1.52E+04	2.68E+04	**4.87E+01**	4.84E+01	3.73E+02
DDE	6.58E+01	3.57E+03	**2.64E+01**	1.87E+01	NA
DDT	3.49E+02	6.48E+03	**4.06E+01**	3.61E+01	4.70E+02
DBCP	6.98E+01	4.81E+05	**2.37E-01**	2.36E-01	7.99E+00
1,2-Dichloroethane	1.12E+03	1.26E+04	**3.40E+00**	3.39E+00	NA
1,1-Dichloroethylene	1.10E+02	1.25E+04	**5.23E+01**	5.21E-01	3.28E+02
Dicyclopentadiene	3.60E+05	**7.84E+03**	4.95E+04	NA	6.65E+03
Dieldrin	8.94E+00	9.10E+01	**1.69E+00**	1.40E+00	1.06E+02
Endrin	4.78E+03	2.22E+05	**3.41E+02**	NA	3.18E+02
Hexachlorocyclopentadiene	1.71E+05	**2.38E+03**	7.44E+03	NA	1.78E+03
Isodrin	1.62E+03	8.32E+03	**7.82E+01**	NA	7.39E+01
Methylene Chloride	1.53E+04	6.99E+05	**4.44E+01**	4.43E+01	2.25E+03
1,1,2,2-Tetrachloroethane	5.42E+02	1.12E+04	**1.49E+00**	1.49E+00	NA
Tetrachloroethylene	2.39E+03	6.30E+05	**5.88E+00**	5.87E+00	4.05E+02
Toluene	1.00E+06	1.00E+06	**7.32E+03**	NA	7.22E+03
Trichloroethylene	2.19E+03	2.09E+05	**2.94E+01**	2.90E+01	NA
Arsenic	**3.03E+01**	1.83E+02	0.00E+00	2.60E+01	8.67E+02
Cadmium	1.28E+04	**2.15E+02**	0.00E+00	2.12E+02	1.05E+03
Chromium	1.28E+05	**3.23E+01**	0.00E+00	3.23E+01	7.30E+01
Lead	**4.60E+03**	1.52E+05	0.00E+00	NA	4.46E+03
Mercury	**1.43E+03**	8.95E+03	0.00E+00	NA	1.24E+03

1 Values reported as mg/kg. Values are 5th percentile PPLVs, based on a 10^{-6} risk level for carcinogens, and an HI of 1.0 for noncarcinogens. Values in bold face represent the driver exposure pathway.

2 Where a chemical is both a carcinogen (CARC) and noncarcinogen (NONCARC), the single-pathway PPLVs summarized represent the carcinogenic endpoint.

Table 6.1-17 Summary of 5th Percentile Direct Single-Pathway PPLVS for the Commercial Worker[1]

Chemical Name	Soil Ingestion SPPLV	Soil Inhalation SPPLV	Dermal Absorption SPPLV	Cumulative Direct PPLV-CARC[2]	Cumulative Direct PPLV-NONCARC[2]
Aldrin	**4.81E+00**	5.76E+03	2.43E+02	4.71E+00	2.04E+02
Benzene	9.47E+02	2.36E+05	**2.97E+02**	2.26E+02	NA
Carbon Tetrachloride	1.11E+03	2.30E+05	**5.40E+01**	5.14E+01	6.24E+02
Chlordane	**4.96E+01**	1.77E+04	5.75E+01	2.66E+01	2.16E+02
Chloroacetic Acid	1.38E+04	1.00E+06	**2.19E+03**	NA	1.88E+03
Chlorobenzene	8.24E+04	1.00E+06	**2.15E+04**	NA	1.68E+04
Chloroform	1.33E+04	9.56E+04	**1.23E+03**	1.11E+03	8.93E+03
DDE	**1.43E+02**	2.83E+05	1.07E+03	1.26E+02	NA
DDT	**1.06E+02**	2.83E+05	9.87E+02	9.58E+01	1.92E+03
DBCP	4.72E+01	1.00E+06	**4.98E+00**	4.51E+00	1.84E+02
1,2-Dichloroethane	5.78E+02	8.76E+04	**8.06E+01**	7.07E+01	NA
1,1-Dichloroethylene	8.66E+01	4.36E+04	**1.16E+01**	1.02E+01	7.74E+03
Dicyclopentadiene	**9.55E+04**	1.79E+05	9.20E+05	NA	5.83E+04
Dieldrin	**2.58E+00**	7.75E+03	1.75E+02	2.54E+00	2.26E+02
Endrin	**1.16E+03**	1.00E+06	2.96E+04	NA	1.12E+03
Hexachlorocyclopentadiene	2.02E+05	**2.08E+04**	1.47E+05	NA	1.67E+04
Isodrin	**2.57E+02**	4.75E+05	1.09E+04	NA	2.51E+02
Methylene Chloride	6.51E+03	1.00E+06	**8.84E+02**	7.78E+02	5.06E+04
1,1,2,2-Tetrachloroethane	3.20E+02	3.83E+04	**3.69E+01**	3.31E+01	NA
Tetrachloroethylene	1.32E+03	1.00E+06	**1.44E+02**	1.30E+02	8.75E+03
Toluene	1.00E+06	1.00E+06	**1.91E+05**	NA	1.38E+05
Trichloroethylene	1.18E+04	1.00E+06	**6.63E+02**	6.27E+02	NA
Arsenic	**2.61E+01**	8.38E+03	0.00E+00	2.60E+01	1.30E+03
Cadmium	5.56E+04	**1.93E+03**	0.00E+00	1.87E+03	1.70E+03
Chromium	6.15E+04	**3.28E+02**	0.00E+00	3.26E+02	7.82E+02
Lead	**7.11E+03**	1.00E+06	0.00E+00	NA	7.06E+03
Mercury	**1.36E+03**	2.39E+05	0.00E+00	NA	1.35E+03E

1 Values reported as mg/kg. Values are 5th percentile PPLVs, based on a 10^{-6} risk level for carcinogens, and an HI of 1.0 for noncarcinogens. Values in bold face represent the driver exposure pathway.

2 Where a chemical is both a carcinogen (CARC) and noncarcinogen (NONCARC), the single-pathway PPLVs summarized represent the carcinogenic endpoint.

Table 6.1-18 Summary of Sites with C_{rep} Values Exceeding 5th Percentile PPLVs in Horizon 0

Chemical[1, 2]	Number of Sites with Chemical-Specific $C_{rep,upper}$ Concentrations Exceeding 5th Percentile PPLVs				
	Biological Worker	Regulated/ Casual Visitor	Recreational Visitor	Industrial Visitor	Commercial Worker
Aldrin	**10**	**1**	**3**	**7**	**5**
Benzene	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0
Chlordane	**4**	**2**	**2**	**4**	**2**
Chloroacetic Acid	**1**	0	**1**	**1**	0
Chlorobenzene	0	0	0	0	0
Chloroform	0	0	0	0	0
DBCP	**1**	**1**	**1**	**1**	**1**
DCPD	0	0	0	0	0
DDE	0	0	0	0	0
DDT	0	0	0	0	0
1,2-Dichloroethane	0	0	0	0	0
1,1-Dichloroethylene	0	0	0	0	0
Dieldrin	**9**	**2**	**4**	**5**	**4**
Endrin	**2**	0	0	**2**	0
HCCPD	0	0	0	0	0
Isodrin	**3**	0	0	**2**	0
Methylene Chloride	0	0	0	0	0
1,1,2,2-Tetrachloroethane	0	0	0	0	0
Tetrachloroethylene	0	0	0	0	0
Toluene	0	0	0	0	0
Trichloroethylene	0	0	0	0	0
Arsenic	**5**	**1**	**1**	**4**	**3**
Cadmium	0	0	0	0	0
Chromium	**5**	0	1	**2**	0
Lead	0	0	0	0	0
Mercury	0	0	0	0	0

1 Boldface type indicates exceedances of 10^{-4} cancer risk or HIs of 1.0.

2 For carcinogens, exceedances of 1×10^{-4} risk levels are noted. For noncarcinogens, exceedances of a target HI of 1.0 are given.

Table 6.1-19 Summary of Acute RME PPLVs for Cumulative Direct Soil Exposure Pathway[1]

Chemical	Receptor-Specific Soil PPLVs (Units: mg/kg)			
	Biological/ Industrial Worker	Regulated/ Casual Visitor	Recreational Visitor	Commercial Visitor
Aldrin[2]	5.6E+01	**3.8E+00**	**3.8E+00**	6.9E+01
Benzene	ND	ND	ND	ND
Carbon Tetrachloride	4.8E+04	**1.1E+04**	**1.1E+04**	2.5E+05
Chlordane	7.2E+02	**1.7E+02**	**1.7E+02**	3.7E+03
Chloroacetic Acid	ND	ND	ND	ND
Chlorobenzene	2.4E+04	**5.6E+03**	**5.6E+03**	1.2E+05
Chloroform	2.2E+04	**5.0E+03**	**5.0E+03**	1.1E+05
DDE	ND	ND	ND	ND
DDT	6.0E+01	**1.4E+01**	**1.4E+01**	3.1E+02
DBCP	6.0E+02	**1.4E+02**	**1.4E+02**	3.1E+03
1,2-Dichloroethane	ND	ND	ND	ND
1,1-Dichloroethylene	2.4E+04	**5.6E+03**	**5.6E+03**	1.2E+05
Dicyclopentadiene	ND	ND	ND	ND
Dieldrin[2]	4.7E+01	**3.7E+00**	**3.7E+00**	6.9E+01
Endrin	2.4E+02	**5.6E+01**	**5.6E+01**	1.2E+03
Hexachlorocyclopentadiene	ND	ND	ND	ND
Isodrin	ND	ND	ND	ND
Methylene Chloride	1.2E+05	**2.8E+04**	**2.8E+04**	6.2E+05
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND
Tetrachloroethylene	2.4E+04	**5.6E+03**	**5.6E+03**	1.2E+05
Toluene	2.4E+05	**5.6E+04**	**5.6E+04**	[3]
TCE	2.9E+05	**6.7E+04**	**6.7E+04**	[3]
Metals				
Arsenic	3.4E+03	**3.0E+02**	**3.0E+02**	5.4E+03
Cadmium	1.9E+03	**1.5E+02**	**1.5E+02**	2.8E+03
Chromium	4.7E+04	**3.8E+03**	**3.8E+03**	6.9E+04
Lead	ND	ND	ND	ND
Mercury	9.4E+04	**7.7E+03**	**7.7E+03**	1.4E+05

[1] Based on an HI of 1.0, and using the exposure assumptions listed in Appendix Table B.6-1 of the IEA/RC report. Values in bold face represent the driver PPLVs for the corresponding receptor population.

[2] RME PPLVs for aldrin and dieldrin were recalculated using an RfD recently updated by EPA (OHEA-EPA 1992) (1.0×10^{-4} mg/kg-day; see Appendix Table B.6-3 in the IEA/RC); this criterion supersedes the value used in the HHEA Addendum. These recalculated PPLVs also reflect the following: (1) dermal RAFs for aldrin and dieldrin were revised to equal 0.0052 and 0.1, respectively, consistent with the assumptions used in the IEA/RC; and (2) concomitant with this revision of the aldrin/dieldrin dermal RAFs, the soil covering assumed for recreational and regulated/casual visitor populations was revised to equal 1.0 mg/cm^2, consistent with recent EPA dermal exposure assessment guidance.

[3] PPLV is greater than 1×10^6 mg/kg, indicating that the allowable soil concentrations are equivalent to exposure to pure compound over all direct soil pathways at the soil intake rates assumed for this analysis.

ND Not Developed; EPA dose-response information not available.

Table 6.1-20 Summary of Subchronic RME PPLVs for Cumulative Direct Soil Exposure Pathway[1]

Chemical	Receptor-Specific Soil PPLVs (Units: mg/kg)			
	Biological/ Industrial Worker	Regulated/ Casual Visitor	Recreational Visitor	Commercial Visitor
Aldrin[2]	8.0E+01	**2.7E+01**	**2.7E+01**	1.0E+02
Benzene	ND	ND	ND	ND
Carbon Tetrachloride	1.2E+03	**1.4E+03**	**1.4E+03**	6.3E+03
Chlordane	1.0E+01	**1.2E+01**	**1.2E+01**	5.4E+01
Chloroacetic Acid	3.5E+03	**3.9E+03**	**3.9E+03**	1.8E+04
Chlorobenzene	3.5E+04	**3.9E+04**	**3.9E+04**	1.8E+05
Chloroform	1.7E+03	**2.0E+03**	**2.0E+03**	9.0E+03
DDE	ND	ND	ND	ND
DDT	8.7E+01	**9.8E+01**	**9.8E+01**	4.5E+02
DBCP	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND
1,1-Dichloroethylene	1.6E+03	**1.8E+03**	**1.8E+03**	8.1E+03
Dicyclopentadiene	3.4E+04	**5.4E+04**	**5.4E+04**	2.0E+05
Dieldrin[2]	6.8E+01	**2.6E+01**	**2.6E+01**	1.0E+02
Endrin	8.7E+01	**9.8E+01**	**9.8E+01**	4.5E+02
Hexachlorocyclopentadiene	8.8E+03	**1.3E+04**	**1.3E+04**	5.1E+04
Isodrin	ND	ND	ND	ND
Methylene Chloride	1.0E+04	**1.2E+04**	**1.2E+04**	5.4E+04
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND
Tetrachloroethylene	1.7E+04	**2.0E+04**	**2.0E+04**	9.0E+04
Toluene	3.5E+05	**3.9E+05**	**3.9E+05**	[3]
TCE	4.3E+05	**4.9E+05**	**4.9E+05**	[3]
Metals				
Arsenic	6.7E+02	**2.7E+02**	**2.7E+02**	9.9E+02
Cadmium	3.4E+02	**1.4E+02**	**1.4E+02**	5.0E+02
Chromium	**7.2E+02**	2.4E+03	2.4E+03	5.3E+03
Lead	ND	ND	ND	ND
Mercury	2.0E+02	**8.2E+01**	**8.2E+01**	3.0E+02

[1] Based on an HI of 1.0. Values in bold face represent the driver PPLVs for the corresponding receptor population.

[2] RME PPLVs for aldrin and dieldrin were recalculated using an RfD recently updated by EPA (OHEA-EPA 1992) (1.0×10^{-4} mg/kg-day; see Appendix Table B.6-3 in the IEA/RC report); this criterion supersedes the value used in the HHEA Addendum. These recalculated PPLVs also reflect the following: (1) dermal RAFs for aldrin and dieldrin were revised to equal 0.0052 and 0.1, respectively, consistent with the assumptions used in the IEA/RC; and (2) concomitant with this revision of the aldrin/dieldrin dermal RAFs, the soil covering assumed for recreational and regulated/casual visitor populations was revised to equal 1.0 mg/cm^2, consistent with recent EPA dermal exposure assessment guidance.

[3] PPLV is greater than 1×10^6 mg/kg, indicating that the allowable soil concentrations are equivalent to exposure to pure compound over all direct soil pathways at the soil intake rates assumed for this analysis.

ND Not Developed; EPA dose-response information not available.

rma\1563G

Table 6.2-1 Mean BMF Calculated by Alternate Methods[1]

Trophic Box	BMF by the Army Calibration Procedure Mean BMF	BMF_{obs} by the Shell Collocated Distributions Approach Mean BMF	BMF_{obs} by the (EPA) Modified Paired Data Approach Mean BMF
Aldrin/Dieldrin			
Soil	1	1	1
Terrestrial Plant	1.6E-02	6.0E-02	1.8E-01
Worm	2.3E-01	1.0E+00	2.5E+00
Insect	7.4E-02	9.7E-02	4.2E-01
Small Bird	2.1E-01	2.7E-01	6.8E-01
Small Mammal	2.7E-01	5.9E-01	3.0E+00
Medium Mammal	3.8E-01	2.7E-01	1.9E+00
Herptile	2.4E+00	2.4E+00	7.7E+00
Kestrel	2.6E+00	4.9E+00	2.3E+01
Owl	8.0E+00	6.9E+00	4.1E+01
Shorebird	3.6E+00	2.3E+00	6.2E+00
Heron	2.9E+00	3.0E+00	8.6E+00
Eagle	6.1E+00	4.4E+00	2.8E+01
DDE/DDT			
Soil	1	1	1
Terrestrial Plant	6.6E-01	9.2E-01	5.2E+00
Worm	1.4E+00	1.1E+00	7.8E+00
Insect	7.5E-01	9.9E-01	3.9E+01
Small Bird	5.4E-01	8.1E-01	3.3E+00
Small Mammal	4.6E-01	6.5E-01	2.8E+00
Medium Mammal	4.9E-01	3.1E+00	6.0E+00
Herptile	1.3E+00	2.5E+00	6.3E+00
Kestrel	9.9E+00	1.4E+01	5.5E+01
Owl	3.2E+01	1.7E+02	3.4E+02
Shorebird	4.8E+01	6.0E+01	1.5E+02
Heron	1.1E+01	1.8E+01	4.2E+01
Eagle	1.9E+01	1.2E+02	2.2E+02

Table 6.2-1 Mean BMF Calculated by Alternate Methods[1]

Trophic Box	BMF by the Army Calibration Procedure Mean BMF	BMF_{obs} by the Shell Collocated Distributions Approach Mean BMF	BMF_{obs} by the (EPA) Modified Paired Data Approach Mean BMF
Endrin			
Soil	1	1	1
Terrestrial Plant	1.4E-01	2.1E-01	1.3E+00
Worm	4.0E-01	2.4E-01	1.1E+00
Insect	1.0E-01	5.3E-02	3.6E-01
Small Bird	1.1E-01	1.3E-01	9.1E-01
Small Mammal	1.7E-01	2.7E-01	1.5E+00
Medium Mammal	3.3E-02	3.6E-01	1.2E+00
Herptile	1.0E+00	9.0E-01	1.5E+00
Kestrel	1.9E-01	2.6E-01	1.3E+00
Owl	8.8E-02	4.0E-01	1.4E+00
Shorebird	9.9E-01	6.0E-01	1.1E+00
Heron	1.1E-01	1.0E-01	1.6E-01
Eagle	6.7E-02	4.0E-01	1.3E+00
Mercury			
Soil	1	1	1
Terrestrial Plant	3.5E-02	1.6E-01	3.1E-01
Worm	6.2E-01	4.0E-01	8.1E-00
Insect	1.1E-02	1.3E-01	2.7E-01
Small Bird	1.1E-01	1.9E-01	3.4E-01
Small Mammal	5.5E-01	1.5E-02	1.7E-01
Medium Mammal	2.8E-01	3.3E-01	7.3E+00
Herptile	6.0E-01	7.8E-01	8.2E-01
Kestrel	3.2E-01	6.8E-02	1.8E-01
Owl	2.6E-01	2.4E-01	4.8E+00
Shorebird	1.2E+0	1.6E-01	1.8E-02
Heron	6.8E-01	7.2E-01	7.6E-01
Eagle	2.3E-01	2.6E-01	5.4E+00

[1] For the three BMF_{obs} methods, kestrel, owl, heron, and eagle BMFs were calculated with the food-web model because there are no available field data. For these four trophic boxes:
$BMF_{obs(k)} = BAF_{lit(k)} * SUM_{(j)(FR(k,j)} * BMF_{obs(j)}$

where:
$BMF_{obs(k)}$ is the BMF for predator trophic box k
$BAF_{lit(k)}$ is the literature-derived BAF distribution for trophic box k
$SUM_{(j)}$ is the summation function over the argument j
$FR_{(k,j)}$ is the mass fraction of predator k's food from prey trophic box j
$BMF_{obs(j)}$ is the BMF for prey trophic box j

Biota	Chemical	Distribution	Mean*	Std. Dev.	LOG Mean	LOG Std Dev.	End Point
Parameter = Bioaccumulation Factor (BAF)							
Small Bird	Aldrin/Dieldrin	Normal	6.6	1.8			
	Endrin	Lognormal	1.0	1.6	0.000	0.470	
	DDE/DDT	Uniform	NA	NA			7.7, 29
	Arsenic	Uniform	NA	NA			0.3, 3
	Mercury	Triangular	0.33	NA			0.001, 2
Small Mammal	Aldrin/Dieldrin	Uniform	NA	NA			0.64, 1.6
	Endrin	Lognormal	0.08	1.0	-2.526	0.001	
	DDE/DDT	Uniform	NA	NA			0.44, 0.98
	Arsenic	Lognormal	0.19	4.7	-1.684	1.543	
	Mercury	Triangular	22.5	NA			0.001, 50
Medium Mammal	Aldrin/Dieldrin	Uniform	NA	NA			0.64, 3.2
	Endrin	Lognormal	0.16	1.1	-1.833	0.095	
	DDE/DDT	Uniform	NA	NA			0.44, 0.98
	Arsenic	Lognormal	0.19	4.7	-1.684	1.543	
	Mercury	Triangular	22.5	NA			0.001, 50
Water Bird	Aldrin/Dieldrin	Normal	16	5.1			
	Endrin	Lognormal	1.0	1.6	0.000	0.470	
	DDE/DDT	Normal	96	26.2			
	Arsenic	Uniform	NA	NA			0.3, 3
	Mercury	Lognormal	4.1	3.4	1.411	1.224	
Kestrel	Aldrin/Dieldrin	Normal	10.5	1.2			
	Endrin	Lognormal	1.0	1.6	0.000	0.470	
	DDE/DDT	Uniform	NA	NA			7.7, 29
	Arsenic	Uniform	NA	NA			0.3, 3
	Mercury	Triangular	0.33	NA			0.001, 2
Owl	Aldrin/Dieldrin	Normal	21.1	3.4			
	Endrin	Lognormal	1.0	1.6	0.000	0.470	
	DDE/DDT	Lognormal	43.7	2.4	3.777	0.875	
	Arsenic	Uniform	NA	NA			0.3, 3
	Mercury	Triangular	0.33	NA			0.001, 2
Shorebird	Aldrin/Dieldrin	Normal	13.3	4.2			
	Endrin	Lognormal	1.0	1.6	0.000	0.470	
	DDE/DDT	Uniform	NA	NA			7.7, 29
	Arsenic	Uniform	NA	NA			0.3, 3
	Mercury	Triangular	0.33	NA			0.001, 2
Heron	Aldrin/Dieldrin	Normal	16	5.1			
	Endrin	Lognormal	1.0	1.6	0.000	0.470	
	DDE/DDT	Normal	93.5	20			
	Arsenic	Uniform	NA	NA			0.3, 3
	Mercury	Lognormal	4.1	3.4	1.411	1.224	

Biota	Chemical	Distribution	Mean*	Std. Dev.	LOG Mean	LOG Std Dev.	End Point
Parameter = Bioaccumulation Factor (BAF)							
Bald Eagle	Aldrin/Dieldrin	Normal	15.9	3.9			
	Endrin	Lognormal	1.0	1.6	0.000	0.470	
	DDE/DDT	Lognormal	27.1	2.4	3.300	0.875	
	Arsenic	Uniform	NA	NA			0.3, 3
	Mercury	Triangular	0.33	NA			0.001, 2

* Mean = arithmetic mean for normal distribution, geometric mean for lognormal distribution, and apex for triangular distribribution

Predator	Prey Item	Biomass Fraction*
Parameter = Dietary Fractions (FR)		
Terrestrial Food Chain		
Small Birds	Soil	0.057
	Terrestrial Plants	0.113
	Earthworm	0.116
	Insect	0.714
Small Mammals	Soil	0.020
	Terrestrial Plants	0.866
	Earthworm	0.008
	Insect	0.106
Medium Mammal	Soil	0.074
	Terrestrial Plants	0.926
	Insect	0.000
Kestrel	Soil	0.029
	Insect	0.184
	Small Mammal	0.665
	Small Bird	0.122
Owl	Soil	0.029
	Small Mammal	0.121
	Medium Mammal	0.830
	Small Bird	0.020
Heron	Soil	0.036
	Reptile	0.060
	Small Mammal	0.013
	Water	0.071
	Aquatic Plant	0.000
	Aquatic Invertebrates	0.024
	Small Fish	0.186
	Large Fish	0.604
	Amphibian	0.006
Bald Eagle	Soil	0.029
	Small Mammal	0.000
	Medium Mammal	0.936
	Small Bird	0.003
	Waterbird	0.030
	Large Fish	0.002
Aquatic Food Chain		
Water bird	Water	0.019
	Sediment	0.038
	Aquatic Plant	0.942
	Aquatic Invertebrates	0.001

Predator	Prey Item	Biomass Fraction*
Shorebird	Terrestrial Plants	0.007
	Insect	0.728
	Sediment	0.160
	Aquatic Invertebrates	0.105

* Fractions reported as zero are pathways considered to be relatively inconsequential to model output due to their small values.

Biota	Distribution	Mean*	Std. Dev.	LOG Mean	LOG Std Dev.
Parameter = Feed Rate (R)	kg/kg body weight/day				
Water Bird	Normal	0.07602	0.0245		
Small Bird	Fixed	0.0879			
Small Mammal	Fixed	0.12			
Medium Mammal	Fixed	0.096			
Shorebird	Lognormal	0.0879	1.652	-2.4315	0.50189
Kestrel	Normal	0.08913	0.02689		
Owl	Normal	0.08913	0.02689		
Heron	Normal	0.08913	0.02689		
Bald Eagle	Normal	0.08913	0.02689		

* Mean = Arithmetic mean for normal distribution, geometric mean for lognormal distribution, and apex for triangular distribribution.

Biota	Chemical	Distribution	Value
Parameter = Maximum Allowable Tissue Concentration (MATC)			
Small Bird	Aldrin/Dieldrin	Fixed	0.15
	Endrin	Fixed	0.052
	DDE/DDT	Fixed	0.14
	Mercury	Fixed	0.017
Small Mammal	Aldrin/Dieldrin	Fixed	0.19
	Endrin	Fixed	NA
	DDE/DDT	Fixed	0.22
	Mercury	Fixed	NA
Medium Mammal	Aldrin/Dieldrin	Fixed	0.19
	Endrin	Fixed	NA
	DDE/DDT	Fixed	0.22
	Mercury	Fixed	NA
Reptile	Aldrin/Dieldrin	Fixed	NA
	Endrin	Fixed	NA
	DDE/DDT	Fixed	NA
	Mercury	Fixed	NA
Kestrel	Aldrin/Dieldrin	Fixed	0.73
	Endrin	Fixed	0.052
	DDE/DDT	Fixed	4.3
	Mercury	Fixed	0.017
Owl	Aldrin/Dieldrin	Fixed	0.76
	Endrin	Fixed	0.087
	DDE/DDT	Fixed	0.53
	Mercury	Fixed	0.017
Water bird	Aldrin/Dieldrin	Fixed	0.24
	Endrin	Fixed	0.09
	DDE/DDT	Fixed	0.18
	Mercury	Fixed	0.01
Shorebird	Aldrin/Dieldrin	Fixed	0.15
	Endrin	Fixed	0.052
	DDE/DDT	Fixed	1.4
	Mercury	Fixed	0.011
Heron	Aldrin/Dieldrin	Fixed	0.87
	Endrin	Fixed	0.043
	DDE/DDT	Fixed	15
	Mercury	Fixed	0.011
Bald Eagle	Aldrin/Dieldrin	Fixed	0.41
	Endrin	Fixed	0.031
	DDE/DDT	Fixed	2.2
	Mercury	Fixed	0.0083

Biota	Chemical	Distribution	Value
Parameter = Toxicity Reference Values (TRV)			
Terrestrial Plant	Arsenic	Fixed	1.9
Small Bird	Aldrin/Dieldrin	Fixed	0.028
	Endrin	Fixed	0.002
	DDE/DDT	Fixed	0.003
	Mercury	Fixed	0.0019
	Arsenic	Fixed	0.38
	Copper	Fixed	0.96
	Cadmium	Fixed	0.24
	DCPD	Fixed	8.9
	Chlordane	Fixed	0.035
	CPMS	Fixed	NA
	$CPMSO_2$	Fixed	NA
	DBCP	Fixed	0.17
Small Mammal	Aldrin/Dieldrin	Fixed	0.004
	Endrin	Fixed	0.010
	DDE/DDT	Fixed	0.029
	Mercury	Fixed	0.0014
	Arsenic	Fixed	0.038
	Copper	Fixed	0.75
	Cadmium	Fixed	0.045
	DCPD	Fixed	2.8
	Chlordane	Fixed	0.10
	CPMS	Fixed	0.24
	$CPMSO_2$	Fixed	0.27
	DBCP	Fixed	0.05
Medium Mammal	Aldrin/Dieldrin	Fixed	0.004
	Endrin	Fixed	0.010
	DDE/DDT	Fixed	0.029
	Mercury	Fixed	0.0014
	Arsenic	Fixed	0.038
	Copper	Fixed	0.75
	Cadmium	Fixed	0.045
	DCPD	Fixed	2.8
	Chlordane	Fixed	0.10
	CPMS	Fixed	0.24
	$CPMSO_2$	Fixed	0.27
	DBCP	Fixed	0.05

NA Data not available to calculate a TRV.

Biota	Chemical	Distribution	Value
Kestrel	Aldrin/Dieldrin	Fixed	0.01
	Endrin	Fixed	0.002
	DDE/DDT	Fixed	0.04
	Mercury	Fixed	0.0019
	Arsenic	Fixed	0.38
	Copper	Fixed	0.96
	Cadmium	Fixed	0.24
	DCPD	Fixed	8.9
	Chlordane	Fixed	0.035
	CPMS	Fixed	NA
	$CPMSO_2$	Fixed	NA
	DBCP	Fixed	0.17
Owl	Aldrin/Dieldrin	Fixed	0.004
	Endrin	Fixed	0.003
	DDE/DDT	Fixed	0.008
	Mercury	Fixed	0.0019
	Arsenic	Fixed	0.38
	Copper	Fixed	0.96
	Cadmium	Fixed	0.24
	DCPD	Fixed	8.9
	Chlordane	Fixed	0.035
	CPMS	Fixed	NA
	$CPMSO_2$	Fixed	NA
	DBCP	Fixed	0.17
Water brid	Aldrin/Dieldrin	Fixed	0.027
	Endrin	Fixed	0.003
	DDE/DDT	Fixed	0.004
	Mercury	Fixed	0.00094
	Arsenic	Fixed	0.38
	Copper	Fixed	0.96
	Cadmium	Fixed	0.24
	DCPD	Fixed	3.2
	Chlordane	Fixed	3.1
	CPMS	Fixed	NA
	$CPMSO_2$	Fixed	NA
	DBCP	Fixed	0.17
Shorebird	Aldrin/Dieldrin	Fixed	0.022
	Endrin	Fixed	0.002
	DDE/DDT	Fixed	0.008
	Mercury	Fixed	0.00094
	Arsenic	Fixed	0.38
	Copper	Fixed	0.96
	Cadmium	Fixed	0.24
	DCPD	Fixed	8.9
	Chlordane	Fixed	0.035
	CPMS	Fixed	NA

Biota	Chemical	Distribution	Value
	$CPMSO_2$	Fixed	NA
	DBCP	Fixed	0.17
Heron	Aldrin/Dieldrin	Fixed	0.03
	Endrin	Fixed	0.003
	DDE/DDT	Fixed	0.004
	Mercury	Fixed	0.00094
	Arsenic	Fixed	0.38
	Copper	Fixed	0.96
	Cadmium	Fixed	0.24
	DCPD	Fixed	8.9
	Chlordane	Fixed	0.035
	CPMS	Fixed	NA
	$CPMSO_2$	Fixed	NA
	DBCP	Fixed	0.17
Bald Eagle	Aldrin/Dieldrin	Fixed	0.002
	Endrin	Fixed	0.001
	DDE/DDT	Fixed	0.005
	Mercury	Fixed	0.00063
	Arsenic	Fixed	0.19
	Copper	Fixed	0.48
	Cadmium	Fixed	0.10
	DCPD	Fixed	5.3
	Chlordane	Fixed	0.035
	CPMS	Fixed	NA
	$CPMSO_2$	Fixed	NA
	DBCP	Fixed	0.17

NA Data not available to calculate a TRV.

Table 6.2-3 Uncertainty Factor Protocol

Basis for Uncertainty	Uncertainty Value Assigned	
Intertaxon Variability Extrapolation Category—		
Same species	1	
Same genus, different species	2	
Same family, different genus	3	
Same order, different family	4	
Same class, different order	5	
Study Duration Extrapolation Category—		
Chronic studies where contaminants attained equilibrium	1	
Chronic studies where equilibrium not attained or possibly not attained, including subchronic studies	5	
Acute studies	20	
Study Endpoint Extrapolation Category—		
	Nonlethal	Lethal
No observed effects level	NOEL: 1	NOEL: 3
No observed adverse effects level	NOAEL: 1	NOAEL: 3
Lowest observed effects level	LOEL: 3	LOEL: 10
Lowest observed adverse effects level	LOAEL: 5	LOAEL: 10
Frank effects level	FEL: 10	FEL: 15
Modifying Factor Category—		
Threatened and endangered species	0 or 2	
Relevance of endpoint to ecological health	-1 to 0	
Extrapolating lab to field	0 to 2	
Study had co-contaminants	-1 to +1	
Endpoint was unclear	-2 to +2	
Study species was obviously highly sensitive	-2 to +2	
Ratios used to get from organ or egg to whole body	0 to 2[1]	
Intraspecific variability	0 to 2	

[1] Used only for MATC (not TRV) uncertainty factor development.

Table 6.2-4 Toxicity Threshold Values Selected for Representative Receptors (Trophic Boxes)[1, 2, 3]

	American Kestrel		Bald Eagle		Great Horned Owl		Great Blue Heron		Shorebird		Water Bird		Small Bird		Small Mammal		Medium Mammal		Reptile		Terrestrial Plant	
Chemical	MATC	TRV	MATC	TRV	MATC	TRV	MATC	TRV	MATC	TRV	MATC	TRV	MATC	TRV	MATC	TRV	MATC	TRV	MATC	TRV	MATC	TRV
Aldrin/ Dieldrin	0.73	**0.01**	0.41	**0.002**	0.76	**0.004**	**0.87**	0.027	0.15	**0.022**	**0.24**	0.027	0.15	**0.028**	0.19	**0.004**	0.19	**0.004**		NA		
DDT/DDE	**4.27**	0.04	**2.17**	0.005	**0.53**	0.008	**15**	0.004	**1.38**	0.008	**0.18**	0.004	0.14	**0.003**	0.22	**0.029**	0.22	**0.029**		NA		
Endrin	**0.05**	0.002	**0.03**	0.001	**0.09**	0.003	**0.09**	0.003	**0.05**	0.002	0.09	**0.003**	**0.05**	0.002	NA	**0.01**	NA	**0.01**		NA		
Mercury	0.02	**0.002**	0.01	**0.001**	0.02	**0.002**	0.01	**0.001**	0.01	**0.001**	**0.01**	0.001	0.02	**0.002**	NA	**0.001**		**0.001**		NA		
Arsenic		0.378		0.189		0.378		0.378		0.378		0.378		0.378		0.038		0.038		NA		1.9
Copper		0.96		0.48		0.96		0.96		0.96		0.96		0.96		0.75		0.75		NA		
Cadmium		0.24		0.103		0.24		0.24		0.24		0.24		0.24		0.045		0.045		NA		
DCPD		8.889		5.333		8.889		8.889		8.889		3.2		8.889		2.833		2.833		NA		
Chlordane		0.035		0.035		0.035		0.035		0.035		3.125		0.035		0.1		0.1		NA		
CPMS		ND		ND		ND		ND		ND		ND		ND		0.235		0.235		NA		
$CPMSO_2$		ND		ND		ND		ND		ND		ND		ND		0.272		0.272		NA		
DBCP		0.167		0.167		0.167		0.167		0.167		0.167		0.167		0.05		0.05		NA		

1 Values shown in bold face were selected for use in the estimation of potential risk based on their total uncertainty and whether or not use of a BAF was necessary.

2 Tissue-based approach was used for calculation of risk from mercury to shorebird from aquatic food chains; other trophic boxes with mixed food chains (bald eagle and great blue heron) used the same approach for aquatic and terrestrial food chains.

3 MATC values are presented in mg/kg, and TRVs are presented in mg/kg-bw-day.

Table 6.2-5 Toxicity Reference Value (Post-UF)[1]

Aldrin/Dieldrin	Critical Value	Intertaxon (1)	Study Duration (Q2)	Study Endpoints (Q3)	Modifying Factor[2] (U)	T&E	Endpoint Relevance	Lab to Field	Co-Contam.	Unclear Endpoint	ID. Sensitive Species	Intraspecific Variability
American Kestrel	0.04	1	1	1	4			1		2		1
Bald Eagle	0.05	5	1	1	6	2		1	0	2		1
Great Horned Owl	0.06	4	1	1	4			1	0	2		1
Great Blue Heron	0.4	5	1	3	1		-1	1				1
Shorebird	0.22	5	1	1	2			1				1
Waterbird	0.4	5	1	3	1		-1	1				1
Small Bird	0.28	5	1	1	2			1				1
Sm. Mammal	0.06	4	1	1	4			2		1		1
Med. Mammal	0.06	4	1	1	4			2		1		1
Reptile	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Trophic Box	Total UF	Final TRV
American Kestrel	4	0.010
Bald Eagle	30	0.002
Great Horned Owl	16	0.004
Great Blue Heron	15	0.027
Shorebird	10	0.022
Waterbird	15	0.027
Small Bird	10	0.028
Sm. Mammal	16	0.004
Med. Mammal	16	0.004
Reptile	NA	NA

1	Values reported as mg/kg bw.
2	If $0 \leq U < 1$, it was replaced with 1; if $U < 0$, it was replaced with 0.5.
Final TRV	Critical value/total UF
NA	Not Available
Total UF	1*Q2*Q3*U
TRV	Toxicity Reference Value
U	Sum of factors to right
UF	Uncertainty Factor

Table 6.2-6 Post-Uncertainty MATC[1]

Aldrin/Dieldrin	Critical Value	Intertaxon (1)	Study Duration (Q2)	Study Endpoints (Q3)	Modifying Factor[2] (U)	T&E	Endpoint Relevance	Lab to Field	Co-Contam.	Unclear Endpoint	ID. Sensitive Species	Tissue to Whole-Body Ratio	Intraspecific Variability
American Kestrel	2.9	1	1	1	4			1		2			1
Bald Eagle	12.2	5	1	1	6	2		1		2			1
Great Horned Owl	12.2	4	1	1	4			1		2			1
Great Blue Heron	1.3	1	1	3	0.5			0	-1				0
Shorebird	2.9	5	1	1	4			1		2			1
Waterbird	7.1	5	1	3	2		-1	1				1	1
Small Bird	2.9	5	1	1	4			1		2			1
Mammal	4.5	4	1	1	6			2		2		1	1

Trophic Box	Total UF	Final MATC
American Kestrel	4	0.73
Bald Eagle	30	0.41
Great Horned Owl	16	0.76
Great Blue Heron	1.5	0.87
Shorebird	20	0.15
Waterbird	30	0.24
Small Bird	20	0.15
Mammal	24	0.19

[1] Values reported as mg/kg bw.
[2] If $0 \leq U < 1$, it was replaced with 1; if $U < 0$, it was replaced with 0.5.

Total UF 1*Q2*Q3*U
U Sum of factors to right
Final TRV Critical value/total UF

Table 6.2-7 HQs and HIs for Exposure through Aquatic Food Chains

Trophic Box	Hazard Quotients for Aldrin/Dieldrin	Hazard Quotients for DDT/DDE	Hazard Quotients for Endrin	Hazard Quotients for Mercury	Hazard Index
Water bird	2.87	1.66	0.63	6.75	11.91
Shorebird	0.19	2.60	1.17	8.30	12.26
Great Blue Heron	2.28	1.06	0.63	15.63	19.60
Bald Eagle	0.93	0.17	0.03	0.21	1.34

Table 6.3-1 Uncertainties Potentially Influencing Assigned Distributions for Soil Intake Parameters

Soil Covering		Soil Ingestion		Dust Loading	
Population and Age Class	Uncertainties	Population and Age Class	Uncertainties	Population and Age Class	Uncertainties
Regulated/Casual Visitor 0 to < 1	• Judgment distribution	Regulated/Casual Visitor 0 to < 1	• Assumed minimal (1 mg/day)	Regulated/Casual and Recreational Visitor All Ages	• Assumed outdoor ambient exposure • Representation of activities by ambient outdoor dust loading conditions • Data measurement error
1 to < 7	• Data measurement error • Extrapolation of sample patch to entire surface area • Data representation of age distribution and activities	1 to < 7	• Judgment 95th percentile (EPA default) • Data median (literature) • Data measurement error • Data representation of age and activities		
7 to < 18	• Data measurement error • Extrapolation of sample patch to entire surface area • Data representation of age and activities	7 to < 75	• Judgment 95th percentile (EPA default) • Shape extrapolated from literature distribution for child		

Table 6.3-1 Uncertainties Potentially Influencing Assigned Distributions for Soil Intake Parameters

Soil Covering		Soil Ingestion		Dust Loading	
Population and Age Class	Uncertainties	Population and Age Class	Uncertainties	Population and Age Class	Uncertainties
18 to < 75	• Data measurement error • Extrapolation of sample patch to entire surface area • Data representation of age and activities				
Recreational Visitor 0 to < 1	• Judgment distribution	0 to < 1	• Assumed minimal (1 mg/day)		
1 to < 7	• Data measurement error • Extrapolation of sample patch to entire surface area • Data representation of age and activities	1 to < 7	• Judgment 95th percentile (EPA default) • Data median (literature) • Data measurement error • Data representation of age and activities		

Table 6.3-1 Uncertainties Potentially Influencing Assigned Distributions for Soil Intake Parameters

Soil Covering		Soil Ingestion		Dust Loading	
Population and Age Class	Uncertainties	Population and Age Class	Uncertainties	Population and Age Class	Uncertainties
7 to < 18	• Data measurement error • Extrapolation of sample patch to entire surface area (data representativeness) • Representation of age and activities (study representativeness)	7 to < 75	• Judgment 95th percentile (EPA default) • Shape extrapolated from literature distribution (child)		
18 to < 75	• Data measurement error • Extrapolation of sample patch to entire surface area (data representativeness) • Representation of age and activities (study representativeness)				

Table 6.3-1 Uncertainties Potentially Influencing Assigned Distributions for Soil Intake Parameters

Soil Covering		Soil Ingestion		Dust Loading	
Population and Age Class	Uncertainties	Population and Age Class	Uncertainties	Population and Age Class	Uncertainties
Commercial Worker	• Theoretical estimate of mean, judgment range	Commercial Worker	• Judgment 50th and 95th percentile	Commercial Worker	• Assumed indoor exposure • Dust loading data measurement error • Outdoor/indoor attenuation data measurement error
Industrial Worker	• Judgment 95th percentile (EPA default) • Distribution shape extrapolated from biological/ maintenance worker	Industrial Worker	• Judgment 95th percentile • Shape extrapolated from literature distribution (child)	Industrial Worker	• Assumed ambient outdoor exposure • Representation of activities by ambient conditions • Data measurement error
Biological/ Maintenance Worker	• Data representation of time spent in activities • Data representation of soil covering to projected activities • Judgment estimate of indoor soil covering distribution	Biological Worker	• Data representation of time spent in activities • Judgment based activity specific distributions	Biological Worker	• Data representation of time spent in activities

Table 6.3-2 Uncertainties Potentially Influencing Assigned Distributions for Time-Dependent Exposure Parameters

Population	TM (Hours/Day)	DW (Days/Year)	TE (Years/Lifetime)
Regulated/Casual Visitor	• Representativeness of chosen activities for neighborhood population • Representativeness of data-based mean for activity-specific distributions • Judgment-based distribution shape • Representativeness of participation rate in multiple daily activities • Representativeness of national means for percent participation in each activity and duration of each activity	• No data specific to visitation of RMA neighborhood subpopulation • Intentional conservative estimation bias • Judgment-based distribution for number of activity days/year • Judgment-based distribution for fraction of activity days occurring at RMA	• Representativeness of PSCo data for neighborhood subpopulation (PSCo 1989) • Positive bias (overestimation) due to analysis method, which under-represents low TE values in population • Negative bias (underestimation) due to moves within same county
Recreational Visitor	• Representativeness of chosen activities for neighborhood population • Representativeness of data-based mean for activity-specific distributions • Judgment-based distribution shape • Representativeness of participation rate in multiple daily activities • Representativeness of national means for percent participation in each activity and duration of each activity	• Intentional conservative estimation bias • Representativeness of chosen activities for neighborhood subpopulation • Representativeness of western region and national means for percent participation in activity • Representativeness of national distribution of number of jogging days per week and assumption of 52 weeks per year for neighborhood subpopulation • Judgment-based distribution for number of activity days/year for some activity-specific distributions • Judgment-based distribution for fraction of activity days occurring at RMA	• Representativeness of PSCo data for neighborhood subpopulation (PSCo 1989) • Positive bias (overestimation) due to analysis method, which under-represents low TE values in subpopulation • Negative bias (underestimation) due to moves within same county
Commercial/Industrial Worker	• Representativeness of national data on hours spent at work	• Incorporation of judgment estimates for vacation time and holidays • Representativeness of western region data on job absence rates (BNA 1974–90)	• Representativeness of Mountain States Employer's Council mean job turnover data used to obtain distribution mean (MSEC 1981–90) • Representativeness of national data on occupational turnover used to obtain distribution shape

Table 6.3-2 Uncertainties Potentially Influencing Assigned Distributions for Time-Dependent Exposure Parameters

Population	TM (Hours/Day)	DW (Days/Year)	TE (Years/Lifetime)
Biological Worker	• Representativeness of on-site work schedule of interviewed personnel at three refuges	• Representativeness of on-site work schedule of interviewed personnel at three refuges	• Representativeness of job tenure history of interviewed personnel at three refuges (Bureau of the Census 1987) • Censored data (current tenure was longer than reported at time of survey)

Table 6.3-3 Uncertainties Potentially Influencing Assigned Distributions for Chemical-Specific Parameters[1]

Henry's Law Constant (K_H)[2]		Soil to Water Partition Coefficient Normalized to Organic Carbon K_{oc} (Kd)[3]		Vapor Pressure (V_p)[2]	
Chemical Group	Uncertainties	Chemical Group	Uncertainties	Chemical Group	Uncertainties
Aldrin Endrin 1,1,2,2-Tetrachloroethane DDT DDE Chlordane HCCPD	• Representation of RMA temperature regime • Experimental measurement error • ≤ 6 data points	Aldrin Endrin 1,2-Dichloroethane Methylene Chloride	• Experimental measurement error • ≤ 6 data points	Endrin Chlorobenzene Chlordane	• Experimental measurement error • Representation of RMA temperature regime • ≤ 6 data points
Isodrin	• Representation of RMA temperature regime • Experimental measurement error • No data, extrapolation across chemicals	Isodrin 1,1-Dichloroethylene HCCPD DCPD DBCP	• Experimental measurement error • ≤ 2 data points • Extrapolation across chemicals	1,1-Dichloroethylene 1,1,2,2-Tetrachloroethane DDE HCCPD	• Experimental measurement error • Representation of RMA temperature regime • ≤ 6 data points • Intentional conservative bias in estimation of SD
DCPD DBCP Chloroacetic Acid	• Representation of RMA temperature regime • Experimental measurement error • No data, extrapolation based on vapor pressure and solubility	Chloroacetic Acid	• ≤ 2 data points • Extrapolation from other partitioning information	Isodrin Chloroacetic DCPD DBCP	• Experimental measurement error • Representation of RMA temperature regime • 2 data points • Judgment range

Table 6.3-3 Uncertainties Potentially Influencing Assigned Distributions for Chemical-Specific Parameters[1]

Henry's Law Constant (K_H)[2]		Soil to Water Partition Coefficient Normalized to Organic Carbon K_{oc} (Kd)[3]		Vapor Pressure (V_P)[2]	
Chemical Group	Uncertainties	Chemical Group	Uncertainties	Chemical Group	Uncertainties
Dieldrin	• Representation of RMA temperature regime • Experimental measurement error	Dieldrin	• Experimental measurement error	Aldrin	• Experimental measurement error • Representation of RMA temperature regime
Toluene		Toluene		Dieldrin	
Benzene		Benzene		Toluene	
Chloroform		Chloroform		Benzene	
1,2-Dichloroethane		Carbon Tetrachloride		Chloroform	
1,1-Dichloroethylene		1,1,2,2-Tetrachloroethane		1,2-Dichloroethane	
Methylene Chloride		Tetrachloroethylene		Methylene Chloride	
Carbon Tetrachloride		Chlorobenzene		Carbon Tetrachloride	
Tetrachloroethylene		TCE		Tetrachloroethylene	
Chlorobenzene		DDT		TCE	
TCE		DDE		DDT	
		Chlordane			
		Arsenic*			
		Cadmium*			
		Chromium*			
		Lead*			
		Mercury*			

[1] See IEA/RC report (Appendix E) for discussion of types of uncertainties.
[2] K_H[2] and V_P[2] not defined for metals.
[3] Kd (distribution coefficient) used for organic COCs lacking K_{oc} data.

7.0 Description of the Feasibility Study Process and the Remedial Alternatives Developed

7.1 Summary of the Feasibility Study Process

The FS process involved two major phases: the Development and Screening of Alternatives and the Detailed Analysis of Alternatives. Each contaminated environment at RMA (water, structures, and soil) was subdivided into several medium groups of similarly contaminated groundwater plumes, structures, or soil sites to organize and streamline the FS process.

At the outset of the Development and Screening of Alternatives, Remedial Action Objectives (RAOs) were identified. These goals provide general guidance for the FS by identifying the contaminants and media of interest, potential exposure pathways, and preliminary remediation goals. For the On-Post Operable Unit, RAOs were developed for water, structures, and soil based on the results of the IEA/RC, an evaluation of ARARs specified in federal and state environmental laws and regulations, and the provisions of the FFA. (ARARs are listed in Appendix A.) The human health and biota remediation goals are to achieve appropriate remediation such that the selected remedy is protective of both humans and biota.

During the Development and Screening of Alternatives, a wide range of alternatives was evaluated for each medium group with respect to effectiveness, implementability, and cost. Those alternatives retained for further consideration were evaluated during the Detailed Analysis of Alternatives against a set of threshold and primary balancing criteria defined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (see Section 8). Also taken into account were RMA-specific considerations such as Army safety procedures and USFWS guidance regarding the future use of the site as a national wildlife refuge.

A range of alternatives including no action, institutional controls, containment, and treatment options was developed for each of the water, structures, and soil medium groups. The No Action alternative (as required by EPA) and the No Additional Action alternative were also developed and used as a baseline against which other alternatives were evaluated. The No Action alternative represents current site conditions with no remedial actions undertaken, ongoing, or planned and IRAs discontinued. The No Additional Action alternative involves no action beyond the IRAs currently being implemented on post.

Once the alternatives for each group were evaluated with respect to the seven threshold and primary balancing criteria, the comparative performance of each alternative was evaluated and a range of alternatives was retained for each medium group/subgroup to use in the development of sitewide alternatives. Tables 7.1-1, 7.1-2, and 7.1-3 present descriptions of all individual technologies used to develop the respective sitewide alternatives for the water, structures, and soil medium groups. It should be noted that the No Action and No Additional Action alternatives were developed for each contaminated medium, but were eliminated from consideration during the comparative analysis conducted for sitewide alternatives because they were not sufficiently protective.

All of the alternatives that were identified have several features in common as follows:

- Land-Use Restrictions – The Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 restricts current and future land use, specifies that the U.S. government shall retain ownership of RMA, and prohibits certain activities such as agriculture, use of on-post groundwater as a drinking source, and consumption of fish and game taken at RMA. Continued restriction on land use or access are included as an integral component of all on-post alternatives. Long-term management includes access restrictions to capped and covered areas to ensure the integrity of the containment systems.
- Five-Year Review – In accordance with CERCLA, a review will be performed a minimum of every 5 years after initiation of remedial action to ensure that the various remedial actions where contamination continues to exist, such as the capped areas or the hazardous waste landfill, remain protective of human health and the environment and comply with ARARs.
- Site Monitoring – The Army will continue to conduct air, groundwater, and surface water monitoring programs at RMA, and will continue to fund USFWS to conduct on-post wildlife monitoring programs. Samples will be collected periodically to assess the effectiveness of the remedy for protection of human health and the environment. The actual compliance monitoring program for each of the environmental media will be finalized during the remedial design.
- Revegetation – Any time vegetation is disturbed during remedial construction, the disturbed areas will be revegetated consistent with a USFWS refuge management plan.
- Long-Term Operation and Maintenance – Areas that are remediated will be operated and maintained as required. Management activities may include maintaining capped and covered areas or operating the on-post hazardous waste landfill or groundwater treatment systems.
- On-Post Water Supply – A sufficient on-post water supply will be maintained to support remedial actions (revegetation, habitat enhancement, maintenance of lake levels).

7.1.1 Area of Contamination

An AOC is defined by EPA (OSWER-EPA 1989b) as the areal extent (or boundary) of contiguous contamination. Such contamination must be continuous, but may contain varying types and concentrations of hazardous substances. For on-site disposal, placement occurs when wastes are moved from one AOC into another AOC. Placement does not occur when wastes are left in place or moved within a single AOC.

Placement does not occur when wastes are:

- Treated in situ
- Capped in place
- Consolidated within the AOC
- Processed within the AOC (but not in a separate unit, such as a tank) to improve its structural stability (e.g., for capping or to support heavy machinery

Placement does occur when wastes are:

- Consolidated from different AOCs into a single AOC

- Moved outside of an AOC (e.g., for treatment or storage) and returned to the same or a different AOC
- Excavated from an AOC, placed in a separate unit, such as an incinerator or tank that is within the AOC, and redeposited into the same AOC

If placement does not occur, land disposal restrictions (LDRs) are not applicable to the Superfund action. Correspondingly, if placement on site does occur, LDRs would be applicable to the Superfund action.

At RMA, an AOC was defined that encompasses all principal threat exceedance areas, the majority of human health exceedance areas, and wildlife risk areas defined by the study area that is the subject of the SFS. The boundaries of the AOC are shown on Figure 7.1-1.

7.1.2 Corrective Action Management Unit

Several of the proposed alternatives for the On-Post Operable Unit include the construction and operation of a new on-post hazardous waste landfill for disposal of principal threat and human health exceedance soil and debris as defined in the Detailed Analysis of Alternatives report. Some of this material is RCRA-listed or potentially RCRA-characteristic hazardous waste (based on TCLP). Therefore, during the development of the Detailed Analysis of Alternatives, it was determined that a Corrective Action Management Unit (CAMU) would be required (EPA 1993). The CAMU will incorporate a future hazardous waste landfill, a Basin F Wastepile drying unit, and an appropriate waste staging and/or management area(s). The CAMU was designated by CDPHE under authority of and in accordance with CHWMA. The CAMU designation provides for landfilling of hazardous wastes and movement of waste into the CAMU from anywhere on post, within or outside the AOC, including treatment units. This ROD also provides for use of the CAMU rule as an ARAR for several remedial alternatives (see Appendix A).

The basis for designation of a CAMU and the requirements for the CAMU that are to be specified as part of the designation are provided in 6 CCR 1007-3, Section 264.552. In addition, Section 264.552(a)(3) specifies that where remediation waste placed into a CAMU is hazardous waste, the CAMU shall comply with Part 265, Subparts B, C, D, and E of 6 CCR 1007-3 (Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities [TSDFs]). When such remediation wastes are to remain in place after closure, Section 264.552(a)(3) also requires compliance with the siting requirements for hazardous waste disposal sites (6 CCR 1007-2, Part 2). The new hazardous waste landfill is the only facility within the CAMU to which these siting requirements apply; however, the CAMU may include additional areas as necessary to implement other actions.

A draft CAMU Designation Document (CDD) was submitted to CDPHE on January 12, 1996. It was resubmitted with additional information on March 15, 1996 and was followed by a public comment period. A public hearing was held April 17, 1996, and the comment period closed May 20, 1996. The CDD contains a discussion of the guidelines to be used for the designation of the RMA CAMU as well as a discussion of the operational, monitoring, closure, and post-closure guidelines that will be implemented following designation of the CAMU.

The following decision-making criteria were addressed in designating the CAMU:

- Facilitation of the remedy
- Risks to human health and the environment
- Justification of inclusion of uncontaminated area
- Containment of remediation waste remaining after closure
- Expeditious timing of remedial activity implementation
- Application of treatment technologies
- Minimization of land area where wastes remain in place

CDPHE designated the CAMU by way of the final CDD (Harding Lawson Associates 1996) and a Corrective Action Order. The CAMU boundaries are shown in Figure 7.1-1.

7.1.3 Development of Criteria for Evaluating Soil Contamination

The NCP (EPA 1990a) indicates that acceptable exposure levels for suspected carcinogens are "generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}" and that the 10^{-6} level shall be used as the point of departure for determining remediation goals. EPA (OSWER-EPA 1991b) indicates that action generally is not warranted for sites with additive excess cancer risks less than 10^{-4} and an HI less than 1.0 for noncarcinogenic contaminants. Therefore, the human health SEC for contaminated soil were defined as the additive excess cancer risks of COCs equal to 10^{-4} and/or additive noncarcinogenic HIs equal to 1.0. The boring-by-boring analysis was used to identify the areas of each site, if any, that exceeded the human health SEC and were therefore candidates for remediation. Sites with contaminant concentrations that result in exceedances of these criteria are termed exceedance sites, and their contaminants and resultant volumes are referred to as exceedance COCs and exceedance volumes. Table 7.1-4 presents the human health SEC, which are based on a 10^{-4} cumulative excess cancer risk and noncarcinogenic HI of 1.0 (the criteria ultimately selected in the Detailed Analysis of Alternatives). The human health SEC are based on the lower of the industrial or biological worker PPLVs for each COC. Acute risk criteria were used as human health SEC where they were lower than the corresponding chronic risk human health SEC.

The NCP (EPA 1990a) and EPA guidance documents also develop the concept of a principal threat. Although EPA guidance allows for considerable interpretation in identifying specific sites or areas as principal threats, the EPA fact sheet "Guide to Principal Threat and Low-Level Threat Wastes" (OERR-EPA 1991) provides the following general definition of principal threats:

> ...those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. They include

> liquids or other highly mobile materials (e.g., solvents) or materials having high concentrations of toxic compounds. No "threshold level" of toxicity/risk has been established to equate to "principal threat." However, where toxicity and mobility of source material combine to pose a potential [excess] cancer risk of 10^{-3} or greater, generally treatment alternatives should be evaluated.

In addition, the guidance includes a determination as to whether a source material is a principal threat waste:

> ...should be based on the inherent toxicity as well as a consideration of the physical state of the material (e.g., liquid), the potential mobility of the wastes in the particular environmental setting, and the liability and degradation products of the material. However, this concept of principal threat waste should not necessarily be equated with risks posed by site contaminants via various exposure pathways.

Principal threats, as defined in EPA's "Guide to Selecting Superfund Remedial Actions" (1990b), include the following:

- Areas contaminated with relatively high concentrations of toxic compounds
- Liquids and other highly mobile materials
- Contaminated media (e.g., sediment or soil) that pose a significant risk of excessive exposure
- Media containing contaminants several orders of magnitude above health-based levels

The objective of identifying the principal threat wastes is to focus the remediation on the areas of highest risk to human health and the environment. This focused approach is especially appropriate to RMA because many sites combine large areas of minimal or low-level contamination with small areas of high-level contamination that fall within the definition of principal threats being several orders of magnitude above health-based levels. Because 10^{-4} was set as the human health SEC, the principal threat criteria for RMA soil were established at a 10^{-3} excess cancer risk and a noncarcinogenic HI of 1,000. These criteria are listed by COC in Table 7.1-4. It should be noted and emphasized that the principal threat criteria are risk-management endpoints for use in directing and prioritizing remedial activities; only the SEC denote protective boundaries based on risks (with varying uncertainties) to health. The areas of RMA that exceed the human health SEC and principal threat criteria are shown in Figure 7.1-1.

7.1.4 Soil Volume Modeling and Estimation

Most of the soil alternatives that were evaluated make use of a volume or area estimate to accurately analyze the proposed remedial actions and to develop costs. These volume or area estimates were developed based on the above-described exceedance criteria.

Human health exceedance volume estimates were generated by one of two methods. The distribution of contaminants in some sites was modeled using a commercial software package (TECHBASE). A three-dimensional model, represented by an array of blocks, was created for each site and was bounded vertically by the ground-surface elevation at the time of sampling and depth of the water table (or to a maximum 10-ft depth based on the exposure assessment performed as part of the IEA/RC) and laterally by the site boundary as defined in the Remedial Investigation Summary Report. The modeling routine then searched within a defined volume (based on sample distribution within the site) around each block and used a three-dimensional inverse distance squared algorithm to estimate contaminant concentrations in each block.

Modeled soil concentrations were compared to the human health SEC to identify blocks to be included in the human health exceedance volume for each site. Similarly, soil concentrations were compared to the principal threat criteria to identify blocks to be included in **principal threat exceedance** volume. Concentrations were evaluated to account for potential cumulative effects of multiple contaminants, and all soil located between ground surface and the deepest exceedance block was counted in the exceedance volume. Areas were estimated by projecting all exceedance blocks to the surface and contouring around the surface projection. Perimeters were also estimated from these projections.

Additional volumes and areas were calculated for sites not considered amenable to modeling. In general, if modeling was subject to great uncertainty due to the physical characteristics of a site, highly heterogeneous or uneven spatial contamination, or limited data availability, information from the Study Area Reports (as summarized in the Remedial Investigation Summary Report) was used for volume and area calculations. A boring-by-boring analysis was performed to identify individual sample exceedances, and depth and lateral extents were projected halfway to the next nonexceedance sample. Volumes and areas were calculated using physical dimensions as listed in the Study Area Reports and measured distances between exceedance and nonexceedance samples.

Biota exceedance volumes were developed based on the potential biota risk areas as identified through the risk assessment process described in Section 6.2. The volume was calculated by multiplying the potential risk area by 1 ft (depth). The potential risk area for a site is defined as the entire biota exceedance area within the boundaries of a site, less any human health exceedance area, to avoid double-counting of the volume.

Potential agent and UXO areas were determined from boundaries presented in the Remedial Investigation Summary Report. Potential volume was calculated using these areas and the depths presented in the Detailed Analysis of Alternatives report. The expected agent or UXO volume of soil reflects a 0.1 percent factor to estimate actual agent or UXO occurrence within the potential volume. In addition, UXO surface debris volume was calculated by multiplying the potential UXO area by 1 ft (depth); the result is considered the maximum potential debris volume. For each site, overlap between agent, UXO, or UXO debris volume and human health or biota volume was calculated. Exceedance volumes were adjusted to prevent double-counting of soil volumes. UXO debris volume may include human health and/or biota exceedance volume. Actual human health exceedance volume or biota exceedance volume would increase to the previously unadjusted volume if less than the maximum potential debris volume is encountered.

The volume and area estimates that resulted from these calculations represent the soil quantities used for all soil alternative detailing. Volume increases due to commonly used excavation practices (such as sidesloping, bottom leveling, and perimeter rounding), although expected to be small, were not included in these calculations. Table 7.1-5 lists human health, principal threat, excess biota, agent, UXO, and UXO debris volumes for each soil medium group, and Table 7.1-6 lists the corresponding areas for each soil medium group.

7.2 Remedial Alternatives for Groundwater

7.2.1 Description of Medium

As described in Section 5, contaminated groundwater plumes were detected primarily in the vicinity of the basins, North and South Plants, and the northern and western sections of RMA (Figure 5.4-3). Plumes are generally moving to the north and northwest. Groundwater contaminant plumes predominantly consist of organic compounds (solvents, chloroform, dieldrin, DIMP, DCPD, DBCP, and organosulfur compounds) and fluoride and chloride salts (Tables 5.4-1 through 5.4-5). The overall concentrations and configurations of the plumes suggest that the greatest contaminant releases to the UFS have occurred from Basin A and the Lime Settling Basins, the South Plants chemical sewer, South Plants Tank Farm and production area, the Army and Shell Trenches in Section 36, and the Former Basin F. Plumes emanating from the Motor Pool/Rail Yard and North Plants areas are other sources of contaminant releases to the UFS.

Four groundwater alternatives were developed based on the contaminant concentrations in the individual plumes and evaluated against the remedial alternative screening criteria (see Section 8). A range of alternatives was developed and analyzed for each plume group. These alternatives included no action, continued operation of existing systems, and groundwater extraction and treatment approaches. Alternatives selected for each plume group were combined into four sitewide alternatives that were evaluated and compared against the screening criteria. Groundwater flow modeling utilizing commercially available software (MODFLOW), as summarized in the South Plants/Basin A groundwater flow model report (Foster Wheeler Environmental 1995c), was conducted to assess flow patterns and estimate flow and extraction rates in the South Plants and Basin A areas.

7.2.2 Remedial Action Objectives

The following RAOs were established for on-post groundwater at RMA:

Human Health

- Ensure that the boundary containment and treatment systems protect groundwater quality off post by treating groundwater flowing off RMA to the specific remediation goals identified for each of the boundary systems.
- Develop on-post groundwater extraction/treatment alternatives that establish hydrologic conditions consistent with the preferred soil alternatives and also provide long-term improvement in the performance of the boundary control systems.

Ecological Protection

- Ensure that biota are not exposed to biota COCs in surface water in concentrations capable of causing acute or chronic toxicity.

7.2.3 Description of Sitewide Remedial Alternatives for Groundwater

Flow of surface water at RMA occurs through a network of streams, lakes, and canals, and flow of groundwater occurs within the alluvium and the uppermost weathered portion of the Denver Formation (UFS). Deeper water-bearing units within the Denver Formation (CFS) are separated from the UFS by low-permeability confining units. Depending on site-specific hydrological characteristics, varying degrees of hydraulic interchange are possible between surface water and groundwater and between the UFS and CFS. In general, analytical and hydraulic data indicate little hydraulic interchange between the UFS and CFS.

The following are considerations for all water alternatives:

- Chloride is expected to attenuate naturally at the NBCS, where it currently exceeds the remediation goal of 250 mg/l. It has been estimated that chloride concentrations will attenuate to concentrations less than the remediation goal at the north boundary within 30 years (MK 1996). Assessment of chloride concentrations will occur during the 5-year site reviews.
- The remediation goal of 540 mg/l for sulfate at the NBCS represents the natural background concentration. It is estimated that sulfate will attenuate to the remediation goal within approximately 25 years (MK 1996). Assessment of sulfate concentrations will occur during the 5-year site reviews.
- NDMA has been detected in the North Boundary Plume Group and at the NBCS. Monitoring for NDMA using a method detection limit of 20 parts per trillion (ppt) is ongoing. If the current monitoring program identifies an NDMA problem, potential design modifications (both on post and at the boundary or adjacent to the boundary) required to achieve the remediation goal at the RMA boundary will be prepared during the remedial design. Any upgrades required for existing treatment systems to address the remediation goal will be incorporated into the remedial actions.

7.2.3.1 Alternative 1 – Boundary Systems

Under Alternative 1, the three boundary systems all continue to operate and the systems installed as IRAs are discontinued. The boundary systems are the following:

- Northwest Boundary Containment System (NWBCS)
- North Boundary Containment System (NBCS)
- Irondale Containment System (ICS)

Each of the boundary systems includes groundwater extraction and reinjection systems and a treatment system that removes organic contaminants through carbon adsorption; the NWBCS and NBCS include slurry walls for containment and control of groundwater flow. The total amount of water currently treated at the boundary systems is about 1 billion gallons per year. Boundary systems will continue to operate as necessary to achieve remedial action objectives until remediation is complete, and the CERCLA Wastewater Treatment Plant continues to operate as needed to support remedial activities.

Under Alternative 1, the following IRAs are discontinued: the Basin F **extraction system**, the Basin A Neck extraction and treatment system (including breaching of the slurry wall to allow groundwater flow), the Rail Yard extraction system, and the Motor Pool extraction system. Monitoring of boundary system influent and effluent concentrations and groundwater monitoring continue. In addition, caps or covers installed in South Plants and Basin A as part of the soil remedy minimize infiltration of precipitation, thereby reducing contaminant migration through lowering of the water table (**passive dewatering**).

The components of this alternative are summarized in Table 7.2-1. The total estimated cost for this alternative (in 1995 dollars) is $111 million (present worth cost of $80 million). A breakdown of capital and operations and maintenance (O&M) costs is presented in Table 7.2-2. Operations are assumed to continue for at least 30 years.

The operation of each of the boundary systems is detailed below.

Northwest Boundary Containment System

Under Alternative 1, operation of the NWBCS for the Northwest Boundary Plume Group continues. The NWBCS is designed to capture and treat organic contaminants, primarily dieldrin, in groundwater approaching the northwest boundary. The NWBCS includes extraction wells, a slurry wall, reinjection wells, and a GAC adsorption system. When the system was constructed, a slurry wall was installed along the northwest boundary to minimize migration of the contaminated groundwater flowing across that boundary. This wall, constructed of soil/bentonite and originally measuring 1,425 ft long by 3 ft wide by approximately 30 ft deep, was subsequently extended by an additional 665 ft in the northeast direction to intercept groundwater flowing through the alluvial channel to the northeast. The slurry wall extension was keyed a minimum of 10 ft into the existing slurry wall and the extension ranged from 28 to 35 ft deep.

Five extraction wells were also added to the original system, two along the slurry wall, and three southwest of the system. Four reinjection wells were installed to the southeast of the newly installed extraction wells to maintain a separation between contaminants migrating to the north versus contaminants migrating to the northwest and to push groundwater toward the NWBCS along a small, localized groundwater divide. One additional extraction well was added to the southwest extension in early 1996 in response to hydrological changes associated with increased pumping rates in off-post SACWSD water supply wells and decreased infiltration rates at the Havana Ponds (south of Lake Mary and Lake Ladora in Section 11). The southwest extension currently extracts 425 gpm and reinjects approximately 230 gpm; the balance (195 gpm) is reinjected at the original NWBCS system. The rest of the NWBCS extracts and reinjects approximately 600 gpm and 795 gpm, respectively, for a total system flow of approximately 1,025 gpm.

Groundwater is pumped from the extraction wells to the influent sump adjacent to the treatment building. The treatment system consists of three identical GAC vessels, two of which are operated in parallel; the third is used as a backup unit. Each vessel contains 40,000 lbs (1,400 cubic ft) of GAC, is operated in an upflow mode, and has a design capacity of 500 gpm and a residence time of 22 minutes. Treated water is currently discharged into an effluent sump from which the water is pumped (using two 500-gpm pumps) through a recharge header pipe to the reinjection (recharge) wells. The system includes two 500-gpm backup pumps. There are 25 recharge wells that range in depth from approximately 40 ft to 60 ft below the ground surface.

The NWBCS generates two sidestreams requiring treatment or disposal, spent carbon and filter solids. The spent carbon in the adsorbers is removed and regenerated at an off-post facility. The filter solids are drummed and disposed in a landfill regulated by RCRA and CHWMA.

North Boundary Containment System

Under Alternative 1, operation of the NBCS for the North Boundary Plume Group continues, but the operation of the extraction well that is currently part of the Basin F Groundwater IRA is discontinued. The NBCS is a pump-and-treat system that consists of 35 extraction wells approximately 35 ft deep, 12 of which are currently operating, and a soil/bentonite slurry wall 6,740 ft long, 3 ft wide, and 30 ft deep. The extracted water is treated at the treatment plant with GAC and recharged through 15 reinjection trenches. The NBCS was upgraded as part of the IRA for this system. The upgraded system has an improved treatment system, 5 new recharge trenches installed in 1990, and 10 recharge trenches installed in 1988. The trenches parallel the line of extraction wells and are located about 45 ft north of the existing soil/bentonite slurry wall. The existing 38 recharge wells are not in operation, but can be used as backups if needed. The trenches were installed close to the slurry wall to better maintain a reverse gradient.

The NBCS treatment system originally included prefiltration units, three 30,000-lb GAC adsorbers operated in parallel, and a combination of cartridge and bag postfilters. Treated effluent is discharged to a sump for groundwater recharge. The treatment plant has undergone minor operational changes (associated mostly with carbon handling) and now has two 20,000-lb GAC adsorbers operated in series; a third unit is available as a backup. The GAC units operate in downflow mode, and the carbon usage is approximately 100,000 lbs per year. The total capacity of the modified extraction/treatment system is estimated to be 450 gpm. Flow through the treatment plant currently averages 270 gpm.

The NBCS generates two sidestreams requiring treatment or disposal, spent carbon and filter solids. The spent carbon in the adsorbers is removed and regenerated at an off-post facility. The filter solids are drummed and disposed in a landfill regulated by RCRA and CHWMA.

Water levels in the Former Basin F area have been declining for years. The new cap and soil covers in this area will cause the water level to drop further.

Irondale Containment System

Originally, the ICS consisted of two rows of extraction wells and one row of recharge wells. A number of modifications to the ICS system configuration were completed by 1991. The extraction systems have changed as some wells have reached cleanup goals and more contaminated wells have been added to the system. Six of the original extraction wells are currently operating as extraction wells and three of the original extraction wells have been converted to injection wells. Nine new recharge wells, which reduce the water table depression caused by heavy SACWSD pumping rates and which enlarge the zone of captured groundwater on the south edge of the ICS, were installed south of the original system. Additionally, four new extraction wells, three of which are currently operating, were installed 2,000 ft upgradient of the original ICS in an area of greater saturated thickness than the original ICS extraction wells.

Under Alternative 1, all groundwater extracted from the Western Plume Group is treated at the ICS. The water is collected in an influent sump and is treated with GAC adsorption before being reinjected into the aquifer. The treatment plant has three existing treatment trains, each capable of treating a maximum of 700 gpm, although historically only two of the trains have been run simultaneously. The treatment system consists of three identical GAC vessels, two of which are operated in parallel; the third is used as a backup unit. Each vessel contains 40,000 lbs of GAC, is operated in an upflow mode, and has a design capacity of 700 gpm and a corresponding residence time of 15 minutes. Alternative 1 does not include the operation of the two IRA systems (Motor Pool and Rail Yard) that feed into the ICS.

The ICS generates two sidestreams requiring treatment or disposal, spent carbon and filter solids. The spent carbon in the adsorbers is removed and regenerated at an off-post facility. The filter solids are drummed and disposed in a landfill regulated by RCRA and CHWMA.

7.2.3.2 Alternative 2 – Boundary Systems/IRAs

Under Alternative 2, all boundary systems continue to operate as for Alternative 1. Passive dewatering is accomplished through installation of the soil caps and covers. In addition, all the IRAs continue to operate as follows:

- The systems in the Motor Pool and Rail Yard areas continue to extract groundwater and pipe it to the ICS for treatment.
- The Basin F Groundwater IRA continues to extract water north of Basin F for treatment at the Basin A Neck IRA System.
- Under the Basin A Neck IRA, water migrating from Basin A continues to be extracted at Basin A Neck and treated by carbon adsorption. A slurry wall helps control contaminant migration. Water from north of Basin F (Basin F Groundwater IRA) is treated by air stripping and carbon adsorption at Basin A Neck.
- The CERCLA Wastewater Treatment Plant continues to operate as needed to support remedial activities.

Operation of the internal groundwater extraction IRA systems continue as necessary until remedial action objectives are met. The other systems operate as necessary to achieve remedial action objectives until remediation is complete. Groundwater and system influent and effluent monitoring continue under this alternative.

The Rail Yard and Motor Pool IRA systems include seven extraction wells to intercept DBCP contamination and two extraction wells to intercept a TCE plume, respectively. These wells became operational in September 1991. Five of the seven wells in the Rail Yard IRA are currently pumping at a total rate of approximately 230 gpm; the two other wells are backup extraction wells and have not been used. The two wells in the Motor Pool area are currently pumping approximately 100 gpm. The groundwater that is extracted from the Motor Pool Area and Rail Yard extraction wells is pumped from the wells through a metering station to a manifold and then flows via an 8-inch-pipeline to the ICS.

To allow for the additional flow at the ICS, the capacity of this system was increased by bringing the third GAC bed on line, although this option has not been required with present flow rates (the ICS is treating approximately 1,030 gpm as of August 1995). With all three trains operating in parallel, the ICS has a maximum design capacity of 2,100 gpm.

The Basin F Groundwater IRA was implemented to capture contamination moving north out of the Basin F Area. Water is extracted using one well at a rate of 1 to 4 gpm and is then piped to the Basin A Neck IRA system where it is treated prior to reinjection into the Basin A Neck recharge trenches.

The Basin A Neck IRA is a pump-and-treat system that intercepts and treats contamination in groundwater as it moves northwest from Basin A. The extraction system consists of seven alluvial wells that currently pump a total flow of approximately 20 gpm. Three gravel-filled recharge trenches (160 ft, 170 ft, and 180 ft in length) are located across the more permeable, deeper portions of the Basin A Neck. A soil/bentonite slurry wall extends 830 ft across the Basin A Neck between the extraction wells and the recharge trenches to limit recirculation of water between the two systems and inhibit any flow of contaminants not captured by the extraction wells. Treated water from the CERCLA Wastewater Treatment Plant is conveyed to the Basin A Neck treatment plant by an underground pipeline, combined with effluent from the plant at a maximum rate of 5 gpm, and reinjected in the Basin A Neck reinjection trenches. The CERCLA Wastewater Treatment Plant treats water in a semibatch mode on an as-needed basis.

Groundwater extracted from both the Basin A Neck and the Basin F Groundwater IRAs is treated at the Basin A Neck IRA treatment facility. Approximately 1 to 4 gpm of groundwater from the Basin F Groundwater IRA is filtered and then treated in an air stripper. The vapor emissions from the air stripper are treated by two vapor-phase GAC vessels operated in series and an additional backup unit. The effluent from the air stripper is combined with the Basin A Neck IRA influent and treated by pre-filtration through a multimedia filter followed by adsorption in two 2,000-lb carbon vessels in series (one backup vessel is on standby). The GAC effluent is filtered through multimedia filters and discharged to a 3,000-gallon effluent tank. Water from the tank is then filtered through 5-micron bag filters and pumped to the recharge trenches.

The Basin A Neck IRA treatment system generates two sidestreams requiring treatment or disposal, spent carbon and filter solids. The spent carbon in the adsorbers is removed and regenerated at an off-post facility. The filter solids are disposed in a landfill regulated by RCRA and CHWMA.

The components of this alternative are summarized in Table 7.2-1. The total estimated cost for this alternative (in 1995 dollars) is $139 million (present worth cost of $98 million). A breakdown of capital and O&M costs is presented in Table 7.2-2. Operations under this alternative are assumed to continue for at least 30 years.

7.2.3.3 Alternative 3 – Boundary Systems/IRAs/On-Post Dewatering

Alternative 3 includes all components described for Alternative 2. In addition, the water table in the Basin A and South Plants areas is lowered by installing a network of dewatering wells **(active dewatering)** in the central areas of South Plants and Basin A and by installing caps or soil covers in the same area as part of the soil remedy (passive dewatering). Extracted water is treated in a new treatment system by air stripping and GAC adsorption and is then reinjected. Concurrently, groundwater in the South Tank Farm Plume is treated by active **in situ biological treatment**. The South Tank Farm Plume is monitored for the presence of LANPL and, if freely drainable product accumulates to a sufficient thickness, this product is separated and treated. Treatment system and groundwater monitoring is conducted.

Alternative 3 involves removing the most contaminated portions of the Basin A Plume Group, lowering and maintaining future groundwater levels beneath Basin A, and dewatering the South Plants groundwater mound, including the South Plants North Source and South Plants Southeast Plumes. Based on modeling results (see Foster Wheeler Environmental 1995c) for the proposed well layout in Basin A and South Plants, an initial pumping rate of approximately 80 gpm will be used for the first 10 years to reduce the groundwater mound. After 10 years, a pumping rate of 35 gpm will be used to maintain groundwater elevations. Dewatering is accomplished using a system of **horizontal wells** that are installed prior to the initiation of structures medium remedial activities. The caps are installed as part of the soil remedy. The successful operation of the alternative relies on the active extraction/dewatering of the aquifer to reverse horizontal gradients and induce inward flow to the dewatering well system.

The operational goal under Alternative 3 for Basin A is to actively dewater contaminated portions of the soil and the alluvial aquifer. During the first decade (Phase I), the extraction system removes an estimated 60 gpm and the water table is artificially lowered 20 ft or more in the center of Section 36, and to a lesser degree in other areas beneath

Basin A. It is estimated that the long-term pumping rate sufficient to maintain this depressed water level is approximately 20 gpm in Basin A once the soil cap or cover is in place (Phase II). The Basin A Neck IRA intercept system continues to operate and extracts contaminants that are downgradient and beyond the influence of the dewatering system. The dewatering systems are expected to be installed prior to installation of the Basin A and South Plants soil covers, which are to be completed as part of the soil remedy.

Under Alternative 3, dewatering and in situ biotreatment occur concurrently in the South Plants area. Because horizontal wells are used, dewatering under the South Plants Central Processing Area can be initiated before or during demolition or capping activities. The water table is lowered approximately 20 ft through extraction of 20 gpm during the first 10 years (Phase I). The water level is then maintained through extraction of 15 gpm in Phase II. The use of horizontal wells provides flexibility in the overall cleanup of South Plants because the wells can be installed from outside the other construction and demolition areas. The concurrent treatment for the South Tank Farm Plume involves in situ biodegradation of benzene. Water is extracted from the South Tank Farm Plume source area at a rate of 10 gpm. The extracted groundwater is transferred to a collection tank and then reinjected after the appropriate amounts of hydrogen peroxide and nutrients have been added; reinjecting the water flushes the plume as it enhances biological growth and degradation of contaminants in the subsurface. When the northernmost cell (Cell I) of the in situ biotreatment system becomes inefficient after several years due to dewatering of the South Plants area, three of the injection wells in Cell 1 are converted to extraction wells and become part of the overall dewatering system. The remainder of the in situ system continues to operate for an estimated 10 years.

Each of the proposed extraction systems under Alternative 3 requires installation of performance monitoring wells. Groundwater-quality and water-level data from the newly installed performance monitoring wells are used to evaluate the effectiveness and operation of the extraction/dewatering system. The final location of the wells is based upon review of existing well locations and screened intervals. Where appropriate, existing wells are utilized in place of construction of new monitoring wells.

The components of this alternative are summarized in Table 7.2-1. The total estimated cost for this alternative (in 1995 dollars) is $179 million (present worth cost of $130 million). A breakdown of capital and O&M costs is presented in Table 7.2-2. Operations under this alternative are assumed to continue for at least 30 years.

7.2.3.4 Alternative 4 – Boundary Systems/IRAs/Intercept Systems

Alternative 4 includes all components of Alternative 2 as well as groundwater extraction from the Section 36 Bedrock Ridge Plume in an interceptor configuration followed by treatment at the existing Basin A Neck IRA (which includes air stripping and GAC adsorption). Treated water is reinjected to the aquifer through the existing recharge trenches. The interceptor configuration is designed to prevent further migration of the Section 36 Bedrock Ridge Plume northeast out of the Basin A area towards the First Creek drainage. Alternative 4 is accomplished in conjunction with the soil remedy, which includes caps or soil covers over the Basin A and South Plants areas, and caps and slurry walls associated with the Shell Trenches and the Army Complex Trenches.

Groundwater-quality and water-level data are collected and used to evaluate the effectiveness and operation of the Bedrock Ridge and Basin A Neck systems. It is assumed that there are sufficient existing wells in both areas to be used for performance monitoring, so no new wells are installed. Wells closed during the implementation of the soil remedy will be replaced if required to maintain adequate performance monitoring. Further evaluation of the hydraulic control provided by the entire system (wells, caps, and slurry walls) will be performed during the remedial design.

Alternative 4 also includes groundwater monitoring of the CFS. Monitoring of the CFS is to be conducted in the South Plants area, the Basin A area, and close to Basin F. Data from these wells are assessed to determine whether contaminant levels within the CFS are increasing or migrating significantly with time. Due to poor construction or documentation of well-installation techniques, screened intervals, and bentonite-seal locations, approximately 30 to 40 CFS wells are closed and abandoned. Both groundwater and system monitoring continues.

Water levels in Lake Ladora, Lake Mary, and Lower Derby Lake will be maintained to support aquatic ecosystems. The biological health of the ecosystems will continue to be monitored. Lake-level maintenance or other means of hydraulic containment or plume control will be used to prevent South Plants plumes from migrating into the lakes at concentrations exceeding CBSGs in groundwater at the point of discharge. Groundwater monitoring will be used to demonstrate compliance.

The components of this alternative are summarized in Table 7.2-1. The total estimated cost for this alternative is $146 million (present worth cost of $104 million). A breakdown of capital and O&M costs is presented in Table 7.2-2. Operations under this alternative are assumed to continue for at least 30 years.

7.3 Description of Sitewide Remedial Alternatives for Structures

7.3.1 Description of Medium

As described in Section 5 and detailed in the structures inventory tables (Tables 5.4-6 through 5.4-9), approximately 94 percent of the remaining 798 structures at RMA were identified as potentially contaminated based on previous use or location in manufacturing areas. To date, 525 structures at RMA have been demolished. The debris has been disposed off post or is awaiting disposal.

7.3.2 Remedial Action Objectives

The RAOs for structures were developed based on potential risks, both physical and chemical, to human and ecological receptors through the potential exposure pathways of inhalation, dermal contact, or ingestion of contaminants potentially present in, or emanating from, structures at RMA. They were also based on the potential for the movement of contaminants through soil, air, or water from structures. The RAOs for the structures medium are as follows:

Human Health

- Prevent contact with the physical hazards and contaminant exposure associated with structures.
- Limit inhalation of asbestos fibers to applicable regulatory standards.
- Limit releases or migration of COCs from structures to soil or water in excess of remediation goals for those media or to air in excess of risk-based criteria for inhalation as developed in the HHRC.

Ecological Protection

- Prevent contact with the physical hazards associated with structures.
- Prevent biota from entering structures that are potentially contaminated.

7.3.3 Description of Sitewide Remedial Alternatives for Structures

Before any structures remedial alternatives can be implemented, each structure must be visually examined to determine the structural integrity of the building. The decontamination status of each structure is also determined with respect to ACM and PCBs.

The scope of the ongoing Asbestos IRA is to remove and dispose all ACM from RMA structures, piping, and tanks. The Asbestos IRA continues as part of the structures remediation, so any asbestos remaining in the structures will be removed as an integral part of the remediation process and disposed in the on-post hazardous waste landfill.

Agent-related and nonagent-related process equipment and piping located in the North Plants and South Plants is being sampled, decontaminated, and dismantled under the Chemical Process-Related Activities IRA. Although much of the equipment in these areas has already been removed, process-related equipment not remediated as part of this IRA will be disposed in the new on-post TSCA-compliant hazardous waste landfill as part of the final remedy.

Army structures have been subject to a comprehensive sampling program under the PCB IRA to identify all PCB-contaminated equipment and structural materials. The results of this program are to be presented in the PCB IRA completion report. PCB-contaminated materials will be disposed in the on-post hazardous waste landfill, which will meet Toxic Substances Control Act (TSCA) requirements. The results of the PCB IRA completion report for Army structures will be incorporated into remediation activities as discussed below.

Equipment and structures for which the Army has responsibility will be handled as follows:

- Equipment – PCB fluids will be drained and sent off post for disposal in compliance with applicable TSCA regulations. PCB-contaminated equipment will be disposed in the new on-post hazardous waste landfill that meets TSCA requirements. The equipment will be disposed under one of three possible scenarios:
  - Identified and disposed as part of the ongoing PCB IRA.
  - Identified under the PCB IRA but disposed under the final structures cleanup.
  - Agent-decontaminated materials to be disposed under the final structures cleanup.
- Structures – The PCB contamination in No Future Use structural materials will be identified in the PCB IRA completion report. Based on a 50 parts per million (ppm) action level, structural materials will be addressed in one of two ways:
  - Structural materials with PCB concentrations of 50 ppm or above that exist above the ground elevation, as well as contaminated parts of ground floor slabs and foundations that will be removed, will be identified prior to demolition, segregated during demolition, and disposed in the on-post TSCA-compliant hazardous waste landfill. Similar materials with PCB concentrations less than 50 ppm will be disposed according to use history as described in the alternative detailing.
  - PCB-contaminated sections of ground floor slabs or foundations at or below grade that are not required to be demolished as part of the remediation and with PCB concentrations of less than 50 ppm will be left in place. However, slabs or foundation materials with PCB concentrations of 50 ppm or greater will be removed during demolition and disposed in the new TSCA-compliant hazardous waste landfill.

Army Future Use structures have been managed for occupancy under current environmental and worker protection regulations. There is no evidence of PCB contamination in this medium group.

Potential PCB contamination in Shell structures are to be identified through visual evidence, and will be disposed in accordance with TSCA requirements and guidance. Structures and equipment for which Shell has responsibility are so indicated in Tables 5.4-6 through 5.4-9 and will be handled as follows:

- All Shell buildings to be demolished during the final remedy will be inspected for equipment containing fluids potentially contaminated with PCBs prior to demolition. Potentially contaminated fluids will be drained and sent off post for disposal in compliance with applicable TSCA regulations. Equipment that contained these fluids, as well as all other equipment, will be disposed in the on-post TSCA-compliant hazardous waste landfill. Significant Contamination History structures will be demolished and the resulting debris will be placed in the new on-post TSCA-compliant hazardous waste landfill. Other Contamination History structures will be evaluated by Shell and EPA for any visual evidence of leaks or spills. If observed in areas where potential PCB releases may be reasonably expected to occur, the affected debris will be disposed in the on-post TSCA-compliant hazardous waste landfill. Examples of this type of visual evidence would include stains near equipment potentially containing PCB fluids or stains in buildings where there are numerous instances of equipment potentially containing PCB-contaminated fluids. Further details of this work will be addressed at the remedial design stage.
- All fluorescent-light ballasts will be disposed at an off post-disposal facility in accordance with applicable TSCA regulations.

Shell does not have responsibility for any structures within the Future Use or Agent History Groups.

Most of the demolition at RMA will consist of dismantling (i.e., reducing a standing building to a pile of debris), using a combination of demolition techniques and equipment such as a backhoe with a thumb attachment, a wrecking ball and crane, or a crane and clamshell, or by performing piece-by-piece disassembly, sawing, or crushing. Additional techniques, such as structural undermining or explosives demolition, may be appropriate in some cases. Standard dust-suppression measures consistent with the remediation goals are used throughout the demolition process to meet state and federal requirements.

As the structural debris is removed, materials are segregated for purposes of recycling and waste classification. Economically recyclable materials, such as scrap metals, are collected for salvage. Structural materials not salvaged are placed in a bermed dirt or concrete staging area. The debris is segregated into potentially hazardous and nonhazardous waste as the structure is dismantled and placed in separate containment areas. The debris is sized for disposal concurrent with stockpiling to limit the amount of settling in the landfill or consolidation area. Due to the potential hazards, these handling activities are limited for Agent History structures.

The debris is then transported by truck to the disposal site. Debris from Agent History structures is monitored for the presence of agent and treated, as necessary, before disposal in the hazardous waste landfill. Agent-contaminated structures will be handled in compliance with AR 385-61, AR 50-6, and Department of Defense regulations in effect at the time of remediation. Action must be taken to treat the agent contamination within the structure or debris to a level consistent with Army regulations (3X or 5X) so it may be properly disposed. Debris from the Significant Contamination and Other Contamination History structures are taken directly to the hazardous waste landfill, depending on the remedial alternative. Floor slabs and foundations at or below grade for the Other Contamination History and Significant Contamination History Groups are left in place unless they must be removed to provide access to underlying contaminated soil (i.e., the slabs and foundations of structures located in the South Plants Central Processing Area within principal threat or human health soil exceedance areas, which are removed to a depth of 5 ft along with the contaminated soil). Floor slabs not removed are broken in place to prevent water ponding and are contained beneath the soil covers specified for the specific areas in which they occur (see Section 7.4).

7.3.3.1 Alternative 1 – Landfill/Cap in Place

Alternative 1 addresses each of the three No Future Use medium groups as follows:

- No Future Use, Significant Contamination History – The structures are dismantled using **dust controls**, metals salvaged (if appropriate), and the remaining debris disposed in the on-post hazardous waste landfill.
- No Future Use, Other Contamination History – The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris consolidated and **capped** in one of three places: the Rail Yard, North Plants, or the South Plants Central Processing Area. Multilayer caps are used for containment of the debris.

- No Future Use, Agent History – The structures are dismantled using dust controls and air monitoring, the debris monitored for the presence of Army chemical agent and caustic washed as necessary, and the resulting debris disposed in the on-post hazardous waste landfill. Spent caustic wash is treated in an evaporator/crystallizer; the resulting waste salts are drummed and disposed in the on-post hazardous waste landfill.

The components of this alternative are summarized in Table 7.3-1. The total estimated cost of this alternative (in 1995 dollars) is $114 million (present worth cost of $106 million). A breakdown of capital and O&M costs for each component of this alternative is presented in Table 7.3-2. This alternative requires approximately 2 years for implementation.

7.3.3.2 Alternative 2 – Landfill/Consolidate

Alternative 2 addresses each of the three No Future Use medium groups as follows:

- No Future Use, Significant Contamination History – The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris disposed in the on-post hazardous waste landfill.
- No Future Use, Other Contamination History – The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris transported to the Basin A consolidation area for use as gradefill.
- No Future Use, Agent History – The structures are dismantled using dust controls and air monitoring, the debris monitored for the presence of Army chemical agent and caustic washed as necessary, and the resulting debris disposed in the on-post hazardous waste landfill. Spent caustic wash is treated in an evaporator/crystallizer; the resulting waste salts are drummed and disposed in the on-post hazardous waste landfill.

The components of this alternative are summarized in Table 7.3-1. The total estimated cost of this alternative (in 1995 dollars) is $112 million (present worth cost of $104 million). A breakdown of capital and O&M costs for each component of this alternative is presented in Table 7.3-2. This alternative requires approximately 2 years for implementation.

7.3.3.3 Alternative 3 – Landfill

Alternative 3 addresses each of the three No Future Use medium groups as follows:

- No Future Use, Significant Contamination History – The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris disposed in the on-post hazardous waste landfill.
- No Future Use, Other Contamination History – The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris disposed in the on-post hazardous waste landfill.
- No Future Use, Agent History – The structures are dismantled using dust controls and air monitoring, the debris monitored for the presence of Army chemical agent and caustic washed as necessary, and the resulting debris disposed in the on-post hazardous waste landfill. Spent caustic wash is treated in an evaporator/crystallizer; the resulting waste salts are drummed and disposed in the on-post hazardous waste landfill.

The components of this alternative are summarized in Table 7.3-1. The total estimated cost of this alternative (in 1995 dollars) is $118 million (present worth cost of $109 million). A breakdown of capital and operating and maintenance costs for each component of this alternative is presented in Table 7.3-2. This alternative requires approximately 2 years for implementation.

7.4 Description of Sitewide Remedial Alternatives for Soil

7.4.1 Description of Medium

As described in Section 5, the majority of contamination is present in the trenches, disposal basins, and the South Plants manufacturing area, covering approximately half of the central six sections of RMA (Figure 5.4-1 and Tables 5.4-11 and 5.4-12). The highest contaminant concentrations tend to occur in soil within 5 ft of the ground surface, although exceptions are noted, particularly at sites where burial trenches, disposal basins, or manufacturing complexes are located. In general, contaminant distribution is significantly influenced most by the physical and chemical properties of the contaminants, the environmental media through which they are transported, and the characteristics of the sources (i.e., former manufacturing and disposal practices).

7.4.2 Remedial Action Objectives

The RAOs identified for the soil medium are the following:

Human Health

- Prevent ingestion of, inhalation of, or dermal contact with soil or sediments containing COCs at concentrations that generate risks in excess of 1×10^{-4} (carcinogenic) or an HI greater than 1.0 (noncarcinogenic) based on the lowest calculated reasonable maximum exposure (5th percentile) PPLV values (which generally represent the on-site biological worker population).
- Prevent inhalation of COC vapors emanating from soil or sediments in excess of acceptable levels, as established in the HHRC.
- Prevent migration of COCs from soil or sediment that may result in off-post groundwater, surface water, or windblown particulate contamination in excess of off-post remediation goals.
- Prevent contact with physical hazards such as UXO.
- Prevent ingestion of, inhalation of, or dermal contact with acute chemical agent hazards.

Ecological Protection

- Ensure that biota are not exposed to COCs in surface water, due to migration from soil or sediment, at concentrations capable of causing acute or chronic toxicity via direct exposure or bioaccumulation.
- Ensure that biota are not exposed to COCs in soil and sediments at toxic concentrations via direct exposure or bioaccumulation.

7.4.3 Description of Sitewide Remedial Alternatives for Soil

The implementation of any soil alternative is tied to structures remediation because most of the structures at RMA are located in areas of soil contamination. In such areas, structures must be demolished before components of the soil remedy, such as excavation or the construction of containment systems, can be implemented.

PCB-contaminated soil at RMA was identified under the PCB IRA program. The remedial activities for PCB-contaminated soil are dependent on the concentration and location as follows:

- The three PCB-contaminated soil areas identified by the PCB IRA with concentrations of 250 ppm or greater will be removed. The limits of contamination will be determined based on visual evidence with immunoassay field confirmation sampling (SW-846).
- There are five PCB-contaminated soil areas identified by the PCB IRA with concentrations from 50 ppm to below 250 ppm. These areas will receive a minimum of 3 ft of soil cover, and the PCB-contaminated soil there will be left in place. The soil cover will be maintained as part of the wildlife refuge and is subject to the institutional controls of the FFA.
- No remaining areas of PCB-contaminated soil with concentrations above 50 ppm have been identified by the PCB IRA. If necessary, any suspected PCB soil contamination areas will be characterized further during the remedial design. If additional PCB-contaminated soil is found in concentrations of 50 ppm or above, the Army will determine any necessary remedial action in consultation with EPA.
- PCB-contaminated soil that is excavated under any soil alternative is disposed in the on-post TSCA-compliant landfill.

7.4.3.1 Alternative 1 – Caps/Covers

Alternative 1 involves the **containment** of 1,200 acres through the installation of a cap and the landfilling of 290,000 bank cubic yards (BCY) of contaminated soil. Under this alternative, **multilayer caps** are installed to contain contaminated soil. The capped areas are located in the central portions of RMA (Figure 7.4-1). The existing cover for the Former Basin F Subgroup is augmented to improve performance and meet EPA guidance governing caps and covers. A composite cap is constructed over the existing cover for the Basin F Wastepile. Approximately 17.8 million BCY of borrow materials are required as backfill and gradefill to achieve the design grades for capping, and an additional 11.3 million BCY of borrow (clay and common fill) are required for construction of the caps.

In addition to capping, all sewer manholes are plugged with cement. Slurry walls are used in conjunction with caps for the Complex Trenches, Shell Trenches, Hex Pit, and Buried M-1 Pits Subgroups to augment the containment of these sites. The groundwater inside the contained area is pumped and treated if necessary.

Areas outside the central portions of RMA that are suspected to have potential chemical agent or UXO presence are screened and cleared. Any **excavated** agent-contaminated soil identified during **agent monitoring** is treated by caustic washing and then landfilled. In addition, any identified HE-filled (high explosive) or agent-filled UXO is excavated, packaged, and **transported** off post to an existing Army facility for detonation and disposal (unless the UXO is unstable and must be detonated on post) or other demilitarization process. The 200,000 BCY of contaminated soil and debris from several sites in the eastern and western portions of RMA are excavated and placed in the on-post hazardous waste landfill along with debris from **munitions screening** operations. The

110,000 BCY of human health exceedances from the Surficial Soil, Lake Sediments, and Agent Storage Medium Groups are also landfilled.

Soil posing risk to biota is generally capped as discussed above. No action is undertaken for soil that potentially poses risks to biota that is located outside of the capped area including Upper Derby Lake and the Surficial Soil, Ditches/Drainage Areas, and Agent Storage Medium Groups. The soil in these areas is sampled periodically. No action (other than monitoring) is conducted for the aquatic lake sediments. Ongoing monitoring of biota in these areas will be conducted in support of design refinement/design characterization.

The components of this alternative are summarized in Table 7.4-1. The total estimated cost for this alternative (in 1995 dollars) is $542 million (present worth cost of $386 million). A breakdown of capital and O&M costs for each component of this alternative is presented in Table 7.4-2. This alternative requires approximately 17 years for implementation.

7.4.3.2 Alternative 2 – Landfill/Caps

Alternative 2 involves containment of approximately 490 acres through the installation of multilayer caps and the landfilling of 2 million BCY of contaminated soil. The areas outside the central portion of RMA are excavated and landfilled. The 110,000 BCY of human health exceedances from the Lake Sediments, Surficial Soil, and Agent Storage Medium Groups are landfilled. Any excavated agent-contaminated soil identified during monitoring is treated by caustic washing and then landfilled. In addition, any HE-filled or agent-filled UXO identified through geophysical surveys or other screening methods are excavated, packaged, and transported off-post to an existing Army facility for detonation and disposal (unless the UXO is unstable and must be detonated on post) or other demilitarization process. Chemical sewer lines in the central portion of the South Plants complex and within the Complex Trenches are plugged with cement and the sanitary sewer manholes are plugged. The remaining chemical sewers and associated contaminated soil are excavated and placed in the on-post hazardous waste landfill.

A 390-acre area in the central portion of RMA is covered with multilayer caps. The capped areas consist of human health exceedance areas and areas with residual contamination in Section 36, the South Plants Central Processing Area, and the Former Basin F (Figure 7.4-2). The existing cover for the Former Basin F Subgroup is augmented to improve performance and meet EPA guidance governing caps and covers. A composite cap is constructed over the existing cover for the Basin F Wastepile. Approximately 8.8 million BCY of borrow materials are required as backfill and gradefill to achieve the design grades for capping, and an additional 3.9 million BCY of borrow (clay and common fill) are required for construction of the caps.

Slurry walls are used in conjunction with caps for the Complex Trenches, Shell Trenches, Hex Pit, and Buried M-1 Pits Subgroups to augment the containment of these sites. The groundwater inside the contained area is pumped and treated if necessary to maintain lowered water table elevations.

Soil posing risk to biota within the central six sections of RMA is generally excavated and landfilled as discussed above. No action is undertaken for soil that potentially poses risks to biota that is located outside of the capped area including Upper Derby Lake and the Surficial Soil, Ditches/Drainage Areas, and Agent Storage Medium Groups. Although a residual risk to biota exists outside the capped area, the magnitude of the residual risk is comparatively low (see Section 6.2.4.3) and the short-term destruction of habitat is minimized. The soil in these areas is sampled periodically. No additional action other than monitoring is conducted for the aquatic lake sediments. Ongoing monitoring of biota in these areas will be conducted in support of design refinement/design characterization.

The components of this alternative are summarized in Table 7.4-1. The total estimated cost for this alternative (in 1995 dollars) is $383 million (present worth cost of $276 million). A breakdown of capital and O&M costs for each component of this alternative is presented in Table 7.4-2. This alternative requires approximately 16 years for implementation.

7.4.3.3 Alternative 3 – Landfill

Alternative 3 involves the containment of 3.4 million BCY of contaminated soil in an on-post hazardous waste landfill. Approximately 100 acres of principal threat or human health exceedance soil areas are contained with a multilayer cap instead of being landfilled, and 300 acres are capped (multilayer cap), after removing the human health exceedance volume and landfilling, to address residual contamination (Figure 7.4-3).

Contaminated soil from nearly all of the sites (3.4 million BCY total) is excavated and landfilled. Chemical sewers and associated contaminated soil are excavated and placed in the on-post hazardous waste landfill. The 87,000 BCY of human health exceedance volume from the Surficial Soil Medium Group, soil with human health exceedances in the Agent Storage Medium Group (2,900 BCY), and human health exceedances and soil that may pose a risk to biota from the Lake Sediments (including portions of Upper Derby Lake) and Ditches/Drainage Areas Medium Groups (58,000 BCY) are also excavated and landfilled. Any excavated agent-contaminated soil identified during monitoring is treated by caustic washing and then landfilled. The excavation of the Former Basin F, Buried M-1 Pits, Shell Trenches, and Hex Pit Subgroups requires the use of **vapor- and odor-suppression measures** such as foam, liners, or a transportable structure.

The sanitary sewer manholes are plugged. Any HE-filled (high explosive) and agent-filled UXO identified through geophysical surveys or other screening methods are excavated, packaged, and transported off post to an existing

Army facility for detonation and disposal (unless the UXO is unstable and must be detonated on post) or other demilitarization process.

The Basin F Wastepile and the Complex Trenches Subgroups are left in place and capped. A composite cap is constructed over the existing cover for the Basin F Wastepile. Following the excavation and landfilling of human health exceedances, 390 acres in Section 36, South Plants Central Processing Area, and the Former Basin F are capped (multilayer caps). Approximately 10.1 million BCY of borrow materials are required as backfill and gradefill to achieve the design grades for capping, and an additional 3.86 million BCY of borrow are required for construction of the cap.

Slurry walls are used in conjunction with the caps for the Complex Trenches Subgroup to augment the containment of this site. The groundwater inside the contained area is pumped and treated.

Soil posing risk to biota within the central six sections of RMA is generally excavated and landfilled as discussed above. No action is undertaken for soil that potentially poses risks to biota in the Surficial Soil Medium Group, but the soil in this area is sampled periodically. Although a residual risk to biota exists in this medium group, the magnitude of the residual risk is comparatively low (see Section 6.2.4.3) and the short-term destruction of habitat is minimized. No action other than monitoring is conducted for the aquatic lake sediments. Ongoing monitoring of the biota in these areas will be conducted in support of design refinement/design characterization.

The components of this alternative are summarized in Table 7.4-1. The total estimated cost for this alternative (in 1995 dollars) is $576 million (present worth cost of $384 million). A breakdown of capital and O&M costs for each component of this alternative is presented in Table 7.4-2. This alternative requires approximately 22 years for implementation.

7.4.3.4 Alternative 4 – Consolidation/Caps/Treatment/Landfill

Alternative 4 involves **consolidation** of 1.5 million BCY of soil with low levels of contamination into Basin A, Former Basin F, and the South Plants Central Processing Area; capping or covering of 1,100 acres of contaminated soil; landfilling of 1.7 million BCY of soil and debris; and treatment of 217,000 BCY of soil by solidification/stabilization (Figure 7.4-4). This alternative also includes a contingent soil volume of 150,000 BCY that may be landfilled. The locations of the contingent volume will be based on visual field observations such as soil stains, presence of barrels, or newly discovered evidence of contamination. In addition, 14 samples from North Plants, Toxic Storage Yards, Lake Sediments, Sand Creek Lateral, and Burial Trenches Medium Groups and up to 1,000 additional confirmatory samples may be used to identify the contingent soil volume requiring landfilling.

Approximately 190,000 BCY of principal threat soil in the Former Basin F are treated by in situ solidification/stabilization, and 26,000 BCY of principal threat and human health exceedance soil from the Buried M-1 Pits are excavated, solidified, and placed in the on-post landfill. Excavation of the Buried M-1 Pits will be conducted using vapor- and odor-suppression measures.

Approximately 1,000 BCY of principal threat material from the Hex Pit are treated using an innovative thermal technology. The remaining 2,300 BCY are excavated and disposed in the on-post hazardous waste landfill. Remediation activities will be conducted using vapor- and odor-suppression measures as required. Treatability testing will be performed during remedial design to verify the effectiveness of the innovative thermal process and establish operating parameters for the design of the full-scale operation. The innovative thermal technology must meet the treatability study technology evaluation criteria as described in the dispute resolution agreement (PMRMA 1996). Treatment will be revised to a solidification/stabilization technology if all evaluation criteria for the innovative thermal technology are not met. Treatability testing for solidification will be performed to verify the effectiveness of the solidification process and determine appropriate solidification/stabilization agents. Treatability testing and technology evaluation will be conducted in accordance with EPA guidance (OSWER-EPA 1989a) and EPA's "Guide for Conducting Treatability Studies Under CERCLA" (1992).

The approximately 650,000 BCY of highly contaminated soil from the Basin F Wastepile and the Section 36 Lime Basins Subgroups is excavated (using vapor- and odor-suppression measures) and disposed in triple-lined cells within the on-post hazardous waste landfill. Soil from the Basin F Wastepile not passing the **EPA paint filter test** (SW-846, Method 9095) will be reduced to acceptable moisture-content levels by using a dryer in an enclosed structure. Any contaminants released from the soil during drying will be captured and treated.

Approximately 1 million BCY of human health exceedance soil from other sites throughout RMA, as well as debris from UXO clearance operations, are landfilled under this alternative. Any excavated agent-contaminated soil identified during monitoring is treated by caustic washing and then landfilled. In addition, any identified HE-filled and agent-filled UXO are excavated, packaged, and transported off post to an existing Army facility for detonation and disposal (unless the UXO is unstable and must be detonated on post) or other demilitarization process.

Slurry walls are used in conjunction with the caps for the Shell Trenches and Complex Trenches Subgroups to augment the containment of these sites. For the purposes of conceptual design and costing during the FS, it was assumed that the groundwater inside the contained area is pumped and treated at the Basin A Neck treatment system (this assumption will be reevaluated during the remedial design). The Shell Trenches and Complex Trenches caps are designed to be **RCRA-equivalent caps**. The complex trenches cap includes a 6-inch-thick formed concrete layer. The sanitary sewer manholes and the chemical sewers located in the South Plants Central Processing Area and Complex Trenches are plugged. The remaining human health exceedance soil and chemical sewer debris are excavated and placed in the landfill.

Soil posing a potential risk to biota within the Secondary Basins as well as the North Plants Manufacturing Area is contained in place using 2-ft-thick soil covers. Soil posing a potential risk to biota within the Ditches/Drainage Areas, Sanitary Landfills, Section 36 Balance of Areas, Sand Creek Lateral, South Plants, and some of the Lake Sediments and Surficial Soil Medium Groups/Subgroups are consolidated as gradefill soil within Basin A, South Plants Central Processing Area, or Former Basin F and are contained beneath the cap or soil covers for those sites. The construction of the cap and covers of these three areas requires approximately 5.7 million BCY of gradefill to provide sufficient slope for proper drainage. Other sites require an additional 3.1 million BCY of backfill and gradefill to achieve design grades for caps/covers. An additional 5.1 million BCY of borrow material are required for construction of all caps/covers. The Former Basin F cap is designed to be RCRA-equivalent. Basin A and the South Plants Central Processing Area are contained with a 4-ft-thick soil cover and, respectively, a 6-inch-thick formed concrete layer and 1-ft-thick crushed concrete layer for prevention of biota intrusion.

The South Plants Balance of Areas is covered with a variable-thickness soil cover. The former human health exceedance area is covered with a 3-ft-thick soil cover and the former potential risk to biota area is covered with a 1-ft-thick soil cover. Prior to placing this cover, two composite samples per acre will be collected to ensure that the soil under the 1-ft-thick soil cover does not exceed human health or principal threat criteria. If the residual soil is found to exceed these levels, the 3-ft-thick cover will be extended over these areas or the exceedance soil will be excavated and landfilled. The top 1 ft of the entire soil cover area will be constructed using uncontaminated soil from the on-post borrow areas.

The Section 36 Balance of Areas will also be covered with a variable-thickness soil cover. The former human health exceedance area is covered with a 2-ft-thick soil cover and the former potential risk to biota area is covered with a 1-ft-thick soil cover.

Soil posing risk to biota is generally excavated and consolidated within the Basin A and South Plants Central Area covers or placed beneath the Basin F cap. No action is undertaken for soil that potentially poses risks to biota that is located outside of this area, i.e., soil within the Lake Sediments or Surficial Soil Medium Groups. Although a residual risk to biota exists in these areas, the magnitude of the residual risk is comparatively low (see Section 6.2.4.3) and the short-term destruction of habitat is minimized. These areas are sampled periodically. No action (other than monitoring) is conducted for the aquatic lake sediments. Ongoing monitoring of the biota in these areas will be conducted in support of design refinement/design characterization.

The components of this alternative are summarized in Table 7.4-1. The total estimated cost for this alternative (in 1995 dollars) is $566 million (present worth cost of $401 million). A breakdown of capital and O&M costs for each component of this alternative is presented in Table 7.4-2. This alternative requires approximately 17 years for implementation.

7.4.3.5 Alternative 5 – Caps/Treatment/Landfill

Alternative 5 is composed of the following features: capping of 530 acres of contaminated soil, landfilling of 4 million BCY of soil and debris, and treatment of 1.1 million BCY of contaminated soil (Figure 7.4-5).

Approximately 1.1 million BCY of principal threat soil are treated by **thermal desorption**, **incineration**, or **solidification/stabilization**. The majority of the soil treated by thermal desorption is from the Basin F Wastepile, Former Basin F and South Plants Central Processing Area Subgroups. The excavation of soil from both the Basin F Wastepile and Former Basin F for treatment may require use of vapor- and odor- suppression measures. Soil in the Shell Trenches and Hex Pit Subgroups (103,000 BCY) is excavated and treated by incineration. The excavation of both the Shell Trenches and Hex Pit also requires use of vapor- and odor-suppression measures. All soil treated by thermal desorption or incineration is placed in the on-post hazardous waste landfill.

A total of 27,000 BCY of soil contaminated with inorganic contaminants are treated by solidification. The majority of the soil to be solidified is excavated from the Buried M-1 Pits Subgroup, which requires vapor- and odor-suppression measures during excavation.

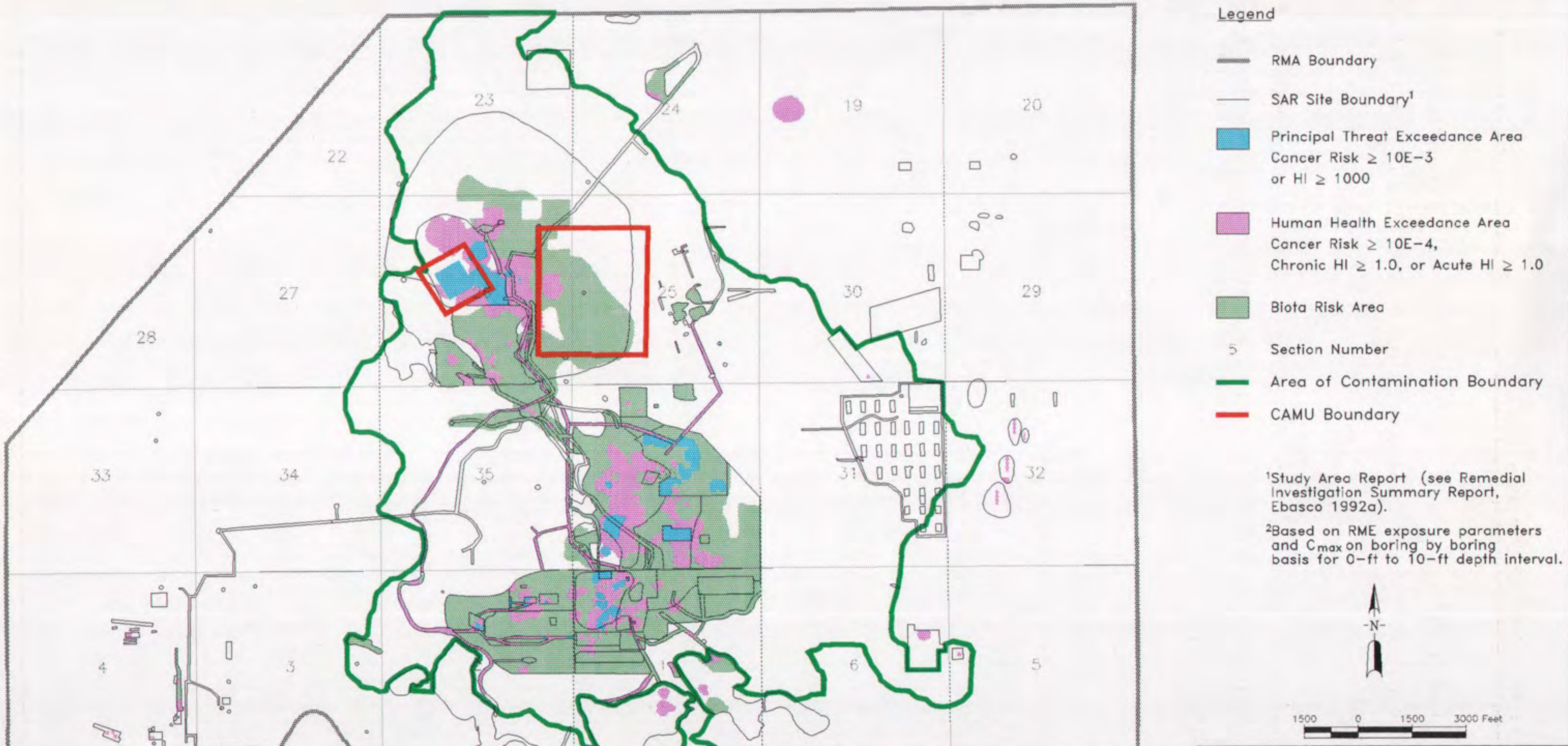
The Complex Trenches Subgroup is left in place and contained with a multilayer cap and slurry walls. The groundwater inside the contained area is pumped and treated as necessary.

Following the excavation of human health exceedance volumes for treatment or disposal, 530 acres in Section 36, the South Plants Central Processing Area, and the Former Basin F are capped (multilayer caps). Approximately 10.5 million BCY of borrow materials are required as gradefill to achieve the design grade for the caps, and an additional 3.9 million BCY of borrow are required for construction of the caps.

Approximately 4 million BCY of contaminated soil, primarily from sites outside of the central portions of RMA, as well as debris from UXO clearance operations, are landfilled under this alternative. The incinerated soil and debris and the thermally desorbed soil are also placed in the on-post hazardous waste landfill. Any agent-contaminated soil identified during screening is treated by caustic washing and then landfilled. In addition, any identified HE-filled and agent-filled UXO is excavated, packaged, and transported off post to an existing Army facility for detonation and disposal (unless the UXO is unstable and must be detonated on post) or other demilitarization process. The sanitary sewer manholes are plugged. The chemical sewers and any associated contaminated soil are excavated and placed in the on-post hazardous waste landfill. The 87,000 BCY of human health exceedance volume from the Surficial Soil Medium Group are also landfilled.

Soil posing risk to biota within the central six sections of RMA is generally excavated and landfilled. An additional 1,600 acres of soil representing a potential risk to the great horned owl are addressed through agricultural practices, which reduces the level of contamination in near-surface soil. No action other than monitoring is conducted for the aquatic lake sediments. Ongoing monitoring of biota in these areas will be conducted in support of design refinement/design characterization.

The components of this alternative are summarized in Table 7.4-1. The total estimated cost for this alternative (in 1995 dollars) is $1.01 billion (present worth cost of $542 million). A breakdown of capital and O&M costs for each component of this alternative is presented in Table 7.4-2. This alternative requires approximately 28 years for implementation.



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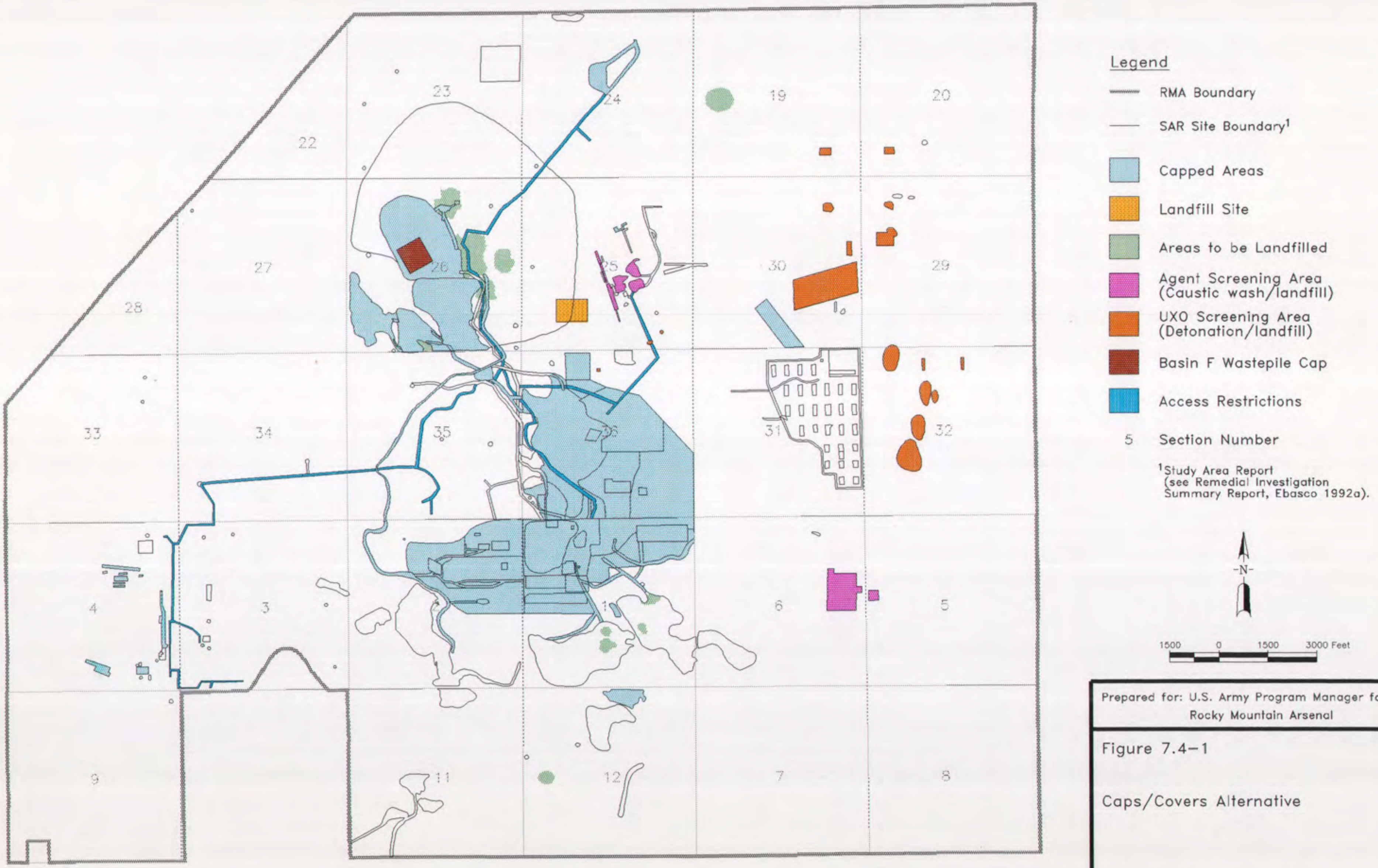
Date 6/06/96
Drawn by XG
Checked by SA

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

Figure 7.1−1

Human Health Exceedance Areas and Biota Risk Area[2]

Foster Wheeler Environmental Corporation
June 1996



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

Figure 7.4−1

Caps/Covers Alternative

Foster Wheeler Environmental Corporation
June 1996

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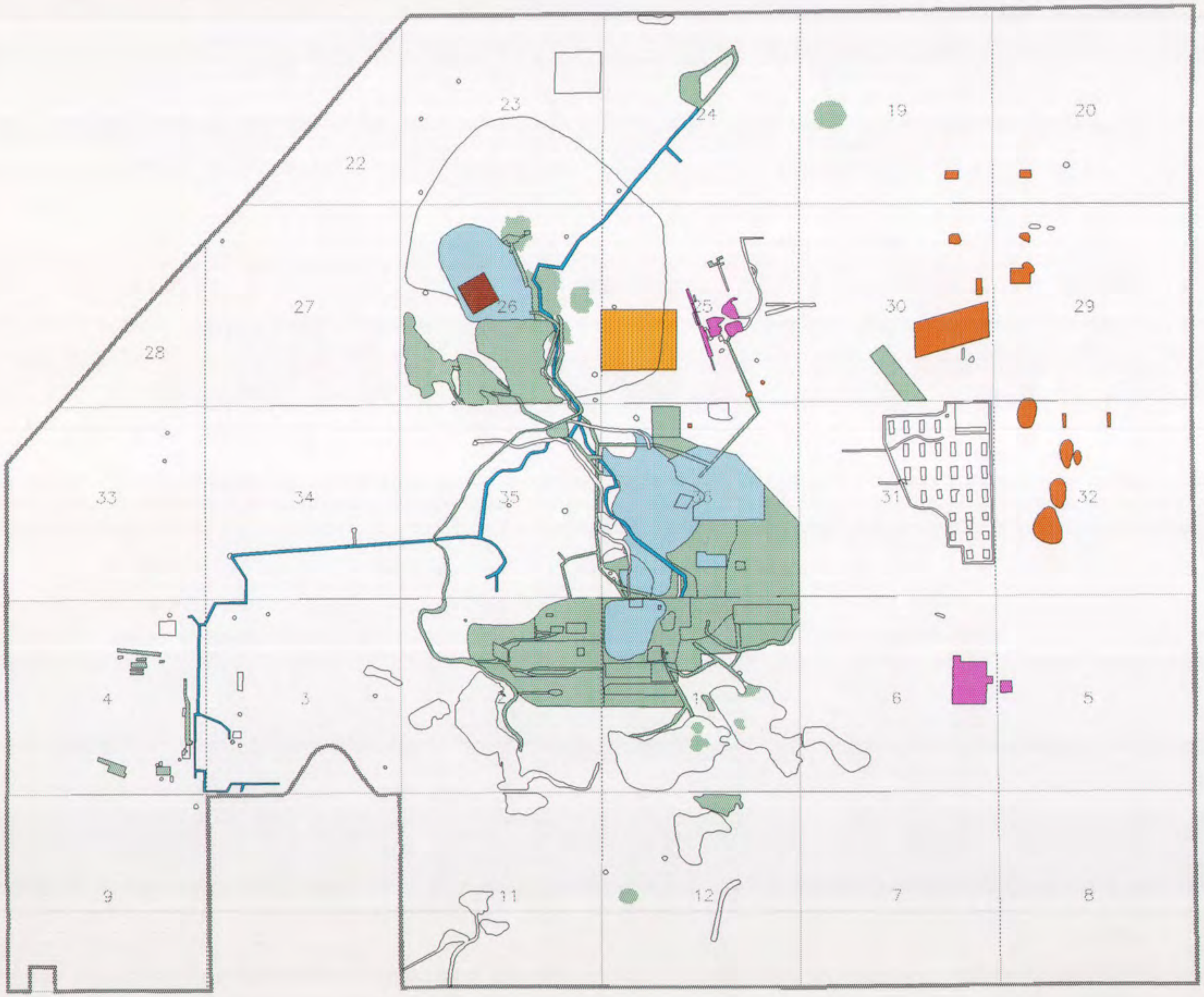

Legend

- RMA Boundary
- SAR Site Boundary[1]
- Capped Areas
- Landfill Site
- Areas to be Landfilled
- Agent Screening Area (Caustic wash/landfill)
- UXO Screening Area (Detonation/landfill)
- Basin F Wastepile Cap
- Access Restrictions
- 5 Section Number

[1] Study Area Report (see Remedial Investigation Summary Report, Ebasco 1992a).

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

Figure 7.4–2

Landfill/Caps Alternative

Foster Wheeler Environmental Corporation
June 1996

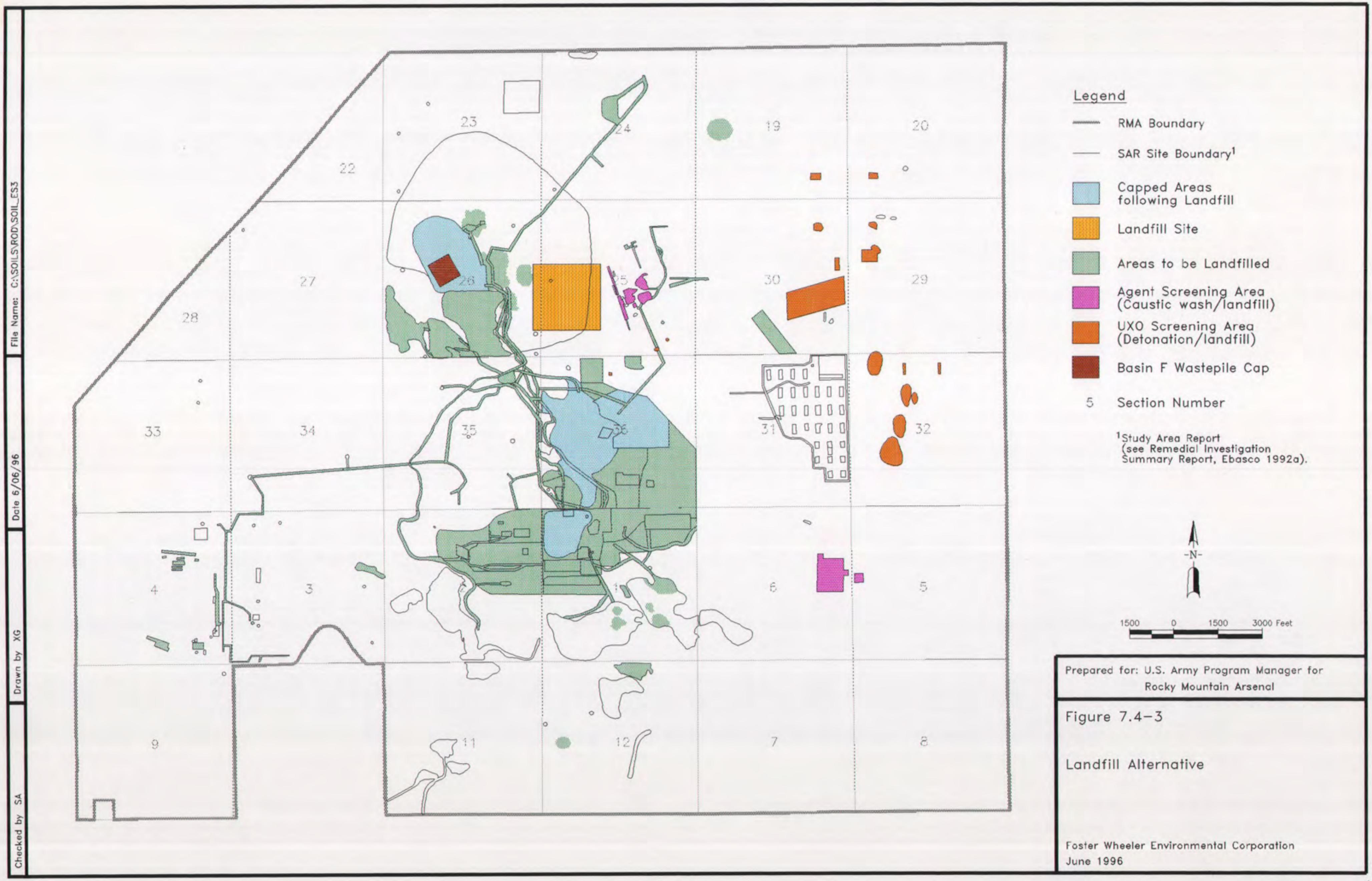

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Figure 7.4-3

Landfill Alternative

Foster Wheeler Environmental Corporation
June 1996

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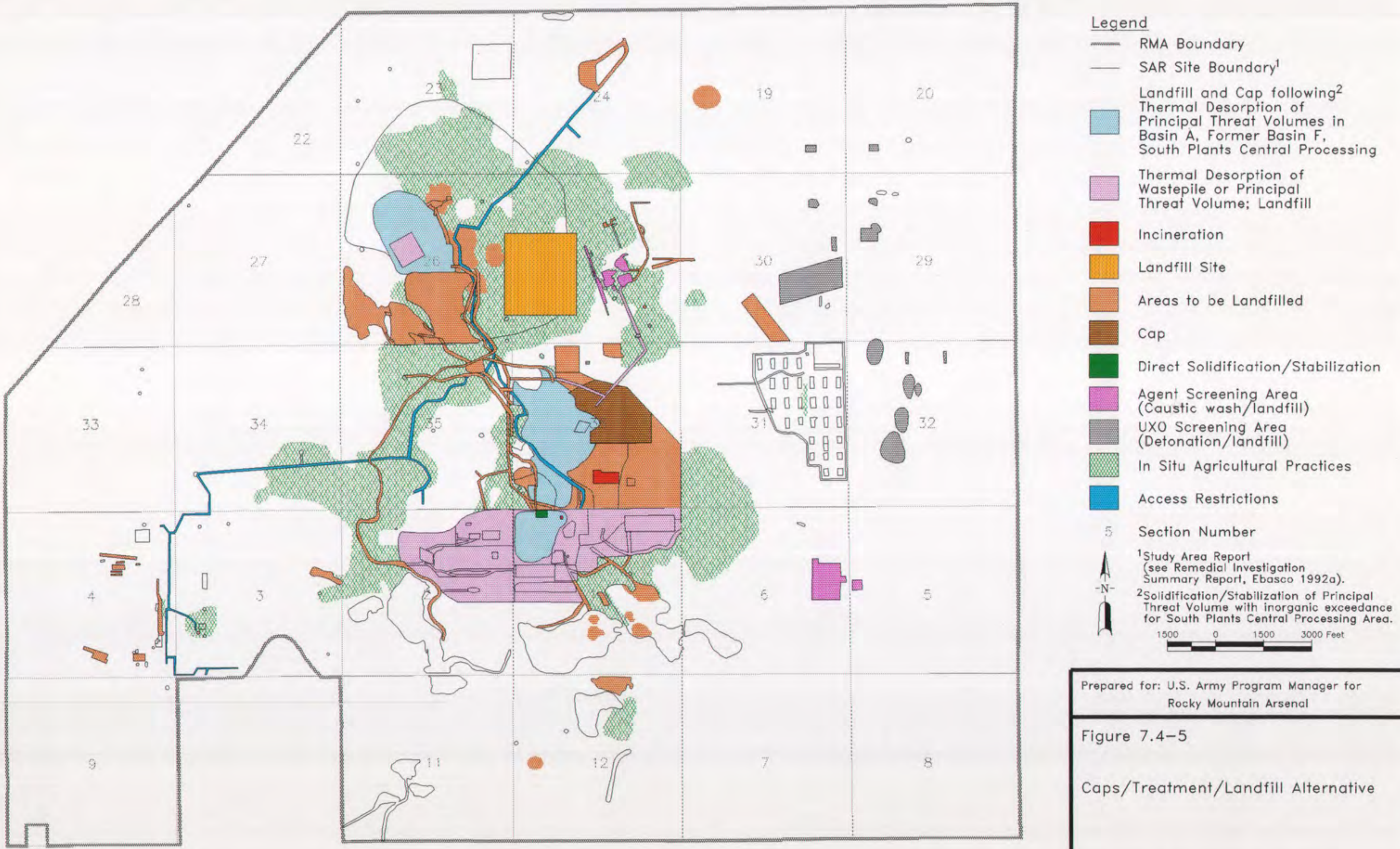
Figure 7.4–4

Consolidation/Caps/Treatment/ Landfill Alternative

Foster Wheeler Environmental Corporation
June 1996



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

Figure 7.4-5

Caps/Treatment/Landfill Alternative

Foster Wheeler Environmental Corporation
June 1996

File Name: C:\SOILS\ROD\SOIL_ES5
Date 6/06/96
Drawn by XG
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Table 7.1-1 Description of Water Technologies[1]

Technology	Description
Dewatering	Dewatering involves the withdrawal of groundwater from an underground water-bearing zone, effectively lowering the water table in an area. A lower water table separates contamination in soil near the surface from groundwater. Prior to dewatering, groundwater levels are close to the ground surface. In areas of shallow groundwater, it is relatively easy for chemical spills or contaminants in soil near the surface to migrate down to the groundwater. Following dewatering, contaminated soil and groundwater are separated from each other and further contamination of groundwater is reduced. Dewatering is also used in construction and demolition activities in areas of shallow groundwater to stabilize subsurface soil. For example, before an old building and its basement can be demolished, the ground around it is dewatered. Once an area is dewatered, heavy equipment can be used and water is prevented from filling up the excavation. Dewatering also reduces the chances that the underground walls will cave in on workers.
Granular-Activated Carbon Adsorption	GAC adsorption refers to the removal of dissolved contaminants from an aqueous stream, although it may also be applied to gaseous streams. In the GAC process, water containing dissolved organic compounds is brought into contact with GAC, onto which the organic compounds preferentially adsorb. The attraction of organic molecules in solution to the surface of the carbon is dependent on the strength of the molecular attraction between the carbon and the organic contaminant, the molecular weight of the contaminant, the type and characteristics of the carbon, the surface area of the carbon, and the pH and temperature of the solution. The GAC process option can be used as a single treatment technology or as one of a series of treatments designed to optimally address a contaminant mixture in a treatment process train.
Air Stripping	Air stripping is an effective and proven method for removal of volatile organic compounds from water. The process involves the removal of the volatiles from an aqueous stream by mass transfer through countercurrent contact of the stream with air. Air stripping is a means for transferring the contamination from the liquid phase to gas (vapor). The gases are collected and require additional treatment.

Table 7.1-1 Description of Water Technologies[1]

Technology	Description
In Situ Biological Treatment	In situ biodegradation, or biological treatment, takes advantage of naturally occurring microorganisms in the aquifer that are capable of breaking down and destroying contaminants. In situ means "in place;" the term is appended to the name of this technology because the degradation occurs underground in the aquifer. The microorganisms that make this treatment technology work are already present in the aquifer, but they are not plentiful enough to significantly decrease the concentration of contaminants in the aquifer. To encourage their growth, oxygen and nutrients containing nitrogen are added to the aquifer. This is done by extracting some of the groundwater, adding chemicals to the water, and then reinjecting it into the aquifer. The microorganism population increases after the nutrients are added. The contaminants serve as a source of food for the microorganisms, with the result that the contaminants are destroyed.
Groundwater Extraction/Reinjection	Groundwater extraction methods may be used to collect contaminated groundwater from aquifers for surface treatment and reinjection, to dewater excavations in areas with a shallow water table, and/or to contain a plume of contaminated groundwater. The design of the extraction system is determined by site-specific conditions and the intended purpose of the system. For example, an intercept system may be designed to capture either the leading edge of a plume or the most contaminated portion of the plume. Under a mass-reduction approach, an extraction system is designed to capture the central mass or most contaminated portion of the plume. In addition to removing the mass of contamination, a mass reduction or dewatering approach eliminates contact between overlying contaminated soil and groundwater by lowering the water table. The layout, pumping rates, well spacing, etc., all differ for each of these examples depending on the desired effect. The groundwater extraction technology under consideration is extraction wells, with provisions for trenches/drains if needed. The reinjection method under consideration is a recharge trench. Extracted water is pumped to a treatment facility and the effluent from treatment is reinjected. Recharge trenches are excavated to a depth sufficient to convey water to the water table and may use any type of buried conduit used to convey liquids by gravity flow.

1 Detailed discussion of all water remediation technologies considered is presented in the Detailed Analysis of Alternatives report.

Table 7.1-2 Description of Structures Technologies[1]

Technology	Description
Structures Demolition	Structures demolition involves the physical dismantling of structures, sizing of debris, and separation of salvageable materials. Dismantling requires the use of medium to heavy equipment to demolish a structure, i.e., to take it apart piece by piece. The structure is broken up using bulldozers, backhoes, wrecking balls, clamshells, universal processors with cutting shears or other similar types of equipment. Contaminants are not treated through this process, but the volume is decreased and converted to a more workable form for subsequent treatment or disposal. Dust-control measures are commonly taken during the operation, generally consisting of spraying or misting water over the work area. Dismantling is applicable to all types and sizes of structures as well as pipes and tanks.
Salvage	Salvage consists of recycling scrap metal, process equipment, and piping. It represents an opportunity to reduce disposal costs and minimize waste streams. Materials that are salvaged include metal structure materials (rebar, support beams, etc.) and process equipment and piping. In addition, salvage includes the recycling of any metal materials that are stockpiled in "boneyards" on post. All metal materials from Army-owned structures are salvaged through the Defense Reutilization and Marketing Office. Metal materials may either be resold to salvage companies, recycled on or off post, or redistributed to Army facilities.
On-Post Landfill	A landfill securely contains contaminated structure debris by providing a physical barrier both above and below the contaminated material. The low-permeability cover protects human and biota receptors from direct contact with the contaminants, and the low-permeability liner restricts contaminant mobility, protecting the underlying soil and groundwater. The landfill technology is applicable primarily for the disposal of untreated soil and debris, but may also be used for the disposal of treated debris and soil/debris mixtures. In addition, oversize materials removed during materials-handling activities for both soil and structures treatment alternatives will also require placement in a landfill.
Caustic Washing of Agent-Contaminated Structure Debris	Caustic washing is a physical/chemical treatment process in which agent-contaminated structural debris is excavated, mixed with caustic wash fluids in an aboveground unit to degrade agent, and then separated from the fluids. The process is carried out at ambient temperature and atmospheric pressure. The makeup of the treatment solution is based upon suspected contaminants and suspected contaminant concentrations. At RMA this process is based upon the suspected presence of GB, VX, lewisite, and mustard. Although there are chemical treatment alternatives that more effectively treat each individual contaminant, this process has been designed to treat all aforementioned compounds and generate by-products of greatly reduced toxicity.

Table 7.1-2 Description of Structures Technologies[1]

Technology	Description
Multilayer Cap	A multilayer cap reduces both the migration of hazardous substances into the surrounding environment by minimizing deep percolation through the contaminated media and the potential for direct exposures by humans or biota to contaminated media through containment (i.e., the isolation of the contaminated media). From top to bottom, a multilayer cap generally consists of three layers: a 4-ft-thick soil/vegetation layer designed to minimize erosion and promote drainage; a 1-ft-thick layer of crushed concrete or cobbles as a biota barrier serving to protect the underlying low-permeability soil layer; and a 2-ft-thick layer of compacted, low-permeability soil. The cap is constructed with sufficient slope to prevent ponding of rainwater. The vegetation used for the top layer consists of locally adapted perennial grasses and low-growing plants selected to minimize erosion and discourage burrowing animals from using the cover as habitat.

1 Detailed discussion of all structures remediation technologies considered is presented in the Detailed Analysis of Alternatives report.

Table 7.1-3 Description of Soil Technologies[1]

Technology	Description
Excavation	Excavation is the removal of soil, debris, drums, pipes, tanks, or any other solid material from the ground. Examples of conventional excavation equipment are bulldozers, backhoes, clamshells, drag lines, front-end loaders, and scrapers. Excavated soil is loaded and transported to a disposal area or treatment facility. Backfilling (using on-post borrow material) and reclamation is required following excavation. Additional process requirements for excavation may include dust suppression, control of air emissions, dewatering, or removal of debris or UXO.
Soil Cover	A soil cover isolates the contaminated media from potential receptors, such as humans or biota, thereby preventing direct exposures through direct contact. A soil cover consists of a variable-thickness layer of soil and may include crushed or formed concrete layers as biota/excavation barriers. Soil covers may be sloped for erosion control and are vegetated with locally adapted perennial grasses and low-growing plants. A soil cover is not intended to provide a low-permeability barrier to infiltration.
Multilayer Cap	A multilayer cap reduces both the migration of hazardous substances into the surrounding environment by minimizing deep percolation through the contaminated media and the potential for direct exposures by humans or biota to contaminated media through containment (i.e., the isolation of the contaminated media). From top to bottom, a multilayer cap generally consists of three layers: a 4-ft-thick soil/vegetation layer designed to minimize erosion and promote drainage; a 1-ft-thick layer of crushed concrete or cobbles as a biota barrier to protect the underlying low-permeability soil layer; and a 2-ft-thick layer of compacted, low-permeability soil. The cap is constructed with sufficient slope to prevent ponding of rainwater. The vegetation used for the top layer consists of locally adapted perennial grasses and low-growing plants selected to minimize erosion and discourage burrowing animals from using the cover as habitat.
Slurry Wall	Slurry walls are vertical barriers that serve to impede the lateral flow of contaminated groundwater. The installation of a slurry wall entails the excavation of a trench, placement of the slurry mixture in the trench, and addition of fill material in the slurry-filled trench. The slurry wall mixture (commonly backfill soil, bentonite, and water) is selected based on compatibility and optimization concerns. The completed slurry wall acts as a low-permeability barrier to lateral groundwater flow. Slurry walls may be installed around sites in conjunction with a multilayer cap to form an isolation cell around the contaminated soil.

Table 7.1-3 Description of Soil Technologies[1]

Technology	Description
Composite Cap	A composite cap reduces both the migration of hazardous substances into the surrounding environment by minimizing infiltration through the contaminated soil and the potential for direct exposures by both humans and biota to contaminated media through containment (i.e., the isolation of the contaminated media). A composite cap consists of multiple layers including a soil/vegetative layer and a flexible-membrane liner overlying a layer of compacted clay. The composite cap design used in the soil alternatives includes a biota-intrusion barrier, drainage layers (sand and geotextile), and a geogrid for stability. The cap is constructed with sufficient slope to prevent ponding of rainwater, and the vegetation used for the top layer consists of locally adapted perennial grasses and low-growing plants selected to minimize erosion and discourage burrowing animals from using the cover as habitat.
On-Post Landfill	A landfill securely contains contaminated soil by providing a physical barrier both above and below the contaminated material. The low-permeability cover protects human and ecological receptors from direct contact with the contaminants, and the low-permeability liner restricts contaminant mobility, protecting the underlying soil and groundwater. The landfill technology is applicable primarily for the disposal of untreated soil and debris, but may also be used for the disposal of treated debris and soil/debris mixtures. In addition, oversize materials removed during materials handling activities for both soil and structures treatment alternatives will also require placement in a landfill.
Thermal Desorption	Thermal desorption uses heat to physically separate volatile (and some semivolatile) organic compounds from soil or sludge. In general, the operating temperature of the desorber (95°C to 540°C) is not high enough to oxidize or destroy the organic compounds to any significant extent, i.e., the desorber separates the organic contaminants so that the secondary combustion chamber may destroy them. Offgas from the secondary combustion chamber is treated for particulates and acid-gas emissions. Thermal desorption also volatilizes some metals; the extent of volatilization is a function of the selected operating temperature. For example, at the higher range of thermal desorption temperatures, mercury is almost entirely volatilized and arsenic is partially removed. Thermal desorption, however, cannot be used as a treatment technology for inorganic contaminant remediation.
Off-Post Demilitarization of UXO	Off-post demilitarization of UXO involves excavation, packaging, and transportation of the UXO to an appropriate Army facility for demilitarization. This process, applicable to any UXO identified involves shipping HE or agent-filled UXO that is safe or rendered safe to an Army facility specially designed for UXO demilitarization.

Table 7.1-3 Description of Soil Technologies[1]

Technology	Description
Caustic Washing of Agent-Contaminated Soil	Caustic washing is a physical/chemical treatment process in which agent-contaminated soil is excavated, mixed with caustic wash fluids in an aboveground unit to degrade agent, and then separated from the fluids. The process is carried out at ambient temperature and atmospheric pressure. The makeup of the treatment solution is based upon suspected contaminants and suspected contaminant concentrations. At RMA, this process is based upon the suspected presence of GB, VX, lewisite, and mustard. Although there are chemical treatment alternatives that more effectively treat each individual contaminant, this process has been designed to treat all aforementioned compounds and generate byproducts of greatly reduced toxicity.
Incineration	Incineration is a high-temperature process that uses either direct or indirect heat exchange to alter or destroy organic contaminants in soil, sludge, sediment, or debris. In general, the operating temperature of the incinerator (640°C to 1,000°C) is high enough to destroy the contaminants by oxidation or pyrolysis. Natural organic material is also burned out of the soil matrix. Incineration will remove, but not destroy, volatile metals such as mercury and arsenic. Off gas from the incinerator passes through a cyclone separator to remove particulates. Residual organic contaminants are destroyed in a secondary combustion chamber. Off gas from the secondary combustion chamber is treated for particulates and acid-gas emissions.
Stabilization/ Solidification	Solidification/stabilization processes use additives, or binding agents, to limit the mobility of contaminants and improve the physical characteristics of the waste by eliminating free liquids and producing a solid with high structural integrity. Although solidification/stabilization has historically addressed inorganic contamination through the use of cement-based agents, the advent of specialized additives has broadened the applicability to media containing both inorganic and organic contamination. Solidification/stabilization can be accomplished using ex situ or in situ processes. Ex situ processes rely on mechanical mixing equipment, such as a pug mill, to properly mix the contaminated soil with the binding agents. Mixing for in situ processes is accomplished using auger or rotor mixers. The binding agents are either placed on the soil surface and are drawn in by the mixing equipment or are injected through nozzles in the augers. An overlapping drilling pattern is used to obtain complete contact with the contaminated soil volume.
Agricultural Practices (Landfarming)	This technology consists of using landfarming techniques either with farm machinery (V-ripper, plow, and disk) or a soil stabilizer along with seeding to facilitate stabilization and attenuation of contaminants in surface soils (0-ft to 1-ft depth interval). Mixing surface contamination with the soil below is expected to promote contaminant loss and to reduce both contaminant exposure to surface receptors and migration of contaminants by surface dust dispersion.

Table 7.1-3 Description of Soil Technologies[1]

Technology	Description
Pipe Plugging	This process option consists of filling the interior of pipes with grout. The purpose is to eliminate this contaminant migration pathway and immobilize contamination within the pipe, reducing its mobility. The technique involves using a mobile grout plant to mix and inject the plugging material into the pipe. The pipes to be plugged are first drained of any residual liquids, and any fittings that block the grout are cut from the pipe run. Aboveground pipe sections are cut into manageable lengths of 100 ft for diameters up to 12 inches and 50 ft for diameters up to 36 inches. The grout is pumped into the pipe run from the low end until it exits the high end, which is closed once grout starts coming out. The lower end is then closed off, and the grout is allowed to harden. Pumping grout from the low end to the high end helps to prevent the formation of voids.

1 Detailed discussion of all soil remediation technologies considered is presented in the Detailed Analysis of Alternatives report.

Table 7.1-4 Site Evaluation Criteria and Principal Threat Criteria for Soil

		Chronic Risk-Based Criteria 0- to 10-ft Interval		Acute and Subchronic Risk-Based Criteria 0- to 1-ft Interval (where lower than chronic)
Contaminants of Concern	Principal Threat Criteria[2]	Site Evaluation Criteria[2]	Preliminary Remediation Goals[2]	Site Evaluation Criteria[2]
Aldrin	720	71	0.72	3.8
Benzene	10,400	1,040	10	
Carbon Tetrachloride[1]	2,300	30	2.3	
Chlordane[1]	3,700	55	3.7	12
Chloroacetic Acid[1]	77,000	77	77	
Chlorobenzene[1]	850,000	850	850	
Chloroform[1]	48,000	370	48	
DDE	13,000	1,300	13	
DDT[1]	14,000	410	14	14
DBCD	200	8	0.2	
1,2-Dichloroethane	3,200	320	3.2	
1,1-Dichloroethene	520	52	0.52	
DCPD[1]	NA	3,700	3,700	
Dieldrin	410	41	0.41	3.7
Endrin[1]	230,000	230	230	56
HCCPD[1]	NA	1,100	1,100	
Isodrin[1]	52,000	52	52	
Methylene Chloride[1]	35,000	2,300	35	
1,1,2,2-Tetrachloroethane	1,500	150	1.5	
Tetrachloroethylene[1]	5,400	410	5.4	
Toluene[1]	NA	7,200	7,200	
TCE	28,000	2,800	28	
Arsenic	4,200	420	4.2	270
Cadmium[1]	24,000	530	50	140
Chromium[1]	7,500	39	7.5	
Lead[1]	NA	2,200	2,200	
Mercury[1]	570,000	570	570	82

1 SEC based on noncarcinogenic PPLV.
2 Units presented in parts per million.

Table 7.1-5 Soil Exceedance Volumes by Medium Group[1,2]

Medium Group/Subgroup	Human Health Exceedance Volume[3] (BCY)	Principal Threat Exceedance Volume (BCY)	Excess Biota Volume; 0-1 ft (BCY)	Expected Agent Volume (BCY)	Expected UXO Volume (BCY)	UXO Debris Volume[4] (BCY)
Munitions Testing	0	0	0		450	89,000
North Plants	220	0	17,000	61		
Toxic Storage Yards	2,700	0	0	220		
Lake Sediments	16,000	0	19,000			
Ditches/Drainage	0	0	23,000			
Surficial Soil	87,000	1,500	460,000			
Basin A	160,000	32,000	88,000	710	94	47,000
Basin F Wastepile	600,000	600,000	0			
Secondary Basins	32,000	0	140,000			
Former Basin F	740,000	190,000	0			
Sanitary/Process Water Sewers	0	0	0			
Chemical Sewers	86,000	46,000	0	69		
Complex Trenches	400,000	400,000	0	1,300	1,300	130,000
Shell Trenches	100,000	100,000	0			
Hex Pit	3,300	3,300	0			
Sanitary Landfills[5]	14,000	0	23,000			
Section 36 Lime Basins	54,000	9,000	0	91		
Buried M-1 Pits	26,000	22,000	0	29		
S.P. Central Processing[6]	110,000	38,000	27,000	160		
S.P. Ditches	33,000	3,400	22,000			
S.P. Balance of Areas	130,000	11,000	510,000	160	50	5,000
Buried Sediments	16,000	0	0			
Sand Creek Lateral	15,000	0	90,000			
Section 36 Balance of Areas	64,000	0	140,000	300	160	78,000
Burial Trenches	28,000	0	0	12	550	57,000
Total	2,700,000	1,500,000	1,600,000	3,100	2,600	410,000

1 All volumes presented to two significant figures. Detailed volume calculations are available in the administrative record (Foster Wheeler 1996).

2 Individual volumes presented here may differ from those presented in the Detailed Analysis of Alternatives report (Volume IV, Appendix A) due to adjustments for overlap between exceedance categories. The total volume listed for each medium group remains consistent with those presented in the Detailed Analysis of Alternatives report.

3 The human health exceedance volume includes the principal threat exceedance volume.

4 The UXO debris volume includes human health exceedance volume as follows: Basin A, 16,500 BCY; Complex Trenches, 43,000 BCY; Section 36 Balance of Areas, 15,000 BCY; and Burial Trenches, 4,000 BCY.

5 This medium group also contains 380,000 BCY of nonhazardous soil and debris.

6 Exceedance volumes are based on a 5-ft depth cutoff due to difficulties in deeper excavation at this site. Additional exceedance volumes for the 5-ft to 10-ft depth interval are 32,000 BCY human health volume, including 17,000 BCY principal threat volume.

Table 7.1-6 Soil Exceedance Areas by Medium Group[1]

Medium Group/Subgroup	Human Health Exceedance Area (sy)	Principal Threat Exceedance Area (sy)	Excess Biota Area (sy)[2]	Potential Agent Area (sy)	Potential UXO Area (sy)
Munitions Testing	0	0	0		270,000
North Plants	330	0	50,000	28,000	
Toxic Storage Yards	1,700	0	0	130,000	
Lake Sediments	45,000	0	57,000		
Ditches/Drainage	0	0	70,000		
Surficial Soil	260,000	4,500	1,400,000		
Basin A	320,000	35,000	260,000	430,000	140,000
Basin F Wastepile	75,000	75,000	0		
Secondary Basins	92,000	0	410,000		
Former Basin F	350,000	110,000	0		
Sanitary/Process Water Sewers	0	0	0		
Chemical Sewers	100,000	49,000	0	76,000	
Complex Trenches	130,000	120,000	0	390,000	390,000
Shell Trenches	32,000	32,000	0		
Hex Pit	860	860	0		
Sanitary Landfills	12,000	0	69,000		
Section 36 Lime Basins	34,000	6,700	0	34,000	
Buried M-1 Pits	8,700	8,700	0	8,700	
S.P. Central Processing	140,000	42,000	80,000	98,000	
S.P. Ditches	50,000	5,500	65,000		
S.P. Balance of Areas	170,000	8,100	1,500,000	48,000	15,000
Buried Sediments	7,900	0	0		
Sand Creek Lateral	34,000	0	270,000		
Section 36 Balance of Areas	150,000	0	430,000	90,000	230,000
Burial Trenches	12,000	0	0	7,100	170,000
Total	2,000,000	500,000	4,700,000	1,300,000	1,200,000

1 All areas presented to two significant figures. Detailed area calculations are available in the administrative record.

2 Biota areas have been calculated to account for overlap with human health exceedance area and potential UXO area.

Table 7.2-1 Description of Water Alternatives

Alternative 1 Boundary Systems	Alternative 2 Boundary Systems / IRAs	Alternative 3 Boundary Systems / IRAs / Dewatering	Alternative 4 Boundary Systems / IRAs / Intercept Systems
Boundary systems continue to operate, but all on-post groundwater IRAs are dismantled. The ICS captures water from the Western Plume Group, the NWBCS captures water from the Northwest Boundary Plume Group, and the NBCS captures water from the North Boundary Plume Group.	Boundary systems continue to operate as in Alternative 1 and the on-post groundwater IRAs remain in operation. The IRAs include the two capture systems at the Motor Pool and Rail Yard area in the Western Plume Group that extract water and pump it for treatment at the ICS, the capture system north of Basin F in the North Boundary Plume Group that extracts water for treatment at the Basin A Neck System, and the Basin A Neck IRA that captures and treats water migrating from Basin A.	Boundary systems and IRAs continue to operate as in Alternative 2. Dewatering and treatment systems are installed to remove the contaminated central portions of the South Plants Plume Group and Basin A Plume Group groundwater. Dewatering accelerates lowering of the water table in South Plants and Basin A; the extracted water is treated in a new system. The South Tank Farm Plume in South Plants is treated separately by in situ biological treatment.	Boundary systems and IRAs continue to operate as in Alternative 2. Additionally, an extraction system is installed in the Section 36 Bedrock Ridge area to minimize contaminant migration from this part of the Basin A Plume Group. The extracted water is piped to the Basin A Neck system. Groundwater plumes in the South Plants area are monitored and lake-level maintenance or other means of hydaulic containment will be used to prevent South Plant plumes from migrating into the lakes at concentrations exceeding CBSGs.

Table 7.2-2 Capital and O&M Costs for Water Alternatives[1,2]

	Capital		Operating		Total	
Plume Group	Total Cost	PW Cost[3]	Total Cost	PW Cost[3]	Total Cost	PW Cost[3]
Alternative 1						
Northwest Boundary	0	0	32,500,000	21,500,000	32,500,000	21,500,000
Western	0	0	5,940,000	4,890,000	5,940,000	4,890,000
North Boundary	0	0	51,200,000	33,900,000	51,200,000	33,900,000
Basin A	28,500	28,500	3,280,000	2,340,000	3,308,500	2,368,500
South Plants	0	0	3,270,000	2,340,000	3,270,000	2,340,000
On-Post Water Supply[4]	15,000,000	14,600,000	0	0	15,000,000	14,600,000
Total	15,000,000	14,600,000	96,200,000	65,000,000	111,000,000	80,000,000
Alternative 2						
Northwest Boundary	0	0	32,500,000	21,500,000	32,500,000	21,500,000
Western	0	0	5,940,000	4,910,000	5,940,000	4,910,000
North Boundary	80,000	80,000	51,400,000	34,100,000	51,480,000	34,180,000
Basin A	0	0	30,700,000	20,500,000	30,700,000	20,500,000
South Plants	0	0	3,270,000	2,340,000	3,270,000	2,340,000
On-Post Water Supply[4]	15,000,000	14,600,000	0	0	15,000,000	14,600,000
Total	15,100,000	14,700,000	124,000	83,400,000	139,000,000	98,000,000
Alternative 3						
Northwest Boundary	0	0	32,500,000	21,500,000	32,500,000	21,500,000
Western	0	0	5,940,000	4,910,000	5,940,000	4,910,000
North Boundary	80,000	80,000	51,400,000	34,100,000	51,480,000	34,180,000
Basin A	7,050,000	6,940,000	41,300,000	27,600,000	48,350,000	34,540,000
South Plants	5,740,000	5,740,000	20,000,000	14,100,000	25,740,000	19,840,000
On-Post Water Supply[4]	15,000,000	14,600,000	0	0	15,000,000	14,600,000
Total	27,900,000	27,400,000	151,000,000	102,000,000	179,000,000	130,000,000
Alternative 4						
Northwest Boundary	0	0	32,500,000	21,500,000	32,500,000	21,500,000
Western	0	0	5,940,000	4,910,000	5,940,000	4,910,000
North Boundary	80,000	80,000	51,400,000	34,100,000	51,480,000	34,180,000
Basin A	3,540,000	3,540,000	29,800,000	19,800,000	33,340,000	23,340,000
South Plants	80,000	80,000	7,400,000	5,100,000	7,480,000	5,180,000
On-Post Water Supply[4]	15,000,000	14,600,000	0	0	15,000,000	14,600,000
Total	18,700,000	18,300,000	127,000,000	85,400,000	146,000,000	104,000,000

1 Detailed discussion of cost estimates is presented in the Detailed Analysis of Alternatives report.

2 All costs presented in 1995 dollars.

3 Present-worth calculations are based on a 3 percent discount rate.

4 Based on acquisition of a water supply of 1,500 acre-feet. Final on-post water requirements will be determined in the water management plan during remedial design.

Table 7.3-1 Description of Structures Alternatives

Alternative 1 Landfill/Cap in Place	Alternative 2 Landfill/Consolidate	Alternative 3 Landfill
• *No Future Use, Significant Contamination History:* The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris disposed in the on-post hazardous waste landfill.	• *No Future Use, Significant Contamination History:* The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris disposed in the on-post hazardous waste landfill.	• *No Future Use, Significant Contamination History:* The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris disposed in the on-post hazardous waste landfill.
• *No Future Use, Other Contamination History:* The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris consolidated and capped (multilayer caps) in one of three places: the Rail Yard, North Plants, or the South Plants Central Processing Area.	• *No Future Use, Other Contamination History:* The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris disposed in the Basin A consolidation area.	• *No Future Use, Other Contamination History:* The structures are dismantled using dust controls, metals salvaged (if appropriate), and the remaining debris disposed in the on-post hazardous waste landfill.
• *No Future Use, Agent History:* The structures are dismantled using dust controls and air monitoring, the debris monitored for the presence of Army chemical agent and caustic washed as necessary, and the resulting debris disposed in the on-post hazardous waste landfill.	• *No Future Use, Agent History:* The structures are dismantled using dust controls and air monitoring, the debris monitored for the presence of Army chemical agent and caustic washed as necessary, and the resulting debris disposed in the on-post hazardous waste landfill.	• *No Future Use, Agent History:* The structures are dismantled using dust controls and air monitoring, the debris monitored for the presence of Army chemical agent and caustic washed as necessary, and the resulting debris disposed in the on-post hazardous waste landfill.

Table 7.3-2 Capital and O&M Costs for Structures Alternatives[1, 2]

Medium Group	Capital Total Cost	PW Cost[3]	Operating Total Cost	PW Cost[3]	Total Total Cost	PW Cost[3]
Alternative 1						
No Future Use, Significant Contamination History	1,088,000	1,014,000	13,206,000	12,252,000	14,294,000	13,266,000
No Future Use, Other Contamination History	72,000	68,000	38,728,000	35,685,000	38,800,000	35,753,000
No Future Use, Agent History	5,888,000	5,517,000	55,323,000	51,345,000	61,211,000	56,862,000
Total	7,048,000	6,599,000	107,257,000	99,282,000	114,000,000	106,000,000
Alternative 2						
No Future Use, Significant Contamination History	1,088,000	1,014,000	13,206,000	12,252,000	14,294,000	13,266,000
No Future Use, Other Contamination History	0	0	36,636,000	34,030,000	36,636,000	34,030,000
No Future Use, Agent History	5,888,000	5,517,000	55,323,000	51,345,000	61,211,000	56,862,000
Total	6,976,000	6,531,000	105,165,000	97,627,000	112,000,000	104,000,000
Alternative 3						
No Future Use, Significant Contamination History	1,088,000	1,014,000	13,206,000	12,252,000	14,294,000	13,266,000
No Future Use, Other Contamination History	4,112,000	3,834,000	37,847,000	35,098,000	41,959,000	38,932,000
No Future Use, Agent History	5,888,000	5,517,000	55,323,000	51,345,000	61,211,000	56,862,000
Total	11,088,000	10,365,000	106,376,000	98,695,000	118,000,000	109,000,000

1 Detailed discussion of cost estimates is presented in the Detailed Analysis of Alternatives report.

2 All costs presented in 1995 dollars.

3 Present-worth calculations are based on a 3 percent discount rate.

Medium Groups/ Subgroups	Alternative 1 Caps/Covers[1]	Alternative 2 Landfill/Caps[1]	Alternative 3 Landfill[1]	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill[1]
Munitions Testing	Munitions screening; off-post detonation of UXO; landfill debris and soil above TCLP.	Munitions screening; off-post detonation of UXO; landfill debris and soil above TCLP.	Munitions screening; off-post detonation of UXO; landfill debris and soil above TCLP.	Munitions screening; off-post detonation of UXO; landfill debris and soil above TCLP.	Munitions screening; off-post detonation of UXO; landfill debris and soil above TCLP.
North Plants	Landfill human health exceedance; agent monitoring during excavation; caustic washing; install soil cover over soil posing risk to biota and processing area.	Landfill human health exceedance; agent monitoring during excavation; caustic washing; install soil cover over soil posing risk to biota and processing area.	Landfill human health exceedance; agent monitoring during excavation; caustic washing; install soil cover over soil posing risk to biota and processing area.	Landfill human health exceedance; agent monitoring during excavation; caustic washing; install soil cover over soil posing risk to biota and processing area.	Landfill human health exceedance; agent monitoring during excavation; caustic washing; install soil cover over soil posing risk to biota and processing area.
Toxic Storage Yards	Landfill human health exceedance; utilize New Toxic Storage Yard for borrow area; agent monitoring during excavation and site preparation; caustic washing.	Landfill human health exceedance; utilize New Toxic Storage Yard for borrow area; agent monitoring during excavation and site preparation; caustic washing.	Landfill human health exceedance; utilize New Toxic Storage Yard for borrow area; agent monitoring during excavation and site preparation; caustic washing.	Landfill human health exceedance; utilize New Toxic Storage Yard for borrow area; agent monitoring during excavation and site preparation; caustic washing.	Landfill human health exceedance; utilize New Toxic Storage Yard for borrow area; agent monitoring during excavation and site preparation; caustic washing.
Lake Sediments	Landfill human health exceedances; additional action determined by Parties based on continuing monitoring of biota in these areas.	Landfill human health exceedances; additional action determined by Parties based on continuing monitoring of biota in these areas.	Landfill human health exceedances and soil posing risk to biota (Upper Derby Lake); deferral to USFWS for aquatic sediments.	Landfill human health exceedances and consolidate soil posing risk to biota (Upper Derby Lake); deferral to USFWS for aquatic sediments.	Landfill human health exceedances and soil posing risk to biota (Upper Derby Lake); deferral to USFWS for aquatic sediments.

Table 7.4-1 Description of Soil Alternatives

Medium Groups/ Subgroups	Alternative 1 Caps/Covers[1]	Alternative 2 Landfill/Caps[1]	Alternative 3 Landfill[1]	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill[1]
Surficial Soil	Landfill human health exceedances; additional action determined by Parties based on continuing monitoring of biota in these areas.	Landfill human health exceedances; additional action determined by Parties based on continuing monitoring of biota in these areas.	Landfill human health exceedances; additional action determined by Parties based on continuing monitoring of biota in these areas.	Landfill human health exceedances; consolidate soil posing risk to biota in Basin A, Former Basin F, and South Plants; additional action determined by Parties based on continuing monitoring of biota in these areas.	Agricultural practices for soil posing risks to biota and landfill human health exceedances.
Ditches/Drainage Areas	Additional action determined by Parties based on continuing monitoring of biota in these areas.	Additional action determined by Parties based on continuing monitoring of biota in these areas.	Landfill soil posing risk to biota.	Consolidate soil posing risk to biota in Basin A.	Landfill soil posing risk to biota.
Basin A	Cap principal threat and human health exceedances and soil posing risk to biota.	Cap principal threat and human health exceedances and soil posing risk to biota.	Landfill principal threat and human health exceedances; cap entire site including soil posing risk to biota.[2]	Construct soil cover with concrete barrier over principal threat and human health exceedances and soil posing risk to biota; consolidate soil posing risk to biota/structural debris from other sites.	Thermal desorption of principal threat soil; landfill human health including treated soil; cap entire site including soil posing risk to biota.[2]
Basin F Wastepile	Modify existing cap according to RCRA requirements (composite cap).	Modify existing cap according to RCRA requirements (composite cap).	Modify existing cap according to RCRA requirements (composite cap).	Landfill entire wastepile (principal threat exceedance) in triple-lined cell (excavate with vapor control) after drying saturated materials.	Thermal desorption of entire wastepile (principal threat exceedance) (excavate with vapor control); landfill treated soil.

Medium Groups/ Subgroups	Alternative 1 Caps/Covers[1]	Alternative 2 Landfill/Caps[1]	Alternative 3 Landfill[1]	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill[1]
Former Basin F	Modify existing cap to RCRA-equivalent cap.	Modify existing cap to RCRA-equivalent cap.	Landfill principal threat and human health exceedances (excavate under vapor enclosure); cap entire site.	In situ solidification/ stabilization of principal threat exceedance volume; cap entire site with RCRA-equivalent cap.	Thermal desorption of principal threat soil (excavate under vapor enclosure); landfill human health exceedances including treated soil; cap entire site.
Secondary Basins	Cap human health exceedances and soil posing risk to biota.	Landfill human health exceedances and soil posing risk to biota.	Landfill human health exceedances and soil posing risk to biota.	Landfill human health exceedances; install soil cover over soil posing risk to biota.	Landfill human health exceedances and soil posing risk to biota.
Sanitary/Process Water Sewers	Plug remaining manholes.	Plug remaining manholes.	Landfill sewer lines.	Plug remaining manholes.	Plug remaining manholes.
Chemical Sewers	Plug sewer lines.	Plug sewer lines in South Plants Central Processing Area and Complex Trenches; landfill remaining principal threat and human health exceedances.[2]	Landfill principal threat and human health exceedances.[2]	Plug sewer lines in South Plants Central Processing Area and Complex Trenches; landfill remaining principal threat and human health exceedances.[2]	Thermal desorption of principal threat soil; landfill human health exceedances including treated principal threat soil.[2]
Complex Trenches	Cap principal threat and human health exceedances and soil posing risk to biota and install a slurry wall around disposal trenches.	Cap principal threat and human health exceedances and soil posing risk to biota and install a slurry wall around disposal trenches.	Cap principal threat and human health exceedances and soil posing risk to biota and install a slurry wall around disposal trenches.	Cap (RCRA-equivalent cap with concrete barrier) principal threat and human health exceedances and soil posing risk to biota and install a slurry wall around disposal trenches.	Cap principal threat and human health exceedances and soil posing risk to biota and install a slurry wall around disposal trenches.

Medium Groups/ Subgroups	Alternative 1 Caps/Covers[1]	Alternative 2 Landfill/Caps[1]	Alternative 3 Landfill[1]	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill[1]
Shell Trenches	Modify existing cover and install slurry wall around trenches.	Modify existing cover and install slurry wall around trenches.	Landfill trenches after materials handling (excavate with vapor control).	Modify existing cover to be RCRA-equivalent cap and modify existing slurry wall around trenches.	Incinerate trenches; landfill treated soil (excavate with vapor control).
Hex Pit	Install cap and slurry wall around trenches.	Install cap and slurry wall around trenches.	Landfill disposal pit after materials handling (excavate with vapor control).	Treatment of approximately 1,000 bcy of principal threat material using an innovative thermal technology and landfill remaining soil (excavate with vapor control). Treatment will be revised to a solidification/ stabilization technology if all evaluation criteria for the innovative thermal technology are not met.	Incinerate disposal pit; landfill treated soil (excavate with vapor control).
Sanitary Landfills	Cap entire site.	Landfill human health exceedances, debris, and soil posing risk to biota.	Landfill human health exceedances, debris, and soil posing risk to biota.	Landfill human health exceedances; consolidate debris and soil posing risk to biota in Basin A.	Landfill human health exceedances, debris, and soil posing risk to biota.
Section 36 Lime Basins	Modify existing cover.	Modify existing cover.	Landfill principal threat and human health exceedances; cap entire site.[2]	Landfill principal threat and human health exceedances in triple-lined cell; repair existing soil cover.[2]	Landfill principal threat and human health exceedances; cap entire site.[2]

Medium Groups/ Subgroups	Alternative 1 Caps/Covers[1]	Alternative 2 Landfill/Caps[1]	Alternative 3 Landfill[1]	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill[1]
Buried M-1 Pits	Install cap and slurry wall around entire site.	Install cap and slurry wall around entire site.	Landfill principal threat and human health exceedances (excavate with vapor control).[2]	Solidification/ stabilization and landfill of principal threat and human health exceedances (excavate with vapor control).[2]	Solidification/ stabilization and landfill of principal threat and human health exceedances (excavate with vapor control).[2]
South Plants Central Processing Area	Cap principal threat and human health exceedances and soil posing risk to biota.	Cap principal threat and human health exceedances and soil posing risk to biota.	Landfill principal threat and human health exceedances; cap entire site including soil posing risk to biota.[2]	Landfill principal threat and human health exceedances (excavate to depth of 5 feet); construct soil cover with biota barrier over entire site including soil posing risk to biota; consolidate soil posing risk to biota from other South Plants sites.[2]	Thermal desorption and solidification of principal threat exceedances; landfill human health exceedances including treated soil; cap entire site including soil posing risk to biota.[2]
South Plants Ditches	Cap principal threat and human health exceedances and soil posing risk to biota.	Landfill principal threat and human health exceedances and soil posing risk to biota.	Landfill principal threat and human health exceedances and soil posing risk to biota.	Landfill principal threat and human health exceedances; consolidate soil posing risk to biota into excavated areas; install soil cover (variable thickness) over entire site.	Thermal desorption of principal threat soil; landfill human health exceedances, including treated soil and soil posing risk to biota.
South Plants Balance of Areas	Cap principal threat and human health exceedances and soil posing risk to biota.	Landfill principal threat and human health exceedances and soil posing risk to biota.[2,3]	Landfill principal threat and human health exceedances and soil posing risk to biota.[2,3]	Landfill principal threat and human health exceedances; consolidate soil posing risk to biota into excavated areas; install soil cover (variable thickness) over entire site.[2,3]	Thermal desorption of principal threat soil; landfill human health exceedances, including treated soil and soil posing risk to biota.[2,3]

Medium Groups/ Subgroups	Alternative 1 Caps/Covers[1]	Alternative 2 Landfill/Caps[1]	Alternative 3 Landfill[1]	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill[1]
Buried Sediments	Cap human health exceedances.	Landfill human health exceedances.	Landfill human health exceedances.	Landfill human health exceedances.	Landfill human health exceedances.
Sand Creek Lateral	Cap human health exceedances and soil posing risk to biota.	Landfill human health exceedances and soil posing risk to biota.	Landfill human health exceedances and soil posing risk to biota.	Landfill human health exceedances; consolidate soil posing risk to biota into Basin A.	Landfill human health exceedances and soil posing risk to biota.
Section 36 Balance of Areas	Cap human health exceedances and soil posing risk to biota.	Landfill human health exceedances and soil posing risk to biota.[2,3]	Landfill human health exceedances and soil posing risk to biota.[2,3]	Landfill human health exceedances; consolidate soil posing risk to biota into Basin A; install soil cover (variable thickness) over entire site.[2,3]	Landfill human health exceedances and soil posing risk to biota.[2,3]
Burial Trenches	Landfill human health exceedances.[2,3]	Landfill human health exceedances.[2,3]	Landfill human health exceedances.[2,3]	Landfill human health exceedances.[2,3]	Landfill human health exceedances.[2,3]

1 Cap consists of a clay/soil cap unless otherwise noted.
2 Agent monitoring during excavation and treatment of any soil containing agent by caustic washing.
3 Munitions screening prior to excavation, off-post detonation of any munitions encountered, and landfilling of munitions debris and associated soil above TCLP.

Table 7.4-2 Capital and O&M Costs for Soil Alternatives[1]

	Capital Cost		O&M Cost		Total Cost	
Medium Group/Subgroup	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]
Sitewide Alternative 1 - Caps/Covers						
Munitions Testing	$ 7,110,000	$ 6,150,000	$ 713,000	$ 296,000	$ 7,820,000	$ 6,450,000
North Plants	$ 2,370,000	$ 1,770,000	$ 1,610,000	$ 670,000	$ 3,980,000	$ 2,440,000
Toxic Storage Yards	$ 4,310,000	$ 3,720,000	$ 1,330,000	$ 554,000	$ 5,640,000	$ 4,270,000
Lake Sediments	$ 3,350,000	$ 2,160,000	$ 154,000	$ 63,800	$ 3,500,000	$ 2,220,000
Surficial Soil	$ 12,420,000	$ 8,470,000	$ 680,000	$ 282,000	$ 13,100,000	$ 8,750,000
Ditches/Drainage Areas	$ -	$ -	$ -	$ -	$ -	$ -
Basin A	$ 58,400,000	$ 52,000,000	$ 3,580,000	$ 1,490,000	$ 61,980,000	$ 53,500,000
Basin F Wastepile	$ 8,160,000	$ 5,920,000	$ 6,360,000	$ 2,640,000	$ 14,500,000	$ 8,560,000
Secondary Basins	$ 53,900,000	$ 34,100,000	$ 2,930,000	$ 1,220,000	$ 56,800,000	$ 35,300,000
Former Basin F	$ 36,300,000	$ 24,400,000	$ 2,730,000	$ 1,130,000	$ 39,000,000	$ 25,500,000
Sanitary/Process Water Sewers	$ 344,000	$ 280,000	$ -	$ -	$ 344,000	$ 280,000
Chemical Sewers	$ 853,000	$ 719,000	$ 2,720,000	$ 1,130,000	$ 3,570,000	$ 1,850,000
Complex Trenches	$ 38,400,000	$ 26,600,000	$ 6,970,000	$ 2,900,000	$ 45,400,000	$ 29,500,000
Shell Trenches	$ 2,930,000	$ 2,400,000	$ 2,650,000	$ 1,100,000	$ 5,580,000	$ 3,500,000
Hex Pit	$ 676,000	$ 588,000	$ 984,000	$ 409,000	$ 1,660,000	$ 1,000,000
Sanitary Landfills	$ 14,300,000	$ 10,300,000	$ 1,000,000	$ 416,000	$ 15,300,000	$ 10,700,000
Section 36 Lime Basins	$ 4,520,000	$ 3,280,000	$ 1,200,000	$ 498,000	$ 5,720,000	$ 3,780,000
Buried M-1 Pits	$ 1,660,000	$ 1,450,000	$ 1,020,000	$ 422,000	$ 2,680,000	$ 1,870,000
South Plants Central Processing Area	$ 26,400,000	$ 21,500,000	$ 1,820,000	$ 757,000	$ 28,200,000	$ 22,300,000
South Plants Ditches	$ 8,590,000	$ 6,600,000	$ 1,410,000	$ 586,000	$ 10,000,000	$ 7,190,000
South Plants Balance Of Areas	$ 126,000,000	$ 96,800,000	$ 7,730,000	$ 3,210,000	$ 134,000,000	$ 100,000,000
Buried Sediments	$ 3,380,000	$ 2,840,000	$ 994,000	$ 413,000	$ 4,370,000	$ 3,250,000
Sand Creek Lateral	$ 16,500,000	$ 10,900,000	$ 2,160,000	$ 897,000	$ 18,700,000	$ 11,800,000
Section 36 Balance Of Areas	$ 46,800,000	$ 33,300,000	$ 3,900,000	$ 1,620,000	$ 50,700,000	$ 34,900,000
Burial Trenches	$ 8,190,000	$ 6,680,000	$ 772,000	$ 321,000	$ 8,960,000	$ 7,000,000
Total	$ 486,000,000	$ 363,000,000	$ 55,400,000	$ 23,000,000	$ 542,000,000	$ 386,000,000

Table 7.4-2 Capital and O&M Costs for Soil Alternatives[1]

	Capital Cost		O&M Cost		Total Cost	
Medium Group/Subgroup	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]
Sitewide Alternative 2 - Landfill/Caps						
Munitions Testing	$5,930,000	$5,130,000	$258,000	$110,000	$6,190,000	$5,240,000
North Plants	$2,160,000	$1,610,000	$1,360,000	$581,000	$3,520,000	$2,190,000
Toxic Storage Yards	$3,230,000	$2,790,000	$391,000	$167,000	$3,620,000	$2,960,000
Lake Sediments	$3,100,000	$2,000,000	$55,600	$23,800	$3,160,000	$2,020,000
Surficial Soil	$11,400,000	$7,510,000	$246,000	$105,000	$11,600,000	$7,620,000
Ditches/Drainage Areas	$0	$0	$0	$0	$0	$0
Basin A	$55,900,000	$49,000,000	$3,580,000	$1,530,000	$59,500,000	$50,500,000
Basin F Wastepile	$8,280,000	$6,190,000	$6,360,000	$2,720,000	$14,600,000	$8,910,000
Secondary Basins	$12,900,000	$8,290,000	$487,000	$208,000	$13,400,000	$8,500,000
Former Basin F	$38,200,000	$25,600,000	$2,730,000	$1,170,000	$40,900,000	$26,800,000
Sanitary/Process Water Sewers	$344,000	$280,000	$0	$0	$344,000	$280,000
Chemical Sewers	$12,000,000	$10,000,000	$608,000	$260,000	$12,600,000	$10,260,000
Complex Trenches	$40,100,000	$27,700,000	$6,970,000	$2,980,000	$47,100,000	$30,700,000
Shell Trenches	$2,980,000	$2,440,000	$2,650,000	$1,140,000	$5,630,000	$3,580,000
Hex Pit	$677,000	$590,000	$984,000	$421,000	$1,660,000	$1,010,000
Sanitary Landfills	$29,700,000	$21,500,000	$1,210,000	$520,000	$30,900,000	$22,000,000
Section 36 Lime Basins	$4,680,000	$3,490,000	$1,200,000	$513,000	$5,880,000	$4,000,000
Buried M-1 Pits	$1,680,000	$1,420,000	$1,020,000	$435,000	$2,700,000	$1,860,000
South Plants Central Processing Area	$17,400,000	$13,800,000	$1,820,000	$780,000	$19,200,000	$14,600,000
South Plants Ditches	$4,780,000	$3,670,000	$162,000	$69,400	$4,940,000	$3,740,000
South Plants Balance Of Areas	$47,600,000	$36,000,000	$2,130,000	$912,000	$49,700,000	$36,900,000
Buried Sediments	$1,890,000	$1,590,000	$45,400	$19,400	$1,940,000	$1,610,000
Sand Creek Lateral	$9,370,000	$6,200,000	$303,000	$130,000	$9,670,000	$6,330,000
Section 36 Balance Of Areas	$26,100,000	$18,600,000	$1,350,000	$576,000	$27,500,000	$19,200,000
Burial Trenches	$6,900,000	$5,460,000	$266,000	$114,000	$7,170,000	$5,570,000
Total	$347,000,000	$261,000,000	$36,200,000	$15,500,000	$383,000,000	$276,000,000

Table 7.4-2 Capital and O&M Costs for Soil Alternatives[1]

Medium Group/Subgroup	Capital Cost		O&M Cost		Total Cost	
	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]
Sitewide Alternative 3 - Landfill						
Munitions Testing	$5,790,000	$4,860,000	$197,000	$70,700	$5,990,000	$4,930,000
North Plants	$2,120,000	$1,590,000	$1,310,000	$470,000	$3,430,000	$2,060,000
Toxic Storage Yards	$3,030,000	$2,620,000	$215,000	$77,000	$3,250,000	$2,700,000
Lake Sediments	$4,320,000	$2,550,000	$84,500	$30,300	$4,400,000	$2,580,000
Surficial Soil	$11,200,000	$7,440,000	$188,000	$67,500	$11,400,000	$7,510,000
Ditches/Drainage Areas	$4,270,000	$2,830,535	$114,000	$40,854	$4,380,000	$2,870,000
Basin A	$74,300,000	$61,600,000	$4,810,000	$1,720,000	$79,100,000	$63,300,000
Basin F Wastepile	$8,310,000	$5,850,000	$6,360,000	$2,280,000	$14,700,000	$8,130,000
Secondary Basins	$12,700,000	$7,450,000	$373,000	$134,000	$13,100,000	$7,600,000
Former Basin F	$138,000,000	$85,900,000	$4,450,000	$1,600,000	$142,000,000	$87,500,000
Sanitary/Process Water Sewers	$10,300,000	$8,390,000	$26,600	$9,516	$10,300,000	$8,400,000
Chemical Sewers	$17,800,000	$14,900,000	$415,000	$149,000	$18,200,000	$15,000,000
Complex Trenches	$40,600,000	$22,800,000	$6,970,000	$2,500,000	$47,600,000	$25,300,000
Shell Trenches	$35,300,000	$24,100,000	$221,000	$79,300	$35,500,000	$24,200,000
Hex Pit	$4,770,000	$4,020,000	$7,300	$2,620	$4,780,000	$4,020,000
Sanitary Landfills	$30,000,000	$16,100,000	$929,000	$333,000	$30,900,000	$16,400,000
Section 36 Lime Basins	$10,100,000	$7,130,000	$1,430,000	$511,000	$11,500,000	$7,640,000
Buried M-1 Pits	$6,890,000	$5,800,000	$83,900	$30,100	$6,970,000	$5,830,000
South Plants Central Processing Area	$28,600,000	$21,900,000	$2,270,000	$815,000	$30,900,000	$22,700,000
South Plants Ditches	$4,710,000	$3,510,000	$124,000	$44,500	$4,830,000	$3,550,000
South Plants Balance Of Areas	$46,600,000	$34,000,000	$1,570,000	$562,000	$48,200,000	$34,600,000
Buried Sediments	$1,870,000	$1,530,000	$34,800	$12,500	$1,900,000	$1,540,000
Sand Creek Lateral	$9,230,000	$6,110,000	$232,000	$83,200	$9,460,000	$6,190,000
Section 36 Balance Of Areas	$25,500,000	$14,800,000	$914,000	$328,000	$26,400,000	$15,100,000
Burial Trenches	$6,770,000	$4,490,000	$199,000	$71,200	$6,970,000	$4,560,000
Total	$543,000,000	$372,000,000	$33,500,000	$12,000,000	$576,000,000	$384,000,000

Table 7.4-2 Capital and O&M Costs for Soil Alternatives[1]

	Capital Cost		O&M Cost		Total Cost	
Medium Group/Subgroup	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]
Sitewide Alternative 4 - Consolidation/Caps/Treatment/Landfill						
Munitions Testing	$6,150,000	$5,320,000	$379,000	$157,000	$6,530,000	$5,480,000
North Plants	$2,120,000	$1,580,000	$1,340,000	$557,000	$3,460,000	$2,140,000
Toxic Storage Yards	$3,160,000	$2,730,000	$334,000	$139,000	$3,490,000	$2,870,000
Lake Sediments	$3,790,000	$2,440,000	$81,700	$33,900	$3,870,000	$2,470,000
Surficial Soil	$20,000,000	$13,500,000	$361,000	$150,000	$20,400,000	$13,700,000
Ditches/Drainage Areas	$2,410,000	$1,600,000	$0	$0	$2,410,000	$1,600,000
Basin A	$52,900,000	$42,500,000	$4,330,000	$1,800,000	$57,200,000	$44,300,000
Basin F Wastepile	$130,000,000	$92,300,000	$2,180,000	$904,000	$132,000,000	$93,200,000
Secondary Basins	$7,840,000	$5,350,000	$2,010,000	$835,000	$9,850,000	$6,190,000
Former Basin F	$83,200,000	$52,800,000	$4,210,000	$1,750,000	$87,400,000	$54,600,000
Sanitary/Process Water Sewers	$344,000	$289,000	$0	$0	$344,000	$289,000
Chemical Sewers	$12,000,000	$10,400,000	$619,000	$257,000	$12,600,000	$10,700,000
Complex Trenches	$47,000,000	$31,100,000	$8,370,000	$3,480,000	$55,400,000	$34,600,000
Shell Trenches	$2,850,000	$2,330,000	$3,400,000	$1,410,000	$6,250,000	$3,740,000
Hex Pit	$5,180,000	$4,480,000	$9,800	$4,100	$5,190,000	$4,480,000
Sanitary Landfills	$14,600,000	$11,200,000	$58,600	$24,300	$14,700,000	$11,200,000
Section 36 Lime Basins	$8,170,000	$6,090,000	$326,000	$135,000	$8,500,000	$6,230,000
Buried M-1 Pits	$24,000,000	$20,100,000	$192,000	$79,800	$24,200,000	$20,200,000
South Plants Central Processing Area	$18,900,000	$15,400,000	$2,950,000	$1,220,000	$21,900,000	$16,600,000
South Plants Ditches	$3,020,000	$2,390,000	$142,000	$58,900	$3,160,000	$2,450,000
South Plants Balance Of Areas	$34,900,000	$27,600,000	$4,960,000	$2,060,000	$39,900,000	$29,700,000
Buried Sediments	$1,830,000	$1,540,000	$66,800	$27,700	$1,900,000	$1,570,000
Sand Creek Lateral	$4,720,000	$3,130,000	$62,400	$25,900	$4,780,000	$3,160,000
Section 36 Balance Of Areas	$19,100,000	$13,600,000	$3,500,000	$1,450,000	$22,600,000	$15,100,000
Burial Trenches	$7,100,000	$6,140,000	$377,000	$157,000	$7,480,000	$6,300,000
Contingent Soil Volume	$9,860,000	$8,020,000	$637,000	$265,000	$10,500,000	$8,300,000
Total	$525,000,000	$384,000,000	$40,900,000	$17,000,000	$566,000,000	$401,000,000

Table 7.4-2 Capital and O&M Costs for Soil Alternatives[1]

	Capital Cost		O&M Cost		Total Cost	
Medium Group/Subgroup	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]	Total Cost	Present Worth[2]
Sitewide Alternative 5 - Caps/Treatment/Landfill						
Munitions Testing	$5,710,000	$4,800,000	$174,000	$52,300	$5,880,000	$4,850,000
North Plants	$2,130,000	$1,590,000	$1,310,000	$393,000	$3,440,000	$1,980,000
Toxic Storage Yards	$3,020,000	$2,610,000	$214,000	$64,100	$3,230,000	$2,670,000
Lake Sediments	$4,300,000	$2,000,000	$74,600	$22,400	$4,370,000	$2,020,000
Surficial Soil	$11,700,000	$6,680,000	$166,000	$49,900	$11,900,000	$6,730,000
Ditches/Drainage Areas	$4,230,000	$2,570,000	$101,000	$30,200	$4,330,000	$2,600,000
Basin A	$73,300,000	$50,200,000	$13,300,000	$4,000,000	$86,600,000	$54,200,000
Basin F Wastepile	$87,200,000	$63,000,000	$206,000,000	$61,900,000	$293,000,000	$125,000,000
Secondary Basins	$12,500,000	$6,550,000	$329,000	$98,800	$12,800,000	$6,650,000
Former Basin F	$151,000,000	$98,600,000	$53,400,000	$16,000,000	$204,000,000	$115,000,000
Sanitary/Process Water Sewers	$344,000	$297,000	$0	$0	$344,000	$297,000
Chemical Sewers	$19,200,000	$16,100,000	$12,800,000	$3,850,000	$32,000,000	$20,000,000
Complex Trenches	$40,800,000	$22,900,000	$6,970,000	$2,090,000	$47,800,000	$25,000,000
Shell Trenches	$52,000,000	$31,100,000	$37,100,000	$11,100,000	$89,100,000	$42,200,000
Hex Pit	$5,490,000	$4,490,000	$1,220,000	$367,000	$6,710,000	$4,860,000
Sanitary Landfills	$29,700,000	$14,000,000	$820,000	$246,000	$30,500,000	$14,200,000
Section 36 Lime Basins	$10,100,000	$5,450,000	$1,410,000	$424,000	$11,510,000	$5,870,000
Buried M-1 Pits	$13,600,000	$10,800,000	$9,090,000	$2,730,000	$22,700,000	$13,500,000
South Plants Central Processing Area	$29,800,000	$24,300,000	$13,000,000	$3,890,000	$42,800,000	$28,200,000
South Plants Ditches	$4,740,000	$3,640,000	$781,000	$234,000	$5,520,000	$3,870,000
South Plants Balance Of Areas	$46,300,000	$36,100,000	$3,480,000	$1,040,000	$49,800,000	$37,100,000
Buried Sediments	$1,860,000	$1,130,000	$30,700	$9,210	$1,890,000	$1,140,000
Sand Creek Lateral	$9,150,000	$5,380,000	$205,000	$61,500	$9,360,000	$5,440,000
Section 36 Balance Of Areas	$25,200,000	$13,400,000	$840,000	$252,000	$26,000,000	$13,700,000
Burial Trenches	$6,700,000	$5,150,000	$177,000	$53,000	$6,880,000	$5,200,000
Total	$650,000,000	$433,000,000	$363,000,000	$109,000,000	$1,012,000,000	$542,000,000

[1] All costs presented in 1995 dollars.

[2] Present-worth calculations based on a 3 percent discount rate.

8.0 Comparative Analysis of Alternatives

The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to the others and to identify the tradeoffs to be made in selecting the preferred alternatives. A preferred alternative was developed for each contaminated medium (groundwater, structures and soil) because the interactions among potential soil alternatives and water or structures alternatives were most effectively addressed in this manner.

The NCP identifies nine criteria to be used in the evaluation of remedial alternatives during the Detailed Analysis of Alternatives (Figure 8.0-1). Criteria 1 and 2 (Overall Protection of Human Health and the Environment, and Compliance with ARARs) are considered "threshold criteria" that must be met by the preferred alternative. Criteria 3 through 7 (Short-Term Effectiveness; Long-Term Effectiveness; Reduction of Toxicity, Mobility, or Volume through Treatment; Implementability; and Cost) are considered "balancing criteria" because they are used to achieve the best overall solution, taking into account technical, cost, institutional, and risk concerns. As required by EPA guidance, costs are compared on a present worth basis. The present worth cost is the amount of principal (in current dollars) needed to yield the total cost over the desired time frame; it accounts for interest gained on principal invested at the start of the project and the cost of inflation over the life of the project. Criteria 8 and 9 (State Acceptance and Community Acceptance) are used to evaluate the feasibility of implementing an alternative in terms of its acceptance by regulatory agencies and the community.

8.1 Comparative Analysis of Alternatives for Groundwater

The four groundwater alternatives compared in this section all include continued operation of the boundary containment and treatment systems that are currently operational at RMA. Three of the four alternatives (Alternatives 2, 3, and 4) involve continued operation of the existing IRAs, and two alternatives (Alternatives 3 and 4) include construction of additional on-post extraction and treatment systems. The No Action alternative (which involves discontinuing the existing boundary systems) was evaluated in the FS, but because it does not achieve the threshold criteria (overall protection of human health and the environment and compliance with ARARs), it was not retained as a potential remedy. A summary of the comparative analysis of the groundwater alternatives is provided in Table 8.1-1.

8.1.1 Overall Protection of Human Health and the Environment

All four groundwater alternatives are protective of human health and the environment because groundwater is treated at the RMA boundary and because restrictions for potable on-post water use imposed by the FFA are observed. Nonpotable uses of on-post groundwater were not anticipated and risk was therefore not considered in the HHRC for such uses. A risk evaluation would be performed prior to any future nonpotable use to ensure that such use is protective of human health and the environment.

A greater degree of protection is provided by Alternative 3 (Boundary Systems/IRAs/Dewatering), which reduces on-post migration through additional on-post extraction and treatment systems. The operation of the dewatering and extraction systems will reduce flow through Basin A Neck, reduce the South Plants groundwater mound, limit migration into the lakes, and prevent flow through the Section 36 bedrock ridge. Migration is also reduced by the on-post systems included in Alternatives 2 (Boundary Systems/IRAs) and 4 (Boundary Systems/IRAs/Intercept Systems). Because Alternative 4 includes an additional on-post system (the Section 36 Bedrock Ridge Extraction System), it is slightly more protective than Alternative 2. Alternatives 2 and 4 also result in a natural lowering of the water table in South Plants when combined with the soil covers or caps in this area. Lowering of the water table will reduce further spreading of contamination, thereby protecting human health and the environment. Alternative 1 (Boundary Systems) is adequately protective of human health and the environment, but is slightly less protective than the other three alternatives because it only addresses groundwater contamination at the boundaries. Site reviews will be conducted every 5 years to evaluate the effectiveness of the remedies and ensure protection of human health and the environment.

8.1.2 Compliance with ARARs

All four alternatives, if selected, are expected to meet chemical-specific ARARs identified for each treatment system and comply with action- and location-specific ARARs. The remediation goals for chloride and sulfate at the NBCS will be achieved through natural attenuation. The goal for sulfate will be the natural background concentration. Assessment of the chloride and sulfate concentrations will occur at the 5-year site review. Monitoring and assessment of NDMA contamination will occur in support of potential design refinement/design characterization to achieve the remediation goals specified for boundary groundwater treatment systems.

8.1.3 Long-Term Effectiveness and Permanence

All four alternatives provide a high degree of long-term effectiveness and permanence because operation of the boundary systems eliminates the potential for off-post exposure and because restrictions for potable on-post water use imposed by the FFA are observed. Nonpotable uses of on-post groundwater were not anticipated and risk was therefore not considered in the HHRC for such uses. A risk evaluation would be performed prior to any future nonpotable use to ensure that such use is protective of human health and the environment.

Boundary system operations are proven, effective, and reliable, and treatment residuals are safely disposed off post. All alternatives also reduce contaminant migration through passive dewatering, a result of a reduction of infiltration and removal of water from process and fire protection pipes in the areas of South Plants and Basin A that will be covered as a part of the selected soil remedy. Additionally, Alternative 2 reduces contaminant migration through operation of the IRAs. Alternative 3 achieves contaminant reduction through active dewatering as well as operation of the on-post IRAs. Alternative 4 reduces contaminant migration through continued operation of the IRAs and the Section 36 Bedrock Ridge Extraction System.

8.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Operation of the boundary systems, which is a component of all four alternatives, provides substantial reduction in toxicity, mobility, or volume through treatment of contaminated groundwater; approximately 1 billion gallons per year of water are currently being treated at the systems. Alternatives 2, 3, and 4 provide additional reduction in toxicity, mobility, or volume because they involve operation of the IRAs and additional on-post extraction/treatment systems. Compared to Alternative 1, Alternatives 2 and 4 treat approximately 170 million additional gallons per year, while Alternative 3 treats an additional 215 million gallons per year for the first 10 years and 190 million gallons per year for the next 20 years. On-post treatment under Alternatives 2, 3, or 4 will be continued until remediation is complete.

All alternatives achieve reductions in contaminant mobility and volume through passive dewatering, which is a result of installation of the soil covers or caps in the Basin A and South Plants areas. Mobility and volume are not reduced through treatment but through passive methods. Alternative 3 achieves the most rapid reduction in toxicity, mobility, or volume through active dewatering, which lowers the water table, thereby reducing migration and leaching of residual contamination from soil. Alternative 4 is slightly more effective in reducing toxicity than Alternative 2 because the additional volume of contaminated water that is extracted and treated is small. Alternative 4 also reduces or prevents the mobility of contaminants in groundwater, thus reducing/preventing their migration into the First Creek alluvial channel.

8.1.5 Short-Term Effectiveness

All four alternatives are protective of workers, the community, and the environment during the construction and implementation phases. Alternative 2 has the least impact as it is already in place and involves no additional actions. Alternatives 1 and 4 have minimal potential impacts. For Alternative 1, these impacts are associated with demolition of the existing IRAs; for Alternative 4, they are associated with drilling and construction of the Section 36 Bedrock Ridge Extraction System. Alternative 3 involves more intrusive activities than the other three alternatives, but it can still be implemented within a fairly short time period and with minimal negative impact to workers, the community, and the environment.

8.1.6 Implementability

Alternative 2 is most easily implemented because it involves continued operation of all existing systems without any additional construction or demolition. Alternatives 1 and 4 are slightly more difficult to implement than Alternative 2 because they involve installation of a small extraction and piping system (Alternative 4) or demolition of the existing IRAs (Alternative 1). Alternative 3 is the most difficult to implement since it requires installation of horizontal well networks and a new treatment system. All of the alternatives use available technologies that are both technically and administratively implementable, although horizontal wells are an innovative technology. The monitoring systems included in each alternative will allow evaluation of the effectiveness of the remedy, and additional actions could be implemented readily if monitoring indicated that ARARs were not being met.

8.1.7 Cost

The total present worth costs for the groundwater alternatives range from $80 million to $130 million (1995 dollars). Alternative 1 has the lowest cost at $80 million, Alternatives 2 and 4 have comparable present worth costs at $98 million and $104 million, respectively, and Alternative 3 is the most expensive alternative at $130 million. A breakdown of O&M costs for the components of each alternative is presented in Table 7.2-2.

8.1.8 State Acceptance

The state of Colorado has been actively involved throughout the RI/FS and remedy selection process for the On-Post Operable Unit. The state was provided the opportunity to comment on the RI/FS documents and on the Proposed Plan, and has taken part in numerous public meetings, including the public meeting on November 18, 1995, to inform the public of the content of the Proposed Plan. Written comments received from the state during the public comment period indicate their concern about the water-supply issue, the Medical Monitoring Program, the Trust Fund, and hydraulic control of the lakes in the South Lakes area.

Responses to the state's comments are provided in the Responsiveness Summary (Section 12).

8.1.9 Community Acceptance

Interested members of the public, including individual citizens, representatives of the local communities, and representatives of national groups, have been actively involved in reviewing the FS and evaluating potential remedial alternatives for the past 2 years as a result of the outreach program described in Section 3. The preferred groundwater alternative for the On-Post Operable Unit was presented to the public in the Proposed Plan, which provides a brief summary of all of the alternatives evaluated during the Detailed Analysis of Alternatives phase of the FS. The original comment period of 60 days was extended to 90 days at the request of some commenters.

The concerns expressed by the public included the water-supply issue, the adequacy of the selected remedy and the monitoring program, the implementation of the Medical Monitoring Program, the establishment of the Trust Fund, and presence of NDMA in groundwater.

Responses to the communities comments are provided in the Responsiveness Summary. (Section 12).

8.1.10 Conclusions

All four groundwater alternatives provide adequate protection of human health and the environment through continued operation of the boundary systems. Alternative 3 is more protective than the other alternatives because it removes the largest amount of contaminants and most rapidly reduces the potential for additional on-post migration. Alternative 4 is more protective than Alternative 2 because it involves additional treatment beyond the existing IRAs, and Alternative 2 is more protective than Alternative 1.

All alternatives will comply with ARARs and all provide equivalent long-term effectiveness and permanence. Alternative 3 provides the greatest reduction in toxicity, mobility, or volume through treatment, but it is less effective in the short term and less implementable than the other three alternatives because it involves construction of new extraction and treatment systems. Alternative 4 provides a greater reduction in toxicity, mobility, or volume through treatment than Alternatives 1 or 2, but it is slightly less effective in the short term and is slightly less implementable than Alternative 2. The short-term effectiveness and implementability of Alternative 1 is similar to that of Alternative 4, but Alternative 1 provides the least reduction in toxicity, mobility, or volume through treatment of contaminated groundwater.

Alternative 1 has the lowest present worth cost because all existing IRAs are discontinued, while Alternative 3 has the highest cost because it involves the most new construction and treatment. The costs of Alternatives 2 and 4 lie between Alternatives 1 and 3. Alternative 4 provides a small amount of additional treatment compared to Alternative 2 at a slightly higher cost.

Alternative 4 is superior to the other groundwater remedial alternatives for the On-Post Operable Unit for the following principal reasons:

- Alternative 4 is preferable to Alternatives 1 and 2 because it provides additional reduction of toxicity, mobility, or volume of contaminated groundwater at a reasonable cost and with minimal short-term effects. It is also readily implementable.
- Although Alternative 3 provides greater reduction of toxicity, mobility, and volume than Alternative 4, it is less readily implementable than Alternative 4. Furthermore, when considered in conjunction with the preferred soil alternative and the continued operation of the boundary groundwater containment and treatment systems, Alternative 3 provides limited added benefit compared to Alternative 4 at a higher cost.

8.2 Comparative Analysis of Alternatives For Structures

The three structures alternatives compared in this section involve removing all No Future Use structures and disposing the debris in the on-post hazardous waste landfill. All structures alternatives include the completion or continuation of structures IRAs as described in Section 7.3.3. The ultimate disposal method for the structures medium groups is chosen based on the following approach:

- The Agent History Group must be disposed in the hazardous waste landfill to comply with Army regulations.
- The Significant Contamination History Group contains structures with use histories that indicate a possibility of significant contamination. This group is disposed in the hazardous waste landfill.
- For the Other Contamination History Group, the disposal options include capping in place, consolidation in Basin A, or disposal in the on-post hazardous waste landfill.

The No Action Alternative (which involves leaving all structures in place) was evaluated in the FS, but it was not retained as a potential remedy because it did not achieve a threshold criterion (overall protection of human health and the environment). A summary of the comparative analysis of the structures alternatives is provided in Table 8.2-1.

8.2.1 Overall Protection of Human Health and the Environment

All three structures alternatives are protective of human health and the environment because all potentially contaminated structures are demolished and disposed to prevent exposure to humans or wildlife. Alternative 3 (Landfill) is slightly more protective than Alternative 2 (Landfill/Consolidate) because all structural debris is placed in the on-post hazardous waste landfill. Alternative 2 is in turn slightly more protective than Alternative 1 (Landfill/Cap in Place) because the debris that is not landfilled is consolidated at one location under a thick soil cover that includes a layer of concrete. Agent-contaminated debris is treated as necessary under all three alternatives, but other treatment is not undertaken because there is a potential for increased worker exposures at no added benefit.

8.2.2 Compliance with ARARs

All three structures alternatives comply with the chemical-, action- and location-specific ARARs listed in Appendix A.

8.2.3 Long-Term Effectiveness and Permanence

All three structures alternatives provide adequate long-term effectiveness and permanence. Removal and disposal of the structures involves significantly less long-term risk than leaving the structures in place and restricting access to them. Additionally, the majority of the structures must be removed to accommodate the soil remedial alternatives. Because structure debris is contained by capping or landfilling, there is low residual risk.

Because high levels of contamination are not expected to be associated with the majority of the structures, the long-term risks associated with waste management are expected to be low. Adequate controls are provided, and the permanence of the solution is verified by long-term monitoring. Alternatives 2 and 3 are slightly more effective in the long term than Alternative 1 because the structural debris is consolidated into central locations (the landfill and, for Alternative 2, Basin A) rather than remaining dispersed under several caps that require additional long-term maintenance.

8.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

All three structures alternatives reduce contaminant toxicity, mobility, or volume through treatment. Demolition of structures reduces the standing volume. Capping or landfilling the structural debris reduces the mobility of contaminants through engineering controls, although this reduction may be compromised should the cap or landfill leak. Caustic washing irreversibly reduces the toxicity, mobility, and volume of Army chemical agent through treatment, but produces a hazardous liquid sidestream that will be treated on post. Alternative 3 is slightly more effective in reducing mobility than Alternative 2 because the structural debris is contained in a landfill, and Alternative 2 is slightly more effective in reducing mobility than Alternative 1 because the debris is consolidated into two central locations rather than dispersed under several caps that require additional long-term maintenance.

8.2.5 Short-Term Effectiveness

All three structures alternatives provide equal short-term effectiveness. Air monitoring and dust controls are required during demolition, transportation, and disposal. Worker protection will be required for physical hazards associated with dismantling and for chemical hazards associated with caustic washing and handling of agent-contaminated debris. Remediation is completed within 3 to 4 years under all three alternatives. Because high levels of contamination are not expected to be associated with the majority of the structures, the risks associated with short-term worker and community exposure are expected to be low for all alternatives.

There are unique concerns for structures with potential Army chemical agent presence. After demolishing the structures, caustic washing is administered to debris, as necessary, and the debris is disposed in the on-post hazardous waste landfill to comply with Army agent regulations. Because the highest probability of encountering agent residues is in process piping and tanks, which are currently being treated and removed as part of the chemical process-related IRA activities, the potential for encountering agent associated with building materials is low. Thus, short-term risks during such remediation activities are considered low for all alternatives.

8.2.6 Implementability

All three structures alternatives are generally technically and administratively feasible, although Alternatives 2 and 3 are more implementable because there are regulatory concerns with capping structural debris in place (Alternative 1). Implementation of structures remediation will require coordination with the remediation scheduled for other environmental media. However, because the time frame during which structures are to be demolished is relatively short, structures remediation should not hinder the remainder of the remediation efforts. The structures demolition must begin in the areas in which soil remediation is planned so that the soil remediation schedule is not delayed. Structures covered under any chemical weapons agreements may need to be removed to comply with the requirements of these agreements.

Significant Contamination History Group and Agent History Group structural debris will be placed into the on-post hazardous waste landfill as demolition proceeds. Accordingly, the landfill must be constructed and in operation prior to the commencement of demolition activities. Other Contamination History Group debris may be placed in the Basin A consolidation area, which requires minimal preparation; in the on-post hazardous waste landfill, which must be ready before demolition begins; or in the areas to be capped, which require minimal preparation. In general, structures must be removed before the soil remedy can be implemented.

8.2.7 Cost

The present worth costs (1995 dollars) are similar for all three alternatives ($106 million for Alternative 1, $104 million for Alternative 2, and $109 million for Alternative 3) because the alternatives only differ with regard to the disposal method for the Other Contamination History Group debris. There are several ongoing structures IRAs whose costs also contribute significantly to the total cost of structures remediation. The total estimated structures IRA costs are $76,000,000, of which $41,000,000 will be spent by the completion of the ROD (and is not included in the above costs), and an additional $35,000,000 will be spent in post-ROD removal actions (not included in the above costs). A breakdown of capital and O&M costs for the components of each alternative is presented in Table 7.3-2.

8.2.8 State Acceptance

The state has been actively involved throughout the RI/FS and remedy selection process for the On-Post Operable Unit. The state was provided the opportunity to comment on the RI/FS documents and on the Proposed Plan, and has taken part in numerous public meetings, including the public meeting on November 18, 1995, to inform the public of the content of the Proposed Plan. Written comments received from the state during the public comment period indicate that there were no major concerns regarding the structures remedy.

Responses to the state's comments are provided in the Responsiveness Summary (Section 12).

8.2.9 Community Acceptance

Interested members of the public, including individual citizens, representatives of the local communities, and representatives of national groups, have been actively involved in reviewing the FS and evaluating potential remedial alternatives for the past 2 years as a result of the outreach program described in Section 3. The preferred structures alternative for the On-Post Operable Unit was presented to the public in the Proposed Plan, which provides a brief summary of all of the alternatives evaluated during the Detailed Analysis of Alternatives phase of the FS. This original comment period of 60 days was extended to 90 days at the request of some commenters.

The concerns expressed by the public included questions with regards to the adequacy of the structures sampling and analytical program. Responses to the community's comments are provided in the Responsiveness Summary (Section 12).

8.2.10 Conclusions

All three structures alternatives provide adequate protection of human health and the environment. Treatment technologies are generally not included because of the exposure risks to workers and the limited benefits for all but the Agent History Group. On-post hazardous waste landfilling for the Significant Contamination History Group is a protective remedy that is included in all three alternatives. The long-term effectiveness of Alternatives 2 and 3 is higher than Alternative 1, which relies on caps in several disposal locations. All three alternatives are equivalent with respect to reduction of toxicity, mobility, or volume through treatment or engineering controls and short-term effectiveness. For Alternative 1, regulatory concerns remain about capping Other Contamination History Group debris in place, which makes its implementibility less certain. Consolidation or landfilling of Other Contamination History Group debris (under Alternatives 2 and 3, respectively) is implementable and cost effective.

Alternative 2 is superior to the other structures alternatives for the On-Post Operable Unit for the following principal reasons:

- Alternatives 2 and 3 are preferable to Alternative 1 because they are more implementable and structural debris is consolidated into one or two disposal locations.
- Alternative 2 is more desirable than Alternative 3 because the Other Contamination History Group structural debris is used as fill in Basin A, reducing the amount of clean borrow needed and reducing the total volume to be landfilled. This alternative is also slightly less costly than Alternative 3.

8.3 Comparative Analysis of Alternatives for Soil

The five soil alternatives that are compared in this section involve a combination of containment (as a principal element) and treatment technologies to reduce contamination. A summary of the comparative analysis of the soil alternatives is provided in Table 8.3-1.

As described in Section 7.1.3, the criteria for evaluating soil contamination helped focus the evaluation of potential remedial activities on areas of highest risk to human health and the environment. Alternatives were developed to include treatment of principal threat volumes, where practicable, with containment or institutional controls being enacted for the balance of the exceedance areas. The sheer volume of contaminated soil present on the site precludes a remedy in which all contaminants could be excavated and cost effectively treated.

8.3.1 Overall Protection of Human Health and the Environment

The five alternatives for soil provide overall protection of human health through a combination of containment and treatment. Alternatives 1 (Caps/Covers), 2 (Landfill/Caps), and 3 (Landfill) provide for protection of human health primarily through containment of human health exceedances, which interrupts exposure pathways and reduces the migration of contaminants to groundwater and the atmosphere. Alternatives 4 (Consolidation/Caps/Treatment/Landfill) and 5 (Caps/Treatment/Landfill) address portions of the most contaminated soil through treatment, but still rely on capping and landfilling to protect human health in the majority of the contaminated areas.

Under each of the five alternatives, the protection of wildlife is generally accomplished through containment of portions of the core areas of RMA that may pose a risk to biota by capping, covering, or landfilling. These actions interrupt the potential for biota exposure, and also prevent burrowing animals from coming into contact with contaminated soil. Outside the core area, these alternatives address surficial soil with low levels of contamination using two different approaches. Alternative 5 includes the treatment of approximately 1,600 acres through agricultural practices, which reduces the level of OCPs in near-surface soil but results in the disturbance of habitat over widespread areas of RMA. The other four alternatives address low-level surficial soil contamination by continued monitoring only, thereby avoiding the disruption of wildlife in these areas during remedial activities and habitat restoration.

Alternatives 3, 4, and 5 are more protective than Alternatives 1 or 2 because larger volumes of contaminated soil are contained in a secure landfill and/or treated. Alternatives 3 and 4 offer equivalent overall protectiveness because there is a tradeoff between landfilling a greater total volume under Alternative 3 versus landfilling the Basin F Wastepile and treating more material under Alternative 4. Alternative 5 is more protective than the other alternatives because more material is treated.

8.3.2 Compliance with ARARs

Each of the five alternatives complies with chemical-, action-, and location-specific ARARs. The number of ARARs, and the difficulties associated with demonstrating compliance with these ARARs, are substantially higher for Alternative 5 based on the complexity of the alternative and the use of thermal treatment technologies.

8.3.3 Long-Term Effectiveness and Permanence

Each of the five alternatives results in minimal residual risk based on the adequacy and reliability of controls offered by each alternative. All five alternatives rely on containment of a significant portion of the contaminated soil to protect human health and the environment, requiring long-term maintenance and monitoring activities. Long-term management also includes access restrictions to capped and covered areas to ensure the integrity of the containment systems. Alternatives 4 and 5 leave smaller volumes of contaminated soil (approximately 8 percent and 40 percent of the human health exceedance volume, respectively, are treated) with lower levels of contamination requiring long-term controls; however, these alternatives still rely on containment of large volumes of contaminated soil (92 and 60 percent, respectively). Alternative 5 also includes the treatment of approximately 1,600 acres through agricultural practices, which reduces the level of OCPs in near-surface soil but results in the disturbance of habitat over widespread areas of RMA. The containment systems for the five alternatives are adequate and reliable for long-term protection of human health and the environment.

Alternative 1 addresses both highly contaminated soil and large volumes of contaminated soil through containment in place. The installation of caps/covers provides adequate protection for human health and wildlife by eliminating exposure to contaminated soil. The caps provide long-term reduction in the migration of contaminants to groundwater. Based on the operation of the existing groundwater systems and the groundwater removal systems to be installed as part of the selected water alternative, this alternative provides long-term effectiveness and a low residual risk. A residual risk may exist for biota because surficial soil that may pose a risk to biota is left in place and monitored. However, widespread areas of wildlife habitat are not disturbed to address this residual risk.

Alternatives 2 and 3 both rely on containment systems that effectively protect humans and biota from exposure to contaminated soil. The bottom liner of a landfill controls the migration of leachate. Landfill covers and caps both provide long-term protection by preventing infiltration into the contaminated materials and releases to the atmosphere. These two alternatives provide similar levels of long-term protection and minimal long-term risks, although landfilling does provide, by virtue of the liner, an increased level of containment than a cap does. Both of these alternatives involve potential risk for biota because surficial soil that may pose a risk to biota is left in place and monitored; however, widespread areas of habitat are not disturbed to address this residual risk.

Alternatives 4 and 5 treat portions of the most contaminated soil, thereby reducing the level of contamination in the soil requiring long-term controls. However, both alternatives use similar containment systems as the other three alternatives to address large volumes of lower-level contamination (92 percent and 60 percent of the human health exceedance volume, respectively). Alternative 5 does treat a larger volume of soil, primarily through treatment of the Basin F Wastepile, but still relies on containment of a large volume of soil to provide long-term protection. Alternatives 4 and 5 provide similar levels of long-term protection, but do not eliminate the need for long-term monitoring and maintenance of capped and landfilled areas.

8.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 4 and 5 provide the greatest reduction in toxicity, mobility, or volume through treatment. These alternatives permanently reduce the toxicity, mobility, or volume of contaminated soil through treatment of 207,000 and 1.1 million BCY of soil, respectively, and they reduce the mobility of contaminants in the remaining soil through containment with caps, soil covers, and landfills. The other three alternatives provide reduction in mobility through containment; however, Alternative 1 provides somewhat lower reduction in mobility because Alternatives 2 and 3 include landfilling of some of the contaminated soil, which provides some measure of additional containment of contaminants and reduction in mobility compared to capping. Ultimately, however, all containment alternatives rely on the effectiveness of the caps and soil covers to reduce infiltration.

8.3.5 Short-Term Effectiveness

The short-term effectiveness of the five alternatives is primarily governed by the risks posed during remedial actions and the time required until remediation goals are achieved. Short-term effectiveness decreases as a result of the increase in risks during remedial actions and the longer time frames for implementation of the more complex remedial alternatives.

Alternatives 1 and 2 have minimal to low short-term risks as the central portions of RMA (with high levels of contamination) are capped in place. Thus, the risks to workers and the surrounding community from the excavation, transportation, and treatment/disposal of soil with high-level contamination are avoided. The implementation time of these alternatives is approximately 17 and 16 years, respectively. Alternative 2 includes the landfilling of 2 million BCY of contaminated soil (instead of containment in place), but the risks associated with excavation, transportation, and disposal of this soil are not significantly increased compared to capping based on the low levels of contamination in the soil to be landfilled. These two alternatives address soil in the core area of RMA that may pose a risk to biota through containment, but do not entail additional remedial actions for surficial soil that may pose a risk to biota, which is left in place and monitored. In this manner, widespread areas of habitat are not disturbed to address soil with a low residual risk.

The other three alternatives involve excavation and treatment/disposal of portions of the most contaminated soil, which increases the short-term risks to workers and the community. Alternative 4 removes a smaller volume of highly contaminated soil, and therefore exhibits lower risks due to excavation, transportation, and disposal activities than Alternatives 3 or 5, which present the highest short-term risk to workers and the community. Under these alternatives, the largest volume of highly contaminated areas is excavated for treatment and/or disposal, requiring specialized vapor- and odor-suppression measures to minimize the release of contaminants. The implementation time frame for Alternative 5 is the longest at approximately 28 years. Although steps can be taken to control short-term risks during remedial actions under these three alternatives, the short-term effectiveness for these alternatives is lower than for Alternatives 1 or 2. Negative-pressure vapor enclosures are one approach to controlling vapors and odors that may be emitted from several areas to be excavated under Alternatives 3, 4, and 5. Work within enclosures would require extensive worker protection and could present significant hazards to workers. Although the air within the enclosure is collected and treated, or, where an enclosure was not used, other measures could be taken to mitigate short-term risks, the short-term risks of contaminant release associated with excavating these areas cannot be completely eliminated.

8.3.6 Implementability

The implementability of the five alternatives varies from easy for Alternatives 1 and 2, which are readily constructed using common construction equipment, to difficult for Alternative 5. This alternative presents difficulties in the construction and operation of the treatment technologies, which have not been implemented at any other site in the country at the scale required at RMA. The implementability of Alternatives 3 and 4 is moderate.

Alternatives 1 and 2 are both considered easy to implement because they consist of the proven and available technologies of capping and landfilling and because they do not require the use of vapor controls. Alternatives 3 and 4 involve a similar level of difficulty in the excavation, transportation, and disposal of large volumes of highly contaminated soil. Alternative 4, which makes use of readily available mobile equipment for treatment of soil by solidification/stabilization, is implementable. Implementability of the innovative thermal technology for the Hex Pit will be determined during remedial design treatability testing. Consolidation of some soil potentially posing risk to biota (as a source of gradefill) decreases the cost and disruption of habitat for borrow areas. Alternative 5 is the most difficult to implement and requires the longest time frame based on the difficulties with implementation of vapor controls, if necessary, and treatment technologies. There is a high level of uncertainty in the performance of thermal technologies on the complex contaminant mixtures and high salt levels in some principal threat soil, leading to a potential for failure to meet the treatment specifications and a potential for extensive shut-down time to modify and maintain the system.

8.3.7 Cost

The estimated present worth cost (in 1995 dollars) for Alternative 2 is the lowest at $276 million. The present worth cost for Alternative 1 is estimated to be $386 million, followed by Alternatives 3 and 4 at $384 and $401 million, respectively. The estimated present worth cost for Alternative 5 is the highest at $542 million for soil remediation. A breakdown of capital and O&M costs for the components of each alternative is presented in Table 7.4-2.

The greatest overall cost uncertainty is associated with the remediation of soil, and the uncertainty is higher for alternatives that include excavation and treatment than for alternatives that minimize the handling of highly contaminated soil through containment in place. The level of cost uncertainty is relatively low for Alternatives 1, 2, and 4 because demonstrated construction and excavation technologies are used. The cost uncertainty associated with Alternative 3 is moderate as demonstrated technologies are used for containment, although large volumes of highly contaminated soil are excavated. Alternative 5 entails the highest degree of cost uncertainty due to the use of complex treatment technologies and the excavation, transportation, treatment, and disposal of large volumes of highly contaminated soil.

8.3.8 State Acceptance

The state has been actively involved throughout the RI/FS and remedy selection process for the On-Post Operable Unit. The state was provided the opportunity to comment on the RI/FS documents and on the Proposed Plan, and has taken part in numerous public meetings, including the public meeting on November 18, 1995, to inform the public of the content of the Proposed Plan. Written comments received from the state during the public comment period indicate their concerns about the Medical Monitoring Program, the Trust Fund, and treatment of the Hex Pit.

Responses to the state's comments are provided in the Responsiveness Summary (Section 12).

8.3.9 Community Acceptance

Interested members of the public, including individual citizens, representatives of the local communities, and representatives of national groups, have been actively involved in reviewing the FS and evaluating potential remedial alternatives for the past 2 years as a result of the outreach program described in Section 3. The preferred soil alternative for the On-Post Operable Unit was presented to the public in the Proposed Plan, which provides a brief summary of all of the alternatives evaluated during the Detailed Analysis of Alternatives phase of the FS. The original comment period of 60 days was extended to 90 days at the request of some commenters.

The concerns expressed by the public included questions related to the Medical Monitoring Program, the Trust Fund, the adequacy of the selection remedy and the monitoring program, and concerns regarding the potential presence of dioxin. Responses to the community's comments are provided in the Responsiveness Summary (Section 12).

8.3.10 Conclusions

Alternative 1 provides the level of protection of human health and wildlife required under CERCLA by preventing exposures to contaminated soil. In addition, this alternative has minimal short-term risks since the central portions of RMA (with high levels of contamination) are capped in place, thereby avoiding the risks from excavation, transportation, and treatment/disposal of soil with high-level contamination. The mobility of the contaminants is reduced by minimizing the amount of infiltration that may mobilize the contaminants from the soil to the groundwater and eliminating the airborne migration pathway. However, no action is taken to reduce the toxicity or volume of the contaminated soil. The implementation time frame for Alternative 1 is less than the other alternatives, although its cost is higher than Alternative 2. The overall effectiveness of Alternative 1 is somewhat lower than the other alternatives based on the lower reduction in mobility resulting from capping as compared to landfilling or the destruction of contaminants through treatment. However, all alternatives rely on capping/landfilling of the majority of the contaminated soil to provide long-term risk reduction.

Alternative 2 protects humans and biota by providing a physical barrier, through capping and landfilling, to prevent exposures and reduce the amount of infiltration that may mobilize contaminants to groundwater. Caps/covers and landfills provide effective containment of the contaminated soil. The contaminated soil from the outlying sections of RMA that is landfilled poses a minor risk to workers and the community during excavation and transportation due to the low level of contamination in the soil. Soil in the core area of RMA with high levels of contamination (such as the Basin A, Disposal Trenches, and Basin F Medium Groups and South Plants Central Processing Area Subgroup) is left in place and capped. The mobility of the contaminants in these areas is further reduced by minimizing the infiltration through the contaminated soil and eliminating the airborne migration pathway. The overall effectiveness of Alternative 2 is high because it provides effective containment of the contaminants by balancing the short-term risks of excavation with long-term effectiveness.

Alternative 3 protects humans and biota by providing a physical barrier that prevents exposure through landfilling and capping. However, significant risks are posed to workers and the community during excavation and transportation of large volumes of highly contaminated soil. Although vapor- and odor-suppression measures are used during the excavation of several sites, the short-term risks associated with excavation of contaminated soil cannot be completely eliminated. The mobility of the contaminants is eliminated by placing the contaminated soil in the landfill, but no action is taken to reduce the toxicity or volume of the contaminated soil. The overall effectiveness of Alternative 3 is moderate because it provides low long-term risk but entails high short-term risks during excavation and transportation of highly contaminated soil.

Alternative 4 protects humans and biota by treating some principal threat materials and providing a physical barrier (i.e., caps, soil covers, and landfill) to prevent exposure. Mobility of the contaminants is reduced by minimizing the amount of infiltration into the contaminated soil below the caps or in the landfill. The toxicity and mobility of contaminated soil is reduced through treatment of some principal threats by solidification/stabilization. Increased short-term risks are posed to workers and the community during excavation, transportation, and landfill of highly contaminated soil. The risks associated with excavation are reduced, but are not eliminated, through the use of vapor- and odor-suppression measures at several excavation areas. In addition, placement of soil excavated from the Basin F Wastepile and Section 36 Lime Basins in a triple-lined landfill cell provides added assurance of containment. The consolidation of 1.5 million BCY of contaminated soil in Basin A, Basin F, and the South Plants Central Processing Area prior to capping these sites lowers the cost of obtaining borrow materials and reduces the area disturbed for borrow. The implementability of this alternative is moderate because highly contaminated soil is excavated. However, the overall effectiveness of Alternative 4 is high because it provides low long-term risk, compensating for the increased short-term risk during excavation.

Alternative 5 treats areas of highly contaminated soil, thereby reducing the contaminant toxicity, mobility, or volume. However, workers and the community are exposed to the highest short-term risks under Alternative 5 (compared to other alternatives) during excavation, transportation, and treatment. Although vapor- and odor-suppression measures are used during the excavation of several sites, the short-term risks associated with excavation of highly contaminated soil cannot be completely eliminated. The mobility of the contaminants is minimized by placing the contaminated soil in a landfill. However, this alternative has a low overall effectiveness based on the high short-term risks during remedial actions and the longer time frame (a minimum of 14 years) until actions are completed. In addition, the implementability of this alternative is very difficult because of the large volume of highly contaminated soil (including the Basin F Wastepile) to be treated by thermal treatment.

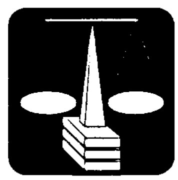
Alternative 4 is superior to the other soil remedial alternatives for the On-Post Operable Unit for the following principal reasons:

- Alternative 4 is preferable to Alternatives 1, 2, and 3 because it provides additional reduction of toxicity, mobility, or volume of contaminated soil through some treatment with minimal short-term effects and more secure containment of the Basin F Wastepile materials in a new triple-lined landfill cells. Alternative 4 is also readily implementable.

- Although Alternative 5 provides greater reduction of toxicity, mobility, or volume through more treatment than Alternative 4, it is much less readily implementable than Alternative 4 because the treatment technologies identified have never been used at the scale required at RMA. Furthermore, Alternative 5 is significantly more costly than Alternative 4, and the uncertainty of execution related to schedule and budget is much higher for Alternative 5 than for Alternative 4.

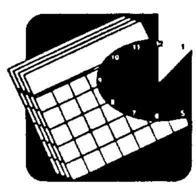
1 Overall Protection of Human Health and the Environment addresses whether or not a remedy provides adequate protection and describes how risks posed through each pathway are eliminated, reduced, or controlled.

2 Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) addresses whether or not a remedy will meet all federal and state environmental laws and standards and/or provides grounds for a waiver.



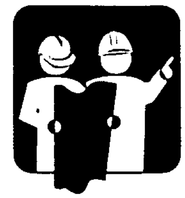
3 Short-Term Effectiveness addresses the period of time needed to complete the remedy and any adverse effects to human health and the environment that may be caused during the construction and implementation of the remedy.

4 Long-Term Effectiveness and Permanence refers to the ability of a remedy to provide reliable protection of human health and the environment over time.



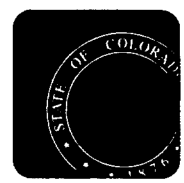
5 Reduction of Toxicity, Mobility, or Volume through Treatment refers to the preference for a remedy that through treatment reduces health hazards, the movement of contaminants, or the quantity of contaminants at the site.

6 Implementability refers to the technical and administrative feasibility of a remedy. This includes the availability of materials and services needed to carry out a remedy. It also includes coordination of federal, state, and local governments to work together to clean up the site.



7 Cost evaluates the estimated capital, operating, and maintenance costs of each alternative in comparison to other equally protective alternatives.

8 State Acceptance indicates whether the state agrees with, opposes, or has no comment on the preferred alternative.



9 Community Acceptance includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment may not be completed until public comments on the Proposed Plan are reviewed.

Figure 8.0-1

Cleanup Evaluation Criteria

Rocky Mountain Arsenal
Prepared by Foster Wheeler Environmental Corporation

Table 8.1-1 Comparative Analysis of Water Alternatives

Criteria	Alternative 1 Boundary Systems	Alternative 2 Boundary Systems/ IRAs (No Additional Action)	Alternative 3 Boundary Systems/ IRAs/Dewatering	Alternative 4 Boundary Systems/ IRAs/Intercept Systems
Overall Protection of Human Health and the Environment	*Protective.* Provides protection through operation of boundary systems.	*Protective.* Provides protection through operation of boundary systems and minimizes on-post migration through operation of IRAs.	*Protective.* Provides protection through boundary systems and minimizes on-post migration through operation of IRAs and additional on-post systems.	*Protective.* Provides protection through boundary systems and minimizes on-post migration through operation of IRAs and additional on-post systems.
Compliance with ARARs	*Complies* with action-, chemical-, and location-specific ARARs through active treatment and natural attenuation of inorganics.	*Complies* with action-, chemical-, and location-specific ARARs through active treatment and natural attenuation of inorganics.	*Complies* with action-, chemical-, and location-specific ARARs through active treatment and natural attenuation of inorganics.	*Complies* with action-, chemical-, and location-specific ARARs through active treatment and natural attenuation of inorganics.
Long-Term Effectiveness and Permanence	*Low residual risk.* Potential for off-post exposure is lowered. No on-post exposure due to FFA restrictions. Long-term monitoring required; contaminant migration reduced through passive dewatering.	*Low residual risk.* Potential for off-post exposure is lowered. No on-post exposure due to FFA restrictions. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and passive dewatering.	*Low residual risk.* Potential for off-post exposure is lowered. No on-post exposure due to FFA restrictions. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and active dewatering.	*Low residual risk.* Potential for off-post exposure is lowered. No on-post exposure due to FFA restrictions. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and passive dewatering.
Reduction of Toxicity, Mobility, or Volume (TMV)	*TMV reduced at boundary.* Contaminants removed by GAC adsorption, reducing toxicity and volume.	*TMV reduced at boundary and on post.* Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; source capture at Basin A Neck and passive dewatering limit migration.	*TMV reduced at boundary and on post.* Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; dewatering and source capture significantly limit migration and mobility.	*TMV reduced at boundary and on post.* Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; source capture and passive dewatering limit mobility.

Selected alternative (shaded)

Table 8.1-1 Comparative Analysis of Water Alternatives

Criteria	Alternative 1 Boundary Systems	Alternative 2 Boundary Systems/ IRAs (No Additional Action)	Alternative 3 Boundary Systems/ IRAs/Dewatering	**Alternative 4 Boundary Systems/ IRAs/Intercept Systems**
Short-Term Effectiveness	*Effective.* Minimal negative impact; achieves RAOs.	*Effective.* No additional impact associated with continued operation; achieves RAOs.	*Effective.* Minimal negative impact associated with installation of dewatering system; achieves RAOs.	***Effective.* Minimal negative impact associated with installation of extraction system; achieves RAOs.**
Implementability	*Technically and administratively feasible.*	*Technically and administratively feasible.* No additional construction involved.	*Technically and administratively feasible.* Treatment by proven technologies except for in situ biological treatment in South Plants.	***Technically and administratively feasible.* Treatment by proven technologies.**
Present Worth Cost	$80 million	$98 million	$130 million	**$104 million**
Conclusion	*Not selected.* Meets evaluation criteria, but provides less protection than other alternatives.	*Not selected.* Meets evaluation criteria, but does not provide additional control and protection beyond what is currently in place.	*Not selected.* Meets evaluation criteria and provides additional on-post controls, but at higher cost than the other alternatives.	***Selected.* Meets evaluation criteria and is consistent with the proposed soil alternative. Provides adequate on-post controls at minimal added cost.**

Selected alternative

Table 8.2-1 Comparative Analysis of Structures Alternatives

Criteria	Alternative 1 Landfill/Cap in Place	Alternative 2 Landfill/Consolidate	Alternative 3 Landfill
Overall Protection of Human Health and the Environment	*Protective.* Debris is contained by capping or landfilling. Agent debris is treated as necessary.	***Protective.* Debris is contained by consolidation or landfilling. Agent debris is treated as necessary.**	*Protective.* Debris is contained by landfilling. Agent debris is treated as necessary.
Compliance with ARARs	*Complies* with action-, chemical-, and location-specific ARARs.	***Complies* with action-, chemical-, and location-specific ARARs.**	*Complies* with action-, chemical-, and location-specific ARARs.
Long-Term Effectiveness and Permanence	*Low residual risk.* Structural debris is contained by capping or landfilling. Adequate controls; long-term monitoring is required. Habitat is improved at site but limited at landfill.	***Low residual risk.* Structural debris is contained by consolidation or landfilling. Adequate controls; long-term monitoring is required. Habitat is improved at site but limited at landfill.**	*Low residual risk.* Structural debris is contained by landfilling. Adequate controls; long-term monitoring is required. Habitat is improved at site but limited at landfill.
Reduction of Toxicity, Mobility, or Volume (TMV)	*TMV Reduced.* Capping or landfilling reduces mobility. Reduction in mobility may be reversed if cap or landfill leaks. Caustic wash irreversibly reduces TMV of agent, but produces a hazardous liquid sidestream that must be treated.	***TMV Reduced.* Consolidation or landfilling reduces mobility. Reduction in mobility reversed if consolidation area or landfill leaks. Caustic wash irreversibly reduces TMV of agent, but produces a hazardous liquid sidestream that must be treated.**	*TMV Reduced.* Landfilling reduces mobility. Reduction in mobility may be reversed if landfill leaks. Caustic wash irreversibly reduces TMV of agent, but produces a hazardous liquid side-stream that must be treated.

Selected alternative

Criteria	Alternative 1 Landfill/Cap in Place	**Alternative 2 Landfill/Consolidate**	Alternative 3 Landfill
Short-Term Effectiveness	*Effective*. Dust controls needed for demolition. Worker protection necessary for physical hazards associated with dismantling and for chemical hazards associated with caustic washing and handling agent-contaminated debris. Habitat improved at site, limited at disposal areas. RAOs achieved in 3 to 4 years.	***Effective*. Dust controls needed for demolition. Worker protection necessary for physical hazards associated with dismantling and for chemical hazards associated with caustic washing and handling agent-contaminated debris. Habitat improved at site, limited at disposal areas. RAOs achieved in 3 to 4 years.**	*Effective*. Dust controls needed for demolition. Worker protection necessary for physical hazards associated with dismantling and for chemical hazards associated with caustic washing and handling agent-contaminated debris. Habitat improved at site, limited at disposal areas. RAOs achieved in 3 to 4 years.
Implementability	*Technically and administratively feasible*. Regulatory concerns with capping.	***Technically and administratively feasible.***	*Technically and administratively feasible.*
Present Worth Cost[1]	$106 million	**$104 million**	$109 million
Conclusion	*Not selected*. Meets evaluation criteria and is consistent with soil remedial alternatives. Not identified as the preferred alternative due to regulatory concerns over capping debris from Other Contamination History structures.	***Selected*. Meets evaluation criteria and is consistent with soil remedial alternatives.**	*Not selected*. Meets evaluation criteria and is consistent with soil remedial alternatives. Not identified as the preferred alternative because it is less cost effective than Alternative 2.

Selected alternative

[1]These costs do not include $35 million in post ROD removal actions.

Table 8.3-1 Comparative Analysis of Soil Alternatives

Criteria	Alternative 1 Caps/Covers	Alternative 2 Landfill/Caps	Alternative 3 Landfill	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill
Overall Protection of Human Health and the Environment	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place.	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place.	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place.	***Protective*. Exposures to humans and animals prevented by containing contaminated soil in place and by treating some of the principal threat volume.**	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place and by treating principal threat volume.
Compliance with ARARs	*Complies* with action-, chemical-, and location-specific ARARs.	*Complies* with action-, chemical-, and location-specific ARARs.	*Complies* with action-, chemical-, and location-specific ARARs.	***Complies* with action-, chemical-, and location-specific ARARs.**	*Complies* with action-, chemical-, and location-specific ARARs. More difficult due to action-specific ARARs regarding treatment.
Long-Term Effectiveness and Permanence	*Minimal residual risk*. Relies on caps and groundwater controls to prevent migration and exposure.	*Minimal residual risk*. Relies primarily on caps and groundwater controls, with some landfilling, to prevent migration and exposure.	*Minimal residual risk*. Relies on landfilling, with some caps and groundwater controls to prevent migration and exposure.	***Minimal residual risk*. Relies on treatment of some highly contaminated soil, groundwater controls, and capping/landfilling to prevent migration and exposure.**	*Minimal residual risk*. Relies on treatment of most of the highly contaminated soil and landfilling/capping to prevent migration and exposure.
Reduction of Toxicity, Mobility, or Volume (TMV)	*TMV Reduced*. Mobility reduced through containment; no toxicity or volume reduction.	*TMV Reduced*. Mobility reduced through containment; no toxicity or volume reduction.	*TMV Reduced*. Mobility reduced through containment; no toxicity or volume reduction	***TMV Reduced*. TMV of some highly contaminated soil reduced through treatment; relies on containment for most mobility reduction.**	*TMV Reduced*. TMV of the most highly contaminated soil reduced through treatment; relies on containment for additional mobility reduction.

Selected alternative

Table 8.3-1 Comparative Analysis of Soil Alternatives

Criteria	Alternative 1 Caps/Covers	Alternative 2 Landfill/Caps	Alternative 3 Landfill	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill
Short-Term Effectiveness	*Effective.* Minimal short-term risk. No excavation or potential releases.	*Effective.* Low short-term risk. High-risk sites not excavated; minimal potential for releases.	*Effective.* Moderate short-term risk. All sites excavated and transported with high potential for releases.	*Effective.* Moderate short-term risk. Some high-risk sites excavated and transported; moderate potential for releases.	*Effective.* Higher short-term risk. Most high-risk sites excavated, transported, and treated; large volumes of less contaminated soil moved; high potential for releases.
Implementability	*Implementable.* Easy to construct caps on schedule; short time to complete.	*Implementable.* Easy to construct caps and landfill for soil with low levels of contamination; short time to complete.	*Moderate implementability.* Construction and permitting of large landfill for highly contaminated material may delay schedule.	*Moderate implementability.* Construction and permitting of large landfill for highly contaminated material may delay schedule.	*Difficult implementability.* Construction and permitting of large landfill and thermal treatment facility may delay schedule. Problems in excavation, treatment, and emissions control; longest time to complete.
Present Worth Cost	Total: $386 million	Total: $276 million	Total: $384 million	Total: $401 million	Total: $542 million
Conclusion	*Not selected.* Higher long-term risks and no substantial cost savings compared to other alternatives.	*Not selected.* Higher long-term risk, although low cost.	*Not selected.* High short-term risks without improving long-term protection, which ultimately relies on containment.	*Selected.* Cost effective; balances short-term risks with higher long-term protection.	*Not selected.* High cost, short-term risks, and difficult to implement.

Selected alternative

9.0 Identification of the Selected Remedy

The selection of the preferred remedy for remediation of groundwater, structures, and soil for the On-Post Operable Unit was based on the NCP evaluation criteria, which are described in Figure 8.0-1 and discussed with respect to each of the alternatives evaluated in Sections 8.1 through 8.3. As a result of these evaluations, the selected remedy for the On-Post Operable Unit consists of implementing Groundwater Alternative 4, Structures Alternative 2, and Soil Alternative 4. These selected alternatives are described in detail in Section 7. Remediation goals for the selected remedy satisfies the evaluation of statutory requirements under CERCLA as described in Section 10.

9.1 Groundwater Alternative 4 – Boundary Systems/IRAs/Intercept Systems

The selected groundwater alternative is Alternative 4. This alternative includes operation of all existing boundary systems and on-post groundwater IRA systems, installation of a new extraction and piping system, and development of an extended monitoring program. The specific components of the alternative are as follows:

- Operation of the three boundary systems, the NBCS, NWBCS, and ICS, continues. These systems include extraction and recharge systems, slurry walls (NBCS and NWBCS) for hydraulic controls, and carbon adsorption for removal of organics. The systems will be operated until shut-off criteria, as described below, are met.
- Operation of existing on-post groundwater IRA systems continues. The Motor Pool and Rail Yard IRA systems, which pipe water to ICS for treatment, will be shut down when shut-off criteria, as described below, are met. The Basin F extraction system continues to extract water that is treated at the Basin A Neck system and the Basin A Neck system continues to extract and treat water from Basin A until shut-off criteria are met.
- A new extraction system will be installed in the Section 36 Bedrock Ridge area. Extracted water will be piped to the Basin A Neck system for treatment (e.g., by air stripping or carbon adsorption).
- Water levels in Lake Ladora, Lake Mary, and Lower Derby Lake will be maintained to support aquatic ecosystems. The biological health of the ecosystems will continue to be monitored.

  Lake-level maintenance or other means of hydraulic containment or plume control will be used to prevent South Plants plumes from migrating into the lakes at concentrations exceeding CBSGs in groundwater at the point of discharge. Groundwater monitoring will be used to demonstrate compliance.
- Confined aquifer wells are monitored in the South Plants, Basin A, and Basin F areas. Specific monitoring wells will be selected during remedial design.
- Those monitoring wells installed in the confined aquifer that may represent pathways for migration from the unconfined aquifer (approximately 30–40 wells) are closed and sealed; replacement wells will be installed if the Parties jointly determine that specific wells to be closed are necessary for future monitoring.
- Chloride and sulfate are expected to attenuate naturally to the CSRGs.
- Monitoring and assessment of NDMA contamination will be performed in support of design refinement/design characterization to achieve remediation goals specified for the boundary groundwater treatment systems.

CSRGs were established for each containment/treatment system on the basis of ARARs and health-based criteria. The ARAR-based values were either Colorado Basic Standards for Groundwater (CBSGs), federal **maximum contaminant levels** (MCLs), or non-zero maximum contaminant level goals (MCLGs). The health-based values are to-be-considered criteria (TBCs) and were based on EPA health advisories and/or EPA Integrated Risk Information System database criteria. All of the boundary CSRGs are consistent with those derived for the ROD for the Off-Post Operable Unit (Harding Lawson Associates 1995). CSRGs were developed for each of the existing boundary and IRA systems, depending on the specific contaminants found upgradient of each system and whether the systems were on post or at the boundary. Tables 9.1-1, 9.1-2, 9.1-3, and 9.1-4 present the CSRGs for the three boundary systems, and the Basin A Neck system. Where the CSRG is below the detection limit, the detection limit is listed next to the CSRG. Except where technically impractical, the detection limit is less than the CSRG.

Criteria for shutting down boundary systems and internal systems have also been developed and are provided as follows:

- Existing wells within the boundary and off-post containment systems can be removed from production when concentrations of constituents detected in the well are less than the ARARs listed in Appendix A and/or it can be demonstrated that discontinuing operation of a well would not jeopardize the containment objective of the systems as identified by the remediation goals described above and the CSRGs listed in Tables 9.1-1, 9.1-2, and 9.1-3. Wells removed from production and monitoring wells upgradient and downgradient of the boundary and off-post containment systems will be monitored quarterly for a period of 5 years to determine whether contaminants have reappeared; however, those wells turned off for hydraulic purposes will not be subject to the quarterly monitoring requirements. Boundary and off-post containment system extraction wells removed from production for water-quality reasons will be placed back into production if contaminant concentrations exceed ARARs. Wells with concentrations less than ARARs can remain in production if additional hydraulic control is required.
- Existing wells within the internal containment systems can be removed from production when concentrations of constituents detected in the wells are less than ARARs listed in Appendix A and/or it can be demonstrated that discontinuing operation of a well would not jeopardize the containment objective of the systems as identified by the CSRGs listed in Table 9.1-4. Wells removed from production and monitoring wells upgradient and downgradient of the internal containment systems will be monitored quarterly for a period of 5 years to determine whether contaminants have reappeared; however, those wells turned off for hydraulic purposes will not be subject to the quarterly monitoring requirements. Internal containment system extraction wells removed from production for water-quality reasons will be placed back into production if contaminant concentrations exceed ARARs. Wells with concentrations less than ARARs can remain in production if additional hydraulic control is required.
- Shell and the Army will operate the ICS for 2 years or until the Rail Yard/Motor Pool plumes no longer require containment at the ICS.

Figure 9.1-1 illustrates the selected alternative. Additional detail on this alternative is provided in the Detailed Analysis of Alternatives report.

9.2 Structures Alternative 2 – Landfill/Consolidate

Structures Alternative 2 is the selected alternative for the structures medium. This alternative applies to all No Future Use structures, i.e., structures in the Other Contamination History, Significant Contamination History, and Agent History Groups. Under this alternative, the following activities will occur:

- All No Future Use structures will be demolished.
- Agent History structures will be monitored for the presence of Army chemical agent, and treated by caustic washing as necessary prior to disposal.
- Both Agent History and Significant Contamination History Group structural debris will be disposed in the on-site hazardous waste landfill.
- Other Contamination History Group structural debris will be used as grade fill in Basin A, which will subsequently be covered as part of the soil remediation.
- Structural assessments and review of ACM and PCB contamination status and disposition of ACM or PCB-contaminated materials will be performed as described in Section 7.3.3.
- Process-related equipment not remediated as part of the Chemical Process-Related Activities IRA will be disposed in the on-post hazardous waste landfill.

An inventory of structures in each medium group is presented in Tables 5.4-6, 5.4-7, 5.4-8, and 5.4-9. Refinement of the Future Use structures inventory will be completed during remedial design. Most of the demolition at RMA will consist of dismantling with standard dust-suppression measures Remediation goals and standards have been identified for each medium group (see Table 9.5-1). The Other Contamination History Group structural debris is disposed by consolidation in Basin A. This procedure includes transporting the debris to the consolidation area and using it as a portion of the gradefill required by the soil remediation. When the consolidation area has been regraded, it will be covered as part of the soil remediation. Significant Contamination History Group and Agent Contamination History Group structural debris is disposed in the on-post hazardous waste landfill. The slabs and foundations of structures located in the South Plants Central Processing Area within principal threat or human health soil exceedance excavation areas are removed to a depth of 5 ft. In most cases, floor slabs and foundations for the Other Contamination History and Significant Contamination History Groups are left behind after demolition (unless contaminated soil is to be excavated from beneath the slabs or foundations). Floor slabs are broken to prevent water ponding. Additional detail on this alternative is provided in the Detailed Analysis of Alternatives Report.

9.3 Soil Alternative 4 – Consolidation/Caps/Treatment/Landfill

The selected soil alternative is Alternative 4. This alternative includes consolidation of 1.5 million BCY of soil with low levels of contamination into Basins A and F and the South Plants Central Processing Area; capping or soil cover of contaminated soil in the Basins, South Plants, North Plants, and Section 36 sites (including Shell and Complex Trenches); treatment (primarily by in situ solidification/stabilization) of 217,000 BCY of principal threat soil; and on-post landfilling of 1.7 million cubic yards of soil and debris, including the Basin F Wastepile. The specific components of this alternative are listed below and are summarized in Table 9.3-1:

- On-Post Hazardous Waste Landfill – Construction of a RCRA- and TSCA-compliant hazardous waste landfill on post.
- Former Basin F – Treatment of approximately 190,000 BCY of principal threat soil in the Former Basin F to a depth of 10 ft (measured from below the base of the overburden) using in situ solidification/stabilization to reduce the mobility of the contaminants and minimize further contamination of groundwater. The mixture of solidification agents will be determined during remedial design by treatability testing. This treatability testing will be used to verify the effectiveness of the treatment process and establish operating parameters for the design of the full-scale operation. The entire site is capped (including the Basin F Wastepile footprint) with a RCRA-equivalent cap that includes a biota barrier.
- Basin F Wastepile – Excavation of approximately 600,000 BCY of principal threat soil and liner materials from the wastepile and containment in dedicated triple-lined landfill cells at the on-post hazardous waste landfill facility. Excavation is conducted using vapor- and odor-suppression measures as necessary. If the wastepile soil fails EPA's paint filter test, the moisture content of the soil will be reduced to acceptable levels by using a dryer in an enclosed structure. Any volatile organics (and possibly some semivolatile organics) released from the soil during the drying process are captured and treated; however, the main objective of this process is drying. Prior to excavation of the wastepile, overburden from the existing cover is removed and set aside. The excavation area is backfilled with on-post borrow material and stockpiled overburden.
- Basin A – Construction of a soil cover consisting of a 6-inch-thick layer of concrete and a 4-ft-thick soil/vegetation layer over the principal threat and human health exceedance soil and soil posing a potential risk to biota, and consolidation of debris and soil posing a potential risk to biota and structural debris from other sites. No RCRA-listed or RCRA-characteristic waste from outside the AOC will be placed in Basin A. Any UXO encountered will be removed and transported off post for detonation (unless the UXO is unstable and must be detonated on post) or other demilitarization process.
- South Plants Central Processing Area – Excavation and landfill of principal threat and human health exceedance soil to a depth of 5 ft and caustic washing and landfill of any agent-contaminated soil found during monitoring. Backfill excavation and placement of a soil cover consisting of a 1-ft-thick biota barrier and a 4-ft-thick soil/vegetation layer over the entire site to contain the remaining human health exceedance soil and soil posing a potential risk to biota. Soil posing a potential risk to biota from other portions of South Plants may be used as backfill and/or gradefill prior to placement of the soil cover.
- South Plants Ditches – Excavation and landfill of principal threat and human health exceedance soil. Excavation of soil posing a potential risk to biota and consolidation under the South Plants Central Processing Area soil cover. Backfill excavated area with on-post borrow material. These sites are contained under the South Plants Balance of Areas soil cover.
- South Plants Balance of Areas – Excavation (maximum depth of 10 ft) and landfill of principal threat and human health exceedance soil and caustic washing and landfill of any agent-contaminated soil found during monitoring. Any UXO encountered will be excavated and transported off post for detonation (unless the UXO is unstable and must be detonated on post) or other demilitarization process. Excavation of soil posing a potential risk to biota and consolidation as backfill and/or gradefill under the South Plants Central Processing Area soil cover and/or for use as backfill for excavated areas within this medium group. The former human health exceedance area is covered with a 3-ft-thick soil cover and the former potential risk to biota area is covered with a 1-ft-thick soil cover. Prior to placing this cover, two composite samples per acre will be collected to verify that the soil under the 1-ft-thick soil cover does not exceed human health or principal threat criteria. If the residual soil is found to exceed these levels, the 3-ft-thick cover will be extended over these areas or the

exceedance soil will be excavated and landfilled. The top 1 ft of the entire soil cover area will be constructed using soil from the on-post borrow areas.

- Section 36 Balance of Areas – Excavation and landfill of human health exceedance soil and UXO debris and excavation and consolidation to Basin A of soil posing a potential risk to biota. The consolidated material is contained under the Basin A cover and the human health excavation area is backfilled with on-post borrow material. Prior to excavation, a geophysical survey is conducted to locate potential UXO. Any UXO encountered will be excavated and transported off post for detonation (unless the UXO is unstable and must be detonated on post) or other demilitarization process. Caustic washing and landfill of any agent-contaminated soil found during monitoring. The former human health exceedance area is covered with a 2-ft-thick soil cover and the former potential risk to biota area is covered with a 1-ft-thick soil cover.
- Secondary Basins – Excavation and landfill of human health exceedance soil. The excavated area is backfilled with on-post borrow material. A 2-ft-thick soil cover is placed over the entire area of Basins B, C, and D, including the potential biota risk area.
- Complex Trenches – Construction of a RCRA-equivalent cap, including a 6-inch-thick layer of concrete, over the entire site. Installation of a slurry wall into competent bedrock around the disposal trenches. Dewatering within the slurry wall is assumed for purposes of conceptual design and will be reevaluated during remedial design. Soil excavated for the slurry wall trench is graded over the surface of the site and is contained under the cap. Prior to installing the slurry wall and cap, a geophysical survey is conducted to locate potential UXO within construction areas. Any UXO encountered will be removed and transported off post for detonation (unless the UXO is unstable and must be detonated on post) or other demilitarization process.
- Shell Trenches – Modification of the existing soil cover to be a RCRA-equivalent cap with a biota barrier. Expansion of the existing slurry wall around the trenches. Dewatering within the slurry wall is assumed for purposes of conceptual design and will be re-evaluated during remedial design. Soil excavated for the slurry wall trench is graded over the surface of the site and is contained under the cap.
- Hex Pit – Treatment of approximately 1,000 BCY of principal threat material using an innovative thermal technology. The remaining 2,300 BCY are excavated and disposed in the on-post hazardous waste landfill. Remediation activities are conducted using vapor- and odor-suppression measures as required. Treatability testing will be performed during remedial design to verify the effectiveness of the innovative thermal process and establish operating parameters for the design of the full-scale operation. The innovative thermal technology must meet the treatability study technology evaluation criteria described in the dispute resolution agreement (PMRMA 1996). Solidification/stabilization will become the selected remedy if all evaluation criteria for the innovative thermal technology are not met. Treatability testing for solidification will be performed to verify the effectiveness of the solidification process and determine appropriate solidification/stabilization agents. Treatability testing and technology evaluation will be conducted in accordance with EPA guidance (OSWER-EPA 1989a) and EPA's "Guide for Conducting Treatability Studies under CERCLA" (1992).
- Section 36 Lime Basins – Excavation and containment of principal threat and human health exceedance soil in a triple-lined landfill cell at the on-post hazardous waste landfill facility. Prior to excavation of exceedance soil, overburden from the existing cover is removed and set aside. The excavated area is backfilled with clean borrow and the soil cover is repaired. Caustic washing and landfill of any agent-contaminated soil found during monitoring.
- Buried M-1 Pits – Approximately 26,000 BCY of principal threat and human health exceedance soil is treated by solidification/stabilization and then landfilled. The mixture of solidification/stabilization agents will be determined during remedial design by treatability testing. This treatability testing will be used to verify the effectiveness of the treatment process and establish operating parameters for the design of the full-scale operation. Excavation is conducted using vapor- and odor-suppression

measures. Caustic washing and landfill of any agent-contaminated soil found during monitoring. The excavated area is backfilled with clean borrow.

- Burial Trenches – UXO in these sites is located using a geophysical survey, excavated, and transported off post for detonation (unless the UXO is unstable and must be detonated on post) or other demilitarization process. Excavation and landfill of human health exceedance soil and backfill with on-post borrow material. Caustic washing and landfill of any agent-contaminated soil found during monitoring. Removal and landfill of munitions debris and nearby soil in excess of TCLP.

- Chemical Sewers – For sewers located within the South Plants Central Processing Area and Complex Trenches area, the sewer void space is plugged with a concrete mixture to prohibit access to these lines and eliminate them as a potential migration pathway for contaminated groundwater. The plugged sewers are contained beneath the soil cover or cap in their respective sites. For sewers located outside the South Plants Central Processing Area and Complex Trenches areas, sewer lines and principal threat and human health exceedance soil are excavated and landfilled. Any agent-contaminated soil found during monitoring is caustic washed and landfilled. Prior to excavation of exceedance soil, overburden is removed and set aside. The excavated area is backfilled with on-post borrow material and the overburden replaced.

- Sanitary/Process Water Sewers – Void space inside sewer manholes is plugged with a concrete mixture to prohibit access and eliminate the manholes as a potential migration pathway for contaminated groundwater. Aboveground warning signs are posted every 1,000 ft along the sewer lines to indicate their location underground.

- North Plants – Excavation and landfill of human health exceedance soil. Any agent-contaminated soil found during monitoring is caustic washed and landfilled. The excavated area is backfilled with on-post borrow material. A 2-ft-thick soil cover is placed over the soil posing a potential risk to biota and the footprint of the North Plants processing area.

- Toxic Storage Yards – Excavation and landfill of human health exceedance soil. Any agent-contaminated soil found during monitoring is caustic washed and landfilled. The excavated area is backfilled with on-post borrow material. The New Toxic Storage Yards are used as a borrow area for both low-permeability soil and structural fill.

- Munitions Testing – UXO in these sites is located using a geophysical survey, excavated, and transported off post for detonation (unless the UXO is unstable and must be detonated on post) or other demilitarization process. Removal and landfill of munitions debris and nearby soil in excess of TCLP.

- Lake Sediments – Excavation and landfill of human health exceedance soil and excavation and consolidation of soil posing risk to biota from Upper Derby Lake to Basin A. The excavated human health exceedance area is backfilled with on-post borrow material and the consolidated material is contained under the Basin A cover. Aquatic sediments are left in place and the area is monitored to ensure that the sediments continue to pose no unacceptable risk to aquatic biota.

- Ditches/Drainage Areas – Excavation and consolidation to Basin A of soil posing a potential risk to biota. The consolidated material is contained under the Basin A cover. The excavated area is backfilled with on-post borrow material.

- Sanitary Landfills – Excavation and landfill of human health exceedance soil and excavation and consolidation to Basin A of landfill debris and soil posing a potential risk to biota. The consolidated material is contained under the Basin A cover. The excavated area is backfilled with on-post borrow material.

- Buried Sediments – Excavation and landfill of human health exceedance soil. The excavated area is backfilled with on-post borrow material.

- Sand Creek Lateral – Excavation and landfill of human health exceedance soil and excavation and consolidation to Basin A of soil posing a potential risk to biota. The consolidated material is contained under the Basin A cover. The excavated area is backfilled with on-post borrow material.
- Surficial Soil – Excavation and landfill of human health exceedance soil and excavation and consolidation to Basin A or Former Basin F of soil posing a potential risk to biota from this medium group and excavation and landfill of soil from the pistol and rifle ranges. The consolidated material is contained under the Basin A cover or Basin F cap, and the human health exceedance area is backfilled.
- Excavation and disposal in the on-post TSCA-compliant landfill of PCB-contaminated soil (three areas identified by the PCB IRA with concentrations of 250 ppm or greater). Soil identified with concentrations ranging from 50 to 250 ppm will be covered with at least 3 ft of soil (five areas identified by the PCB IRA).
- Contingent Volume – Excavation and landfill of up to 150,000 BCY of additional volume to be identified based on visual field observations. An additional 14 samples from North Plants, Toxic Storage Yards, Lake Sediments, Sand Creek Lateral, and Burial Trenches and up to 1,000 additional confirmatory samples may be used to identify the contingent soil volume requiring excavation.
- Remedy components for all sites include reconditioning the surface soil and revegetating areas disturbed during remediation with locally adapted perennial vegetation.

Exceedance volumes for all medium groups are listed in Table 7.1-5. For sites with excavation as part of the selected remedy, the exceedance volume is considered the volume to be excavated and no confirmatory sampling will occur during implementation, other than to identify contingent volume.

Additional detail on this alternative is provided in the Detailed Analysis of Alternatives report. Figure 9.3-1 shows the selected sitewide soil remedy; Figures 9.3-2, 9.3-3, and 9.3-4 show the major excavation areas and cap or cover components of the selected soil remedy; and Figure 9.3-5 shows the areas where exceedance volumes are left in place and the type of containment systems used in those areas following implementation of the selected remedy. Tables 9.3-2 and 9.3-3 show the disposition of exceedance volumes and Table 9.3-4 details the capped/covered areas for the selected soil remedy. A process will be presented in future implementation documents that will allow for independent confirmation that volumes (defined spatially) are removed. The process will allow for verification by the state or EPA during remedial action.

9.4 Additional Components of the Selected Remedy

The Army, Shell, EPA, USFWS, and state of Colorado have agreed to several additional components that will be included in the overall on-post remedy. These components have been considered in the selection of the preferred alternatives and are as follows:

- Provision of $48.8 million held in trust to provide for the acquisition and delivery of 4,000 acre-feet of potable water to SACWSD and the extension of the water-distribution lines from an appropriate water supply distribution system to all existing well owners within the DIMP plume footprint north of RMA as defined by the detection limit for DIMP of 0.392 parts per billion (ppb). In the future, owners of any domestic wells, new or existing, found to have DIMP concentrations of 8 ppb (or other relevant CBSG at the time) or greater will be connected to a water-distribution system or provided a deep well or other permanent solution. The Army and Shell have reached an Agreement in Principle with SACWSD, enclosed as Appendix B of this ROD, regarding this matter.

- In compliance with NEPA, PMRMA will separately evaluate the potential impacts to the environment of both the acquisition of a water supply for SACWSD and for extension of water-distribution lines.

- The Army and Shell will fund ATSDR to conduct an RMA Medical Monitoring Program in coordination with CDPHE. The program's nature and scope will include baseline health assessments and be determined by the on-post monitoring of remedial activities to identify exposure pathways, if any, to any off-post community.

  A Medical Monitoring Advisory Group (MMAG) has been formed to evaluate information concerning exposure pathways and identify and recommend appropriate public health actions to CDPHE and ATSDR and to communicate this information to the community. CDPHE and ATSDR will use the recommendations of the MMAG to jointly develop an appropriate medical monitoring plan and jointly define the trigger for when such a plan will take effect. Any human health assessment completed by CDPHE and ATSDR will be formally reviewed by the Parties and the MMAG prior to issuance to the public. The MMAG includes representatives from the affected communities, regulatory agencies, local governments, Army, Shell, USFWS, and independent technical advisors. Any necessary technical advisors will be identified in coordination with CDPHE and funded through ATSDR.

  The primary goals of the Medical Monitoring Program are to monitor any off-post impact on human health due to the remediation and provide mechanisms for evaluation of human health on an individual and community basis, until such time as the soil remedy is completed. On behalf of the communities surrounding RMA, the MMAG will develop and submit to CDPHE and ATSDR specific recommendations defining goals, objectives, and the methodology of a program designed to respond effectively to RMA-related health concerns of the community.

  Elements of the program could include medical monitoring, environmental monitoring, health/community education or other tools. The program design will be determined through an analysis of community needs, feasibility, and effectiveness.

- Trust Fund – During the formulation and selection of the remedy, members of the public and some local governmental organizations expressed keen interest in the creation of a Trust Fund to help ensure the long-term operation and maintenance of the remedy once the remedial structures and systems are installed. In response to this interest, the Parties have committed to good-faith best efforts to establish a Trust Fund for the operation and maintenance of the remedy, including habitat and surficial soil. Such operation and maintenance activities will include those related to the new hazardous waste landfill; the slurry walls, caps, and soil and concrete covers; all existing groundwater pump-and-treat systems; the groundwater pump-and-treat system to intercept the Section 36 Bedrock Ridge Plume; the maintenance of lake levels or other means of hydraulic containment; all monitoring activities required for the remedy; design refinement for on-post surficial soil as described in Section 9.4; and any revegetation and habitat restoration required as a result of remediation.

  These activities are estimated to cost approximately $5 million per year (in 1995 dollars). The principal and interest from the Trust Fund would be used to cover these costs throughout the lifetime of remedial program.

  The Parties recognize that establishment of such a Trust Fund may require special legislation and that there are restrictions on the actions federal agencies can take with respect to proposing legislation and supporting proposed legislation. In addition to the legislative approach, the Parties are also examining possible options that may be adapted from trust funds involving federal funds that exist at other remediation sites. Because of the uncertainty of possible legislative requirements and other options, the precise terms of the Trust Fund cannot now be stated.

  A trust fund group will be formed to develop a strategy to establish the Trust Fund. The strategy group may include representatives of the Parties (subject to restrictions on federal agency participation), local governments, affected communities, and other interested stakeholders, and will be convened within 90 days of the signing of the ROD.

Notwithstanding these uncertainties, it is the intent of the Parties that if the Trust Fund is created it will include the following:

  - A clear statement that will contain the reasons for the creation of the Trust Fund and the purposes to be served by it.
  - A definite time for establishing and funding the Trust Fund, which the Parties believe could occur as early as 2008, when the remedial structures and systems may have been installed.
  - An appropriate means for competent and reliable management of the Trust Fund, including appropriate criteria for disbursements from the Trust Fund to ensure that the money will be properly used for the required purposes.

- Continued operation of the CERCLA Wastewater Treatment Plant to support the remediation activities.
- Stored, drummed waste identified in the waste management element of the CERCLA Hazardous Waste IRA may be disposed in the on-post hazardous waste landfill in accordance with the CDD (Harding Lawson Associates 1996).
- Continued monitoring, as part of design refinement, for areas that may pose a potential risk to biota as outlined in the following process:
  - The BAS of technical experts (such as ecotoxicologists, biologists, and range/reclamation specialists) from the Parties will focus on the planning and conduct of both the USFWS biomonitoring programs and the SFS/risk assessment process. The BAS will provide interpretation of results and recommendations for design refinements to the Parties' decision makers.
  - The ongoing USFWS biomonitoring programs and the SFS/risk assessment process will be used to refine design boundaries for surficial soil and aquatic contamination to be remediated.
    - Phase I and the potential Phase II of the SFS will be used to refine the general areas of surficial soil contamination concern. The field BMFs will be used to quantify ecological risks in the Area of Dispute, identify risk-based soil concentrations considered safe for biota, and thus refine the area of excess risks (Figure 6.2-6).
    - Pursuant to the FFA process, USFWS will conduct detailed site-specific exposure studies of contaminant effects and exposure (tissue levels and Army-provided abiotic sampling) on sentinel or indicator species of biota (including the six key species identified in the IEA/RC report as appropriate). These studies will address both the aquatic resources and at least the surficial soil in and around the Area of Dispute. These site-specific studies will be used in refining contamination impact areas in need of further remediation.
    - Results from both the SFS/risk assessment process and the site-specific studies will be considered in risk-management decisions, which may further refine the areas of surficial soil and aquatic contamination to be remediated. (In the event of a conflict between management of RMA as a wildlife refuge and performance of remedial response actions, the Rocky Mountain Arsenal National Wildlife Refuge Act indicates that response actions will take priority.)
  - The BAS will serve as a technical resource to the Parties' decision makers by using technical expertise in analyzing, and potentially collecting, data sufficient to support design refinement for surficial soil areas and aquatic resources that will break unacceptable exposure pathways in consideration of minimizing habitat disturbance. Further, it will assess through monitoring the efficacy of remedies in breaking unacceptable pathways to biota. If any additional sites are identified, the remedy will be implemented as follows:

- It will be staged to allow habitat recovery.
- It will be performed first on locations selected through a balance of factors such as:
  - The Parties agree an area has a negative impact on or excessive risk to fish or wildlife.
  - The effort will not be negated by recontamination from other remediation activities.
  - The existing fish and wildlife resource value.
- It will include revegetation of a type specified by USFWS; if the initial revegetation is not successful, the appropriate adjustments will be made and revegetation again implemented.
- It will provide that the locations and timing of remediation are to be determined with consideration of and in coordination with USFWS refuge management plans and activities.

- The SFS, biomonitoring programs, and recommendations of the BAS will be used to refine the areas of remediation during remedial design.

- Any UXO encountered during remediation will be excavated and transported off post for detonation (unless the UXO is unstable and must be detonated on post) or other demilitarization process.
- Within 180 days after issuance of the Notice of Availability for the ROD, the Army will append to the ROD a complete, detailed schedule for completion of activities associated with the selected remedy. The schedule will identify the enforceable project milestone dates for design activities. Future design documents will detail milestone dates for implementation activities. Revisions to this schedule will be initiated prior to the start of each fiscal year to allow adequate time for review and concurrence by the Parties.

9.5 Remediation Goals and Standards

The treatment components of the selected groundwater remedy will meet the CSRGs presented in Tables 9.1-1 through 9.1-4, and the components of the selected soil and structures remedy will meet the remediation goals and standards presented in Table 9.5-1. The selected remedies will comply with the performance standards as provided in Appendix A (ARARs).

9.6 Cost of the Selected Remedy

The total estimated cost (in 1995 dollars) for the selected remedy is $2.2 billion (present worth $1.8 billion). Table 9.6-1 presents the capital and O&M costs for the selected alternatives. The time required for implementation is approximately 17 years, with groundwater system operations continuing for at least 30 years. The implementation of the remedy could be accelerated if funding is available that exceeds $100 million/year.

9.7 Long-Term Operations

Long-term operations are those ongoing activities that will be performed after the initial remediation work is completed and that will continue after EPA releases the site to USFWS as a wildlife refuge. These include monitoring and maintaining containment systems, such as the caps and the landfill, and continuing the operation of groundwater treatment systems.

Soil sites where covers or caps are constructed will be inspected on a regular basis, and damage to the vegetative cover or any eroded soil will be repaired. Long-term management also includes access restrictions to capped and covered areas to ensure the integrity of the containment systems. Where human health exceedances are left in place at soil sites, groundwater will be monitored, as necessary, to evaluate the effectiveness of the remedy. The on-site hazardous waste landfill will be closed and monitored according to RCRA and TSCA requirements. Long-term activities at this facility will include leachate collection and disposal, regular cover inspections with repair of vegetative cover damage or erosion, and sampling of upgradient and downgradient wells to monitor for migration of landfill contaminants into the groundwater. Monitoring activities for biota will continue by USFWS in support of evaluating the effectiveness of the selected remedy.

Long-term activities for the water medium include continued operation of the NWBCS, NBCS, ICS, the Basin A Neck and North of Basin F Groundwater IRA systems, and the new Section 36 Bedrock Ridge groundwater Extraction System. Operation of wells within these systems may be discontinued according to the shutdown criteria listed in Section 9.1. Maintenance of lake levels and groundwater monitoring will be continued as described in Section 9.1.

A network of monitoring wells will be sampled to evaluate the effectiveness of the remedy. A select number of deep wells will also be sampled to monitor any contamination in the confined aquifer. Surface water will be monitored and managed in a manner consistent with the selected remedy.

There are no long-term activities directly associated with the structures medium groups as all potentially contaminated structures will be demolished and the structural debris placed into the on-post hazardous waste landfill or used as fill under the Basin A cover. These sites will be monitored and maintained as described above.

Technical working groups or subcommittees will combine their efforts to evaluate the effectiveness of the remedy and make recommendations to the Parties' decision makers. In addition, site reviews will be conducted at least every 5 years (following the signing of the ROD) for all sites where contaminants that exceed remediation goals are left in place. The effectiveness of containment remedies will be evaluated to determine what additional remedial actions may be required if containment is found to be inadequate. In the event other contaminants not included as COCs are identified as a concern (e.g., dioxin) during or after design or implementation, an evaluation will be conducted as required by EPA guidance (OSWER-EPA 1989a) to ensure that the remedial action is protective of human health and the environment. At a minimum, evaluations will be part of the 5-year site review.

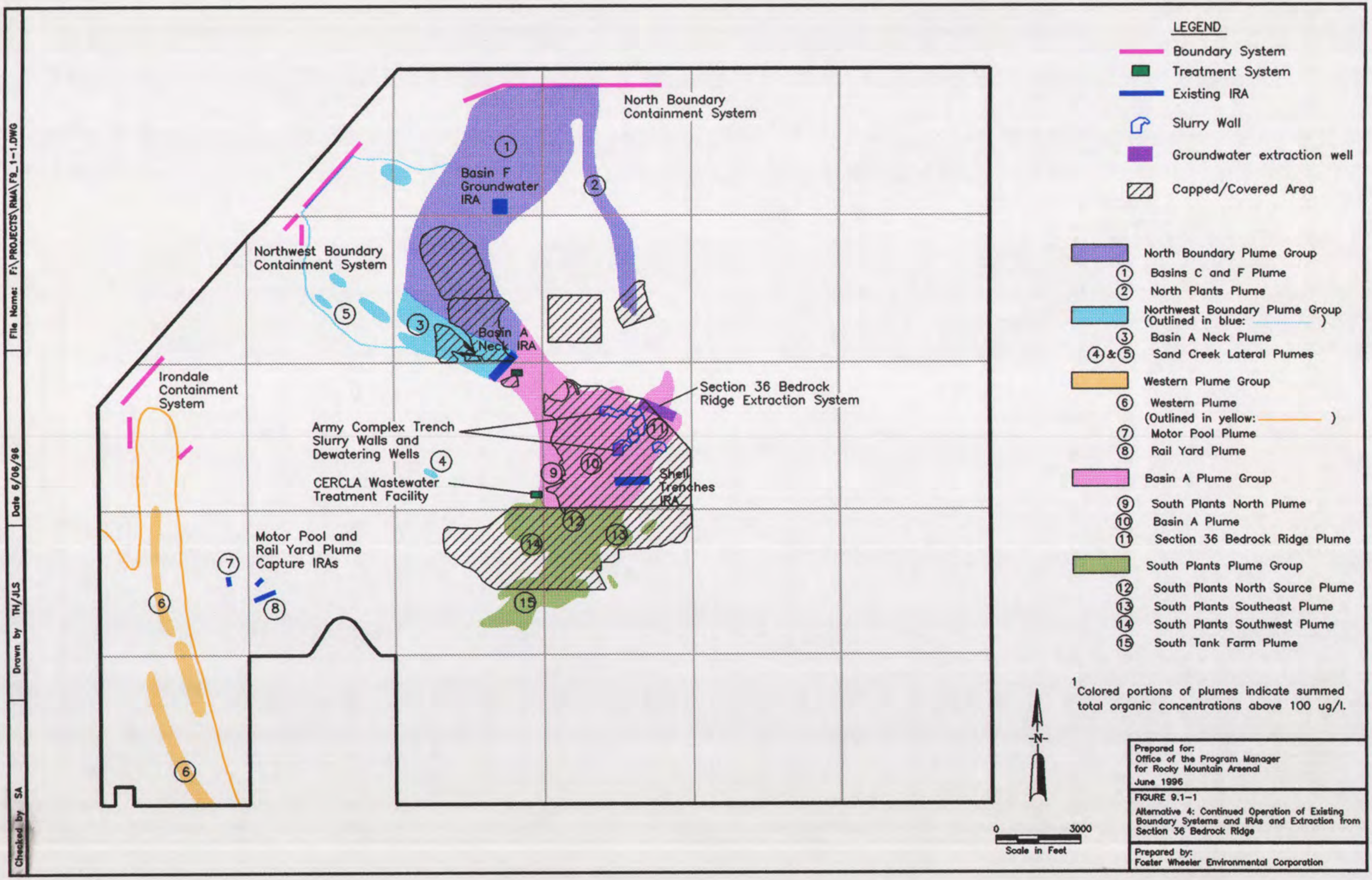
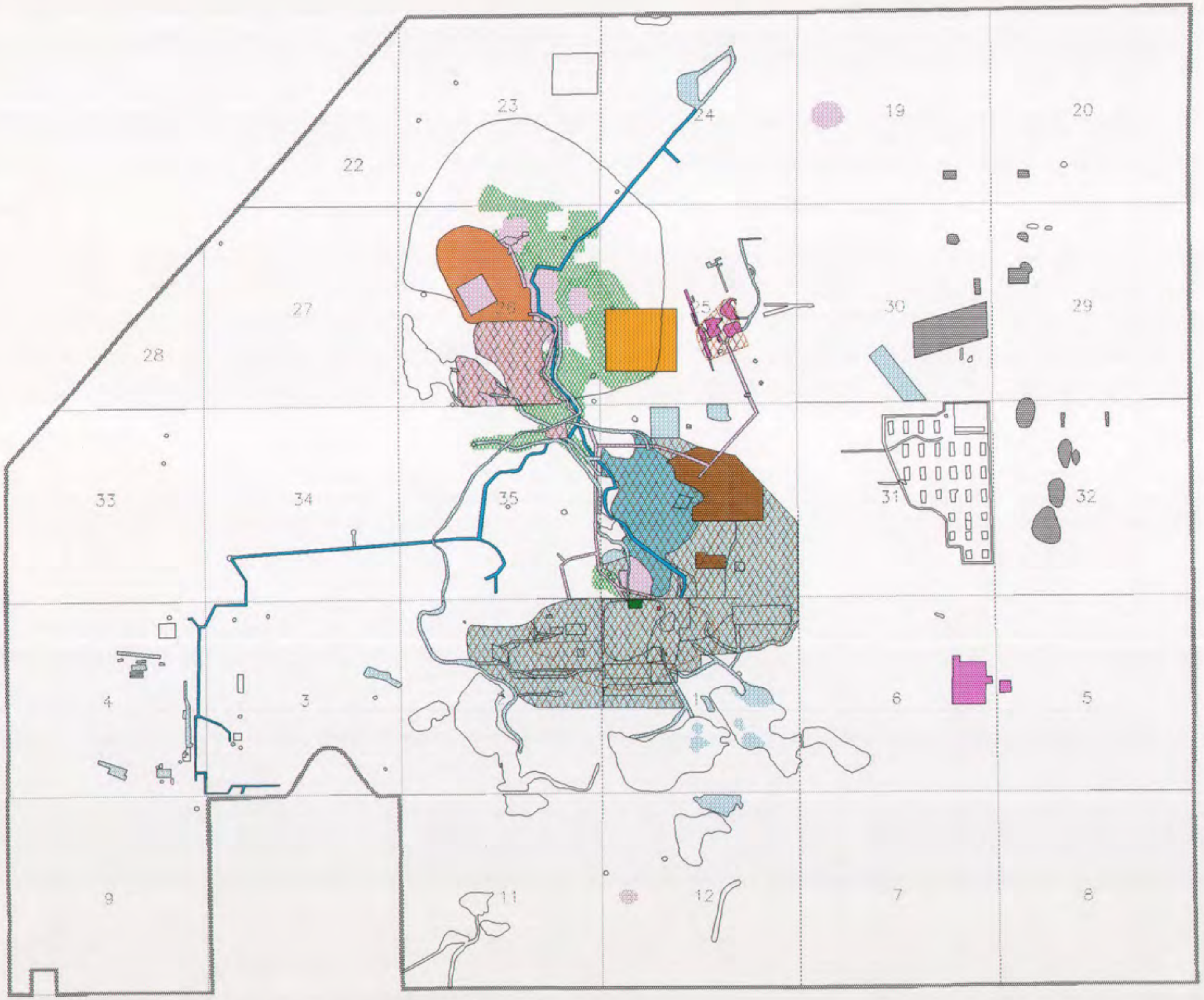


FIGURE 9.1–1 Alternative 4: Continued Operation of Existing Boundary Systems and IRAs and Extraction from Section 36 Bedrock Ridge



Legend

- RMA Boundary
- SAR Site Boundary[1]
- In-situ Solidification of Principal Threat Volume; RCRA-Equivalent Cap
- RCRA-Equivalent Caps
- Direct Solidification/Stabilization
- Innovative Thermal Treatment (Hex Pit)
- Basin A Consolidation Area
- Landfill Human Health Soil,[2] Consolidation of Biota Soil
- Landfill Human Health Soil[3]
- Landfill Site
- Soil Covers
- Agent Screening Area (Caustic wash/landfill)
- UXO Screening Area (Detonation/landfill)
- Surficial Soil Consolidation
- Access Restrictions
- 5 Section Number

[1] Study Area Report (see Remedial Investigation Summary Report, Ebasco 1992a)

[2] Debris from the Sanitary Landfills Medium Group will be consolidated.

[3] Wastepile material will be dried prior to landfilling, if necessary, to pass EPA paint filter test.

-N-

1500 0 1500 3000 Feet

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

Figure 9.3-1

Selected Soil Remedy Consolidation/Caps/Treatment/Landfill

Foster Wheeler Environmental Corporation
June 1996

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Date 6/06/96

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Checked by SA

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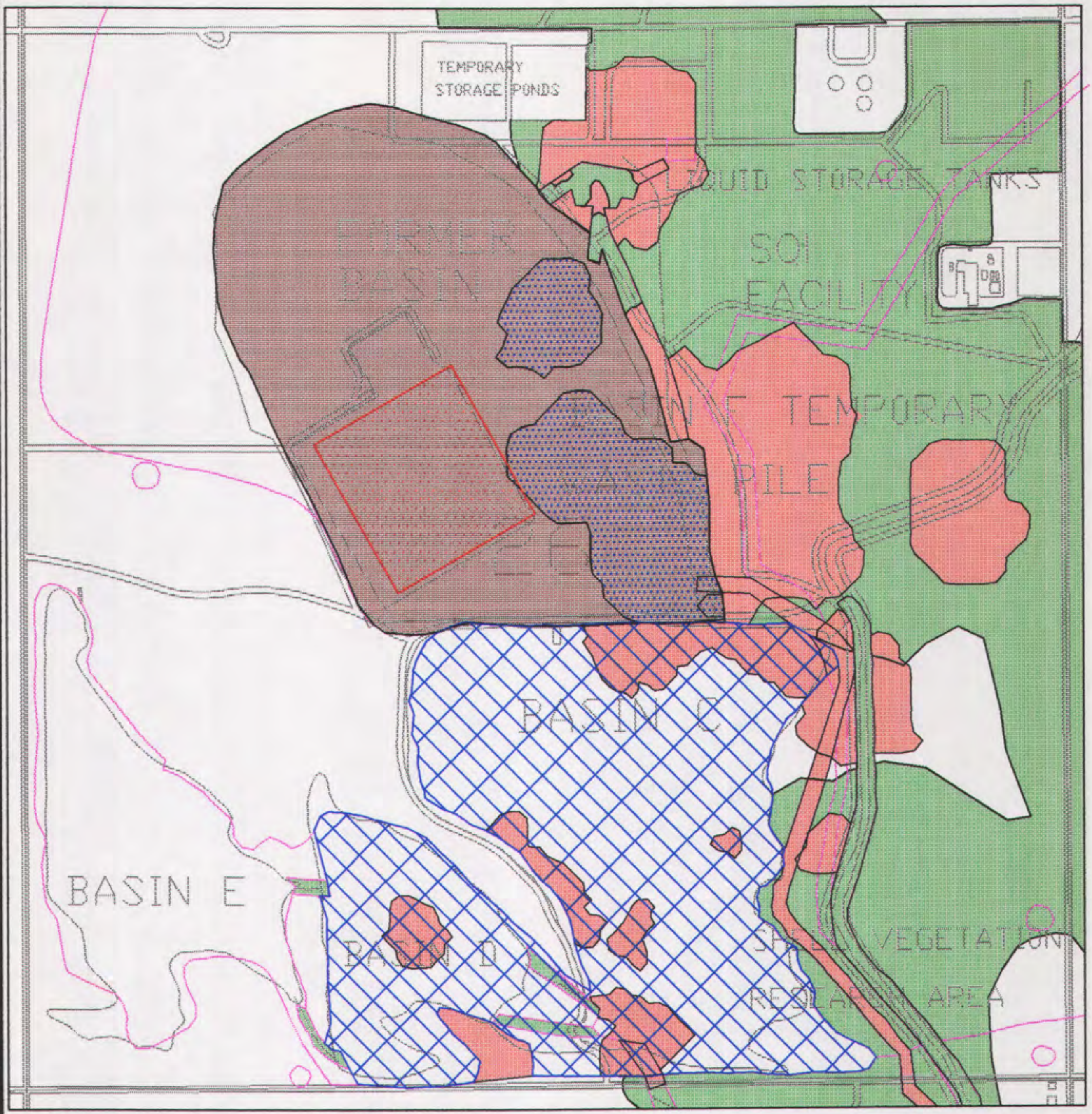


Legend

- Former Basin F Solidification Area
- RCRA–Equivalent Cap
- Human Health and Principal Threat Excavation Area
- Biota Excavation Area
- Basin F Wastepile Excavation
- 2–Foot Soil Cover Area
- SAR Site Boundary (Study Area Report; see Remedial Investigation Summary Report, Ebasco 1992a.)
- 31 Section Number
- Section Line
- Drainage
- Road
- Railroad

-N-

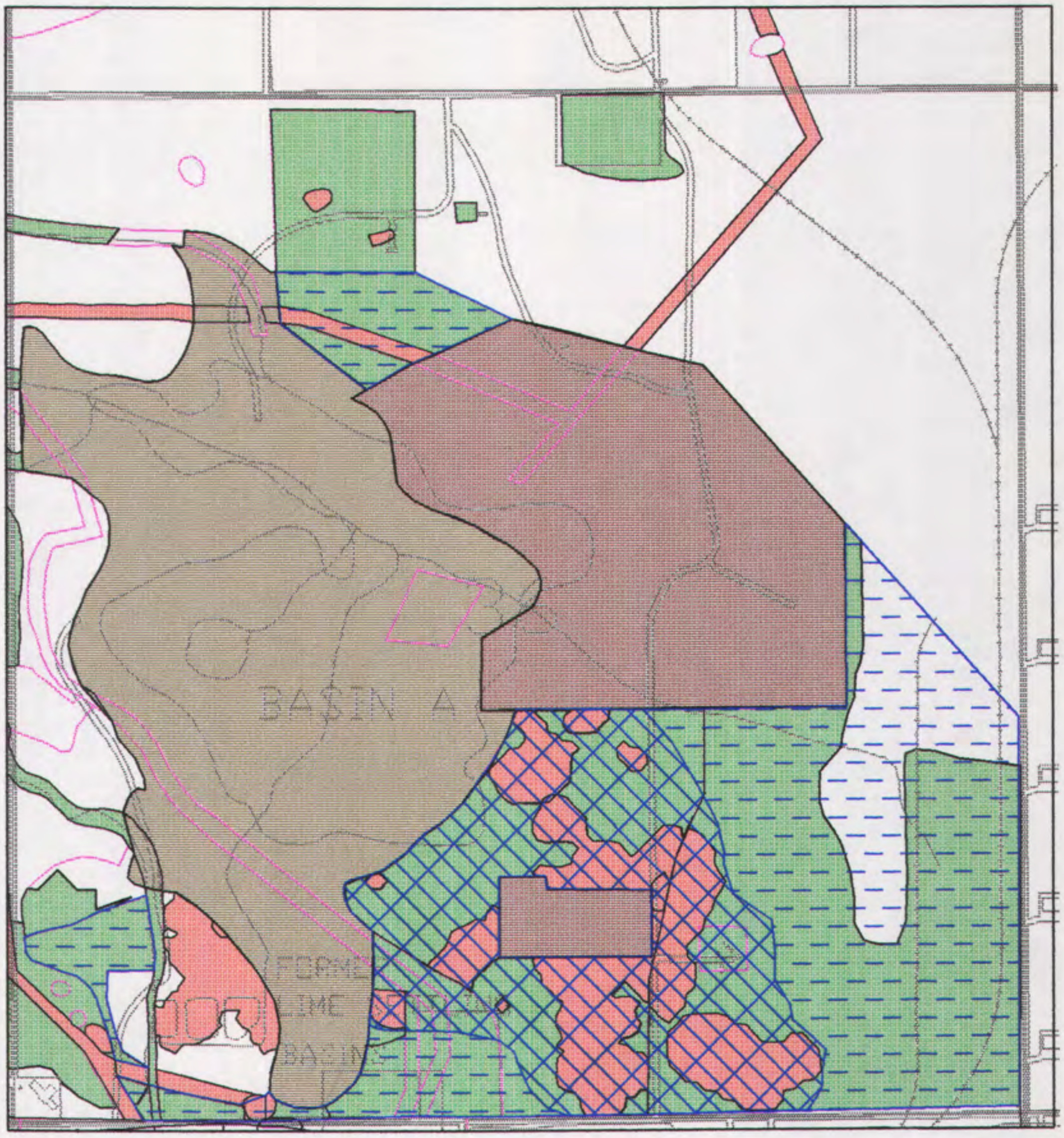
0 400 800
Scale in Feet

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

Prepared July 1996

Figure 9.3–2
Section 26 Excavation Areas and Cap/Cover Components

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.



Legend

- Basin A Consolidation Area with 4-Foot Soil Cover/6-Inch Concrete Layer
- RCRA-Equivalent Caps
- Human Health and Principal Threat Excavation Area
- Biota Excavation Area
- 2-Foot Soil Cover Area
- 1-Foot Soil Cover Area
- SAR Site Boundary (Study Area Report; see Remedial Investigation Summary Report, Ebasco 1992a.)
- 31 Section Number
- Section Line
- Drainage
- Road
- Railroad

-N-

0 500 1000
Scale in Feet

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

Prepared June 1996

Figure 9.3-3

Section 36 Excavation Areas and Cap/Cover Components

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

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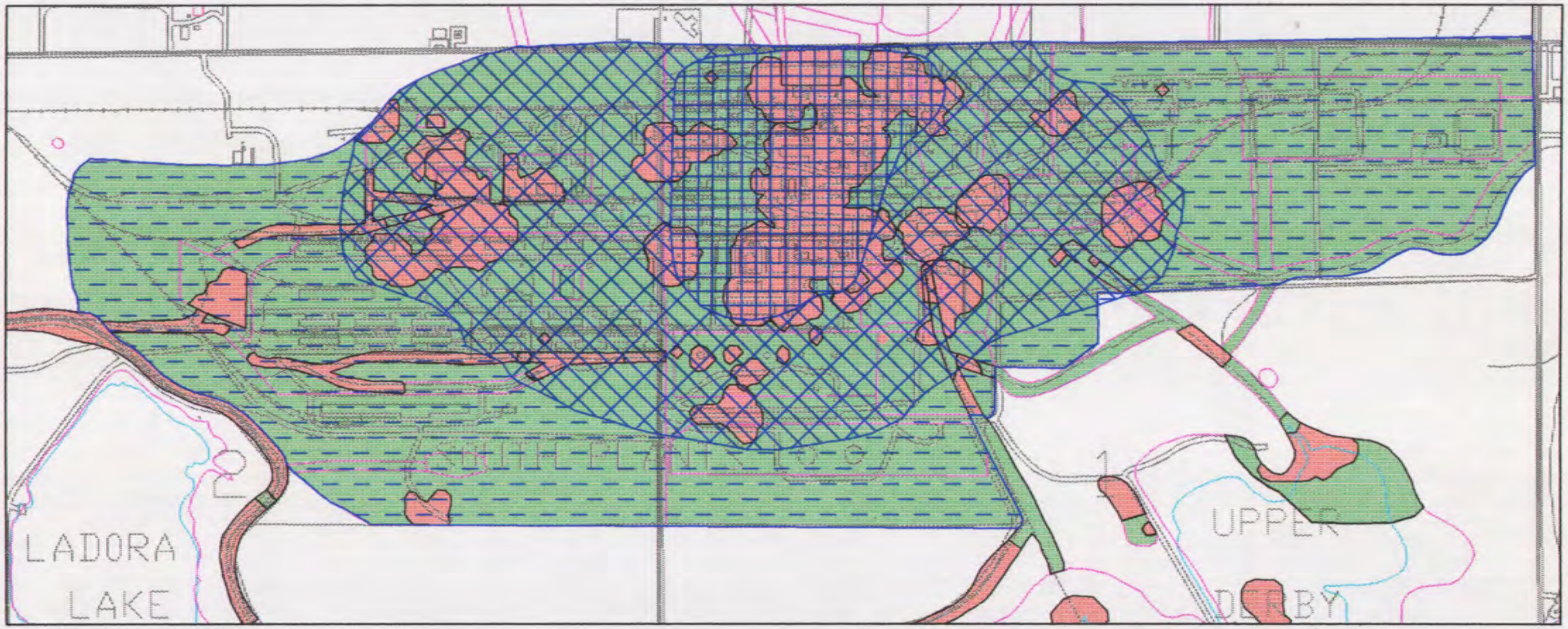

Legend

- Human Health and Principal Threat Excavation Area
- Biota Excavation Area
- South Plants Central Processing Area Cover (4–foot soil cover with biota barrier)
- 3–Foot Soil Cover Area
- 1–Foot Soil Cover Area
- SAR Site Boundary (Study Area Report; see Remedial Investigation Summary Report, Ebasco 1992a.)
- 31 Section Number
- Section Line
- Drainage
- Road
- Railroad

N

0 500 1000
Scale in Feet

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

Prepared June 1996

Figure 9.3–4
South Plants Excavation Areas and Cover Components

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corp.

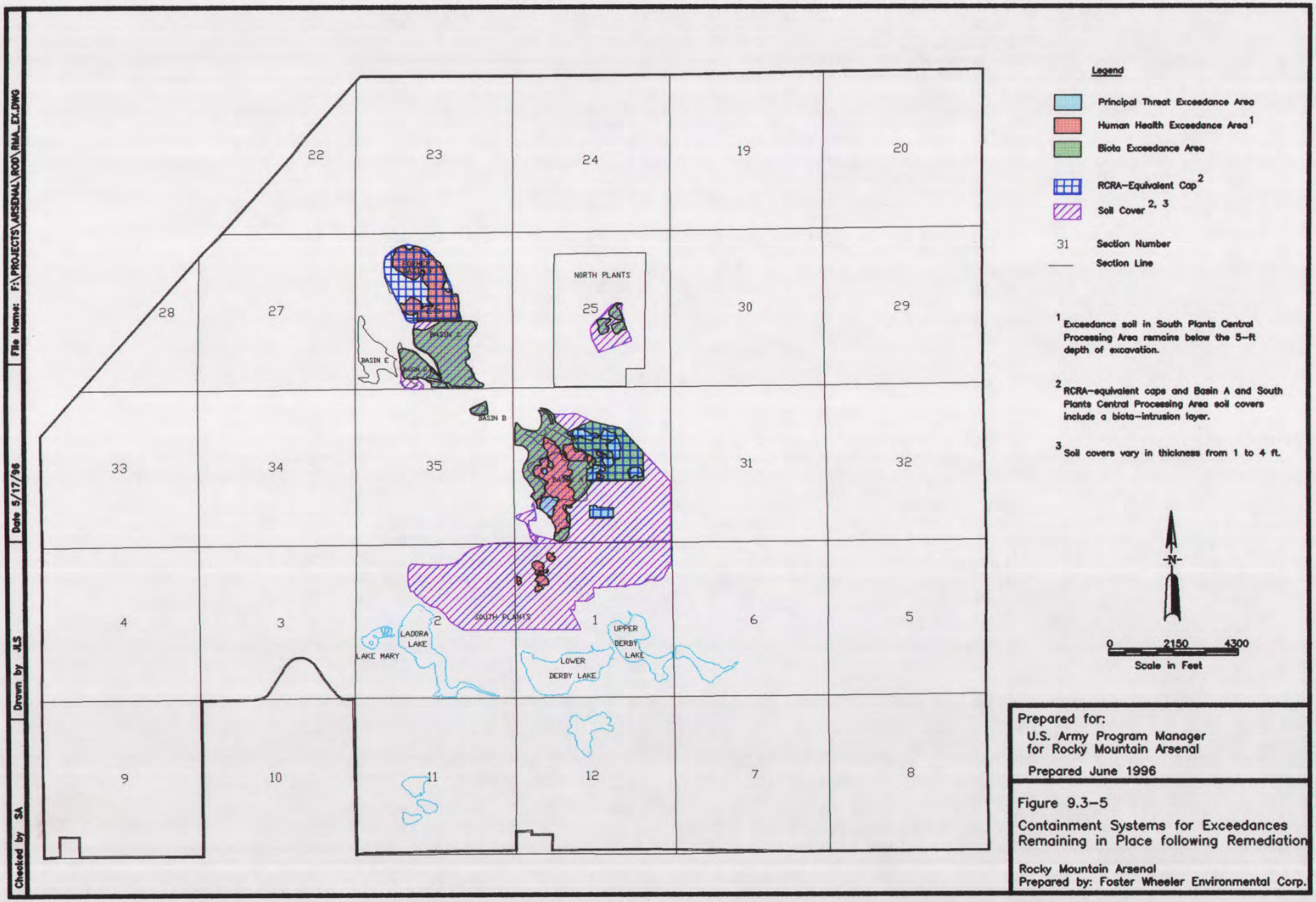

Figure 9.3–5
Containment Systems for Exceedances Remaining in Place following Remediation

Table 9.1-1 CSRGs for the Northwest Boundary Containment System

Chemical Group/Compound	Containment System Remediation Goals (µg/l)	
VHOs (Volatile Halogenated Organics)		
Trichloroethylene	3[1]	
Chloroform	6[2]	
OPHBGs (Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related)		
DIMP (Diisopropylmethyl phosphonate)	8[2]	
Other Organics		
NDMA (n-Nitrosodimethylamine)	0.007[4]	(0.033)[3]
OCPs (Organochlorine Pesticides)		
Dieldrin	0.002[2]	(0.05)[3]
Endrin	0.2[2]	
Isodrin	0.06[1]	
Arsenic	2.35[1]	

[1] Health-based value from the ROD for the Off-Post Operable Unit (Harding Lawson Associates 1995).
[2] Colorado Basic Standards for Groundwater. The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.
[3] Current certified reporting limit or practical quantitation limit readily available from a certified commercial laboratory.
[4] Risk-based value from Integrated Risk Information System (OHEA-EPA 1995).

Table 9.1-2 CSRGs for the Irondale Containment System

Chemical Group/Compound	Containment System Remediation Goals (µg/l)
VHOs (Volatile Halogenated Organics)	
Trichloroethylene	5[1,2]
Other Organics	
DBCP (Dibromochloropropane)	0.2[1,2]

1 Colorado Basic Standards for Groundwater. The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.
2 Federal maximum contaminant levels, 40 CFR 141.

Table 9.1-3 CSRGs for the North Boundary Containment System

Chemical Group/Compound	Containment System Remediation Goals (µg/l)	
VHOs (Volatile Halogenated Organics)		
1,2-Dichloroethane	0.4[1]	(1.0)[5]
1,2-Dichloroethylene	70 [1,2]	
Carbon tetrachloride	0.3 [1]	(0.99)[5]
Chloroform	6 [1]	
Methylene chloride	5 [1,2,6,7]	
Tetrachloroethylene	5 [1,2]	
Trichloroethylene	3 [3]	
VHCs (Volatile Hydrocarbon Compounds)		
DCPD (Dicyclopentadiene)	46 [3]	
VAOs (Volatile Aromatic Organics)		
Benzene	3 [3]	
Xylenes	1,000 [3]	
Toluene	1,000 [1,2]	
OSCMs (Organosulfur Compounds; Mustard Agent Related)		
1,4-Oxathiane	160 [3]	
Dithiane	18 [3]	
OSCHs (Organosulfur Compounds; Herbicide Related)		
Chlorophenylmethyl sulfide	30 [4]	
Chlorophenylmethyl sulfone	36 [4]	
Chlorophenylmethyl sulfoxide	36 [4]	
OPHGBs (Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related)		
DIMP (Diisopropylmethyl phosphonate)	8 [1]	
OPHPs (Organophosphorous Compounds; Pesticide Related)		
Atrazine	3 [1,2]	
Malathion	100 [3]	

Table 9.1-3 CSRGs for the North Boundary Containment System

Chemical Group/Compound	Containment System Remediation Goals (µg/l)	
OCPs (Organochlorine Pesticides)		
Aldrin	0.002[1]	(0.05)[5]
Dieldrin	0.002[1]	(0.05)[5]
Endrin	0.2[1]	
Isodrin	0.06[3]	
Other Organics		
DBCP (Dibromochloropropane)	0.2[1,2]	
NDMA (N-Nitrosodimethylamine)	0.007[6]	(0.033)[5]
Arsenic	2.35[3]	
Anions		
Fluoride	2,000[1,10]	
Chloride	250,000[1,8]	
Sulfate	540,000[1,8,9]	

1 Colorado Basic Standards for Groundwater. The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.
2 Federal maximum contaminant levels, 40 CFR 141.
3 Health-based value from the ROD for the Off-Post Operable Unit (Harding Lawson Associates 1995).
4 EPA Region VIII Health Advisory value.
5 Current certified reporting limit or practical quantitation limit readily available from a certified commercial laboratory.
6 Risk-based level from the Integrated Risk Information System (OHEA-EPA 1995).
7 Methylene chloride is a common laboratory contaminant and analytical anomalies may be observed during compliance monitoring.
8 As described in Section 7.2.2, chloride and sulfate are expected to attenuate naturally, achieving remediation goals with time.
9 Inorganic CSRG for sulfate may be the natural background concentration.
10 The federal MCL for fluoride is 4,000 µg/l.

Table 9.1-4 CSRGs for the Basin A Neck IRA Treatment System

Chemical Group/Compound	Containment System Remediation Goals (µg/l)	
VHOs (Volatile Halogenated Organics)		
1,2-Dichloroethane	0.4[1]	(1.1)[4]
1,1,1-Trichloroethane	200[1,2]	
1,1-Dichloroethylene	7[1,2]	
Carbon tetrachloride	0.3[1]	(1.0)[4]
Chlorobenzene	100[1,2]	
Chloroform	6[1]	
Tetrachloroethylene	5[1,2]	
Trichloroethylene	5[1,2]	
VHCs (Volatile Hydrocarbon Compounds)		
Dicyclopentadiene	46[3]	
VAOs (Volatile Aromatic Organics)		
Benzene	5[1,2]	
OPHPs (Organophosphorus Compounds; Pesticide Related)		
Atrazine	3[1,2]	
SHOs (Semivolatile Halogenated Organics)		
Hexachlorocyclopentadiene	50[1]	
OCPs (Organochlorine Pesticides)		
DDT (Dichlorodiphenyltrichloroethane	0.1[1]	
Dieldrin	0.002[1]	(0.1)[4]
Endrin	0.2[1]	
OSCHs (Organosulfur Compounds; Herbicide Related)		
Chlorophenylmethylsulfide	30[3]	
Chlorophenylmethylsulfone	36[3]	
Chlorophenylmethylsulfoxide	36[3]	
Dicyclopentadiene	46[3]	
OSCMs (Organosulfur Compounds; Mustard Agent Related)		
1,4-Oxathiane	160[3]	
Dithiane	18[3]	

Chemical Group/Compound	Containment System Remediation Goals (µg/l)
Arsenic	50[1,2]
Mercury	2[1,2]

[1] Colorado Basic Standards for Groundwater. The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.
[2] Federal maximum contaminant levels, 40 CFR 141.
[3] Health-based value from the ROD for the Off-Post Operable Unit (Harding Lawson Associates 1995).
[4] Current practical quantitation limit or certified reporting limit.

Table 9.3-1 Summary of the Selected Soil Remedy

Medium Groups/Subgroups	Remedial Action
Munitions Testing	Munitions screening; off-post detonation of UXO (450 BCY); landfill debris and soil above TCLP (89,000 BCY).
North Plants	Landfill human health exceedance (220 BCY); agent monitoring during excavation; caustic washing; construct soil cover over biota risk area and processing area footprint (160,000 SY).
Toxic Storage Yards	Landfill human health exceedance (2,700 BCY); utilize New Toxic Storage Yard for borrow area; agent monitoring during site excavation and preparation; caustic washing.
Lake Sediments	Landfill human health exceedances (16,000 BCY); consolidate soil posing risk to biota from Upper Derby Lake (19,000 BCY) into Basin A or South Plants; deferral to USFWS for aquatic sediment.
Surficial Soil	Landfill human health exceedances (87,000 BCY); consolidate soil posing risk to biota in Basin A/Former Basin F/South Plants (460,000 BCY).
Ditches/Drainage Areas	Consolidate soil posing risk to biota in Basin A (23,000 BCY).
Basin A	Construct soil cover with formed concrete layer over principal threat and human health exceedances and soil posing risk to biota (670,000 SY); consolidate debris and soil posing risk to biota (790,000 BCY) and structural debris (160,000 BCY) from other sites.
Basin F Wastepile	Landfill entire wastepile (principal threat exceedance) (600,000 BCY) in triple-lined cell (with vapor controls) after drying saturated materials.
Former Basin F	In situ solidification/stabilization of principal threat volume (190,000 BCY); construct RCRA-equivalent cap over entire site (including Basin F Wastepile footprint) (525,000 SY).
Secondary Basins	Landfill human health exceedances (32,000 BCY); construct soil cover over soil posing risk to biota (520,000 SY).
Sanitary/Process Water Sewers	Plug remaining manholes.
Chemical Sewers	Plug sewer lines in South Plants Central Processing Area and Complex Trenches; landfill remaining principal threat and human health exceedances (64,000 BCY).
Complex Trenches	Construct RCRA-equivalent cap with formed concrete layer over principal threat and human health exceedances and soil posing risk to biota (390,000 SY) and install a slurry wall around disposal trenches.
Shell Trenches	Modify existing cover to be a RCRA-equivalent cap (32,000 SY) and modify existing slurry wall around trenches.

Table 9.3-1 Summary of the Selected Soil Remedy

Medium Groups/Subgroups	Remedial Action
Hex Pit	Treatment of buried material (1,000 BCY) using an innovative thermal technology (with vapor controls); landfill remaining volume (2,300 BCY). Solidification/stabilization will become the selected remedy if all evaluation criteria for the innovative thermal technology are not met.
Sanitary Landfills	Landfill human health exceedances (14,000 BCY); consolidate debris and soil posing risk to biota in Basin A (410,000 BCY).
Section 36 Lime Basins	Landfill principal threat and human health exceedances in triple-lined cell (54,000 BCY); repair existing soil cover.[1]
Buried M-1 Pits	Solidification of principal threat and human health exceedances (26,000 BCY) and landfill (with vapor controls).[1]
South Plants Central Processing Area	Landfill principal threat and human health exceedances (110,000 BCY); construct soil cover over entire site including soil posing risk to biota (220,000 SY); consolidate soil posing risk to biota from other sites (370,000 BCY).[1]
South Plants Ditches	Landfill principal threat and human health exceedances (33,000 BCY); consolidate soil posing risk to biota into excavated areas or South Plants Central Processing Area (22,000 BCY); construct soil cover over entire site (120,000 SY).
South Plants Balance of Areas	Landfill principal threat and human health exceedances (130,000 BCY); consolidate soil posing risk to biota into excavated areas or South Plants Central Processing Area (510,000 BCY); construct soil cover over entire site (1,700,000 SY).[1,2]
Buried Sediments	Landfill human health exceedances (16,000 BCY).
Sand Creek Lateral	Landfill human health exceedances (15,000 BCY); consolidate soil posing risk to biota into Basin A (90,000 BCY).
Section 36 Balance of Areas	Landfill human health exceedances and debris (140,000 BCY); consolidate soil posing risk to biota into Basin A (140,000 BCY); construct soil cover over entire site (850,000 SY).[1,2]
Burial Trenches	Landfill human health exceedances and debris (85,000 BCY).[1,2]
Contingent Volume	Landfill identified volume (up to 150,000 BCY).

[1] Agent monitoring during excavation and treatment of any soil containing agent by caustic solution washing.

[2] Munitions screening prior to excavation, off-post detonation of any munitions encountered, and landfill munitions debris/soil above TCLP.

Table 9.3-2 Final Disposition of Soil Exceedance Volumes[1]

Medium Group/Subgroup	RCRA Landfill[2]	Enhanced RCRA Landfill[2]	Consolidation in Basin A	Consolidation in Basin F	Consolidation within South Plants	Treatment[3]	Caustic Washing and Landfill	UXO Demilitarization Off Post
Munitions Testing	89,000							450
North Plants	220						61	
Toxic Storage Yards	2,700						220	
Lake Sediments	16,000		19,000					
Ditches/Drainage Areas			23,000					
Surficial Soil	87,000		109,000	351,000				
Basin A								5
Basin F Wastepile		600,000						
Secondary Basins	32,000							
Former Basin F[3]						190,000		
Sanitary/Process Water Sewers								
Chemical Sewers	61,000						20	
Complex Trenches								130
Shell Trenches								
Hex Pit[3]	2,300					1,000		
Sanitary Landfills	14,000		406,000					
Section 36 Lime Basins		54,000					91	
Buried M-1 Pits[3]						26,000	29	
South Plants Central Processing Area	110,000						160	
South Plants Ditches	33,000				22,000			
South Plants Balance of Areas	135,000				510,000		160	50
Buried Sediments	16,000							
Sand Creek Lateral	15,000		90,000					
Section 36 Balance of Areas	142,000		140,000				300	160
Burial Trenches	85,000							550
Totals	840,000	654,000	787,000	351,000	532,000	217,000	1,040	1,340

1 All volumes given in bank cubic yards. The soil volumes referenced in this table are summarized in Table 7.1-5, and are based on the TECHBASE software and other calculations. All soil volumes referenced in this table are subject to the addition of "contingent volumes" based on findings during implementation of remedial activities.

2 Landfill volume does not include contingent soil volume (up to 150,000 BCY), structures demolition debris, treated material volume, or landfill daily cover.

3 Treatment detailed as follows: Former Basin F, in situ solidifcation; Hex Pit, innovative thermal; Buried M-1 Pits, solidification and landfill.

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Table 9.3-3 Untreated Soil Exceedance Volumes Remaining In Place[1,2]

Medium Group/Subgroup	Human Health	Principal Threat	Biota	Agent	UXO	UXO Debris	Consolidated Soil from Other Sites	Total Volume Remaining in Place
Munitions Testing								
North Plants			17,000					17,000
Toxic Storage Yards								
Lake Sediments								
Ditches/Drainage Areas								
Surficial Soil								
Basin A	160,000	32,000	88,000	710	89	47000[3]	787,000	1,080,000
Basin F Wastepile								
Secondary Basins			140,000					140,000
Former Basin F	550,000						351,000	901,000
Sanitary/Process Water Sewers								
Chemical Sewers	24,000	11,500		49				24,000
Complex Trenches	400,000	400,000		1,300	1,170	130,000[4]		532,000
Shell Trenches	100,000	100,000						100,000
Hex Pit								
Sanitary Landfills								
Section 36 Lime Basins								
Buried M-1 Pits								
South Plants Central Processing Area	32,000[5]	17,000[5]	27,000				370,000	429,000
South Plants Ditches								
South Plants Balance of Areas							162,000	162,000
Buried Sediments								
Sand Creek Lateral								
Section 36 Balance of Areas								
Burial Trenches				12				
Totals	1,270,000	561,000	272,000	2,070	1,260	177,000	1,670,000	3,390,000

1 All volumes given in bank cubic yards.
2 All volumes remaining in place are contained beneath soil covers or caps.
3 Debris volume remaining includes 17,000 BCY human health exceedance volume and 30,000 BCY of biota risk volume.
4 Debris volume remaining includes 43,000 BCY human health exceedance volume and 87,000 BCY of biota risk volume.
5 Remaining volume at a depth greater than 5 ft.

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Table 9.3-4 Cap and Soil Cover Components[1]

Medium Group/Subgroup	RCRA-Equivalent Caps	Soil Covers: 4 ft minimum thickness	3 ft minimum thickness	2 ft minimum thickness	1 ft minimum thickness
Munitions Testing					
North Plants				157,000	
Toxic Storage Yards					
Lake Sediments					
Ditches/Drainage Areas					
Surficial Soil					
Basin A[2]		667,000			
Basin F Wastepile					
Secondary Basins				523,000	
Former Basin F	525,000				
Sanitary/Process Water Sewers					
Chemical Sewers					
Complex Trenches[2]	390,000				
Shell Trenches	32,000				
Hex Pit					
Sanitary Landfills					
Section 36 Lime Basins					
Buried M-1 Pits					
South Plants Central Processing Area		230,000			
South Plants Ditches[3]					
South Plants Balance of Areas			826,000		1,010,000
Buried Sediments					
Sand Creek Lateral					
Section 36 Balance of Areas				345,000	506,000
Burial Trenches					
Totals	947,000	897,000	826,000	1,030,000	1,520,000

[1] All areas given in square yards.

[2] Cap or cover includes a 6-inch formed concrete layer.

[3] South Plants Ditches sites are included under the South Plants Balance of Areas cover area.

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
RCRA/TSCA Hazardous Waste Landfill	Munitions Testing; Secondary Basins; Chemical Sewers; Sanitary Landfills; South Plants Central Processing Area; South Plants Ditches; South Plants Balance of Areas; Buried Sediments; Sand Creek Lateral; Section 36 Balance of Areas; Burial Trenches; Buried M-1 Pits; Hex Pit; North Plants; Toxic Storage Yards; Lake Sediments; Surficial Soil; No Future Use Structures, Significant Contamination History; No Future Use Structures, Agent History	Landfill • Standard: Landfill principal threat and human health soil exceedance volumes, UXO debris, agent-contaminated material, and structural debris. • Standard: Design landfill to meet state 1,000-year siting criteria. • Standard: Ensure all material disposed in landfill passes EPA paint filter test. Cap • Standard: Minimize infiltration by limiting the hydraulic conductivity of the clay/synthetic composite barrier layer (1×10^{-7} cm/sec or less for clay layer). • Standard: Meet or exceed all RCRA, TSCA, and state requirements. Liner • Standard: Minimize percolation by limiting the hydraulic conductivity of the compacted clay layer to 1×10^{-7} cm/sec or less. • Standard: Install two composite liners, each consisting of 3 ft of compacted clay and a synthetic liner. • Standard: Meet or exceed all RCRA, TSCA, and state requirements.	RCRA/TSCA regulations; State RCRA regulations; CAMU Designation Document

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
Enhanced RCRA Hazardous Waste Landfill	Basin F Wastepile; Section 36 Lime Basins	Landfill • Standard: Landfill principal threat and human health soil exceedance volumes and agent-contaminated material. • Standard: Design landfill to meet state 1,000-year siting criteria. • Standard: Ensure all material disposed in landfill passes EPA paint filter test. Cap • Standard: Minimize infiltration by limiting the hydraulic conductivity of the clay/synthetic composite barrier layer (1 x 10^{-7} cm/sec or less for clay layer). • Standard: Meet or exceed all RCRA, TSCA, and state requirements. Enhanced liner • Standard: Minimize percolation by limiting the hydraulic conductivity of the compacted clay layer to 1 x 10^{-7} cm/sec or less. • Standard: Install two composite liners, each consisting of 3 ft of compacted clay and a synthetic liner, and one additional composite liner. • Standard: Meet or exceed all RCRA and state requirements.	RCRA regulations; State RCRA regulations; CAMU Designation Document

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
RCRA-Equivalent Cap	Former Basin F; Complex (Army) Trenches w/concrete layer; Shell Trenches	• Ensure cap performance is equivalent to RCRA landfill cap with these objectives: – Standard: Allow no greater range of infiltration through the cap than the range of infiltration that would pass through an EPA-approved RCRA cap. – Standard: Prevent contact between hazardous materials and humans/biota by using biota barriers and maintaining institutional controls. – Goal: Serve as effective long-term barriers. – Standard: Demonstrate cap performance equivalent to a RCRA landfill cap according to an EPA- and state-approved demonstration that will include comparative analysis and field demonstration. • Goal: Maximize runoff and minimize ponding. • Standard: Maintain cover percolation less than or equal to the percolation of the underlying native soil. • Goal: Minimize erosion by wind and water. • Goal: Prevent damage to integrity of cap by biota and humans. • Goal: Maintain cover of locally adapted perennial vegetation.	State and federal RCRA regulations
UXO Clearance	Munitions Testing; Basin A; Section 36 Balance of Areas; Complex (Army) Trenches; Burial Trenches; South Plants Balance of Areas	• Standard: Identify, transport off post, neutralize, and destroy explosives/explosive residue. • Standard: Ensure excavation of all identified munitions-contaminated soil exceeding TCLP (Munitions Testing and Burial Trenches) and munitions debris and disposal in the on-post RCRA landfill.	Army surety safety and UXO regulations

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
Agent Decontamination	North Plants; Toxic Storage Yard; Section 36 Balance of Areas; Buried M-1 Pits; Burial Trenches; South Plants Central Processing Area; South Plants Balance of Areas; Section 36 Lime Basins; Chemical Sewers; No Future Use Structures, Agent History	• Standard: Certify 3X decontamination or caustic wash of soil and structural debris to achieve 3X decontamination. • Standard: Ensure disposal of 3X-decontaminated soil and structural debris in the on-post RCRA landfill.	Army surety safety regulations
Soil Cover (South Plants Consolidation Area)	South Plants Central Processing Area; South Plants Ditches; South Plants Balance of Areas	• Standard: Consolidate biota soil exceedance volume in South Plants Central Processing Area. • Standard: Maintain minimum cover thickness of 4 ft. • Goal: Minimize infiltration through cover. • Goal: Maximize runoff and minimize ponding. • Standard: Maintain cover percolation less than or equal to the percolation of the underlying native soil. • Goal: Minimize erosion by wind and water. • Goal: Prevent damage to integrity of cover by biota and humans. • Standard: Prevent biota and humans from accessing underlying contaminated soil by using biota barriers and maintaining institutional controls. • Goal: Maintain cover of locally adapted perennial vegetation.	Detailed Analysis of Alternatives; EPA guidance

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
Soil Cover with Concrete Layer (Basin A Consolidation Area)	Basin A; Lake Sediments; Surficial Soil; Section 36 Balance of Areas; Sand Creek Lateral; Sanitary Landfills; Ditches/Drainage Areas; No Future Use Structures, Other Contamination History	• Standard: Consolidate biota soil exceedence volume and structural debris in Basin A. • Standard: Maintain minimum cover thickness of 4 ft. • Goal: Maximize runoff and minimize ponding. • Standard: Maintain cover percolation less than or equal to the percolation of the underlying native soil. • Goal: Minimize erosion by wind and water. • Goal: Prevent damage to integrity of cover by biota and humans. • Standard: Prevent biota and humans from accessing underlying contaminated soil by using biota barriers and maintaining institutional controls. • Goal: Maintain cover of locally adapted perennial vegetation.	Detailed Analysis of Alternatives; EPA guidance
Soil Cover	Secondary Basins; North Plants; South Plants Ditches; South Plants Balance of Areas; Section 36 Balance of Areas	• Standard: Maintain minimum cover thicknesses specified in Section 9.3 of ROD. • Goal: Maximize runoff and minimize ponding. • Standard: Maintain cover percolation less than or equal to the percolation of the underlying native soil. • Goal: Minimize erosion by wind and water. • Goal: Prevent damage to integrity of cover by biota. • Standard: Prevent humans from accessing underlying contaminated soil by maintaining institutional controls. • Goal: Maintain cover of locally adapted perennial vegetation.	Detailed Analysis of Alternatives; EPA guidance
Solidification/ Stabilization	Former Basin F	• Standard: Comply with requirements of Basin F closure plan and design documents.	State RCRA regulations; EPA guidance

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
Innovative Thermal Technology	Hex Pit	• Standard: Design to achieve 90% or greater destruction of contaminants. • Standard: Landfill all treatment residuals and untreated material in the on-post hazardous waste landfill.	EPA guidance
Solidification/ Stabilization	Buried M-1 Pits	• Standard: Design to reduce contaminant concentrations in leachate; a 90 to 99% reduction in contaminant concentrations in leachate is a general guidance and may be varied within a reasonable range considering the effectiveness of the technology and the cleanup goals for the site. • Goal: Design treatability testing to achieve a 90% reduction in contaminant concentrations in leachate. • Standard: Landfill all solidified material in the on-post RCRA landfill. • Standard: Provide adequate unconfined compressive strength after solidification/stabilization to meet disposal requirements.	EPA guidance
Plugging	Sanitary/Process Water Sewers; Chemical Sewers	• Standard: Interrupt exposure pathway by permanently plugging all Sanitary Sewer manholes. • Standard: Interrupt exposure pathway by permanently plugging all chemical sewer lines and manholes not excavated.	Detailed Analysis of Alternatives

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
Slurry Wall	Complex (Army) Trenches; Shell Trenches	• Goal: Minimize groundwater flow across the slurry wall with a design goal 1x 10^{-7} cm/sec hydraulic conductivity. • Goal: Construct slurry wall with sufficient thickness to withstand maximum hydraulic gradient. • Goal: Construct slurry wall with materials that are compatible with the surrounding groundwater chemistry. • Goal: Minimize migration by keying the slurry wall in an underlying low permeability strata. • Goal: Dewater as necessary to ensure containment.	Detailed Analysis of Alternatives
Drying	Basin F Wastepile	• Standard: Ensure dried material passes EPA paint filter test. • Standard: Comply with requirements of Basin F closure plan and design documents.	State regulations
Excavation	Munitions Testing; Secondary Basins; Chemical Sewers; Sanitary Landfills; South Plants Central Processing Area; South Plants Ditches; South Plants Balance of Areas; Buried Sediments; Sand Creek Lateral; Section 36 Balance of Areas; Burial Trenches; Hex Pit Buried M-1 Pits; North Plants; Toxic Storage Yards; Lake Sediments; Section 36 Lime Basins; Surficial Soil; Ditches/Drainage Areas; Basin F Wastepile	• Standard: Excavate all contaminated soil identified in the ROD for treatment, landfilling, or consolidation that corresponds to the areal and vertical extent detailed by the soil volume calculations in the administrative record.	State regulations; EPA guidance

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
PCB Removal		Equipment • Standard: Remediate in accordance with PCB IRA requirements. Structures • Standard: Remove structural materials with PCB concentrations of 50 ppm or greater that exist above ground level, as well as contaminated parts of floor slabs and foundations identified for removal, and dispose in the on-post TSCA-compliant landfill. • Standard: PCB-contaminated sections of floor slabs or foundations that are not identified for removal, and that have PCB concentrations of less than 50 ppm, will be left in place. Soil • Standard: Interrupt exposure pathway with a minimum of 3 ft of soil in the five areas identified as having PCB contamination <250 ppm. • Standard: Removal of contamination >250 ppm in the three areas identified by the PCB IRA and disposal in on-post TSCA-compliant landfill. • Standard: If necessary, any suspected PCB soil contamination areas will be characterized further during remedial design. If additional PCB-contaminated soil is found with concentrations of 50 ppm or greater, the Army will determine any necessary remedial action in consultation with EPA.	TSCA PCB regulations
Asbestos Removal		• Standard: Removal of asbestos and ACM to attain TSCA requirements.	TSCA asbestos regulations; State regulations

Technology	Medium Group/Subgroup	Remediation Goals[1] and Standards[2]	Primary Components of Rationale[3]
Groundwater Treatment System	Groundwater	• Standard: Capture and treat contaminated groundwater to meet or exceed CSRGs as specified in the ROD.	CBSG, MCL, MCLG, Risk-based criteria
Structure Demolition	No Future Use Structures, Agent History	• Standard: Certify 3X decontamination or caustic wash to achieve 3X decontamination.	State regulations; Army surety safety regulations
Structure Demolition	No Future Use Structures, Significant Contamination History; No Future Use Structures, Other Contamination History	• Standard: Demolish all structural material identified in the ROD for landfilling or consolidation.	State regulations
Air Emissions Control	All medium groups	• Goal: Control emissions, as necessary, during remediation. • Standard: Control emissions and odors for Basin F Wastepile excavation and Former Basin F remediation, in accordance with Basin F closure plan and design documents. • Standard: Meet air quality and odor standards that are ARARs. • Goal: Control air emissions as necessary to attain criteria that will be developed via an air pathway analysis program that will ensure that the remedial action will be protective of human health and the environment and minimize nuisance odors.	

[1] A broadly defined remediation objective supported by regulatory requirement, regulatory guidance, on agreement by the Parties. Typically, goals are less quantitative or measurable than standards.

[2] A quantitative or physical objective for remediation design that is based on a regulatory requirement, regulatory guidance, standard practice, or agreement by the Parties.

[3] This column indicates only a reference to ARARs in Appendix A as a portion of the rationale used to support the remediation goal. It does not include ARARs, nor is it intended to replace any ARARs. A complete listing of ARARs is presented in Appendix A.

Table 9.6-1 Total Estimated Cost for the Selected Remedy[1,2]

	Capital		Operating and Maintenance		Total Cost	
Cost Element	Total Cost[3]	Present Worth Cost	Total Cost[3]	Present Worth Cost	Total Cost[3]	Present Worth Cost
Soil	$530 million	$380 million	$41 million	$17 million	$570 million	$400 million
Water	$19 million	$18 million	$130 million	$85 million	$150 million	$100 million
Structures[4]	$7 million	$6.5 million	$140 million	$130 million	$150 million	$140 million
Pre-ROD Costs[5]	$750 million	$750 million	—	—	$750 million	$750 million
PMRMA Mission Support	$550 million	$430 million	—	—	$550 million	$430 million
Total Cost	$1.9 billion	$1.6 billion	$310 million	$230 million	$2.2 billion	$1.8 billion

1 Detailed cost information is provided in the Detailed Analysis of Alternative report.
2 All costs presented in 1995 dollars.
3 Total cost does not account for inflation over the time frame for remediation.
4 Structures cost includes $35 million to complete ongoing IRAs.
5 Pre-ROD costs include RI/FS and IRA costs and are listed to illustrate the total costs for complete remediation of RMA.

10.0 Statutory Determinations

This section describes how the selected remedy meets statutory requirements and complies with CERCLA and NCP requirements.

10.1 Consistency with the Statutory Requirements of CERCLA in Section 121

The selected remedy complies with Section 121 of CERCLA as described below.

10.1.1 Protection of Human Health and the Environment

The selected remedy will result in the remediation of the On-Post Operable Unit contaminated groundwater, structures, and soil consistent with the RAOs established for these media. It will eliminate, reduce, or control risks posed through each exposure pathway by engineering controls, treatment, or institutional controls so that cumulative site risks are reduced to acceptable levels. All human health, principal threat, and biota risk is being addressed by the selected remedy, thus resolving the risks at the On-Post Operable Unit. Additional biota studies are being performed in support of design refinement in areas (termed the Area of Dispute) where the potential risks to biota have not been agreed upon. There will be no unacceptable short-term risks or cross-media impacts caused by implementation of the remedy.

10.1.1.1 Groundwater

The groundwater remedial actions proposed under Alternative 4 will address the potential risks to human health and the environment by continuing treatment of groundwater at the boundary systems (NWBCS, NBCS, and ICS) as well as the on-post groundwater IRA systems (Basin A Neck, Motor Pool/Rail Yard, and North of Basin F IRAs), and through construction of a new groundwater extraction system northeast of the Army Complex Trenches (in the Section 36 Bedrock Ridge area). The toxicity, mobility, and volume of contaminated groundwater will be reduced through activated carbon (primarily) and air stripping treatment technologies. The extent of NDMA groundwater contamination and potential design refinements to achieve the remediation goals are currently being evaluated (see Section 7.2.2).

Contaminant concentrations at the RMA boundary will be reduced to meet or surpass the CSRGs, which represent applicable federal or state standards and are consistent with the ROD for the Off-Post Operable Unit. Consumption of groundwater or surface water on post will be restricted by institutional controls in accordance with the FFA. Nonpotable uses of on-post groundwater were not anticipated and risk was therefore not considered in the HHRC for such uses. A risk evaluation would be performed prior to any future nonpotable use to ensure that such use would be protective of human health and the environment. Continued monitoring of shallow (unconfined aquifer) and deeper (confined aquifer) groundwater and 5-year reviews of the site will be used to evaluate the effectiveness of the remedy. Water levels in Lake Ladora, Lake Mary, and Lower Derby

Lake will be maintained to support aquatic ecosystems. The biological health of the ecosystems will continue to be monitored. Lake-level maintenance or other means of hydraulic containment or plume control will be used to prevent South Plants plumes from migrating into the lakes at concentrations exceeding CBSGs in groundwater at the point of discharge. Groundwater monitoring will be used to demonstrate compliance.

10.1.1.2 Structures

The structures remedial actions proposed under Alternative 2 will address the potential risks to human health and the environment by demolishing and disposing of all No Future Use structures (approximately 94 percent of all remaining structures at RMA, which include all contaminated and potentially contaminated structures). As the structural debris is removed, materials are segregated for purposes of recycling and waste classification. Economically recyclable materials such as scrap metals are collected for salvage. Demolition debris from structures in the Significant Contamination History Group will be placed in the on-post hazardous waste landfill. Structures in the Agent History Group will be monitored following demolition, and any debris showing agent contamination will be treated; all debris from this group will then be placed in the on-post hazardous waste landfill. Debris from structures in the Other Contamination History Group will be used as fill under the cover in Basin A. Chemical process-related equipment, ACM, and PCB contamination not addressed during IRAs will be segregated during demolition and disposed in the on-post hazardous waste landfill (see Section 7.3.3).

These remedial actions achieve the structures remedial action objectives and reduce the mobility of contaminants through containment in the on-post hazardous waste landfill or under the Basin A cover. The potential for exposure to humans or biota is thereby controlled. Toxicity is reduced through treatment of agent-contaminated structural debris by caustic washing.

10.1.1.3 Soil

The soil remedial actions proposed under Alternative 4 will address the potential risks to human health and the environment using a combination of containment (as a principal element) and treatment technologies. A discussion of the human health and ecological risks is presented in Section 6.1 and Section 6.2, respectively. Approximately 180,000 BCY of principal threat soil at the Former Basin F site will be treated to a depth of 10 ft below the base of the overburden by in situ solidification/stabilization and the site will be contained with a RCRA-equivalent cap. All soil/sludge from the Buried M-1 Pits will be treated by ex situ solidification/stabilization, followed by placement in the on-post hazardous waste landfill. Approximately 1,000 BCY of principal threat soil from the Hex Pit will be treated using an innovative thermal technology. Solidification/stabilization will become the selected remedy for the Hex Pit if all evaluation criteria for the innovative thermal technology are not met. These treatment actions, in addition to the more than 11 million

10.1.2 Compliance with ARARs

A comprehensive listing of chemical-, location-, and action-specific ARARs and TBCs that are pertinent to the selected remedy were developed and are presented in Appendix A. The identified ARARs and TBCs address the water, soil, and structures at RMA. A summary of location- and chemical-specific ARARs for the selected remedy is presented in Tables 10.1-1 and 10.1-2, respectively. A summary of action-specific ARARs related to the selected remedy is presented in Table 10.1-3. Not every action specified in the summary of action-specific ARARs (Table 10.1-3) will apply to every activity in the selected remedy. For example, ARARs regarding air emissions during demolition do not apply to GAC adsorption of contaminants from groundwater.

The identified ARARs and TBCs comply with Section 121(d) of CERCLA. ARARs were identified according to the procedures outlined in the most recent EPA guidance (OERR-EPA 1988a, b; OSWER-EPA 1989b, c) and the NCP.

10.1.2.1 Chemical-Specific ARARs

RMA chemical-specific ARARs set concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants. Such ARARs either set protective cleanup levels for the COCs in the designated media or indicate an appropriate level of discharge based on health- and risk-based analyses and technological considerations. Chemical-specific ARARs were established for individual groundwater treatment systems, surface water, soil, and structures and are presented in Appendix A and are summarized in Table 10.1-2. The selected remedy will comply with all chemical-specific ARARs, which are described below by medium.

Water

RMA groundwater and surface water ARARs include federal standards based on the following regulatory programs:

- Safe Drinking Water Act (SDWA) MCLs: 40 CFR 141 Subparts B and G, 40 CFR 143.3
- SDWA Maximum Contaminant Level Goals: 40 CFR 141 Subpart F
- Clean Water Act (CWA) Water Quality Criteria: 33 USC Section 1313
- RCRA MCLs: 40 CFR Section 264.94

With respect to state standards, ARARs cited include any state provisions that are equivalent to or more stringent than federal requirements:

- Colorado Rules and Regulations Pertaining to Hazardous Waste
- Colorado Basic Standards for Groundwater
- Colorado Primary Drinking Water Regulations
- Colorado Basic Standards and Methodologies for Surface Water

ARARs and TBCs for groundwater and surface water were identified by evaluating the current lists of target contaminants addressed by the groundwater and surface water monitoring programs and identifying corresponding standards, regulations, or requirements.

Structures

TSCA establishes cleanup levels for PCB spills occurring after May 4, 1987 and EPA (OERR-EPA 1990) presents cleanup standards that may serve as TBCs for PCB-contaminated structural surfaces and debris. The LDR Best Demonstrated Available Technology (BDAT) levels are ARARs for structural debris if placement occurs. Placement considerations are detailed in Section 7.1.1.

Soil

The proposed RCRA Corrective Action Rule example action levels (55 FR 30798, July 27, 1990), LDR Universal Treatment Standard (UTS) and TSCA PCB Spill Cleanup Policy (40 CFR Part 761 Subpart G), are TBC values for soil and sediments at RMA. LDR BDAT levels (40 CFR Part 268) are cited ARARs if placement occurs. Several other Colorado and federal laws and regulations set specific values for certain contaminants in specific media, but no laws other than TSCA, Clean Air Act, and RCRA set specific values that are likely ARARs or TBCs for RMA soil and sediments. EPA proposed soil treatment standards in the UTS rule on September 14, 1993, but deferred action on soil LDRs when that rule was finalized; consequently, UTSs are TBCs with respect to soil at RMA. In addition, there are no chemical-specific standards set by SDWA or CWA or the state equivalents for soil and sediments. TSCA establishes guidance on action levels for PCBs in soil.

Air

RMA chemical-specific ARARs for air include the following: National Ambient Air Quality Standards (40 CFR 50) and National Emission Standards for Hazardous Air Pollutants (40 CFR 61). State standards that are equivalent or more stringent than federal requirements are also considered ARARs, specifically the Colorado Ambient Air Standards (5 CCR 1001-5 Regulation 3 and 5 CCR 1001-14) and Control of Hazardous Air Pollutants (5 CCR 1001-8).

10.1.2.2 Location-Specific ARARs

RMA location-specific ARARs are those requirements that restrict, depending upon the location or characteristics of the site and the requirements that apply to it, remedial activities or limit allowable contaminant levels. Examples of such regulations include siting laws for hazardous waste facilities, laws regarding activities in wetlands or floodplains, and laws regarding preservation of historic or cultural sites. The selected remedy will comply with all location-specific ARARs, which are listed in Appendix A and summarized in Table 10.1-1.

gallons of contaminated liquids from the Former Basin F already treated by incineration as part of the Basin F IRA, will achieve permanent reductions in the toxicity, mobility, or volume of some highly contaminated soil. Although the selected remedy in large part is a containment remedy, these treatment components satisfy CERCLA statutory preference for treatment. The large volume of contaminated soil present on the site precludes a remedy in which all contaminants could be excavated and cost-effectively treated.

Approximately 1.7 million BCY of contaminated soil from a number of soil medium groups at RMA (Basin F Wastepile, Section 36 Lime Basins, South Plants Central Processing Area, South Plants Ditches, South Plants Balance of Areas, Secondary Basins, Munitions Testing, Chemical Sewers, Sanitary Landfills, Lake Sediments, Surficial Soil, Buried Sediments, Sand Creek Lateral, Section 36 Balance of Areas, and Burial Trenches) will be contained in the on-post hazardous waste landfill. Another 1.5 million BCY of soil that may pose a risk to biota will be excavated and used as fill under the Basin A and South Plants soil covers and Basin F RCRA-equivalent cap. The Army and Shell Trenches will be contained in place with slurry walls and RCRA-equivalent caps. Soil covers will be constructed over all of the South Plants area; the processing areas of the North Plants; all of Basins A, B, C and D; and the Section 36 Balance of Areas. PCB-contaminated soil will be remediated as described in Section 9.3. These containment actions, in conjunction with institutional controls, will prevent exposure of humans to contaminants, reduce exposure of biota to contaminants, and reduce contaminant mobility.

10.1.1.4 Additional Components of the Remedy

Additional actions described in Section 9.4 that contribute to protection of human health and the environment and are an integral part of the on-post remedy are the following:

- Provision of $48.8 million held in trust to provide for the acquisition and delivery of 4,000 acre-feet of potable water to SACWSD and the extension of water-distribution lines from an appropriate municipal water supply distribution system to all existing well owners within the DIMP plume footprint north of RMA as defined by the detection limit for DIMP of 0.392 parts per billion. The Army and Shell have reached an Agreement in Principle with SACWSD, enclosed as Appendix B of this ROD, regarding this matter.
- In compliance with NEPA, PMRMA will separately evaluate the potential impacts to the environment of both the acquisition of a replacement water supply for SACWSD and for the extension of water-distribution lines.
- The Army and Shell will fund ATSDR to conduct an RMA Medical Monitoring Program in coordination with CDPHE. The primary goals of the Medical Monitoring Program are to monitor any off-post impact on human health due to the remediation and provide mechanisms for evaluation of human health on an individual and community basis until such time as the soil remedy is completed. Elements of the program could include medical monitoring, environmental monitoring, health/community education, or other tools. The program design will be determined through an analysis of community needs, feasibility, and effectiveness.
- Trust Fund – During the formulation and selection of the remedy, members of the public and some local governmental organizations expressed keen interest in the creation of a Trust Fund to help ensure

the long-term operation and maintenance of the remedy once the remedial structures and systems have been installed. In response to this interest, the Parties have committed to good-faith best efforts to establish a Trust Fund for the operation and maintenance of the remedy, including habitat and surficial soil. Such operation and maintenance activities will include those related to the new hazardous waste landfill; the slurry walls, caps, and soil and concrete covers; all existing groundwater pump-and-treat systems; the groundwater pump-and-treat system to intercept the Section 36 Bedrock Ridge Plume; the maintenance of lake levels or other means of hydraulic containment; all monitoring activities required for the remedy; design refinement for areas that may pose a potential risk to biota as described in Section 9.4; and any revegetation and habitat restoration required as a result of remediation.

These activities are estimated to cost approximately $5 million per year (in 1995 dollars). The principal and interest from the Trust Fund would be used to cover these costs throughout the lifetime of the remedial program.

The Parties recognize that establishment of such a Trust Fund may require special legislation and that there are restrictions on the actions federal agencies can take with respect to proposing legislation and supporting proposed legislation. In addition to the legislative approach, the Parties are also examining possible options that may be adapted from trust funds involving federal funds that exist at other remediation sites. Because of the uncertainty of possible legislative requirements and other options, the precise terms of the Trust Fund cannot now be stated.

A trust fund group will be formed to develop a strategy to establish the Trust Fund. The strategy group may include representatives of the Parties (subject to restrictions on federal agency participation), local governments, affected communities, and other interested stakeholders, and will be convened within 90 days of the signing of the ROD.

Notwithstanding these uncertainties, it is the intent of the Parties that if the Trust Fund is created it will include the following:

- A clear statement that will contain the reasons for the creation of the Trust Fund and the purposes to be served by it.
- A definite time for establishing and funding the Trust Fund, which the Parties believe could occur as early as 2008, when the remedial structures and systems may have been installed.
- An appropriate means for competent and reliable management of the Trust Fund, including appropriate criteria for disbursements from the Trust Fund to ensure that the money will be properly used for the required purposes.

- Restrictions on land use or access are incorporated as part of this ROD. The Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 and the FFA restrict future land use, and prohibit certain activities such as agriculture, use of on-post groundwater as a drinking source, and consumption of fish and game taken at RMA. Continued restrictions on land use or access are included as an integral component of all on-post alternatives. Long-term management includes access restrictions to capped and covered areas to ensure the integrity of the containment systems.
- Continued operation of the CERCLA Wastewater Treatment Plant to support the remediation activities.
- Stored, drummed waste identified in the waste management element of the CERCLA Hazardous Wastes IRA may be disposed in the on-post hazardous waste landfill in accordance with the CDD (Harding Lawson Associates 1996).
- Continued monitoring as part of remedial design to refine the remediation of surficial soil and lake sediments that may pose a potential risk to wildlife (see Section 6.2.4.3).

10.1.2.3 Action-Specific ARARs

RMA action-specific ARARs and TBCs are standards that restrict or control specific remedial activities related to the management of hazardous substances or pollutants. These requirements are triggered by a particular remedial activity, not by specific chemicals or the location of the activity. There may be several ARARs for any specific action. These action-specific ARARs do not in themselves determine the appropriate remedial alternative, but indicate performance levels to be achieved by an alternative. The selected remedy will comply with all action-specific ARARs, which are listed in Appendix A and summarized in Table 10.1-3.

10.1.2.4 Other Requirements

In addition to the chemical-, location-, and action-specific ARARs and TBCs cited above, there are a number of other requirements and potential requirements that constrain or direct remedial actions at RMA. These additional items are detailed in Appendix A and include the following:

- Federal Facility Agreement
- Endangered Species Act
- Migratory Bird Treaty Act
- Bald and Golden Eagle Protection Act
- Army UXO and agent management and disposal requirements
- Chemical Weapons Convention

10.1.3 Cost Effectiveness

Cost effectiveness is determined by evaluating three of the five balancing criteria to determine overall effectiveness: long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; and short-term effectiveness. Overall effectiveness is then compared to cost to ensure that the remedy is cost effective.

Proportional to cost, the selected remedy for groundwater, structures, and soil provides the best overall effectiveness of all the alternatives considered. The selected remedy will achieve the remedial action objectives for the contaminated media and greatly reduce the toxicity, mobility, or volume of contamination. The remedy makes use of proven technologies that will be protective over the long term and minimize or mitigate short-term impacts during remediation. The selected remedy is therefore cost effective in mitigating risks posed at the site by contaminated groundwater, structures and soil.

10.1.4 Utilization of Permanent Solutions to the Maximum Extent Practicable

The selected remedy for the On-Post Operable Unit makes use of proven treatment and containment technologies for the most highly contaminated soil and structures at RMA, and makes use of reliable groundwater treatment technologies. Approximately 207,000 BCY of contaminated soil will be treated, and more than 1.8 million BCY of soil and structural debris will be contained in a new RCRA- and TSCA-compliant hazardous waste landfill to be constructed on post. Groundwater treatment will continue at a rate of several hundred million gallons per year until shut-off criteria are met, at which time pumping rates may be reduced.

Although the selected remedy in large part is a containment remedy, this remedy provides the best balance of tradeoffs in terms of long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The remedy uses permanent solutions and alternative treatment technologies to the maximum extent practicable. Components of the selected remedy satisfy the statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element. The large volume of contaminated soil present on the site precludes a remedy in which all contaminants could be excavated and cost effectively treated. The selected remedy has received state and community acceptance.

10.2 State and Community Acceptance

10.2.1 State Acceptance

The state of Colorado concurs with the selected remedy for RMA as providing the best balance of the nine criteria. The state also concurs with the selected ARARs.

10.2.2 Community Acceptance

Based on comments to the Proposed Plan, community members view the remedy as an acceptable approach to reduce risks at a reasonable cost, with the proviso that an additional water supply, Medical Monitoring Program, and Trust Fund be established as described in Section 9.4. Some community members feel that additional treatment of soil should be performed.

10.3 Consistency with NCP

The process used to select the remedy for RMA is consistent with the NCP. Specifically, alternatives were first identified and screened from a broad range of alternatives that achieved the RAOs and then evaluated against the nine evaluation criteria presented in the NCP (see Section 8). Also in accordance with the NCP, the selected remedy fulfills the following requirements:

- It will be protective of human health and the environment.
- It will attain ARARs or provide grounds for invoking a waiver.
- It will be cost effective (provided that it first satisfies the threshold criteria).
- It will use permanent solutions to the maximum extent practicable.

10.4 Consistency with NEPA

Implementation of the selected remedy is in compliance with NEPA. Numerous studies conducted in support of the FS process have indicated that there are no likely significant environmental impacts. Therefore, in accordance with the procedures contained in Army Regulation 200-2, PMRMA is advising the public that the remediation program is in compliance with NEPA and that no further documentation is necessary. However, PMRMA will separately evaluate the potential impacts to the environment of both the acquisition of a replacement water supply by SACWSD and for the extension of water-distribution lines.

10.5 Summary

The preferred remedy for the On-Post Operable Unit includes Groundwater Alternative 4, Structures Alternative 2, and Soil Alternative 4. The remedy was selected in accordance with the requirements of CERCLA and the NCP. The remedial actions that comprise the selected remedy will reduce the toxicity, mobility, or volume of contamination and address the risks to human health and the environment through treatment and institutional controls for contaminated groundwater; demolition, treatment (as necessary for Army agent), and containment for all No Future Use structures; and a combination of containment (as a principal element) and treatment technologies for contaminated soil.

Table 10.1-1 Summary of Location-Specific ARARs for the Selected Alternatives

ARAR/TBC	Requirement	Citation	Description
Location-Specific	Protection of Wetlands	Executive Order 11990 42 USC Section 1344 40 CFR Part 230, Subpart H 33 CFR Parts 320-330 40 CFR 6.302(a) 40 CFR 6, Appendix A, Sections 3(a) and 3(a)	Requires consideration of impacts to wetlands in order to minimize their destruction, loss, or degradation, and to preserve/enhance wetland values. Potentially applicable to activities which would impact wetlands
	Protection of Floodplains	Executive Order 11988 40 CFR 257.3-1(a) 40 CFR 264.18(b) 6 CCR 1007-3, 264.18(b) 40 CFR 6. Appendix A 40 CFR 6.302(b) Section 3(a), 3(b), and 3(b)(4) 44 FR 43239 (July 24, 1979)	Potentially applicable to activities occurring within the 100-year floodplain.
	Endangered Species Act	16 USC 1531	Establishes requirements for the protection of federally listed threatened and endangered species and their habitat. Potentially applicable to activities which could affect threatened or endangered species or their habitat. Note: the Endangered Species Act, along with the Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act, are not ARARs, but independently apply to remedial activities.
	RCRA Subtitle C - Location Standards	40 CFR 264.18(a) 6 CCR 1007-3, 264.18(a) 6 CCR 1007-2, Part 2	New treatment facilities, storage facilities, or hazardous waste disposal facilities should not be within 200 ft of a fault. Facilities should not be located in areas prone to earthquakes, floods, fire, or other disasters that could cause a breakdown of the public water system.
	Fish and Wildlife Coordination Act and Wild and Scenic Rivers Act	16 USC Part 661-663 40 CFR 6.302 (e) and (g) 16 USC 1274 et seq.	Fish or wildlife resources that may be affected by actions resulting in control or structural modification of any natural stream or body of water should be protected. Federal agencies taking such actions must consult with USFWS. The Wild and Scenic Rivers Act established requirements for water resource projects affecting wild, scenic or recreational rivers in the National Wild and Scenic Rivers system. Applicable to area(s) affecting stream or river.

Table 10.1-1 Summary of Location-Specific ARARs for the Selected Alternatives

ARAR/TBC	Requirement	Citation	Description
	National Historic Preservation Act	16 USC 470 aa et seq. 36 CFR 800 44 FR 6068	The National Historic Preservation Act identifies procedures for protection of Historically and Culturally Significant Properties, including Colorado's delegated responsibilities under the act. Applicable to historically or culturally significant properties.
	Prehistoric, historic, or archeological sites owned or controlled by a federal agency	36 CFR 60 36 CFR 63 Proposed 36 CFR 66	Department of Interior regulations for determining site eligibility for the National Register of Historic Places and standards for data recovery should be complied with.
	Historical, prehistoric, and archeological resources and State register of Historic Places Act	CRS § 24-80-401 et seq. CRS §24-80.1-101 et seq.	Consultation with the Colorado Historic Society, the State Archaeologist, and State Register of Historic Places is required before an action is taken.
	Cultural resource owned or controlled by a federal agency	35 FR 8921	Executive Order 11593: Any federal agency controlling culturally significant resources is the designated leader in the preservation of those resources. This order ensures that all culturally significant resources located on an agency's property are protected. The federal agencies are responsible for identifying, evaluating, and nominating (where appropriate) to the National Register of Historic Places all culturally significant resources found on their land.
	Archeological or historic site owned or controlled by a federal agency	16 USC 469 et seq.	The Archeological and Historic Preservation Act of 1974 requires that a federal agency notify the Secretary of Interior regarding any agency project that will destroy a significant archeological site. The Secretary of the notifying agency may support data recovery programs to preserve the resource.

ARAR/TBC	Requirement	Citation	Description
	Historically significant property owned and managed by the U.S. Army	Army Regulation 420 32 CFR 650.181 to 193 Technical Manual 5-801-1 Technical Note 78-17 32 CFR 229	U.S. Department of the Army has procedures and standards for preserving historically significant properties and procedures for implementing the Archeological Resources Protection Act. Department of the Army Regulations 420 prescribe Army policy procedures and responsibilities for compliance with the National Historic Preservation Act of 1966, as amended, for maintaining the preservation of historically significant sites, the hiring of qualified personnel to manage the sites, and the conduct of state-of-the-art preservation standards regarding personnel and projects for accomplishment of the historic preservation program. This regulation also requires that each installation prepare a historic preservation plan or have documentation on file indicating that no resources appropriate for such management planning exist.
	Archaeological resources on U.S. Department of the Army installations	16 USC 470 aa et seq.	The Archeological Resources Protection Act of 1979 establishes criminal and civil penalties for anyone damaging archeological resources. This act also allows the Secretary of the Army to issue excavation permits for archeological resources.
	Prehistoric, historic, or archeological sites owned or controlled by the U.S. Army	16 USC 470a 36 CFR 800	The National Historic Preservation Act of 1966 requires the Secretary of the Interior to inventory, evaluate, and nominate (where appropriate) significant properties to the National Register of Historic Places.
		43 CFR 3	Preservation of American antiquities: Provides for the protection of historic or prehistoric remains of any object of any antiquity on federal lands.
		43 CFR 7 36 CFR 296	Protection of archeological resources: Provides for the protection of archeological resources located on public lands.
		Executive Order No. 11593, May 13, 1971, 36 FR 8921, Section 2(b)	According to Executive Order No. 11593, each federal agency shall exercise caution to ensure that any such property that might qualify for inclusion is not inadvertently transferred, sold, demolished, substantially altered, or allowed to deteriorate significantly.

ARAR/TBC	Requirement	Citation	Description
		16 USC 470 aa et seq. 36 CFR 60.6	Based on the historical and field inventory information, the significance of all identified sites should be evaluated following criteria set forth in 36 CFR 60.6 and in accordance with guidelines from the Colorado State Historic Preservation Office before conducting any ground-altering activity. The act also requires the Army agency to consult with the Advisory Council on historic issues that may affect those significant properties. A federal agency should take into account the effect of the project on any National Register-listed or eligible property and is directed to complete an appropriate data recovery program before such a site is damaged or destroyed.
	National Historic Landmark Program	36 CFR 65	The National Historic Landmark Program was established to identify and designate National Historic Landmarks and encourage the long range preservation of nationally significant properties that illustrate or commemorate the history and prehistory of the United States.
	Colorado Requirements for Siting of Hazardous Waste Disposal Sites	6 CCR 1007-2, Part 2	State siting requirements control the location, design, and design performance of hazardous waste disposal sites. Such disposal sites must be located and designed in a manner that ensures long-term protection of human health and the environment. Disposal sites must be designed to prevent adverse effects on: • Groundwater • Surface water • Air quality • Public health and the environment
	National Wildlife Refuge System Administration Act	16 USC 668dd et seq.	The National Wildlife Refuge Administration Act prohibits the taking or possessing any fish, bird, mammal, or other wild vertebrate or invertebrate animals or part or nest or egg thereof within any such area; or enter, use, or otherwise occupy any such area for any purpose; unless such activities are performed by persons authorized to manage such area or unless such activities are permitted.

Table 10.1-2 Summary of Chemical-Specific ARARs for the Selected Alternatives

ARAR/TBC	Requirement	Citation	Description
Chemical Specific	Safe Drinking Water Act	40 CFR 141	Drinking water standards that apply to specific contaminants and have been determined to have an adverse effect on human health. These standards, expressed as MCLs and MCLGs, are potential ARARs for groundwater and/or surface water cleanup and replacement standards
	Colorado Primary Drinking Water Regulations	5 CCR 1003-1	
	Clean Water Act Ambient Water Quality Criteria	Guidance Criteria 33 USC Sections 1313-1314	Federal Water Quality Criteria established for the protection of human health and or aquatic organisms are not enforceable; however, Section 121(d)(2)(A) of CERCLA states that remedial actions must attain FWQC where they are relevant and appropriate under the circumstances of a release or threatened release.
	RCRA MCLs	40 CFR Section 264.94	Concentration limits for hazardous constituents in groundwater used for the protection of groundwater.
	Colorado Rules and Regulations Pertaining to Hazardous Waste	6 CCR 1007-3	Provides definitions and the general and specific standards necessary for the storage, treatment, and disposal of hazardous waste.
	Colorado Basic Standards for Groundwater	5 CCR 1002-8	Statewide standards and a system of classifying groundwater and adopting water quality standards for such classifications to protect existing and potential uses of groundwater.
	Colorado Basic Standards and Methodologies for Surface Water	5 CCR 1002-8	Basic standards and an antidegradation rule for maintaining and improving the quality of surface waters in Colorado.
	RCRA Corrective Action Rule	40 CFR Part 264 Subpart S 6 CCR 1007-3, Part 264, Subpart(s) 55 FR 30798, July 27, 1990 (TBC)	Corrective action standards proposed to establish a comprehensive regulatory framework for implementing the EPA's corrective action program under RCRA. The proposed standards include constituent-specific concentration levels for the protection of groundwater and soil.
	PCB Remedial Action Guidance	Guidance on Remedial Actions for Superfund Sites with PCB Contamination 40 CFR 761 Subpart G (TBC)	Provides recommended approach for evaluating and remediating Superfund sites with PCB contamination. Provide spill cleanup requirements for PCB spills that occurred after May 4, 1987.
	National Ambient Air Quality Standards	40 CFR 50	Sources cannot cause or contribute to an exceedance of a national ambient air quality standard.

Table 10.1-2 Summary of Chemical-Specific ARARs for the Selected Alternatives

ARAR/TBC	Requirement	Citation	Description
	National Emissions Standards for Hazardous Air Pollutants	40 CFR 61, Subpart M	No visible emissions allowed unless alternative waste management procedures followed.
	Colorado Ambient Air Quality Standard	5 CCR 1001-5, Regulation 3 5 CCR 1001-14	Sources cannot cause or contribute to an exceedance of a national or Colorado ambient air quality standard.
	Colorado Standards for Control of Hazardous Air Pollutants	5 CCR 1001-8	Standard for hazardous air pollutants not to be exceeded.

Table 10.1-3 Summary of Action-Specific ARARs for the Selected Alternatives

ARAR/TBC	Requirement	Citation	Description
Action-Specific	Worker Protection		
	Health and safety protection	29 CFR Part 1910	29 CFR 1910 provides guidelines for workers engaged in activities requiring protective health and safety measures regulated by OSHA. Requirements provided in 29 CFR 1910.120 apply specifically to the handling of hazardous waste/materials at uncontrolled hazardous waste sites. Note: OSHA regulations are independently applicable regulatory requirements, not ARARs.
		29 CFR 1910.120 (b) to (j)	29 CFR 1910.120 (b) through (j) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA.
		29 CFR 1926 Subpart P	29 CFR 1926 Subpart P provides guidelines for workers engaged in activities related to construction and utilization of trenches and ditches.
	Worker exposure	ACGIH 1991-1992 (TBC) NIOSH 1990 (TBC) 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH.
	Air Emissions		
	Particulate emissions	5 CCR 1001–3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3 5 CCR 1001-2, Section II	Colorado air pollution regulations require owners or operators of sources that emit fugitive particulates to minimize emissions through use of all available practical methods to reduce, prevent, and control emissions. In addition, no off-site transport of particulate matter is allowed. Fugitive dust-control measures will be written into workplans in consultation with the state. Estimated emissions from the proposed remedial activity per Colorado APEN requirements.

ARAR/TBC	Requirement	Citation	Description
	Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61 42 USC Section 7412	Emission of certain hazardous air pollutants is controlled by NESHAPs. Remediation activities could potentially cause emission of hazardous air pollutants. National standards for site remediation sources that emit hazardous air pollutants are scheduled for promulgation by the year 2000. Standards will be developed for 189 listed hazardous air pollutants.
	Volatile organic chemical emissions	5 CCR 1001-9, Regulation 7	VOC regulations apply to ozone nonattainment areas. The air quality control area for RMA is currently nonattainment for ozone. Storage and transfer of VOCs and petroleum liquids are controlled by these requirements. Disposal of VOCs is regulated for all areas, including ozone nonattainment. The regulations control the disposal of VOCs by evaporation or spilling unless reasonable available control technologies are utilized.
	Odor emissions	5 CCR 1001-4, Regulation 2	Colorado odor emission regulations require that no person shall allow emission of odorous air contaminants that result in detectable odors that are measured in excess of the specified limits.
	Air emissions from diesel-powered vehicles associated with excavation and backfill operations	5 CCR 1001-15, Regulation 12	Colorado Diesel-Powered Vehicle Emission Standards for Visible Pollutants apply to motor vehicles intended, designed, and manufactured primarily for use in carrying passengers or cargo on roads, streets, and highways, and state.
	Standards for asbestos waste disposal	40 CFR 61 Subpart M	Prevents discharge of visible emissions during collection, processing, packaging, or transporting any asbestos-containing waste; requires disposal of asbestos-containing waste as soon as possible at disposal site; requires transport vehicles be marked appropriately during loading and unloading operations.
	PM/CO Emissions	42 USC Section 7502-7503	New or modified major stationary sources in a nonattainment area are required to comply with the lowest achievable emission rate.

ARAR/TBC	Requirement	Citation	Description
	Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Remediation activities must be conducted in a manner that does not cause adverse impacts on visibility. Visibility impairment interferes with the management, protection, preservation, or enjoyment of federal Class I areas.
		5 CCR 1001-14 CRS Section 42-4-307(8)	The Colorado Ambient Air Quality Standard for the AIR Program area is a standard visual range of 32 miles. The averaging time is 4 hours. The standard applies during an 8-hour period from 8:00 a.m. to 4:00 p.m. each day (Mountain Standard Time or Mountain Daylight Time, as applicable). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.
	Design/installation of caps/covers	Final Covers on Hazardous Waste Landfills and Surface Impoundments (EPA/530/SW-89/047) (TBC)	Caps and covers must be designed and installed to prevent wind dispersal of hazardous wastes. They should be designed, constructed, and installed as specified in this EPA report.
	Smoke and opacity	5 CCR 1001-3, Regulation 1, Section II.A	Remedial activities must be conducted in a manner that will not allow or cause the emission into the atmosphere of any air pollutant that is in excess of 20% opacity.
	Waste Characterization		
	Solid waste determination	40 CFR 260 6 CCR 1007-3 Part 260 40 CFR 260.30-31 6 CCR 1007-3 Section 260.30-31 40 CFR 261.2 6 CCR 1007-3 Section 261.2 40 CFR 261.4 6 CCR 1007-3 Section 261.4	A solid waste is any discarded material that is not excluded by a variance granted under 40 CFR 260.30 and 260.31. Discarded material includes abandoned, recycled, and waste-like materials. These materials may have any of the following qualities: • Abandoned material may be – Disposed – Burned or incinerated

ARAR/TBC	Requirement	Citation	Description
			– Accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material that is – Used in a manner constituting disposal – Burned for energy recovery – Reclaimed – Speculatively accumulated • Waste-like material is material that is considered inherently waste-like.
	Solid waste classification	6 CCR 1007-2, Section 1	If a generator of wastes has determined that the wastes do not meet the criteria for hazardous wastes, they are classified as solid wastes. The Colorado solid waste rules contain five solid waste categories: industrial wastes, community wastes, commercial wastes, special wastes, and inert material.
	Determination of hazardous waste	40 CFR 262.11 6 CCR 1007-3 Section 262.11 40 CFR Part 261 6 CCR 1007-3 Part 261	Wastes generated during remedial activities must be characterized and evaluated according to the following method to determine whether the waste is hazardous: • Determine whether the waste is excluded from regulation under 40 CFR 261.4 • Determine whether the waste is listed under 40 CFR 261 • Determine whether the waste is identified in 40 CFR 261 by testing the waste according to specified test methods or by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used.
	<u>Waste Management</u>		
	Discharge of liquid wastes	40 CFR Part 122 40 CFR Part 125 40 CFR Part 129 40 CFR 262 40 CFR 264	Any wastewater generated during remedial activities will be routed to the on-post CERCLA Wastewater Treatment Plant if it is not hazardous waste and will not interrupt the existing treatment system. If wastewater is routed to the on-post treatment plant, it must be treated in accordance with NPDES requirements.

ARAR/TBC	Requirement	Citation	Description
	Asbestos waste handling management	40 CFR 61, Subpart M	Prevents discharge of visible emissions during collection, processing, packaging, or transporting any asbestos-containing wastes; requires disposal of asbestos-containing waste as possible at disposal site; requires transport vehicles be marked appropriately during loading and unloading operations.
		5 CCR 1001-10, Regulation Part B, Section 8.B.III.c.8	Asbestos waste will be managed according to applicable substantive requirements for asbestos handling, transportation, and storage.
	Asbestos waste storage management	6 CCR 1007-2, Part B, Section 5.4	Asbestos waste will be managed according to applicable substantive requirements for asbestos storage.
	PCB storage	40 CFR 761.65	Storage facilities must be constructed with adequate roofs and walls; have impervious floors with curbs (no floor drains expansion joints or other openings); and be located above 100-year floodplain (applies to PCBs at concentrations of 50 ppm or greater)
			Temporary storage (<30 days) of PCB containers containing nonliquid PCBs, such as contaminated soil, rags, debris, need not comply with above requirements. Containers must be dated when they are placed in storage.
			All storage areas must be properly marked and stored articles must be checked for leaks every 30 days.
	PCB decontamination standards	40 CFR 761.79	PCB containers to be decontaminated by triple rinsing of internal surfaces with solvent containing <50 ppm PCB.

Table 10.1-3 Summary of Action-Specific ARARs for the Selected Alternatives

ARAR/TBC	Requirement	Citation	Description
	PCB chemical waste landfilling standards	40 CFR 761.75	Landfill must be located in thick, relatively impermeable soil formation or on soil with high clay and silt content; synthetic membranes must be used when these conditions cannot be met. In addition, other structural requirements include avoidance of location in a floodplain; required runon/runoff structures if below the 100-year floodplain; and ground/surface water monitoring for specified parameters. PCB wastes must be segregated from wastes not chemically compatible with PCBs. The landfill must include a leachate monitoring system.
	PCB incineration standards	40 CFR 761.70	Incineration requirements for nonliquid PCB apply to PCB concentrations >50 ppm and include specified dwell times; combustion efficiency of 99.9999 percent; process record/monitoring requirements; automatic shut-off standards; a maximum mass air emission of 0.001 g PCB per kg of PCB entering the incinerator.
	TSCA-PCB design standards	40 CFR 761 Subpart D	On-post hazardous waste landfills shall be designed and operated in compliance with applicable substantive requirements of 40 CFR 761 Subpart D.
	Treatment, storage, or disposal of RCRA hazardous waste.	Part 264.100 (e)(2) 6 CCR 1007-3 Section 264.100(e)(2)	Corrective action program.
		Part 264 Subpart I 6 CCR 1007-3 Part 264 Subpart I	Applicability of the requirements of containers.
		Part 264 Subpart F 6 CCR 1007-3 Part 264 Subpart F	Corrective action for solid waste management units.
		Part 264 Subpart J 6 CCR 1007-3 Part 264 Subpart J	Applicability of the requirements for tanks or tank systems.

ARAR/TBC	Requirement	Citation	Description
		Part 264 Subpart L 6 CCR 1007-3 Part 264 Subpart L	Design and operating requirements for waste piles.
		Part 264 Subpart M 6 CCR 1007-3 Part 264 Subpart M	Design and operating requirements for land treatment.
		Part 264 Subpart N 6 CCR 1007-3 Part 264 Subpart N	Design and operating requirements for landfills.
		Part 264 Subpart O 6 CCR 1007-3 Part 264 Subpart O	Applicability of incinerator requirements.
		Part 264.16 (a)(1) 6 CCR 1007-3 Section 264.16(a)(1)	Personnel training.
		Part 264.31 (a) 6 CCR 1007-3 Section 264.31(a)	Facility design and operation requirements.
		Part 264.51 (a) 6 CCR 1007-3 Section 264.51(a)	Purpose and implementation of contingency plans.
		Part 264.52 (a) 6 CCR 1007-3 Section 264.52(a)	Content of contingency plans.
		Part 264 Subpart cc 6 CCR 1007-3 Part 264 Subpart cc	Air emission standards for tanks.

ARAR/TBC	Requirement	Citation	Description
	Management of Remediation Wastes		
	Corrective action management units	40 CFR 264, Subpart S 6 CCR 1007-3, Part 264 Subpart S 6 CCR 1007-2, Part 2	The CAMU regulations allow for exceptions from otherwise generally applicable LDRs-UTS and minimum technology requirements for remediation wastes managed at CAMUs. These regulations provide flexibility and allow for expedition of remedial decisions in the management of remediation wastes. One or more CAMUs may be designated at a facility. Placement of hazardous remediation wastes into or within the CAMU does not constitute land disposal of hazardous wastes so the LDRs-UTS are not triggered.
	Temporary Units	6 CCR 1007-3 Section 264.553 40 CFR 264.553	Design, operating, or closure standards for temporary tanks and container storage areas may be replaced by alternative requirements. The TU must be located within the facility boundary, used only for the treatment/storage of remediation waste, and will be limited to one year of operation with a one year extension upon approval by the regulatory authority.
	Detonation of UXO Containing High Explosives	AR 75-15 AR-385-10 AR 385-64 AMC-R 385-100	If UXO is encountered during excavation, workers must comply with the substantive requirements of AMC-R 385-100, AR 75-15, AR 385-10, and AR 385-64.
	UXO detonation	AR 75-15	HE UXO will be detonated in compliance with the substantive requirements of AR 75-15 regarding demilitarization of class V materials.
	On-post detonation of UXO	40 CFR 264 Subpart X 6 CCR 1007-3 Section 264 Subpart X	On-post detonation of UXO must comply with the substantive requirements of the environmental performance standards described in 40 CFR 264 Part 264, including 264.601 (6 CCR 1007-3 Section 264.601) and substantive portions of the monitoring, analysis, reporting, and corrective action requirements of 40 CFR 264.602 (6 CCR 1007-3, Section 264.602).

ARAR/TBC	Requirement	Citation	Description
	Chemical Agent Decontamination		
	Agent decontamination	AR 385-61 AR 50-6	Decontamination of chemical agent-contaminated material must comply with the requirements of AR 385-61 and AR 50-6.
	Decontamination and Disposal Standards for Chemical Agents	AR 385-61 AR 50-6	Army regulations provide standards for decontamination of items exposed to chemical agents. Material, equipment, and clothing that has been decontaminated to the 3X level may be landfilled in a RCRA-approved hazardous waste landfill.
	Treatment and disposal of hazardous debris	40 CFR 268.45 6 CCR 1007-3, Part 268.45	Hazardous debris generated during remedial activities must be treated using specific technologies to extract, destroy, or immobilize hazardous constituents on or in the debris if placement occurs. In certain cases, the debris may no longer be subject to RCRA Subtitle C regulation after treatment.
	On-post land disposal of hazardous wastes	40 CFR Part 264 6 CCR 1007-3 Part 264 40 CFR Part 268 6 CCR 1007-3 Part 268 EPA/540/G-89/006 (TBC)	Based upon a determination of whether the disposal technique constitutes placement, LDRs-UTS may be applicable. If placement occurs, the on-site disposal facility must comply with the substantive requirements of 40 CFR Part 264 (6 CCR 1007-3 Part 264) and 40 CFR Part 268 (6 CCR 1007-3 Part 268).
	Treatment, storage, or disposal of hazardous waste	40 CFR Part 264 6 CCR 1007-3 Part 264	If remedial activities at RMA generates hazardous wastes, the wastes must be treated and stored in accordance with RCRA regulations.
		40 CFR Part, Subpart L 6 CCR 1007-3 Section 264, Subpart L 40 CFR Part 268 6 CCR 1007-3 Part 268	Wastes stored in stockpiles that are determined to be RCRA hazardous wastes must be stored, treated, and disposed in compliance with RCRA regulations, including LDRs-UTS if placement occurs.
		40 CFR Part 264, Subpart I 6 CCR 1007-3, Section 264, Subpart I Section 264.171-173	Applicability of the requirements for containers.

ARAR/TBC	Requirement	Citation	Description
	<u>Stormwater Management</u>		
	Discharge of stormwater to on-post surface waters	40 CFR Parts 122-125	Stormwater runoff, snow melt runoff, and surface runoff and drainage associated with industrial activity (as defined in 40 CFR 122) from RMA remedial actions that disturb 5 acres or more and that discharge to surface waters must be conducted in compliance with the stormwater management regulations.
	<u>Dredged Material Management</u>		
	Discharge of Dredged Materials	40 CFR 230 Subpart B	Dredging operations in wetland areas must be managed in accordance with the applicable requirements based on the impacts resulting from specific dredged material discharges associated with sediment removal activities.
	Certification of Federal Licenses and Permits (401 Certification)	33 USC Section 1341 Section 401 of Clean Water Act	Provides for state review of facility operations for the purposes of ensuring that applicable effluent limitations or other limitations or other applicable water quality requirements will not be violated.
	<u>Wastewater Treatment/Disposal</u>		
	Discharge of wastewater to the treatment plant	40 CFR Part 122 40 CFR Part 125 40 CFR Part 129	Any wastewater generated during cleanup or remedial actions will be directed to the on-post RMA wastewater treatment plant and treated in accordance with NPDES requirements.
		40 CFR Part 262 6 CCR 1007-3 Part 262	Wastewater that is determined to be a hazardous waste must be treated in accordance with the provisions of RCRA.
		40 CFR Part 264 6 CCR 1007-3 Part 264	Some of the Colorado standards for owners and operators of hazardous waste management, storage, and disposal facilities are more stringent than the equivalent federal regulations. These standards are detailed on Appendix A, Table A-12.
		40 CFR Part 144.13(c) 40 CFR Part 146	Injection trenches and wells must be constructed per the requirements of EPA's Underground Injection Control Program.

ARAR/TBC	Requirement	Citation	Description
	<u>Monitoring</u>		
	Groundwater monitoring	40 CFR 264 Subpart F 6 CCR 1007-3 Part 264 Subpart F 2 CCR 402-2, Rule 10 RCRA Groundwater Monitoring TEGD (TBC)	Groundwater monitoring will be conducted for the presence of hazardous constituents in the groundwater downgradient from solid waste management units. Monitoring wells should be constructed and installed according to the requirements of 2 CCR 402-2, Rule 10 and the guidance in the RCRA Groundwater Monitoring TEGD.
		6 CCR 1007-3	Colorado groundwater regulations specify requirements for determining background groundwater quality.
	<u>Noise abatement</u>	Colorado Revised Statute, Section 25-12-103	The Colorado Noise Abatement Statute provides that "Applicable activities shall be conducted in a manner so any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Noise is defined to be a public nuisance if sound levels radiating from a property line at a distance of twenty-five feet or more exceed the sound levels established for the specified time periods and zones."

11.0 Documentation of Significant Changes

The Proposed Plan indicated that the preferred remedy for the Hex Pit would be identified prior to the ROD and that remedies being considered involved solidification and thermal treatment technologies. As this ROD details, the selected remedy for the Hex Pit is treatment using an innovative thermal technology. Treatment will be applied to approximately 1,000 BCY of principal threat material; the remaining 2,300 BCY of soil will be excavated and disposed in the on-post hazardous waste landfill. Process performance will be evaluated through treatability testing during remedial design. Solidification/stabilization will become the selected remedy if all evaluation criteria for the innovative thermal technology are not met.

There are no other significant changes to the ROD. However, overall remedy implementation time frames and present worth costs presented in the ROD differ slightly from those presented in the Proposed Plan due to modifications in scheduling and funding limitation assumptions.

Glossary

Glossary

Active Dewatering – Lowering the water table by pumping and extraction or other water-removal methods.

Acute Exposure – Based on the exposure model developed for RMA, an exposure duration of 1 to 14 days.

Agent – A solid, liquid, or gas that through its chemical properties produces lethal or damaging effects on man, animals, material, or plants or that produces a screening or signaling smoke. Examples of chemical agents at RMA include Sarin (GB), a nerve agent, and mustard (HD), a blistering agent.

Agent Monitoring – Analytical technique used during excavation to survey soil for the presence of Army chemical agent.

Agricultural Practices – A process that involves tilling the soil with farm machinery and seeding it with locally adapted vegetation in a manner consistent with RMA refuge management plan. Agricultural practices have been shown to reduce the level of surficial soil contamination.

Air Monitoring – Collection of air samples that are analyzed for key contaminants to ensure that allowable concentrations are not exceeded.

Air Stripping – As it applies to groundwater treatment, extracting contaminated groundwater and pumping to an air stripper, which is a tall, hollow vessel. The water is pumped to the top of the vessel and allowed to splash down to the bottom. As the water passes through the air, contaminants are transferred from the water to the air, which is in turn treated before it is discharged to the atmosphere.

Alternative – An option for cleaning up a site.

Applicable or Relevant and Appropriate Requirements (ARARs) – Federal and state legal requirements that a selected remedy for a site will meet, such as allowable levels of chemicals in water.

Bioaccumulation – The amplification of the concentration of a chemical between the initial source (e.g., water, soil, or sediment) and a specified target species or trophic box. A bioaccumulative chemical can increase in concentration in a living organism as the organism breathes contaminated air, drinks contaminated water, or consumes contaminated food.

Biomagnification – The process by which tissue concentrations of bioaccumulative chemicals increase as a chemical passes up the food chain (e.g., from plant to insect, mouse, and hawk). It is measured as the ratio of the concentration of a chemical in an organism to the concentration in the diet of the organism.

Boundary System – Groundwater extraction, containment, and treatment system at RMA boundaries. There are three such systems, the Irondale, Northwest, and North boundary systems.

Cap – An in-place containment technology. The standard cap design consists of a layer of soil/vegetation, a crushed layer of concrete or cobbles, and a layer of low-permeability soil. Caps are sloped for erosion control and are vegetated with locally adapted perennial grasses and low-growing plants.

Caustic Washing – A treatment process in which agent-contaminated soil or structural debris is treated with caustic (high pH) fluids to degrade the agent compounds.

CERCLA – Comprehensive Environmental Response, Compensation and Liability Act. Also known as Superfund, a law passed in 1980 that establishes a program to identify inactive hazardous waste sites, ensure they are cleaned up, evaluate damages to natural resources, and create claims procedures for parties remediating the sites.

Chronic Exposure – Based on the exposure model developed for RMA, an exposure duration of 7 to 30 years.

Composite Sample – A representative sample that has been combined from several samples of the same medium. In this sampling method, samples are systematically collected either vertically and/or horizontally from a medium and thoroughly mixed together to form a representative sample. Examples of composite samples are depth composites often used in subsurface soil sampling and area composites used in surficial soil sampling.

Conceptual Remedy – Agreement for a Conceptual Remedy for the Cleanup of the Rocky Mountain Arsenal. Signed by the Parties on June 13, 1995, it outlines the general approach for the remediation of RMA. The Conceptual Remedy was the result of dispute resolution (as provided in the FFA) and formed the basis for the Detailed Analysis of Alternatives report and Proposed Plan.

Consolidation – Movement of soil with low levels of contamination to areas proposed for capping or covering. The consolidated soil is placed underneath the cap or cover to develop slopes so that surface-water runoff can be controlled and collected.

Containment – A remedial action that interrupts exposure pathways through the use of physical barriers and reduces the spread of contamination.

Contaminant of Concern (COC) – A chemical selected for evaluating potential human or animal health effects. Selection is based on concentration, toxicity, and site-specific information.

Cover – A layer of clean soil that isolates contamination in place, thereby preventing exposure to humans and animals. A soil cover consists of a variable thickness layer of soil and may include crushed or formed concrete layers as biota/excavation barriers. Soil covers may be sloped for erosion control and are vegetated with locally adapted perennial grasses and low-growing plants.

Detection Limit – The lowest concentration of a chemical that can be distinguished from the background response of an analytical instrument.

Dismantling – Controlled demolition of a structure using heavy equipment. Contaminants are not treated in this process, but the volume of structural material is decreased and converted into a more workable form for disposal.

Dust Controls – An action, such as spraying water or foam, used to control the emission of dust (e.g., during excavation activities).

EPA Paint Filter Test – A test that demonstrates the presence or absence of free liquid in waste material to be landfilled (based on a test method in SW 846, Method 9095).

Ex Situ – Not in the original place (Latin). With reference to hazardous waste treatment, this refers to excavation or extraction from the ground prior to treatment.

Excavation – The removal of soil, debris, drums, pipes, tanks, or any other solid material from the ground.

Exposure Duration – The amount of time a receptor is exposed to a chemical.

Exposure Pathway – The pathway a chemical travels from the source to the individual. At RMA, two pathways were evaluated, direct (consuming, contacting, or breathing contamination) and indirect (breathing contaminated vapors).

Extraction System – A system of wells used to remove groundwater from an aquifer.

Feasibility Study (FS) – An investigation that recommends the selection of a protective, cost-effective alternative for remediation. It usually is begun during the Remedial Investigation (RI); together these investigations are commonly referred to as the RI/FS.

Federal Facility Agreement (FFA) – A legal document that sets the framework for cleanup at RMA.

Gas Chromatography/Mass Spectrometry (GC/MS) – A laboratory analytical method used to detect organics in soil or water.

Geophysical Survey – A technique used to locate buried metal, such as unexploded ordnance, using nonintrusive instruments that measure various properties of subsurface materials.

Granular Activated Carbon (GAC) – A treatment method used to remove organic chemicals from contaminated groundwater.

Habitat Modifications – The exclusion of biota from contaminated areas by installing physical barriers (e.g., a chain-link fence) or changing the quality of the habitat (e.g., sowing grasses that are less attractive to biota as an environment in which to live).

Hazard Index (HI) – A value that represents the summation of hazard quotients for a particular chemical for all exposure pathways evaluated.

Hazard Quotient (HQ) – The ratio of the estimated actual daily chemical intake (dose) to the estimated allowable daily intake that is not likely to cause adverse health effects.

Hazardous Waste Landfill – A secure disposal facility that is specially designed, operated, closed, and monitored to control the potential release of hazardous substances into the environment.

Horizontal Well – A well that is drilled with a major portion of its length parallel to the ground surface and that could be used to capture contamination in plumes.

Human Health Exceedance – At RMA, soil posing risk to human health as determined by concentrations of chemicals present above action levels developed in the Integrated Endangerment Assessment/Risk Characterization for carcinogens (an excess lifetime cancer risk of 10^{-4}) and noncarcinogens (a hazard index of 1.0).

Hydrology – The science dealing with the properties, distribution, and circulation of water.

ICP Metals – Metals detected by Inductively Coupled Plasma, a laboratory analytical method.

Implementability – The ability to execute and complete the remedial actions required under an alternative. Evaluation of implementability includes, for example, considering the availability of materials and skilled workers.

In Situ – In the original place (Latin). With reference to hazardous waste treatment, this refers to treatment in the ground (i.e., without excavation or extraction).

In Situ Biological Treatment – An in-place biodegradation process that takes advantage of the naturally occurring micro-organisms in the aquifer. Oxygen and nutrients containing nitrogen are added to the aquifer so that organisms grow more numerous. As the population increases, the organisms turn to the contamination present in the aquifer as a source of food, thereby breaking down and destroying the contamination.

In Situ Vitrification – A thermal treatment process using electrical current to melt soil or sludges in place, resulting in a chemically inert and stable glass product.

Incineration – A treatment technology involving destruction of waste or contamination by controlled burning at high temperatures.

Inorganic – Pertaining to or composed of chemical compounds that do not contain carbon as the principal element, i.e., matter other than plant or animal.

Interim Response Action (IRA) – A remedial measure that is implemented in an expedited time frame before the final remedy and that has been determined to be necessary and appropriate for the site.

Maximum Contaminant Level (MCL) – The maximum permissible level of a contaminant in water delivered to users of a public water system as specified in the Safe Drinking Water Act. MCLs are enforceable water-quality standards and are applicable or relevant and appropriate requirements for groundwater remediation.

Medium *(pl. media)* – A specific environment such as groundwater, surface water, soil, sediment, or air.

Medium Groups – Similarly contaminated soil sites, groundwater plumes, or structures.

Migration Pathway – The way in which a chemical moves through the environment. For example, a constituent in soil may be susceptible to transport by wind suspension as fugitive dust, by alluvial erosion during periods of seasonal and/or episodic surface-water runoff, or by dissolving in infiltrating rainwater.

Multilayer Cap – A cap that prevents exposure to humans and animals by isolating the contamination. From top to bottom, it generally consists of three layers: a 4-ft-thick soil/vegetation layer, a 1-ft-thick layer of crushed concrete or cobbles, and a 2-ft-thick layer of compacted low-permeability soil to provide long-term minimization of infiltration.

Munitions Screening – Technique used prior to excavation to survey soil for the presence of munitions (weapons and ammunition) and/or munitions debris.

National Oil and Hazardous Substances Pollution Contingency Plan (NCP) – The federal regulations that govern the implementation of CERCLA.

National Priorities List – A list published by the U.S. Environmental Protection Agency that ranks all of the CERCLA sites in order of priority for remediation.

Operable Unit – Term for a geographic area or a separate activity undertaken as part of a cleanup conducted under CERCLA.

Organic – Pertaining to or composed of compounds that contain carbon as a principal element.

Organizations – The U.S. Army, U.S. Environmental Protection Agency, U.S. Agency for Toxic Substances and Disease Registry, U.S. Fish and Wildlife Service, U.S. Department of Justice, and Shell Oil Company. They signed the Federal Facility Agreement.

Parties – U.S. Department of the Army, Shell Oil Company, State of Colorado, U.S. Environmental Protection Agency, and U.S. Fish and Wildlife Service. They oversee the remedial process at RMA.

Passive Dewatering – Lowering the water table without actively removing the water by pumping and extraction or other methods. It is accomplished by limiting the infiltration of water across an area using controls such as a cap or cover or elimination of water utilities.

Plume – An area of contaminated groundwater containing one or more chemicals at concentrations that exceed remediation goals.

Preliminary Pollutant Limit Value (PPLV) – Risk-based concentrations of chemicals in soil that are considered protective of human health given a defined set of exposure and toxicity assumptions.

Principal Threat Exceedance – At RMA, soil that is considered to be highly toxic or highly mobile that would pose a significant risk to human health should an exposure occur (i.e., more than 10^{-3} excess lifetime cancer risk or a hazard index of 1,000).

Probabilistic PPLVs – Risk-based concentrations of chemicals in soil developed to represent the likelihood of a potential effect on an organism as a result of exposure to a chemical constituent. In a probabilistic evaluation, a range of input values can be assigned to reflect variability, the shape of the range defined, and a prescribed certainty assigned to a range of results, thereby providing an informed context within which risks can be managed. At RMA, for example, the use of a 5th percentile preliminary pollutant limit value (PPLV) would protect 95 percent of an exposed human population.

RCRA-Equivalent Cap – A cap with physical barriers that achieve the performance standards of a cap as described in the Resource Conservation and Recovery Act, a law that regulates the management of hazardous waste from point of generation to disposal. A multilayer cap was assumed to be RCRA equivalent in this ROD for purposes of costing alternatives.

Receptor – The animal or person for which potential exposure and risk to a chemical is evaluated.

Record of Decision (ROD) – A public document that records and explains the cleanup alternative(s) to be used at a CERCLA site. It is based on information from the Remedial Investigation/Feasibility Study, public comments, and community concerns.

Remedial Investigation (RI) – A study that reports the types, amounts, and locations of contamination at a site.

RF Heating – A thermal treatment process using radio frequency (RF) energy to heat soil in place, volatilizing contaminants, which are collected at the ground surface.

Slurry Wall – A buried vertical barrier commonly made of a soil and bentonite clay mixture.

Soil Cover – See **Cover.**

Soil Posing Risk to Biota – Area containing a potential risk to biota as defined by a hazard quotient greater than 1.0. The hazard quotient is calculated using a biota risk model based on an animal's foraging range (the average area over which they obtain their food). "Biota" refers to wildlife.

Soil Vapor Extraction – Removes volatile compounds from contaminated soil in the unsaturated zone by applying a vacuum using vapor extraction wells and blowers. Vacuum blowers induce air flow through the soil matrix, stripping volatile compounds from the soil. Contaminated vapor is withdrawn through extraction wells, collected, and treated. Enhanced soil vapor extraction may use heating elements to include removal of some semivolatile compounds.

Soil Venting – A technique used to extract contaminated vapors from soil above the water table, usually by applying a vacuum to a system of wells.

Solidification/Stabilization – A process in which a hardening agent (such as cement) is combined with contaminated soil. The mixture is allowed to harden, fixing the contaminants in a less leachable form.

Subchronic Exposure – Based on the exposure model developed for RMA, an exposure duration of 2 weeks to 7 years.

Supplemental Field Study (SFS) – An assessment designed to determine whether potential risk to wildlife is present in the area peripheral to the center of RMA.

Surface Heating – General technology name for soil treatment technologies that involve heating soil to volatilize contaminants. During treatment, volatile and semivolatile organic compounds are vaporized from the solid phase and either recovered or destroyed by an off-gas treatment system.

TCLP – Toxicity Characteristic Leaching Procedure. A test used to evaluate whether a waste exhibits characteristics of toxicity as specified in the Resource Conservation and Recovery Act.

Thermal Desorption – A process that uses heat to vaporize (desorb) contamination from solid materials. The air stream generated during the process is treated to remove the contaminants.

Transportation – The movement of structural, soil, or liquid material from a site to disposal or treatment facilities.

Unexploded Ordnance (UXO) – Generic term for military munitions that are potentially active. Munitions are filled with high explosives (HE-filled) or chemical agent.

Unsaturated Zone – The subsurface zone above the water table. Also known as the vadose zone.

Use History – Narratives (e.g., plant operational records, official Army and Shell histories, depositions from operating personnel) that describe how a particular structure was used during its operational history. To focus investigations at RMA, structures were grouped into similarly contaminated (or uncontaminated) medium groups based on use histories.

Vapor- and Odor-Suppression Measures – Vapor-suppressing materials, such as foam or liners, or a transportable structure, used during excavation to control emissions of odors and gases.

Volatile – A chemical constituent that readily evaporates (volatilizes) from a solid or liquid state to a gaseous or vapor state. This process may be enhanced by applying heat or reducing pressure or by a combination of these processes.

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