PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

U.S. ARMY MATERIEL COMMAND

— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

DRAFT FINAL
DETAILED ANALYSIS
OF ALTERNATIVES REPORT
VERSION 2.0
TECHNOLOGY DESCRIPTIONS
VOLUME VII of VII

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THE CONDUCT OF THE FEASIBILITY STUDY (FS) UNDER CERCLA IS ACCOMPLISHED IN TWO STEPS. THE FIRST STEP, THE DEVELOPMENT AND SCREENING OF ALTERNATIVES (DSA), INVOLVES IDENTIFYING AND SCREENING A BROAD SELECTION OF ALTERNATIVES THAT ACHIEVE THE REMEDIAL ACTION OBJECTIVES (ROAS). THE SECOND STEP IS THE DAA. THE OBJECTIVES OF THE DAA INCLUDE THE FOLLOWING: (1) PROVIDE A MORE DETAILED DEFINITION OF EACH ALTERNATIVE RETAINED IN THE DSA, AS NECESSARY, WITH RESPECT TO THE VOLUMES OR AREAS OF CONTAMINATED MEDIA TO BE ADDRESSED, THE TECHNOLOGIES TO BE USED, AND ANY PERFORMANCE REQUIREMENTS ASSOCIATED WITH THOSE TECHNOLOGIES. (2) ASSESS EACH ALTERNATIVE AGAINST THE DAA EVALUATION CRITERIA IDENTIFIED IN THE NATIONAL CONTINGENCY PLAN AND DEFINED IN U.S. EPA GUIDANCE (EPA 1988). (3) PERFORM A COMPARATIVE ANALYSIS AMONG THE ALTERNATIVES TO EVALUATE THE RELATIVE PERFORMANCE OF EACH ALTERNATIVE WITH RESPESCT TO EACH EVALUATION CRITERION. (4) SELECT A PREFERRED ALTERNATIVE FOR EACH MEDIUM GROUP BASED ON THE COMPARATIVE ANALYSIS. THE DAA REPORT CONSISTS OF SEVEN VOLUMES. VOLUME I - EXECUTIVE

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EBASCO SERVICES INCORPORATED
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LIST OF ACRONYMS AND ABBREVIATIONS

µg/l	micrograms per liter
3-D	three-dimensional
ACGIH	American Conference of Governmental Industrial Hygienists
ACM	asbestos–containing material
AMC	Army Materiel Command
AOC	Area of Contamination
AOPs	advanced oxidation processes
AR	Army Regulations
ARARs	applicable or relevant and appropriate requirements
Army	U.S. Army
atm-m^3/mol	atmospheres per cubic meters per mole
ATP	Anaerobic Thermal Processor
ATSDR	Agency for Toxic Substances and Disease Registry
BCY	bank cubic yard
BDAT	best demonstrated available technology
BEST	Basic Extraction Sludge Treatment
BFI	Browning Ferris Industries
BOD	Biological Oxygen Demand
BTEX	benzene, toluene, ethylbenzene, and xylenes
BTU	British thermal unit
CAMU	Corrective Action Management Unit
CAR	Contamination Assessment Report
CCA	chromated-copper-arsenate
CCR	Code of Colorado Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CLC2A	Chloroacetic Acid
cm/sec	centimeters per second
cm^2	centimeters squared
COC	contaminant of concern
CPE	chlorinated polyethylene
CPRP	Chemical Personnel Reliability Program
CRL	certified reporting limit
CSI	Conservation Services, Inc.
CSPE	chlorosulfonated polyethylene
CWA	Clean Water Act
CY	cubic yards
DA	Department of the Army
DAA	Detailed Analysis of Alternatives
DADS	Denver Arapahoe Disposal Service, Inc.
db(A)	decibels
DBCP	dibromochloropropane
DCPD	dicyclopentadiene
DDE	dichlorodiphenylethane
DDT	dichlorodiphenyltrichloroethane
DHHS	Department of Health and Human Services
DIMP	diisopropylmethyl phosphorate
DNAPL	dense nonaqueous phase liquid
DOD	Department of Defense

DOT	Department of Transportation
DRE	destruction removal efficiency
DRMO	Defense Reutilization and Marketing Office
DSA	Development and Screening of Alternatives
EA	Endangerment Assessment
Ecology	U.S. Ecology, Inc.
EDSVEP	Enhanced Deep Soil Vapor Extraction Process
ENSCO	Environmental Systems Company
Envirosafe	Envirosafe Services of Idaho, Inc.
EOD	Explosive Ordnance Disposal
EPA	U.S. Environmental Protection Agency
ERC	Ecological Risk Characterization
ESSVEP	Enhanced Surface Soil Vapor Extraction Process
ETTS	Ecotechniek Thermal Treatment System
FC2A	fluoroacetic acid
FFA	Federal Facility Agreement
FML	flexible membrane liner
fpm	feet per minute
FRP	fiber - reinforced plastic
FS	feasibility study
ft/day	feet per day
ft	feet or foot
ft^3	cubic feet
GAA	granulated activated alumina
GAC	granular activated carbon
GB	isopropylmethylphosphonosfluoridate (nerve agent-sarin)
gpm	gallons per minute
H:V	horizontal to vertical
H_2O_2	hydrogen peroxide
HBr	hydrogen bromide
HCCPD	hexachlorocyclopentadiene
HCL	hydrochloric acid
HCPD	Hexachloro pentadiene
HDPE	high-density polyethylene
HE	high explosive
HEP	habitat evaluation protocol
HEPA	high efficiency particulate
HF	hydrofluoric acid
Hg	mercury
HHEA	Human Health Exposure Assessment
HHRC	Human Health Risk Characterization
HI	hazard index
ICP	inductively coupled plasma
ICS	Irondale Containment System
IDLH	Immediately Dangerous to Life and Health
IEA	Integrated Endangerment Assessment
IITRI	IIT Research Institute
IRA	interim response action
IT	International Technology
IWT	International Waste Technologies
K_{oc}	partition coefficient
kw	Kilowatt
kWh	Kilowatt hour

L	Lewisite
lbs	pounds
lbs/acre	pounds per acre
LCY	loose cubic yards
LCY/hr	loose cubic yards per hour
LDR	land disposal restriction
LF	Linear Foot
LNAPL	light nonaqueous phase liquid
LT^3	Low-Temperature Thermal Treatment
LTTA	Low-Temperature Thermal Aeration
mg/l	micrograms per liter
mg/cm^3	milligrams per cubic centimeter
mg/m^3	milligram per cubic meter
mg/kg	milligrams per kilogram
mg/l	microgram per liter
MKE	Morrison–Knudsen Engineering
ml/g	milliliters per gram
mm	millimeters
MMBTU	million British thermal units
mph	miles per hour
MTR	minimum technology requirement
NaOH	sodium hydroxide
NBCS	North Boundary Containment System
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NWBCS	Northwest Boundary Containment System
O&M	operations and maintenance
OAS	Organizations and State
°C	degrees Centigrade
OCP	organochlorine pesticides
OCPD	dicyclopentadiene
°F	degrees Fahrenheit
OPHGB	organophosphorus compounds, GB-agent related
OPHP	organophosphorus Compounds; pesticide related
OSCH	organosulfur compounds; herbicide related
OSCM	organosulfur Compounds; mustard agent related
OSHA	Occupational Health and Safety Administration
PAHs	polynuclear aromatic hydrocarbons
PBC	probabalistic biota criteria
PCB	polychlorinated biphenyls
pcf	pounds per cubic foot
PCP	pentachlorophenol
PEC	plume evaluation criteria
PKPP	potassium pyrophosphate
ppb	parts per billion
PPE	personal protective equipment
PPLV	preliminary pollutant limit value
ppm	parts per million
PRG	preliminary remediation goal
psi	pounds per square inch
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RAO	remedial action objectives

RCRA	Resource Conservation and Recovery Act
RF	radio frequency
RI	Remedial Investigation
RISR	Remedial Investigation Summary Report
RMA	Rocky Mountain Arsenal
ROD	Record of Decision
RPO	representative process option
SACWSA	South Adams County Water and Sanitation District
SAR	Study Area Report
SARA	Superfund Amendments and Reauthorization Act
SCC	Secondary Combustion Chamber
SEC	Site evaluation criteria
SF	square feet
Shell	Shell Oil Company
SHO	Semivolatile halogenated organics
SITE	Superfund Innovative Technology Evaluation
STC	Silicate Technology Corporation
SVE	soil vapor extraction
SVOCs	semivolatile organic compounds
SY	square yards
T.DI.	Services HT-5
TBC	to be considered
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TEA	triethylamine
TEC	Target Effluent Concentrations
TIS	transportable incineration system
TMV	toxicity, mobility, and volume
TOC	total organic carbon
tpd	tons per day
TSCA	Toxic Substances Control Act
TSD	Treatment Storage and Disposal
TSMG	two-step geometric mean
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USPCI	U.S. Pollution Control, Inc.
UV	ultraviolet
UXO	unexploded ordnance
VAO	volatile aromatic organic compounds
VHC	volatile hydrocarbon compounds
VHO	volatile halogenated organics
VOC	volatile organic compound
VX	ethyl s-dimethyl aminoethyl methyl phosphonothiolate (nerve agent)
WES	Waterways Experimental Station

1.0 INTRODUCTION

The Technology Description Volume is intended to provide detailed descriptions of all technologies that are part of any of the alternatives considered in the Detailed Analysis of Alternatives (DAA). The volume is divided into sections according to general response action categories and technology types, and each technology type is represented by its selected representative process option (RPO). The technology descriptions address all media to which the technologies apply, e.g., direct thermal treatment is described both as it applies to the soils and structures media. It should be noted that the descriptions in this document generally represent only one part of a complete alternative that consists of several technologies.

Each technology description provides an overview of the process and summarizes which media and contaminants are treated by the process. Process performance is discussed in the document based on the limitations and effectiveness of the technologies. Studies from other sites are compared with Rocky Mountain Arsenal (RMA) conditions and RMA-specific treatability studies are discussed. Literature reviews and cost data are presented in summary form in tables. The level of detail may vary between sections depending on the level of development and experience pertaining to the particular technology. Detailed information about equipment needs, pre- and post-treatment requirements, and sidestreams generated is also provided, as are summaries of capital and operations and maintenance (O&M) costs for expected applications and brief discussions of applicable or relevant and appropriate requirements (ARARs). Detailed listings of the action-specific ARARs can be found in Appendix A.

2.0 NO ACTION

The No Action General Response Action Category is the baseline from which all remedial alternatives evaluated in the feasibility study (FS) process are measured. U.S. Environmental Protection Agency (EPA) guidance dictates that a "no action" alternative be developed and evaluated through the FS process. This alternative is normally established as the "do nothing" alternative, leaving the site or operable unit in its existing condition. At many sites, including RMA, the No Action alternative may include previous cleanup or mitigation actions or current ongoing actions. For RMA, two alternatives were developed for this category: No Action and Continued Existing Action. The following sections will describe these alternatives in detail.

2.1 THE NO ACTION ALTERNATIVE

As required by EPA guidance, the No Action alternative represents current site conditions with no remedial actions undertaken. However, baseline conditions may differ from site to site within RMA based on the planned, ongoing, or completed interim response actions (IRAs) taken at a particular site.

2.1.1 No Action Alternative for the Soils Medium

The No Action alternative for soils requires the Army to take no further action at a particular site. The level of protectiveness at the site is determined solely by the current conditions at the site (or, if an IRA is planned or ongoing, conditions at its completion). For example, the No Action alternative for the surficial soils sites (the 0- to 6-inch depth interval) does not include any remedial activities, while the No Action alternative for the Basin F Wastepile site includes using the soil and composite liner and cap currently in place. The No Action alternative for many sites requires no long-term or recurring maintenance. If remedial action has been completed through an IRA, however, the site may require continued leachate collection and treatment, cap maintenance, plowing, revegetation, or mowing. Currently, the No Action alternative would require some form of monitoring or maintenance for the following sites only: Basin F Wastepile, the Shell Trenches, the M-1 Pits, and the Lime Basins.

Included in the cost of the No Action alternative for soils is the cost of performing 5-year reviews for 30 years following the Record of Decision (ROD). These 5-year reviews, as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), include a site assessment and review of the ROD. These costs are built into all RMA soils alternatives.

2.1.2 No Action Alternative for the Water Medium

The No Action alternative is significantly different for the water medium at RMA than for either the structures or soils media because extensive, continuous remediation systems are currently capturing and treating RMA groundwater plumes. Continued operation of these systems is being considered in the DAA, however, as "continued existing action" alternatives. For the purpose of compliance with National Contingency Plan (NCP) in evaluating a true "no action" alternative, the No Action alternative for water requires the termination of existing groundwater treatment systems and the restoration of the original flow pathways prior to the commencement of current operating systems would be required. Costs for the No Action alternative for the water medium, therefore, include shutting down the extraction wells and breaching the slurry walls currently in place so that groundwater can resume its natural flow. Well abandonment, treatment plant dismantling, and long-term on-post groundwater monitoring were not estimated for each individual plume group due to the applicability of the costs to all alternatives. Treatment plant dismantling is considered under the Structures FS.

2.1.3 No Action Alternative for Structures

The No Action alternative for structures encompasses no physical activities for structures. The structures are allowed to deteriorate naturally and, following collapse, left as is. No attempt to restrict entry through locks, boards, signs or fences is performed, and physical and chemical hazards within the structures are accessible to wildlife and humans. Asbestos and polychlorinated biphenyls (PCB) abatement is handled by the Army outside of the CERCLA process, and is not to be identified in the ROD. If structures are impeding the remediation of the underlying soils, then the No Action alternative is not to be selected for that area.

2.2 THE CONTINUED EXISTING ACTION ALTERNATIVE

The Continued Existing Action alternative was developed for the water medium to account for the extensive amount of remediation already ongoing for RMA groundwater plumes. The Army and Shell constructed groundwater containment and treatment systems in the 1980s to ensure that water leaving RMA was within specified health-based standards. These boundary systems, the North Boundary Containment System (NBCS), the Northwest Boundary Containment and Treatment System (NWBCS), and the Irondale Containment System (ICS), operate continuously using granular activated carbon (GAC) adsorption to remove contaminants from the groundwater, reinjecting the treated water at the RMA boundary.

Several internal systems have also been constructed to capture and treat groundwater. These systems include the Basin A Neck IRA, the Basin F Groundwater IRA, and the Motorpool/Rail Yard IRA. The CERCLA Wastewater Treatment Plant, designed to treat water generated through remedial activities and well testing, does not treat groundwater related to an IRA. This system is included in several alternatives evaluated during in the DAA. The internal IRA systems are considered as part of the Continued Existing Action alternative and the costs of operating both the boundary systems and the IRAs are included in the costs presented in the DAA. These costs are also included in all on-post treatment alternatives evaluated in the DAA.

The Continued Existing Action alternative also includes all known or planned upgrades and modifications to the existing systems, although it does not include any modification to handle increased contaminant loading or increased flow rates due to other capture/treatment alternatives. The Continued Existing Action alternative does not apply to the soils or structures media due to their one-time treatment strategy versus the long-term capture and treatment strategy for water.

3.0 INSTITUTIONAL CONTROLS

The Institutional Controls General Response Action Category is often considered the "minimal" or "limited action" alternative for CERCLA response, providing risk reduction through administrative actions or through exposure pathway restrictions. Administrative actions may include deed restrictions, public education, land use restrictions, and long-term environmental monitoring to measure potential contaminant mobility and natural attenuation. Exposure pathways can be interrupted by using fencing to restrict site access, by excluding biota from sites using physical barriers (e.g., cobble layers, Agropyron cristatum and Elytrigia intermedia grasses), and by implementing health and safety protection for workers on site.

Institutional controls may be appropriate for sites where the potential for exposure is minimal, allowing finite remediation resources to be used for more contaminated or threatening areas. For example, plugging the sewer pipes and initiating restrictions on digging may be adequate institutional controls to address contamination in soils along sewer lines where relatively low levels of contamination are found at depth and are covered by clean soil. Institutional controls, however, may also be selected for highly contaminated sites where the risks to workers or the community during remediation would be high and would exceed the risks currently present at the site. In this case, institutional controls could include fencing the site and restricting access to prevent exposure.

Institutional controls may be included as components of other types of alternatives. For example, if a site is remediated through containment or treatment, institutional controls such as monitoring or site access restricitons may be implemented during and after the site is remediated. Costs of implementing these institutional controls are, however, included in the overall cost of the containment and treatment alternatives. Due to the NCP's preference for permanent reduction in contaminant toxicity, mobility, or volume (TMV), the Institutional Controls alternative is evaluated as less desirable than treatment or containment alternatives.

The Army conducts its CERCLA program at RMA under the direction of a Federal Facility Agreement (FFA). The FFA for RMA, signed in 1989 by the Army, EPA, Shell Oil Company, U.S. Department of Interior, U.S. Department of Justice, and the Agency for Toxic Substances and Disease Registry (ATSDR) dictates the participation of all signatories and the responsibilities of each party (EPA et al. 1989/RIC 89068R01). The FFA also includes land and resource use restrictions that will be incorporated into all future actions undertaken at RMA. These restrictions prohibit the following:

- Residential development
- Use of groundwater or surface water as a source of potable water
- Consumption of all fish and game
- Agriculture, excluding erosion control or restoration following remedial actions

In accordance with the FFA, additional land use restrictions cannot be unilaterally imposed by the United States, but require the review and approval of the parties signatory to the FFA as an amendment to the Technical Program Plan or as a component of the ROD (as an institutional control alternative) for the on-post operable unit of RMA. As specified in the FFA, the United States will retain title to RMA and could assume the long-term responsibility of implementing and enforcing institutional controls, so deed restrictions would not apply if the land does not transfer ownership. Appendix A presents other applicable action-specific ARARs.

Because the FFA restrictions are in place, the institutional controls alternatives for all three contaminated media describe items or actions in addition to the FFA. Due to the differing nature of the three media at RMA, the institutional control alternative presents differing scenarios for each medium. The Water FS, for example, did not develop the institutional controls alternative for on-post groundwater plumes due to the restrictions already in place through the FFA and the inapplicability of ARARs to on-post groundwater.

3.1 PROCESS DESCRIPTION

A number of institutional controls alternatives for RMA soils may be developed based on the risk and potential for exposure by human and biota receptors. Institutional controls for soils include use restrictions, access restrictions, public education programs, habitat modification, and environmental monitoring and site reviews (Table 3.1-1). Based on the risk at the site and the depths of contamination, a combination of these elements may apply to a particular medium group. For example, if the site is a risk only to biota, then habitat modification or exclusion of biota may be selected, and if the site is a risk to human health, then additional access restrictions may be required. Institutional controls alternatives for soils medium attempt to mitigate the exposure pathway for contaminants through methods that do not reduce TMV. Institutional controls alternatives for certain sites where there is the potential for explosive threats or Army agent were developed to provide alternatives that reduce risk to workers and the community and at the same time meet soils remedial action objectives through pathway elimination.

Institutional controls for structures include exclusion techniques for both biota and humans. Due to existing regulations regarding the abandonment of structures, institutional controls only include actions taken to exclude entrance to structures where there is potential for exposure to contaminants. These exclusion techniques include the use of locks, boards, fences, and signs as the primary attempt to restrict access. In the process of restricting access, additional repairs may be required to close up holes in structures or foundations; such repairs are included in the costs of the institutional controls alternative. These institutionally controlled structures require continual long-term maintenance to ensure that building deterioration does not allow access.

3.1.1 Access Restrictions

Locks, boards, fences, and signs are institutional controls designed to protect human health and the environment by preventing access to a structure. Implementation of institutional controls requires materials and labor to accomplish the task and is an inexpensive but nonpermanent solution.

Physical barriers consisting of window and door seals, framing covers, and plastic well covers are room closure options. These options are best suited for extreme cases of contamination or where the possibility exists for sidestream contamination, and are also helpful in conjunction with in situ treatment in order to prevent contaminant migration to uncontaminated areas. The use of locks and boards is another room closure option; however, the materials used are much less likely to provide containment for higher levels of contamination. This option would, however, make unauthorized entry more difficult. These room closure options may be used together in order to be applicable to both sidestream and unauthorized entry concerns.

Fencing to limit human access to a soils site or structure consists of a 6-foot (ft)-high chain-link fence topped by three strands of barbed wire and located around the 10-ft buffer zone of a site. Warning signs are posted every 200 ft along the fence to inform the public of potential hazards. Gates to allow pedestrian or vehicle entry would be included as appropriate.

Measures to exclude biota include fencing to limit entry, a cobble barrier layer to deter burrowing, or a visual barrier of Agropyron cristatum and Elytrigia intermedia grasses seeded in a 80- to 120-ft swath to prevent migration of rodents into a contaminated site. The cobble barriers are more costly and less effective than the visual barriers for deterring rodents. Except for small areas, biota exclusion is not effective in preventing birds from accessing the site because top as well as side closure is required.

3.1.2 Public Education

Public education includes producing informational exhibits, videos, and fact sheets for distribution at the visitors center to stress the importance of respecting access restrictions to contaminated sites and to explain the potential risks of contaminant exposure. Other potential community education activities include open houses or site tours, public notices and meetings, and news releases or news conferences.

3.1.3 Pre- and Post-Treatment Requirements

Pre-treatment requirements for institutional controls are limited. Prior to constructing a fence or modifying the habitat through revegetation, any remedial actions such as principal threats treatment that require access or disturb the area should be completed. Air monitoring may also be conducted prior to implementation of institutional controls to allow for the appropriate selection of personal protective equipment (PPE) for workers implementing the controls.

Post-treatment requirements include the long-term maintenance of fences and vegetation to perpetuate the effectiveness of access restrictions and controls. Soil monitoring is also conducted over the long term to observe natural contaminant degradation/attenuation and potential migration of contaminants. Because contaminants remain on site, site reviews are conducted every 5 years and, if justified, institutional controls can be abandoned in favor of removing or treating wastes.

3.1.4 Sidestream Generation

No sidestreams should be generated by institutional controls. However, if the control options are breached in some manner, it is likely that contaminant release could occur.

3.1.5 Results From Other Sites

Final action RODs reviewed from fiscal year 1990 show that 56 out of 70 sites with contaminant concentrations above health-based levels used institutional controls for short-term impacts or engineering control supplements, and that none used institutional controls as the primary remedy (EPA 1991).

3.2 PROCESS PERFORMANCE

3.2.1 Effectiveness

Implementation of institutional controls will not result in risks to the general public. Workers may be required to use PPE during these activities to prevent potential exposure to contaminants. Environmental impacts from this alternative are minimal, although wildlife access to fenced areas

is restricted, an effect which may be desirable in implementing institutional controls for contaminated areas.

Fencing is a proven method of limiting site access and, along with other institutional control measures, reduces the potential for exposure to contaminants. Fencing and other institutional controls do not preclude the possibility of trespassers entering the site and potentially suffering and exposure. Routine inspection and repair are required to maintain the effectiveness of the fence. Long-term monitoring would measure potential migration of contaminants at the site.

The technologies involved in institutional control alternatives are demonstrated, readily available, and easily implementable. With periodic maintenance, fencing is reliable and effective, but does not completely prevent access by trespassers. Soil and groundwater sampling measures potential contaminant mobility and natural attenuation at sites making use of institutional control measures and monitors their effectiveness. If future remedial actions are found to be necessary, institutional controls do not preclude or interfere with their implementation.

3.2.2 Limitations

EPA guidance states that institutional controls may not be substituted as the sole remedy for active response measures unless such active measures are determined not to be practicable (EPA 1990). However, institutional controls should be included for mitigation of short-term impacts or as a supplement to engineering controls at a site (EPA 1991). Additionally, institutional controls may provide adequate protection for sites with very low-level risks.

Contaminants are left in place under this alternative, so the magnitude of residual risk is unchanged and there is no reduction in contaminant TMV, and principal threats at a site are not addressed.

Moreover, because implementation of institutional controls does not reduce contamination, the human or biota preliminary remediation goals are not being met. Protection of human health and

the environment relies upon restricted site access to reduce the potential for exposure; however, this alternative cannot totally preclude access by trespassers.

3.2.3 Cost Summary

The base cost for purchase and installation of a 6-ft-high fence made out of aluminized, 6-gauge chain-link steel topped by three strands of barbed wire is estimated to be $15 per linear foot (/LF) (Means 1991). The costs for room closure with window/door seals, framing covers, and plastic wall covers are $3.46 per square foot (/SF) for labor and $2.60/SF for material, for a total of $6.06/SF (EBASCO 1992/RIC92363R01), assuming that there is no safety factor (i.e., reduced productivity related to working in PPE) and that 25 percent of the surface area is affected. The costs for room closure through use of locks/boards were estimated in the Detailed Screening of Alternatives (DSA) to be 40 percent of the previous room closure method, for a total cost of $2.38/SF, assuming that there is no safety factor and that 25 percent of the surface area is affected. Table 3.2-1 presents a summary of capital and O&M costs.

REFERENCES

RIC 92363R01
EBASCO (EBASCO Services Incorporated) 1992. Final Development and Screening of Alternatives Report, Version 4.1.

EPA (U.S. Environmental Protection Agency) 1990. Fiscal Year 1990 Record of Decision Forum.

EPA 1991. Fiscal Year 1991 Record of Decision Forum.

RIC 89068R01
EPA et al. 1989. FFA (Federal Facility Agreement Pursuant to CERCLA Section 120). Docket No. CERCLA VIII-89-13.

Means (R.S. Means Company, Inc.) 1991. Means Heavy Construction Cost Data 1991.

Institutional Control	Description
5-Year Site Review	Every 5 years data is compiled from monitoring activities to evaluate the current status of the site.
Environmental Monitoring	Annual groundwater, air, and soil monitoring may be performed to evaluate the changing status of the site.
Public Education	Forms of educating the public include, but are not limited to, informational pamphlets, brochures, and videos. Site visits and tours may include interacting with the news media and presenting seminars.
Access Restrictions	This control consists of fencing the perimeter of a site to adequately prevent terrestrial and human access. Bilingual signs of appropriate dimensions and letter size will be posted on the fence at 200 ft spacing. In addition to fences with locked gates, sites with structures could include window and door seals, frame covers, wall covers, or locks. Boards could be used to limit access through doors and windows. Sewers can be plugged by pumping in cement and posting signs to warn against digging.
Use Restrictions	In addition to those defined in the FFA, restrictions could be imposed on particular contaminated areas to prohibit public access or intrusive activities.
Habitat Modification	Areas can be revegetated with a mix of grasses such as wheatgrass to discourage habitat use by biota.

Expenditure	Amount
Direct Costs	**Unit Cost ($)**
6-ft-high chain-link fence topped by three strands of barbed wire	15/LF[1]
Window/door seals	6.06/sq ft[2]
Lock/boards	2.38/sq ft[2]
Public education program	13,500[3]
Habitat Modification	0.17/SY
Sewer Plugging	150
Annual O&M	
Habitat maintenance	0.01/SY per yr
Fence maintenance	0.75/LF per yr
Public information	4,500/yr
5-year review (30 yrs)	27,000/review

1 Means 1991
2 EBASCO 1992
3 Saco Tannery Site, REM III Program

LF Linear Foot
SF Square Foot
SY Square Yard
yr Year
O&M Operations and Maintenance

4.0 EXCAVATION, DEMOLITION, AND TRANSPORTATION

This section details the process options of excavation, demolition, and transportation as follows: Section 4.1 describes excavation, a removal technology applicable only to the soils medium groups; Section 4.2 describes the processes available for demolition of the various structures, tanks, and piping present at RMA, which is applicable to the structures medium groups; and Section 4.3 describes transportation methods that are applicable to the structures, soils, and water medium groups.

4.1 EXCAVATION

Excavation is the removal of soil, debris, drums, pipes, tanks, or any other solid material from the ground. The following discussion provides a general description of conventional excavation equipment and discusses RMA-specific applications, including costs. Examples of conventional excavation equipment are bulldozers, backhoes, clamshells, drag lines, front-end loaders, and scrapers.

4.1.1 Process Description

In order to determine the best method for excavation, the equipment must not only be evaluated according to site conditions but also according to what is required of the equipment and how it is used. Four removal scenarios being considered in the DAA include the following: (1) excavate, load, haul, dump, and compact the solid material in an on-post disposal area and fill the excavation with clean backfill; (2) excavate, load, and haul the solid material to an off-post-treatment facility and fill the excavated area with clean backfill; (3) excavate, load, and haul the solid material to an on-post-treatment facility, return treated material to backfill the excavated area, and compact; and (4) excavate, load, and haul borrow soils to backfill and revegetate the sites.

The three most common combinations of equipment for excavation and transport of soil are a scraper teamed with a bulldozer, a front-end loader teamed with a bulldozer and trucks for transport, and a backhoe with trucks for transport. A drag line, clamshell, floating dredge, or

lake drainage techniques may be used specifically in areas where dredging is needed. A power shovel may be employed in areas where high, steep faces are being excavated. During remediation, the equipment used for excavation may change depending on site-specific conditions or changes in the size of the excavation. For all excavation processes, the stability of both cut and fill earth slopes is of paramount importance for worker safety. If workers are required to enter a trench deeper than 5 ft, it must be shored or shielded. Larger excavations must be sloped back or benched to protect workers and equipment. Most RMA excavations are to be no deeper than 10 ft.

Scrapers and Bulldozers

Scrapers can load, haul, and discharge material and are a compromise between the best loading and hauling machines. Scrapers may be pulled by crawler or wheel-mounted tractors, or they may be propelled by single or twin engines. Scrapers may consist of one bowl or two-bowl tandem units, and may or may not have elevating scrapers. Scrapers can scrape up or deposit a uniformly thick layer of soil. They are very useful for excavating and regrading large areas at a shallow depth (2 to 10 ft assuming there is no debris). Scrapers may be used in areas above the water table and in areas that have been cleared for unexploded ordnance (UXO).

Bulldozers may be crawler-mounted tractors or wheel-mounted tractors. Choosing the type of tractor depends on the size of the project, site conditions, and the type of excavation that is required. Bulldozers are primarily used for clearing, rough grading, and stockpiling; they can also be used in combination with front-end loaders to push the dirt into piles for front-end loaders to place in trucks or haulers. Bulldozers may also aid scrapers in loading hard soils by pushing the scraper. However, the scrapers' blades will require frequent replacement. A bulldozer may be used for the final scraping because it is able to scrape to a more exact depth. Various blades and attachments are available to suit site-specific requirements.

A scraper will not perform well in muddy conditions or in extremely hard soil unless the soil has been previously ripped by a bulldozer, nor will it perform well in areas containing debris.

Based on the preceding discussion, a scraper and bulldozer may be used effectively and efficiently for excavating select portions of the following soils medium groups: Basin A, Secondary Basins, Lime Basins, Munitions Testing, and Surficial Soils. More specifically, scrapers may be used in these areas above the water table, outside of trenches, and where no debris or possible UXO exists. In Basin A subgroup alternatives, a scraper and bulldozer combination exposes large surface areas, possibly causing volatilization of contaminants and air emission problems, as well as water infiltration into the construction site. The water table is relatively deep below the Secondary Basins and Surficial Soils Medium Groups and would not interfere with the excavation operation. Debris may be a problem for scrapers in these areas, as is the haul distance required (as a general rule of thumb, a scraper is most efficient for haul distances of less than approximately 1,500 ft). Hauling must also be performed along controlled haul roads since scrapers tend to have some spillage of material. Scrapers are best suited for excavation depths of 2 to 10 ft over large areas such as surficial soil sites.

Front-End Loader, Bulldozer, and Trucks

Front-end loaders are best suited for loading trucks or feed hoppers from stockpiles, but may be used to excavate, load, or even haul material a very short distance. Front-end loaders may use crawler- or wheel-mounted tractors. These units can excavate and load a large volume of material at one time due to the availability of large buckets. The front-end loader is best suited for excavating soils above the water table because the tractor must enter the excavation. Large, wheel-mounted front-end loaders are articulated to provide more maneuverability. Small front-end loaders have front-wheel steering and very small front-end loaders, such as a Bobcat, are skid steered.

The hydraulic- or cable-controlled power shovel on the front-end loader, used to excavate large, steep faces and to minimize volatilization and exposed surface area, excavates in the direction opposite of a backhoe: the dipper or shovel is pushed against the face of the excavation and material is forced into the shovel. It has a tractor unit that may be crawler- or wheel-mounted, and attached to the boom is a "dipper stick" and "dipper."

If the excavation is below the water table, the tractor has to contend with mud, even after dewatering, unless the soil drains well. In determining cycle times, the front-end loader must back out from the excavation, turn, and move forward to load awaiting trucks. After loading, the front-end loader must back away from the truck, turn, and return to the excavation. The operation is more complicated than for a backhoe under similar conditions, creating a longer cycle time. The front-end loader is not recommended in areas of potential UXO presence because the loader and the operator must enter the face of the excavation. Prior ripping of the soil by a bulldozer may be recommended to increase the excavating efficiency of a front-end loader.

Based on the preceding evaluation, a front-end loader and bulldozer may be recommended for the excavation of sites in the Basin F Wastepile, Secondary Basins, Buried Sediments/Ditches, Munitions Testing, and Surficial Soils Medium Groups. The front-end loader and bulldozer are also considered for use in limited areas of the Basin A, Sanitary Landfills, and Ditches/Drainage Areas Medium Groups and the Former Basin F, Complex Trenches, Shell Trenches, Hex Pits, South Plants Central Processing, South Plants Ditches, South Plants Tank Farm, South Plants Balance of Areas, Sand Creek Lateral, North Plants/Central Ditches, Motor Pool Ditches, Section 36 Balance of Areas, Burial Trenches, North Plants, and Toxic Storage Yards Subgroups. More specifically, front-end loaders and bulldozers may be used in alternatives developed for these subgroups in areas above the water table and where UXO does not occur. The front-end loader applies to all medium groups where loading of stockpiled material is proposed.

Backhoes and Trucks

Backhoes are most efficient when used in trenching applications or for the excavation of relatively small pits. Backhoes may be used in excavations below the water table. The backhoe does not have to enter the excavation like front-end loaders, scrapers, or bulldozers, so it does not have to contend with mud or water. Given the geometry of a backhoe, the operator is shielded from the face of the excavation and so it is the safest choice when excavating areas with potential UXO presence. Several types of backhoes are available depending on the depth of

excavation required. For linear excavations (e.g., ditches and disposal trenches), the backhoe is the most appropriate piece of excavation equipment. Conventional backhoes can reach depths of 30 ft, long-reach excavators can reach depths of 50 ft, and telescopic excavators can reach depths of 70 ft. A backhoe bucket may be changed out rather easily or can be fitted with a rammer attachment to demolish foundations.

Cycle times of the backhoe and the haul distance dictate the number of trucks that are required to maintain consistent backhoe production. Truck size, bucket size, and the type of material being excavated also affect production. The backhoe contrasts with a front-end loader in that it only has to rotate to dump its material into the haul unit, thus reducing a great deal of maneuvering time. Cycle times were used to develop costs for this excavation scenario.

Based on the preceding evaluation, the backhoe is applicable to all medium groups and is the equipment of choice for areas requiring excavation below the water table, in areas with potential UXO presence, and in trenches. The backhoe is the most suitable and efficient piece of equipment to excavate Basin A, Former Basin F, Basin F Wastepile, deep areas of Basin F Exterior, Sanitary/Process Water Sewers, Chemical Sewers, Complex Trenches, Shell Trenches, Hex Pits, Disposal Trenches, Agent Storage, Ditches/Drainage Areas, Lime Basins, and South Plants Medium Group/Subgroups. If the lakes are not drained, dredging may be required for excavation. If excavation of the more contaminated sediments near the inlets is chosen, a backhoe would be much more efficient than dredging equipment. A backhoe will also perform well for the other sites that may only be partially excavated to remove principal threat volumes.

Dredges

Dredging, as applied to the soils medium groups, involves the removal of sediments from the small, relatively shallow lakes at RMA. The small size of the lakes limits the types of dredging equipment that are appropriate. Dredging is accomplished through either on-shore or off-shore operations. On-shore operations use conventional excavation equipment such as crane-mounted

drag lines or clamshells. Off-shore operations use small, portable barge-mounted hydraulic dredges and are accomplished using either remote-controlled devices or on-board operators.

On-shore operations employ clamshells and draglines that use crane-mounted attachments. There are crawler-mounted, wheel-mounted, and truck-mounted crane units. The size of the attachment and boom vary according to the size of the job and the dimensions and clearance of the site. Clamshells are generally employed on large, deep excavations. The clamshell bucket, attached to a cable, is hinged and falls to the ground in the open position, thus embedding the teeth into the ground. When the cable is then drawn by a winch, the mouth is forced closed by tension of the cable and the material is enclosed inside the bucket. Draglines make use of open buckets attached to cables. The buckets are swung out and allowed to dip into the excavation, the cables holding the buckets in an upright position during retrieval. Clamshells and draglines may only be used to remove materials within 100 ft of the shoreline, and require watertight transport units, dewatering facilities, and silt curtains in the lake to prevent spread of contaminated silt.

Off-shore operations employ small, portable barge- or float-mounted hydraulic dredges. The dredges, remotely operated by shore-bound personnel or controlled by an on-board operator, excavate sections up to 8 ft in width per pass. Dredges, usually bound to cables anchored on the shoreline, traverse the length of the cable. This technique allows the accurate dredging of an entire lake. However, several self-propelled dredges with low-torque, high-speed motors, allow the efficient excavation of specific areas where contamination may be localized. Limitations of this dredging technique center around the cost of constructing settling basins and using a clarifier to dewater the dredged sediments.

Another dredging technique is to completely drain the lake prior to using heavy equipment to excavate the contaminated sediments. Draining the lakes would be effective if all the contaminants could be trapped in the lake sediments and the lake bottom was sufficiently dewatered to allow heavy excavating equipment to operate within the lake. This can be a risky

technique since lakes have been known to be re-flooded, thus stranding the equipment. An additional constraint of draining the lakes would be the loss of all fish life and lake ecosystems.

Table 4.1-1 describes the applicability of excavation equipment to the soils medium subgroups based on current understanding of site conditions. The basins, South Plants, and the lakes may be fully excavated or just the principal threat volumes may be excavated. Backfilling and reclamation is required following excavation. The selected alternative therefore affects the combination of excavation equipment required.

Additional process requirements for excavation may include dust suppression, control of air emissions, dewatering, or removal of debris or UXO. Dust suppression may be required during excavation of sites where dry, fine-grained material exists. This may be accomplished with a water truck or by spraying a dust suppression compound on the soil. Air monitoring performed at the site will indicate whether dust suppression is required.

Some excavation sites may require the use of containment structures to control air emissions. The types of emissions requiring control include volatile organic compounds (VOCs), contaminated fugitive dust, and particulates or noxious odors. The structures confine the emissions as an air pollution control system continuously removes contaminants from the air space. The control system is designed to maintain contaminants at a level that does not require Level "A" PPE and is designed to prevent the use of Level "B" PPE by workers within the structures.

Dewatering may be required in areas where the water table exists above the depth of the excavation. Excavation in parts of Basin A and South Plants areas may require dewatering. Extraction wells are most likely to be used for dewatering purposes. The wells are designed to achieve maximum drawdown, but the exact number and placement depends on site-specific conditions determined during the design phone. If wells do not sufficiently dewater the excavation area, dewatering trenches or vertical barriers such as sheet piling may be required.

Some sites may require removal of debris or UXO before excavation can begin. Debris or UXO is removed using construction equipment such as backhoes, bulldozers, or front-end loaders. If UXO is present, special equipment (e.g., remote-controlled equipment) may be used to ensure the safety of the workers. The site is excavated and the soil sifted to separate any UXO or debris. Once the UXO has been separated from the soil it is shipped off post to be demilitarized by specially trained personnel. Section 9.0 describes how UXO is removed and demilitarized in more detail.

4.1.2 Process Performance

Excavation is performed with proven technologies. The potential risks associated with excavation to the community and workers are volatilized contaminants and fugitive dust, which are monitored throughout the excavation process. If the dust or contaminant concentrations are above safe levels, water or other vapor- and dust-suppressing agents may be sprayed to reduce the dust emission levels. Containment structures are used if required.

The type of containment structure selected to control air emissions during the execution of Basin F Wastepile and the Shell Trenches subgroups is an air-supported structure. The air-supported structure covers the entire area of excavation and is made out of a synthetic fabric coated to decrease permeability. The fabric cover incorporates steel cables to withstand tensile stresses induced by maintaining increased air pressure within the structure. Air pressure within the structure under normal working conditions is to be 0.10 pounds per square inch (psi) greater than exterior, and is designed to withstand a wind load of 80 miles per hour (mph). To withstand stresses associated with snowfall, the structure is designed to include a 125-ft crown that encourages snow to slide off the structure. A snow load does require an adjustment in the air pressure within the structure. A 4-ft snow load, for example, requires an increase to the 0.25 to 0.30 psi range. A temporary foundation is installed using large, modular concrete blocks as dead-weight ballast to the tensile force in the steel cable. Because the concrete blocks are not buried in the area of the former Basin F or are not within the enclosure, decontamination or disposal is not anticipated. An air pollution control system to remove contaminants from the air

space within the enclosure will ensure a non-immediately dangerous to life and health (IDLH) atmosphere. During the demonstration project for radio frequency (RF)/microwave heating in former Basin F, the activated carbon adsorption system used for the demonstration was ineffective at removing ammonia-type odors (Weston 1992). Therefore, it is anticipated a wet scrubber control system is to be utilized to control these odors as well as dust and particulates for the wastepile excavation enclosure. The wastewater from the wet scrubber system is basic and can be used to neutralize the acidic blowdown water from the thermal desorber and then treated at the CERCLA Wastewater Treatment Plant.

Air emissions within the enclosure are minimized both by reducing the number of internal combustion engines used to excavate and transport excavated material and by equipping the remaining combustion engines with emission controls. For example, conveyor belts are used to move excavated material to a screw auger that conveys the material through a penetration in the enclosure for loading into trucks or rolloff containers for transport to the thermal desorber facility. Moreover, the excavation and loading equipment are equipped with emission control systems similar to those used in the underground mining industry or are powered by hydraulic pressure via umbilicals from power units located outside the enclosure.

The construction of haul roads and dewatering in areas where the water table exists above the depth of the excavation is accomplished prior to excavation. In addition, temporary staging areas may need to be constructed to stage, segregate, or temporarily store excavated materials.

Backfilling, compacting, and site reclamation are post-treatment processes related to excavation activities. The backfill may be obtained from an uncontaminated area on post or obtained off post. The use of backfill material from uncontaminated on-post areas costs less than does the use of off-post materials. Therefore, fill material is to be taken from on-post sources unless a specified type of material cannot be found on post. After soils are treated, they may be used as backfill. When backfilling is complete, the site is seeded with native grasses and plants in accordance with a future refuge management plan to reduce erosion and allow cover for wildlife.

Water produced from dewatering and the dust generated from excavation are the major sidestreams associated with excavation. Groundwater is treated at one of the on-post-treatment facilities and reinjected on post. The groundwater may be piped or hauled to the appropriate treatment systems.

Capital and operations costs for excavation are dependent upon the specific types of equipment employed at a site. Costs are based upon current (1992) rental rates, maintenance materials and labor, and estimated cycle times of specific equipment types. Table 4.1-2 details the estimated excavation costs.

4.2 STRUCTURES DEMOLITION

Demolition is applicable to the structures medium at RMA. It forms part of ten alternatives in the Process History subgroup of the No Future Use, Manufacturing History Medium Group, four alternatives in the Non-Process History Subgroup of the No Future Use, Manufacturing History Medium Group, and seven alternatives in the No Future Use, Agent History Medium Group. These medium groups include 855 structures. The structure materials include wood, steel, reinforced concrete, and masonry, and the sizes of the structures range from small guard shacks to complex multistory production buildings. The structures' histories encompass a wide range of uses including chemical processing, raw materials and finished product storage, power generation, and administrative support.

Dismantling uses 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, or other similar types of equipment. Contaminants are not treated with 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.

4.2.1 Process Description

The conditions at RMA are such that dismantling is the chosen method of demolition. The alternatives developed for the structures medium make use of a combination of clamshells, bulldozers, backhoes with thumb attachments on the bucket, and wrecking balls. It was assumed that prior to dismantling, process equipment, piping, and all asbestos-containing materials (ACM) is removed from the structures. Ongoing IRAs (PMRMA 1988/RIC 88329R02 and PMRMA 1989/RIC 89222R02) have removed or are in the process of removing process equipment, piping, sewers, and asbestos from selected structures, reducing the volume of contaminated materials to be handled during demolition. Agent-contaminated structures and process equipment will be decontaminated under another IRA, eliminating the potential exposure problems with those contaminants. As part of the demolition process, interim containment, storage, and transfer areas may have to be constructed. It may be necessary to stockpile metal prior to recycling or disposal. Demolition debris may have to be stockpiled prior to treatment or disposal. Decontamination facilities are to be built to decontaminate metals prior to recycling. Throughout the demolition process, air monitoring is conducted to ensure the safety of the workers and the surrounding community.

4.2.2 Process Performance

Demolition of structures at RMA requires the removal of the structure along with any contamination associated with it. The major concern for demolition is releasing large amounts of potentially contaminated dusts into the atmosphere. The air-borne contamination caused by dust release is minimized using dust control measures such as water mists. Continuous air monitoring is used to monitor the effectiveness of the controls.

Demolition has been accomplished at RMA under the Hydrazine Facility IRA (PMRMA 1988/RIC 88329R02) and will be completed under the structures Pilot Demolition Program. Results from these demolition examples will be a factor in determining additional methods to be considered for structures demolition.

Pre-treatment of structures undergoing demolition requires isolating the designated structure from its surroundings, obtaining permits if required, removing any materials to be preserved, and terminating utility connections. Separately regulated materials such as asbestos or PCBs must be removed prior to demolition. If there is potential agent presence in the structural materials, special monitoring and personnel protective measures must be taken. An exclusion zone must be established to prevent contaminant exposure by passersby and adjacent structures. Surface treatments may also occur prior to demolition.

Post-treatment of structure demolition consists of removing the debris and restoring the site. The structural debris may be tested after demolition to determine the appropriate treatment/disposal option.

Table 4.2-1 outlines the costs associated with demolition. Capital costs involved in demolition are those that would be required to initiate contractual agreements for subsequent remedial action. Operations costs are based on unit costs for demolition of the standing volume (cubic yards [CY]) of specific materials.

4.3 TRANSPORTATION

Transportation is the physical removal of structural, soil, or liquid material from a site. Transportation methods include using end-dump trucks, rock trucks, off-road dump trucks, conveyor belts, railroad cars, and rolloff containers to ship materials to a designated location.

4.3.1 Process Description

Off-Post Transportation

Off-post transportation for contaminated materials at RMA is expected to be limited, especially for the soils medium, because the large volume of materials and accompanying costs do not make off-post-treatment or disposal feasible. However, for structural materials, liquids, or soils containing UXO or Army agent, off-post transportation to a treatment, disposal, or salvage facility is a viable option.

For alternatives requiring off-post transportation, drummed materials are transported in 55-gallon drums on flat-bed trucks or bulked into liquid tanker trucks or railroad tanker cars. Drums containing unknown solids and sludges need to be sampled prior to transport off post to determine content, appropriate action, and compliance with applicable Department of Transportation (DOT), EPA, or state requirements.

Under the off-post landfill alternative, approximately 140,000 CY of demolition materials from the structures medium require transportation. Size reduction of materials prior to transportation will be accomplished using either a concrete crusher mounted to an excavation unit, a portable hammer-mill, or a combination of the two devices. For costing purposes, it was assumed that contaminated materials are transported to a hazardous waste landfill approximately 70 miles from RMA, and that uncontaminated materials are transported to a municipal/industrial landfill 10 miles from RMA. The actual landfills used are to be determined at the time of disposal based on availability and acceptance of the materials for disposal. Transportation to these locations is accomplished using end-dump rock trailers, gondola railroad cars, or rolloff containers carried on flat-bed railroad cars.

UXO- or agent-contaminated soils may require treatment and disposal in an off-post-treatment, storage, and disposal (TSD) facility. Soils containing UXO materials remain under Army control and are transported to the Army UXO treatment facility at Fort Carson in Colorado Springs, Colorado. Any materials that contain Army agent may be shipped to a similar Army facility in Tooele, Utah for treatment and disposal. Materials contaminated by UXO or agent are transported using tractor-trailer trucks or railroad cars (if the disposal facilities have railroad access and off-loading capabilities).

On-Post Transportation

Solid materials may be transported on post by several methods including conveyor belt systems, tractor-trailer trucks, off-road dump trucks, all-purpose dump trucks, bottom- or end-dump tractors, scrapers, or an on-post railroad system. Liquids are generally transported in vacuum

tanker trucks, 55-gallon drums, or for long-term transportation needs, dedicated pipelines, (e.g., for groundwater pump-and-treat systems).

On-post transportation methods were analyzed and compared against one another to derive the most cost-efficient transportation type. Cost efficiency was based on cycle times of the excavation unit, load-carrying capacity of the haul unit, long-term maintenance, and a uniform haul distance of 4 miles. Based on these constraints, it was determined that off-road, end-dump trucks were the most efficient method of haul for on-post solid materials.

The construction of haul roads for on-post transportation may be accomplished using soils in the vicinity of the site, if available, or by hauling soils from another area. The haul roads would most likely be constructed with a bulldozer, but the material could be deposited by a scraper, front-end loader, or simply dumped by a hauling truck for the front-end loader or bulldozer to spread into place. A water truck may be used to obtain optimum moisture content for compaction. Once constructed, the haul road may be maintained by a bulldozer or road grader and a water truck. The cost for equipment used to maintain a haul road is recouped in the increased hauling efficiency provided by a well-maintained haul road. It was assumed that the existing RMA road system is also utilized for transporting material. Therefore, constructed haul roads should not be much more than one-half mile long since roads already exist on every section line. Any road constructed of contaminated soil or that is contaminated in the transport process requires reclamation along with the site.

Drummed materials, such as generated liquid or solid sidestreams, are transported on post. This can be accomplished by transporting the 55-gallon drums on either a vacuum truck or flatbed truck. These materials would be transported on post to either the CERCLA Wastewater Treatment Plant or other treatment plant.

4.3.2 Process Performance

All of the transportation methods described herein are proven, effective processes for the transfer of materials both at RMA and at CERCLA sites nationwide. Contamination may be mobilized during loading and transportation; however, appropriate engineering controls minimize dust generation and volatile emissions.

The effectiveness of off-post transportation is limited by the risk of release of contamination in transportation accidents and high operating costs due to long hauling distances, greater costs for equipment decontamination and manifesting, and chemical sampling to ensure regulatory compliance. The potential for contamination release during off-post and on-post transportation is minimized by using dust suppressants and bed liners and covers and by evaluating alternate transportation routes to minimize potential exposures.

Prior to the off-post transportation of structural materials, sizing may be required so that landfill and transportation capacity is efficiently used. Before off-post transportation of materials from RMA can proceed, all materials need to be properly manifested, documented, and covered and be capable of satisfying all regulatory transportation requirements. The transport vehicles may require thorough decontamination prior to traveling off post, and all vehicles traveling from an uncontaminated area, either on or off post, are required to drive through a wheel-wash station.

On-post transportation primarily involves transportation of liquid waste to the CERCLA Wastewater Treatment Plant or other treatment plants and transportation of soil and structural waste to an on-post disposal or treatment facility. Size reduction of structural materials may be required. The transport vehicles would require decontamination.

Dust generation and organic vapor emissions may occur during transportation activities. Proper lining, covering, and packaging of materials prior to transport and dust suppression on dirt roads and excavation sites minimizes dust emissions. Properly selected PPE protect transportation and excavation personnel.

Table 4.3-1 list the costs associated with off-post transportation. Capital and operations costs for transportation are dependent upon the specific types of equipment employed at a site. Costs are based on current (1992) rental rates, current maintenance materials costs, and the estimated cycle-related costs of a specific transportation method.

REFERENCES

RIC 88329R02

PMRMA. 1988, October. Final Decision Document for the Interim Response Action at the Rocky Mountain Arsenal Hydrazine Blending and Storage Facility.

RIC 89222R02

PMRMA. 1989, July. Final Interim Response Action Technical Plan, Asbestos Removed — Phase II — Removal. Version 3.0.

Roy F. Weston, Inc. 1992. Final Rocky Mountain Arsenal In Situ Radio Frequency Heating/Vapor Extraction Pilot Test Report.

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Basin A (830,000 bcy)			
Load/Haul/Dump/Compact in an On-Post Landfill, Fill Excavation	+ Use in areas above water table/no debris[C] or UXO.	+ Use in areas above water table with no UXO[A] risk.	⊕ Applies to all areas, including below water table. Best protection against UXO[A], loads faster[B].
Load/Haul to Treatment Facility, Return to Ground/Compact	+ Use in areas above water table/no debris[C] or UXO.	+ Use in areas above water table with no UXO[A] risk. Best choice for loading soil stockpiles at treatment facility.	⊕ Applies to all areas including below water table. Best protection against UXO[A], loads faster[B].
Basin F Wastepile (600,000 bcy)			
Load/Haul to Treatment Facility, Return to Ground/Compact	– Will volatilize contaminants[C].	⊕ Best choice for loading stockpiles at treatment facility. Best option to minimize volatilization, may also use power shovel.	+ Applicable and efficient[B].
Secondary Basins (300,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Cap Excavation	+ Fastest option/no debris[C].	+ Applicable	+ Applicable
Load/Haul to Treatment Facility, Return to Ground/Compact	+ Fastest option/no debris (need to load at treatment site)[C].	+ Applicable, best choice for loading soil stockpiles at treatment facility.	+ Applicable

A A front-end loader works in the excavation and does not shield the worker from the face of the excavation. A backhoe works outside the excavation and is shielded from the face of the excavation.
B A backhoe only rotates to dump and the tractor unit does not have to maneuver around to dump the load like a front-end loader.
C Scraper will only be used for hauling less than 1,500 ft and within area of contamination.
⊕ Equipment is able to excavate all of site in the most efficient manner.
\+ Equipment is only able to excavate certain areas of site or may not be most efficient method to excavate all of site.
– Equipment will not efficiently excavate site or is not able to excavate site.
bcy Bank cubic yards
uxo Unexploded ordinance
ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Former Basin F (790,000 bcy)			
Load/Haul to Treatment Facility, Return to Ground/Complex	+ Applicable for shallow excavation and short haul distances.	+ Applicable, best choice for loading stockpiles at treatment facility.	⊕ Applicable and efficient[B]. Best option for areas below water table on deep excavation.
Basin F Exterior (77,000 bcy)			
Load/Haul/Dump Complex to an On-Post Landfill, Fill Excavation	+ Applicable for excavating deeper than 2 ft but haul distances may be too long[C].	+ Applicable for very large area of shallow excavation.	+ Applicable for deeper excavation but not most efficient for large areas of shallow excavation.
Load/Haul to Treatment Facility, Return to Ground/Compact	+ Applicable for excavating deeper than 2 ft, but haul distance may be too long[C].	+ Applicable for very large area of shallow excavation	+ Applicable for deeper excavation but not most efficient for large areas of shallow excavation.
Sanitary/Process Water Sewers (170,000 bcy)			
Load/Haul/Dump Compact to an On-Post Landfill, Fill Excavation	– Not applicable	– Not applicable	⊕ Best suited for trenching.
Load/Haul to Treatment Facility, Return to Ground/Compact	– Not applicable	+ Best choice for loading soil stockpiles at treatment facility.	⊕ Best suited for trenching.

A A front-end loader works in the excavation and does not shield the worker from the face of the excavation. A backhoe works outside the excavation and is shielded from the face of the excavation.

B A backhoe only rotates to dump and the tractor unit does not have to maneuver around to dump the load like a front-end loader.

C Scraper will only be used for hauling less than 1,500 ft and within area of contamination.

⊕ Equipment is able to excavate all of site in the most efficient manner.

\+ Equipment is only able to excavate certain areas of site or may not be most efficient method to excavate all of site.

– Equipment will not efficiently excavate site or is not able to excavate site.

bcy Bank cubic yards

uxo Unexploded ordinance

ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Chemical Sewers (82,000 bcy)			
Load/Haul/Dump Compact to an On-Post Landfill, Fill Excavation	– Not applicable	– Not applicable	⊕ Best suited for trenching.
Load/Haul to Treatment Facility, Return to Ground/Compact	– Not applicable	+ Best choice for loading soil stockpiles at treatment facility	⊕ Best suited for trenching.
Complex Trenches (510,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Use above water table, UXO[A] risk.	⊕ Applies to all areas, including below water table. Best protection against UXO[A] and efficient[B].
Load/Haul to Treatment Facility, Return to On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Use above water table, possible UXO[A] risk and best choice for loading soil stockpiles at treatment facility.	⊕ Best protection against UXO[A] and efficient[B]. Applies to all areas, including below water table.
Shell Trenches (100,000 bcy)			
Load/Haul to Treatment Facility, Compact to an On-Post Landfill, Fill Excavation	– Not Applicable.	+ Use above water table, best choice for loading soil stockpiles at treatment facility.	⊕ Applies to all areas, including below water table.

A A front-end loader works in the excavation and does not shield the worker from the face of the excavation. A backhoe works outside the excavation and is shielded from the face of the excavation.

B A backhoe only rotates to dump and the tractor unit does not have to maneuver around to dump the load like a front-end loader.

C Scraper will only be used for hauling less than 1,500 ft and within area of contamination.

⊕ Equipment is able to excavate all of site in the most efficient manner.

\+ Equipment is only able to excavate certain areas of site or may not be most efficient method to excavate all of site.

– Equipment will not efficiently excavate site or is not able to excavate site.

bcy Bank cubic yards

uxo Unexploded ordinance

ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Hex Pits (3,300 bcy)			
Load/Haul to Treatment Facility, Compact to an On-Post Landfill, Fill Excavation	– Not Applicable.	+ Use above water table. Best choice for loading soil stockpiles at treatment facility.	⊕ Applies to all areas, including below water table.
Sanitary Landfills (430,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Applicable	⊕ Most efficient[B]
Load/Haul to Treatment Facility, On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Best choice for loading soil stockpiles at treatment facility.	⊕ Most efficient[B]
Section 36 Lime Basins (200,000 bcy)			
Load/Haul to Treatment Facility, Return to Ground/Compact	– Debris and water will cause problems.	+ Water will cause problems even with dewatering, unstable ground but best choice for loading soil stockpiles at treatment facility.	⊕ Long-arm needed, will have to backfill excavation as work proceeds. Dragline or clamshell may be best option
Buried M-1 Pits (29,000 bcy)			
Load/Haul to Treatment Facility, Compact to an On-Post Landfill, Fill Excavation	– Debris and water will cause problems.	+ Applicable but excavation below water table will cause problems.	+ Applicable to all areas, including below water table.

A A front-end loader works in the excavation and does not shield the worker from the face of the excavation. A backhoe works outside the excavation and is shielded from the face of the excavation.

B A backhoe only rotates to dump and the tractor unit does not have to maneuver around to dump the load like a front-end loader.

C Scraper will only be used for hauling less than 1,500 ft and within area of contamination.

⊕ Equipment is able to excavate all of site in the most efficient manner.

\+ Equipment is only able to excavate certain areas of site or may not be most efficient method to excavate all of site.

– Equipment will not efficiently excavate site or is not able to excavate site.

bcy Bank cubic yards

uxo Unexploded ordinance

ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
South Plants Central Processing (620,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Can use in areas above water table (may need to rip weathered bedrock).	⊕ Can excavate below water table, and ram foundations. Will need bulldozer for surface rubble.
Load/Haul to Treatment Facility, Compact to an On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Can use in areas above water table (may need to rip weathered bedrock) and best choice for loading soil stockpiles at treatment facility.	⊕ Can excavate below water table, and ram foundations. Will need bulldozer for surface rubble.
South Plants Ditches (200,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Not applicable to ditches and debris may cause problems.	+ Applicable	⊕ Best suited for trenching.
Load/Haul to Treatment Facility, Return to Ground/Compact	– Not applicable to ditches and debris may cause problems.	⊕ Best choice for loading soil stockpiles at treatment facility.	⊕ Best suited for trenching.
South Plants Tank Farm (240,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Can use in areas above water table (may need to rip weathered bedrock).	⊕ Can excavate below water table, and main foundation. Will need bulldozer for consolidating surface rubble.

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bcy Bank cubic yards
uxo Unexploded ordinance
ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Load/Haul to Treatment Facility, Return to Ground/Compact	– Debris will cause problems.	+ Can use in areas above water table (may need to rip weathered bedrock) and best choice for loading soil stockpiles at treatment facility.	⊕ Can excavate below water table, and main foundation. Will need bulldozer for consolidating surface rubble.
South Plants Balance of Areas (720,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Can use in areas above water table (may need to rip weathered bedrock)	⊕ Can excavate below water table, and main foundation. Will need bulldozer for consolidating surface rubble.
Load/Haul to Treatment Facility, Return to On-Post Landfill, Fill Excavation	– Debris will cause problems.	+ Can use in areas above water table (may need to rip weathered bedrock) and best choice for loading soil stockpiles at treatment facility.	⊕ Can excavate below water table, and main foundation. Will need bulldozer for consolidating surfaced rubble.
Buried Sediments (180,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill Excavation	– Not applicable, water and debris may cause problems.	⊕ Best choice for buried sediments.	+ Applicable
Load/Haul to Treatment Facility, Return to Ground/Compact	– Not applicable, water and debris may cause problems.	⊕ Best choice for buried sediments and loading soil stockpiles at treatment facility.	+ Applicable

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bcy Bank cubic yards
uxo Unexploded ordinance
ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Sand Creek Lateral (39,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Not applicable	+ Use in areas above water table.	⊕ Best suited for trenching and applies to all areas, including below water table.
Load/Haul to Treatment Facility, Return to Ground/Compact	– Not applicable	+ Use in areas above water table. Best choice for loading soil stockpiles at treatment facility.	⊕ Best suited for trenching and applies to all areas, including below water table.
Section 36 Balance of Areas (390,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	+ Applicable except for long haul application.	+ May need to rip ground and may be used in balance of areas where UXO is not present.	⊕ Applicable, efficient[B], potential UXO[A] for balance of areas..
Load/Haul to Treatment Facility, Return to On-Post Landfill, Fill Excavation	+ Applicable except for long haul application.	+ May need to rip ground; may be used in balance of areas where UXO is not present and best choice for loading soil stockpiles at treatment facility.	⊕ Applicable, efficient[B], potential UXO[A] for balance of areas..
Burial Trenches (36,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	+ Debris may cause problems[C].	+ Use in areas above water table with no UXO risk.	⊕ Applies to all areas, including below water table. Best protection against UXO[A]; loads faster[B].

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B A backhoe only rotates to dump and the tractor unit does not have to maneuver around to dump the load like a front-end loader.

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bcy Bank cubic yards

uxo Unexploded ordinance

ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Load/Haul to Treatment Facility, Return to On-Post Landfill, Fill Excavation	+ Debris may cause problems[C].	+Use in areas above water table with no UXO[A] risk. Best choice for loading soil stockpiles at treatment facility.	⊕ Applies to all areas, including below water table. Best protection against UXO[A]; loads faster[B].
Munitions Testing (450 bcy)			
Load/Haul/Transport to Off-Post Treatment Facility, Fill Excavation	– Cannot transport off post.	⊕ May need to rip ground first but most practical for shallow excavation (0-2 ft); is not suggested for areas with UXO risk.	+ Could be used but not most practical choice for large areas of shallow excavation. Best protection against UXO[A].
Load/Haul to Treatment Facility, Return to Ground/Compact	+ Applicable for excavating deeper than 2 ft where UXO is not present and haul distance is small[C].	⊕ May need to rip ground first but most practical for shallow excavation (0-2 ft); is not suggested for areas with UXO risk. Best choice for loading soil stockpiles at treatment facility.	+ Could be used but not most practical choice for large areas of shallow excavation. Best protection against UXO[A].
North Plants (670 bcy)			
Load/Haul to a Treatment Facility, Return to On-Post Landfill, Fill Excavation	– Not applicable	+ Applicable but may be difficult to excavate small areas of deep contamination in North Plants, particularly near buildings.	⊕ Best choice to excavate small, sometimes paved areas in North Plants.

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B A backhoe only rotates to dump and the tractor unit does not have to maneuver around to dump the load like a front-end loader.
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bcy Bank cubic yards
uxo Unexploded ordinance
ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Load/Haul to Treatment Facility, Return to Ground/Compact	– Not applicable	+ Applicable but may be difficult to excavate small areas of deep contamination in North Plants, particularly near buildings.	⊕ Best choice to excavate small, sometimes paved areas in North Plants.
Toxic Storage Yards (660 bcy)			
Load/Haul to a Treatment Facility, Return to On-Post Landfill, Fill Excavation	– Not applicable	+ Applicable	⊕ Best choice to excavate small sometimes paved areas in Toxic Storage Yard.
Load/Haul to Treatment Facility, Return to Ground/Compact	– Not applicable	+ Applicable and the best choice for loading soil stockpiles at treatment facility	⊕ Best choice to excavate small sometimes paved areas in Toxic Storage Yard.
Lake Sediments (370,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Not applicable unless lakes completely drained.	– Not applicable unless lakes completely drained.	+ Will work for partial excavation of "hot spots" near inlets but otherwise not applicable unless lakes are drained. Dredging with dragline, clamshell or floating dredge is the only option if the lakes are not drained.
Load/Haul to Treatment Facility, Return to On-Post Landfill	– Not applicable unless lakes completely drained and cannot transport off post.	+Not applicable unless lakes completely drained but best choice for loading soil stockpiles at treatment facility.	+ Will work for partial excavation of "hot spots" near inlets but otherwise not applicable unless lakes are drained. Dredging with dragline, clamshell or floating dredge is the only option if the lakes are not drained.

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+ Equipment is only able to excavate certain areas of site or may not be most efficient method to excavate all of site.
– Equipment will not efficiently excavate site or is not able to excavate site.
bcy Bank cubic yards
uxo Unexploded ordinance
ft Feet

Site	Scraper/Bulldozer	Bulldozer/Front-End Loader/Trucks	Backhoe/Trucks
Surficial Soils (820,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	+ Applicable for excavating deeper than 2 ft, but haul distance may be too long[C].	⊕ Applicable for very large area of shallow excavation.	+ Applicable, but not most efficient for very large area of shallow excavation.
Ditches/Drainage Areas (25,000 bcy)			
Load/Haul/Dump/Compact to an On-Post Landfill, Fill Excavation	– Not applicable	+ Applicable, but not as efficient as backhoe.	⊕ Best suited for excavation of ditches and drainages.
Load/Haul to Treatment Facility, Return to Ground/Compact	– Not applicable	+ Applicable, but not as efficient as backhoe. Is best for loading soil stockpiles at treatment site.	⊕ Best suited for excavation of ditches and drainages.

A A front-end loader works in the excavation and does not shield the worker from the face of the excavation. A backhoe works outside the excavation and is shielded from the face of the excavation.

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bcy Bank cubic yards

uxo Unexploded ordinance

ft Feet

Table 4.1-2 Excavation Costs

Item Description	Capital Cost	O&M Cost	Unit Cost (Units)
Excavation of borrow material		3.91/BCY	
Excavation of soil with agent or isolated exceedances		4.55/BCY	
Excavation of dike materials		3.91/BCY	
Sewers and ditch excavation		3.82/BCY	
Excavation of Shell Trenches with vapor controls	10,000,000	88.42/BCY	
Excavation of Army Complex Trenches with vapor controls	12,300,000	107.35/BCY	
Excavation of Hex Pit with vapor controls	500,000	100.07/BCY	
Excavation of debris from surface soil		3.91/BCY	
Dredging	790,000	9.82/BCY	
Excavation of overburden		1.51/BCY	

1 Based on total volume of structural demolition materials currently at RMA (Task 24 Database)

BCY Bank Cubic Yards

Table 4.2-1 Demolition Costs

Item Description	Capital Unit Costs	O&M Unit Costs
Demolition of manufacturing structures	–	11.02/CY
Demolition of agent structures	–	23.31/CY
Shredding structure debris	0.31/cy	13.32CY
Backfill of structure excavation	–	8.05/CY
Restoration of structure excavation	–	0.08/SF

CY Cubic Yard
SF Square Feet

Table 4.3-1 Transportation Costs

Item Description	Capital Unit Cost	O&M Unit Costs
Transportation of hazardous waste on post	—	$1.07/CY
Transportation of nonhazardous waste on post	—	$0.86/CY
Transportation of hazardous waste off post	—	$0.19/CY
Transportation of nonhazardous waste offpost	—	$0.13/CY
Loading of hazardous debris	—	$1.55/CY
Loading of nonhazardous debris	—	$1.28/CY
Transfer Station	$0.24/CY	$0.41/CY

1 Based on total volume of structural demolition materials currently at RMA (Task 24 Database)

CY Cubic Yards

5.0 GROUNDWATER EXTRACTION/REINJECTION

Groundwater extraction methods may be used to collect groundwater from aquifers for surface treatment and reinjection, and reinjection methods employ the same general technologies to return the water to the aquifer. Groundwater extraction methods also may be employed to dewater areas such as the South Plants groundwater mound, or dewater excavations in areas with a shallow water table. 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 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 soils and groundwater by lowering the water table. The layout, pumping rates, well spacing, etc., differs for each of these examples depending on the desired effect. The groundwater extraction technology under consideration in the DAA is extraction wells, with provisions for trenches/drains if needed. The reinjection method under consideration in the DAA is a reinjection trench. Extracted water is pumped to a treatment facility and the effluent from treatment is reinjected. The following discussion gives a general description of the groundwater extraction/reinjection methods and then describes specific RMA applications, including costs.

5.1 OVERVIEW OF PROCESS

Extraction/Reinjection Wells

Extraction wells can be used to remove contaminated groundwater for treatment, lower the water table in a particular area, and/or contain a plume of contaminated groundwater. They are flexible in that they can be used to extract groundwater from any depth. Extraction wells use pumps to raise groundwater to the surface, resulting in a cone of depression that forms around each well that captures groundwater around the well. With proper placement and operation, a groundwater extraction system can capture contaminants in groundwater and control migration of contaminated groundwater. Therefore, extraction wells can serve both as a groundwater containment

technology and a collection technology. Figure 5.1-1 displays a cross-sectional view of an extraction well.

Various drilling methods exist to create the borehole for an extraction well. The drilling method is determined according to geologic conditions, which are well characterized at RMA. All drilling methods alter the hydraulic characteristics of formation materials in the vicinity of the borehole (Driscoll 1986). Therefore, wells must be developed to produce water and operate properly. There are two primary methods of well completion—natural development and filter packing. Filter packing is the method of choice at RMA. The proper filter pack size is selected based on the geologic conditions determined when drilling the borehole. The proper screen slot size is determined according to the size of the filter pack material and the chosen screen length is based on aquifer conditions.

The well-casing size and material must also be determined. The inner diameter of the casing must be large enough to accommodate the pump, which is sized according to expected extraction rates. Common casing and screen materials are stainless steel and polyvinyl chloride (PVC). The type of material chosen depends on site-specific groundwater chemical characteristics and required strength and service life.

Recharge Trenches

Recharge trenches include any type of buried conduit used to convey liquids by gravity flow. Recharge trenches are excavated to a depth sufficient to convey water to the water table. The recharge trenches are generally 2- to 3-ft wide and excavated using a backhoe. The trenches may be excavated to a depth of approximately 30 ft using conventional backhoes and to much greater depths using telescopic backhoes or clamshells. (For more information on excavation, refer to Section 4). Recharge trenches are typically excavated within 2 ft of the water table, lined with a geotextile filter fabric, backfilled with clean gravel, and covered with a geotextile filter fabric and approximately 3 ft of soil. Well points are placed in the gravel pack during construction at a distance that would uniformly distribute the reinjected water. The recharge trenches can cross-

cut possible impermeable geologic layers to ensure that water is recharged back to the underlying aquifer. A geotextile filter barrier encloses the gravel pack of the trench to minimize siltation of the trench. The most appropriate geotextile filter material is selected based on the geologic conditions and soil properties. Choosing the proper geotextile filter material is critical to reduce clogging and stabilize the trench walls. Figure 5.1-2 displays a cross-sectional view of a recharge trench.

5.1.1 Process Description

Groundwater extraction/reinjection methods are evaluated according to their applicability to the five plume groups identified at RMA—the Northwest Boundary Plume Group, the Western Plume Group, the North Boundary Plume Group, the Basin A Plume Group, and the South Plants Plume Group.

Groundwater extraction with wells is a proven, implementable method that has been used extensively at RMA at the boundary and IRA systems. Extraction wells are recommended and costed for all plume groups. Several monitoring wells and/or piezometers are installed around the extraction wells at varying depths and distances from the wells to monitor system performance. Reinjection wells are generally not recommended due to a history of plugging at RMA and the proven effectiveness of recharge trenches at RMA.

For reinjection, recharge trenches are effective in returning treated water to the aquifer. Such systems are currently in use at the NBCS and the Basin A Neck IRA system where they are operating effectively. Recharge trenches are the most likely method to recharge treated water to the subsurface for most plume groups because of their applicability to typical RMA conditions and history of operation at RMA. Monitoring wells and/or piezometers are installed within and around the recharge trench at various depths and distances to monitor system performance.

Appendix A presents ARARs that apply to the extraction and reinjection of groundwater.

5.1.1.1 Pre- and Post-Treatment

Pre-treatment for the extraction wells include purging and developing wells. Developing the wells is required so that water may be extracted efficiently through the gravel pack and aquifer material near the well. During development, very fine materials that reduce flow are removed. Post-treatment for extraction wells and recharge trenches include periodic redevelopment and the addition of a sodium hypochlorite solution containing a surfactant to prevent clogging.

5.1.1.2 Costs

The costs of extraction wells and recharge trenches depends on the size of the system designed and site-specific conditions: the larger a system is, the lower the percentage mobilization costs are compared to the total system cost.

The capital cost of extraction wells is approximately $60 to $80/ft depending on site-specific conditions. The cost per foot includes installation and pumps. The O&M and other miscellaneous costs depend on system size, design, replacement rates determined by corrosion and wear, and are described in the alternative description sections of the DAA. Monitoring wells cost approximately $30/ft and O&M includes labor and chemical analysis costs.

The capital cost for reinjection trenches is approximately $12/SF, which is figured by multiplying the length of the trench by the depth of the trench. A $30,000 mobilization cost is also associated with recharge trenches. The O&M and miscellaneous costs depend on system size and design.

5.1.2 Process Performance

Groundwater extraction removes contaminated groundwater from the aquifer to a surface system where it can be treated and reinjected. In terms of long- and short-term effectiveness, on-post groundwater extraction, treatment, and reinjection controls contaminants that are close to the sources and may reduce operation time of the boundary systems. Source control through extraction also reduces the possibility of vertical and horizontal migration of contaminants.

Groundwater extraction methods may not completely restore aquifers to health-based drinking water standards due to aquifer characteristics and characteristics of the contaminants. The primary aquifer conditions that render pump-and-treat technology less effective are subsurface heterogeneity and low hydraulic conductivity or permeability. The primary characteristics of contaminants that render pump-and-treat technology less effective are water insolubility and high sorbing affinity for the aquifer materials (Mott 1992). Although evidence suggests pump-and-treat systems may not effectively reduce contamination in aquifers below health-based standards, pump-and-treat systems are shown to effectively contain most plumes and possibly remove a large mass of contamination (Doty and Travis 1991). The extraction systems chosen for RMA were selected for mass removal or interception of contaminants and not for restoration of the aquifer to health-based standards since groundwater extraction for potable use is not permitted within RMA boundaries. In the long term, the extraction systems will reduce contaminant loading on the boundary systems and possibly reduce operation time of the boundary systems.

Groundwater extraction and reinjection methods are implementable and proven technologies. The cost of extraction/reinjection methods are relatively low when compared to impermeable barrier/containment methods. The same volume of water that is extracted must be reinjected to replenish the aquifer and maintain the regional water balance. Tables 5.1-1 and 5.1-2 present information related to the performance of the extraction/reinjection systems.

REFERENCES

Driscoll, Fletcher G. 1986. Groundwater and Wells. Johnson Division, St. Paul Minnesota, p. 497.

Mott, R. M. 1992. Aquifer Restoration Under CERCLA: New Realities and Old Myths. Environmental Reporter. August.

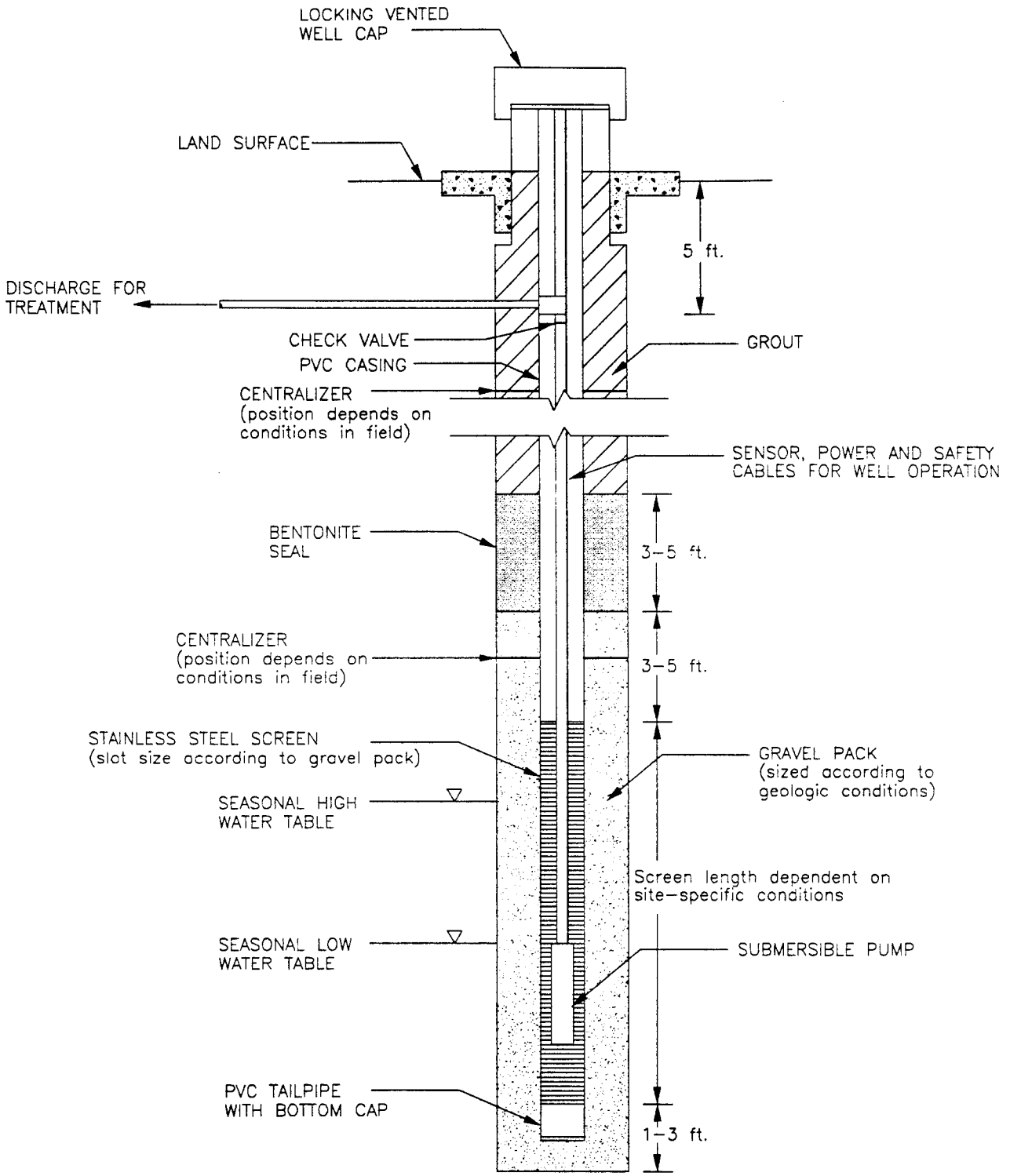
Doty, C.B., and C.C. Travis. 1991. The Effectiveness of Groundwater Pumping as a Restoration Technology. ORNL/TM-11866. Prepared by: Risk Analysis Section, Health and Safety Division, Oak Ridge National Laboratory. Prepared for: United States Department of Energy.

Table 5.1-1 Performance for Extraction

Technology	Applicability at RMA	Advantages	Disadvantages	Cost
Wells	The boundary and IRA systems have proven their implementability.	Works as a hydraulic barrier to contain/remove contaminants. Extracts high volumes of water from greater depths. Easy to maintain and cost-effective installation.	High O&M costs when used in high concentration plumes. Not effective in low-permeability zones. Potential vertical migration of contaminants along casing.	$60–80 per ft

Table 5.1-2 Performance of Reinjection Method

Technology	Applicability at RMA	Advantages	Disadvantages	Cost
Recharge Trenches	More effective at RMA, because they clog less easily than wells.	Reinjects larger quantities of water over a larger area. More effective in shallow water tables and low-permeability areas. Cross-cuts fractures more easily.	Not cost effective for returning water to deep aquifers. More difficult to install than wells.	$12 per sq ft



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Office of the Program Manager
for Rocky Mountain Arsenal

FIGURE 5.1–1

Extraction Well

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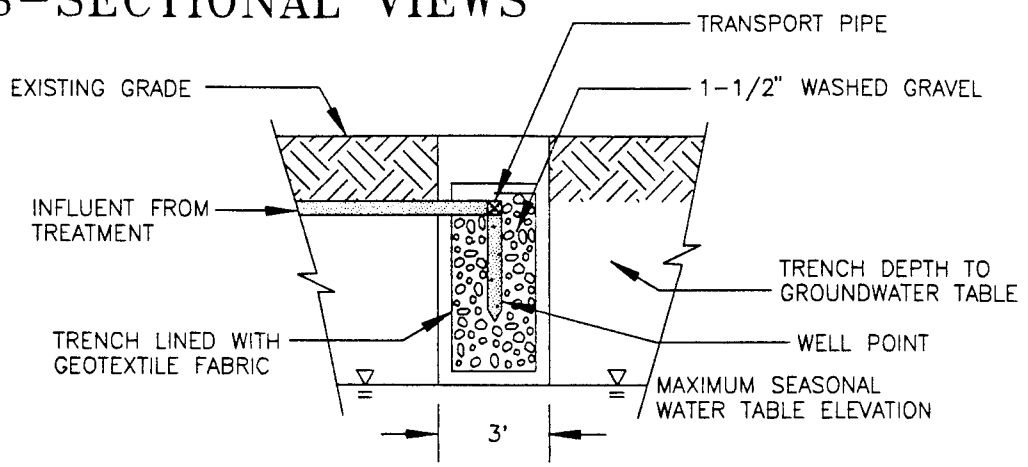
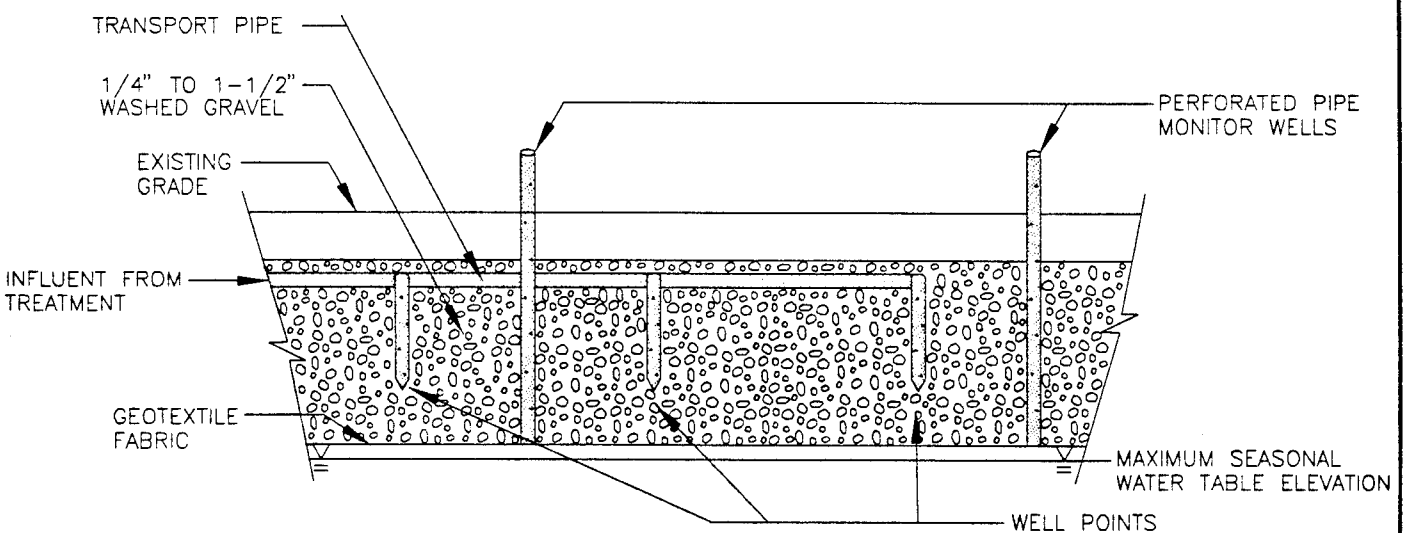
EBASCO SERVICES INCORPORATED

CROSS-SECTIONAL VIEWS





PLAN VIEW

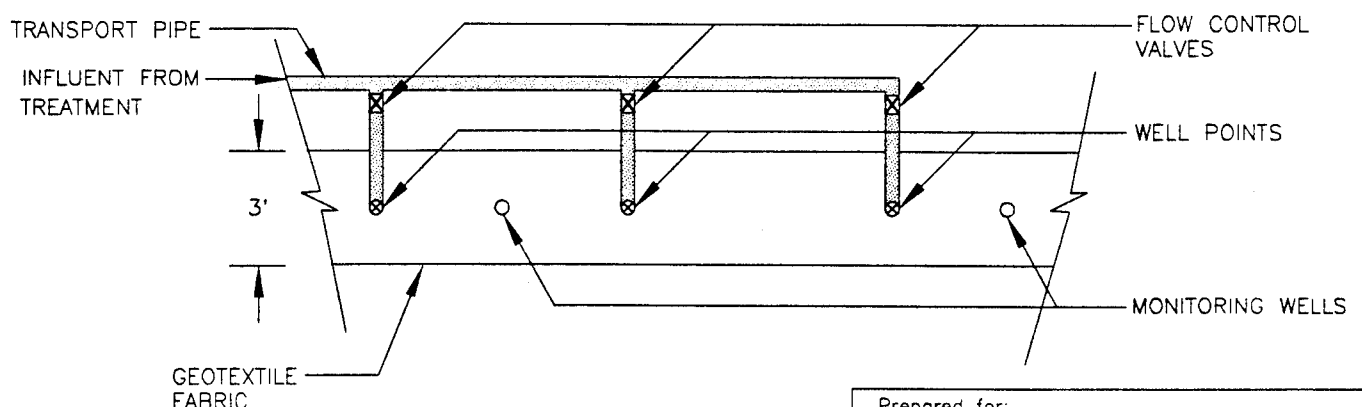


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FIGURE 5.1-2

Typical Recharge Trench

Prepared by:
EBASCO SERVICES INCORPORATED

6.0 CONTAINMENT

This section describes process options used in alternatives within the Containment General Response Action Category. These options interrupt exposure pathways through the use of physical barriers and decrease the mobility of the contaminants through the reduced leaching of contaminants from soil. The word "clay" is used for brevity in the terms "clay/soil cover" and "clay/soil cap" and does not preclude the use of other types of soil in the implementation of those alternatives so long as all remediation goals and criteria are met. Section 6.1 describes the clay/soil cover process option, and Section 6.2 describes a clay/soil cap. Section 6.3 presents the slurry wall process option, which is utilized for containing soils in ditches, and Section 6.4 describes the composite cap. Section 6.5 discusses the on-post hazardous and nonhazardous waste landfills and slurry wall. Section 6.6 presents the off-post landfill process option for structural debris, which includes both hazardous waste and solid waste landfills.

6.1 CLAY/SOIL COVER

A clay/soil cover allows potential agent-contaminated soils to remain on post as long as engineering controls provide a physical barrier, but is not intended to provide a low-permeability barrier to infiltration as does a clay/soil cap, which is described in Section 6.2. The clay/soil cover provides a barrier to protect human and biota receptors from directly contacting potential agent-contaminated soil. This process is applicable to soils within the Munitions Testing and Agent Storage Medium Groups. Implementation of a clay/soil cover requires the identification and removal of surface and subsurface UXO prior to installation of the cover to be protective of personnel and equipment.

6.1.1 Process Description

The clay/soil cover, 4 ft of clean, noncohesive borrow soil, provides protection to potential human and biota receptors because the exposure pathways are interrupted. The upper 6 inches of the 4-ft clay/soil layer consists of topsoil to support the development of a vegetative layer. The bottom 3-1/2 ft of noncohesive soils facilitate root development in plants. The clay/soil cover is only minimally compacted in order to facilitate the establishment of the vegetative cover

(i.e., to allow root penetration). The specific installation and design of the clay/soil cover is dependent on the properties and engineering characteristics of the soil used for the cover.

Prior to placing the soil cover, surface sweeps and geophysical surveys are conducted to ensure the safety of heavy equipment and personnel in near-surface soils with potential UXO presence. The surface sweep is conducted by personnel with expertise in UXO identification and hazard assessment. UXO personnel carefully inspect the site to ensure all areas of the site have been inspected for potential UXO presence at the surface. Following the surface sweep, a magnetometer survey is conducted to identify any near-surface UXO/debris. If UXO is found during the survey, standard clearance procedures are followed (see Section 9).

The cover will be slightly convex, with an upper slope of between 1.5 and 3 percent to reduce infiltration and erosion of the cover. Areas to be covered that have existing slopes within this range would not require additional fill for grading before the cover is installed, but areas with slopes less than 1.5 percent are graded and filled in order to achieve a grade of 1.5 percent. Prior to placing the cover, the subgrade is compacted in a rough grading operation to improve contact between the subgrade and the cover.

The vegetation used in the soil/vegetation layer must be capable of surviving at a sufficient density to minimize erosion of the cover with little or no maintenance. The vegetation used is locally adapted perennial grasses and low-growing plants that are resistant to drought and temperature extremes. The grasses and plants are selected to impede erosion as they allow surface runoff from major storm events and discourage burrowing animals from using the revegetated cover as a habitat.

Following the installation of the cover, site controls involving access controls and biota relocation are implemented to maintain the integrity of the cover. Therefore, the controls ensure that the cover limits potential exposure to humans and biota from UXO- and agent-contaminated soils. Institutional controls ensure that the cover is not disturbed or excavated, and any burrowing

animals are relocated to ensure the protection of burrowing animals from physical hazards below the cover. Maintenance activities ensure repair of any erosion damage, and the integrity of the cover is evaluated as part of the 5-year review.

Appendix A presents the action-specific ARARs governing the monitoring of a soil/clay cover over untreated materials. Information to-be-considered (TBCs) in the design of a clay/soil cap (Section 6.2) is also detailed in Appendix A. ARARs and TBCs regarding the design of the upper-most layers of a cap should be considered in the design of a cover, including promoting drainage and minimizing erosion.

Table 6.1-1 presents the costs for installing and monitoring a clay/soil cover. The installation of a clay/soil cover does not entail any capital costs. The operating costs for installing a cover are estimated to range from $9.14/SY to $9.50/SY based on the PPE requirements during installation. In some cases, an additional cost will be incurred to bring the existing grade of the cover to the 1.5 percent minimum grade. The operating costs include subgrade preparation, hauling the cover materials from a borrow area, placing the materials, and purchasing and placing topsoil. The cost of vegetating the topsoil is estimated at $0.18/SY. The long-term monitoring costs are estimated at $ 0.32/SY annually, including anticipated maintenance and reviews.

6.1.2 Process Performance

The clay/soil cover acts to cover agent-contaminated soils, thus preventing direct contact with human and biota receptors. Implementation requires the identification and removal of near-surface and subsurface UXO prior to installation to protect personnel and heavy equipment. Access restrictions, biota relocation, maintenance, and 5-year reviews ensure the integrity of the cover.

6.2 CLAY/SOIL CAP

A clay/soil cap both reduces the migration of hazardous substances into the surrounding environment by minimizing infiltration through the contaminated soil and reduces the possibility

of human and biota exposure by direct contact by isolating the contaminated media. Additionally, some hazardous organic contaminants may possibly naturally degrade to nonhazardous compounds during the life of the containment system. Clay/soil caps are used in containment or in conjunction with other treatment alternatives for most of the biota and human health exceedance subgroups. In many alternatives developed for the soils medium, the clay/soil cap is used either as the sole containment structure (Alternative 6) or in combination with a slurry wall (Alternative 5). The clay/soil cap is also applicable to the containment of structural debris.

6.2.1 Alternative Components

The clay/soil cap consists of three primary layers, the uppermost layer being essentially the same as the clay/soil cover described in Section 6.1.1. From top to bottom, the clay/soil cap consists of the following:

- A 4-ft-thick soil/vegetation layer of clean borrow material capable of supporting vegetation to minimize erosion and promote drainage
- A 1-ft-thick middle layer of cobbles to protect the underlying low-permeability soil layer from burrowing animals
- A 2-ft-thick bottom layer of compacted, low-permeability soil

The compacted soil layer must be located entirely below the maximum depth of frost penetration to prevent damage from freeze/thaw cycles. The maximum depth of frost penetration is approximately 42 inches in the Denver area. Therefore, the 4-ft-thick soil/vegetation layer plus the 1-ft-thick biota barrier is more than adequate to prevent damage to the compacted clay layer. Additionally, a 4-ft-thick soil/vegetation layer successfully accommodates root systems of the vegetated surface and attenuates rainfall infiltration to the underlying compacted soil layer.

To prevent ponding of rainwater due to irregularities in the top layer of the cap, it is constructed with a slope of 1.5 to 3 percent. Areas to be capped with existing slopes within this range do not require additional fill, but areas with existing slopes less than 1.5 percent are graded and

filled in order to achieve the desired crown and 1.5 percent slope. Compaction of the soil/vegetation layer is minimal to facilitate root development and allow sufficient infiltration to maintain root development through dry periods.

Figure 6.2-1 shows a detail of a clay/soil cap. As described in Section 6.1.1, the soil/vegetation layer consists of clean borrow material. This borrow material must be capable of sustaining plant species that minimize erosion. The borrow material available at RMA consists of fine- to medium-grained noncohesive soils that are capable of supporting native vegetation.

The vegetation used for the soil/vegetation layer, locally adapted perennial grasses and low-growing plants that are resistant to drought and temperature extremes, must be capable of surviving with little or no maintenance. In addition, the grasses and plants must impede erosion as they allow surface runoff from major storm events. The plant density should minimize top-layer erosion to no more than 2 tons per acre per year (0.011 inch per acre per year), which was calculated using the U.S. Department of Agriculture (USDA) Universal Soil Loss equation according to EPA guidance on caps and landfill covers (EPA 1989).

The 1-ft-thick biota barrier is comprised of a layer of large, tightly wedged cobbles to prevent the intrusion of burrowing animals into the lower layers of the cap. Gravel is used to fill any voids within the layer. Debris from demolished structures could be used for the biota barrier depending on the alternatives selected for structures. With time, soil from the overlying soil layer infiltrates and fills the voids even more tightly, although the effectiveness of either layer is not compromised. The grasses and low-growing plants used for cover have shallow root systems that do not fully penetrate the soil/vegetation layer.

The 2-ft-thick low-permeability soil layer provides long-term minimization of infiltration into the contaminated soil unit. This layer is constructed such that the hydraulic conductivity of the unit is no greater than 1×10^{-7} centimeters per second (cm/sec). The compacted clay layer is a minimum of 24 inches thick, as specified by the EPA for hazardous waste cap design (EPA

1989), and is based upon constructability considerations and the ability to provide a uniform overall permeability. The low-permeability soil layer should be installed as a series of 6-inch lifts to allow any localized inconsistencies in one lift to be "sealed" by another. The lifts should be compacted a few percent wet of the optimum moisture content to ensure that the lowest permeability is attained.

The specific design of the low-permeability soil layer is dependent on the properties and engineering characteristics of the clay being compacted. However, the preferred soil material has low to medium plasticity and a liquid limit of less than 50 percent by weight.

Appendix A presents the action-specific ARARs governing the monitoring of a clay/soil cap over untreated materials. These ARARs include several design considerations regarding promoting drainage and minimizing erosion.

Table 6.2-1 lists the costs for installation and monitoring a clay/soil cap. The installation of a clay/soil cap does not entail a capital cost. The operating costs for installing a clay/soil cap are estimated at $23.30/SY. Depending on site-specific conditions, an additional cost may be incurred to bring the existing grade of the cover to 1.5 percent. The operating costs include subgrade preparation hauling the cover materials from a borrow area, placing the soil and cobble layers, and purchasing and placing topsoil. The cost of vegetating the topsoil is estimated at $0.18/SY. The long-term monitoring costs are estimated at $0.80/SY annually, including anticipated maintenance and reviews. Several sites at RMA are currently contained with a clay/soil cap as part of an IRA. The costs for upgrading the caps at these sites, which consist of the Former Basin F, Section 36 Lime Basins, and Shell Trenches subgroups, are lower than the estimated costs in Table 6.2-1 by approximately $0.50/SY since the uppermost 2 ft of the existing clay/soil cover are stripped, stockpiled, and used in the modified cap/cover.

6.2.2 Factors Determining Alternative Performance

The clay/soil cap is implementable with standard equipment, and personnel with experience and knowledge of the process are available to perform the work. The containment system stems the migration of contaminants and isolates contaminated media, reducing the possibility of human and biota exposure. The process does not provide extensive reduction in TMV, although the toxicity and volume of contaminants in the soil decrease through natural attenuation/degradation. As with a soil cover, access restrictions, biota relocation, maintenance, and 5-year reviews ensure the integrity of the cover; however, the cobble barrier assists in preventing exposure to burrowing animals.

The major concerns regarding the effectiveness of a clay/soil cap are that the cap might not be installed as designed or that the low-permeability soil layer might not be uniform. To avoid this, quality assurance/quality control (QA/QC) during construction is essential. The installation of the clay/soil cap should be monitored to ensure that the layers are uniform and free from damage, the materials for each layer are as specified, and that each layer is constructed as specified.

6.3 SLURRY WALL

Slurry walls are vertical barriers that serve to impede the lateral flow of contaminated groundwater. The slurry wall mixture (backfill soil, bentonite, and water) is selected based on compatibility and optimization concerns. Slurry walls are included within Alternative 5 in conjunction with the installation of a clay/soil cap. This alternative is applicable to several human health exceedance medium groups including the Disposal Trenches and Sanitary Landfills Medium Groups. The slurry wall process is also applicable for pump-and-treat groundwater systems and the combination is already in use at the NBCS and NWBCS at RMA.

6.3.1 Process Description

The installation of a slurry wall entails the excavation of a trench with an excavator, extended-reach excavator, or a clamshell. The slurry of bentonite and water is pumped into the trench to prevent the walls of the trench from collapsing. The fill material—a soil and bentonite

mixture—is then placed into the slurry-filled trench. In general, the soils excavated from the trench are mixed with bentonite and used as slurry wall backfill. There are two groundwater flow impediment mechanisms in all slurry trench cut-off walls. The first is the impermeable layer formed within the trench by the soil and bentonite fill material. The second is the impermeable layer formed in the trench walls by the bentonite material permeating into the interstices of the soil on each side of the trench wall. Both processes serve to impede the lateral flow of groundwater, although which layer acts as the primary inhibitor of flow is under debate. Slurry walls may be installed around sites in conjunction with the placement of a clay/soil cap in order to form an isolation cell around the contaminated soil. Installation of a slurry wall prior to a soil/clay cap allows the compacted soil layer to be "keyed" into the top of the slurry wall (Figure 6.3-1).

Slurry walls are constructed to achieve a low permeability. In general, the average depth is estimated at 30 ft, although the required depth of the slurry wall varies across a site. The slurry wall is keyed into the Denver Formation at varying depths depending upon amount of fracturing within the formation, and the slurry wall width is generally 2 to 3 ft based on equipment used. The width and depth of the slurry wall may change based on the site-specific conditions encountered.

The slurry mixture consists of dry bentonite mixed with water to form a pumpable mixture. The ratio of bentonite to water as well as the specifications for the mixture of soils and bentonite for the fill material are based on laboratory-scale engineering and compatibility testing. In general, the soils used in the soil/bentonite backfill should be well graded with a large percentage of fine-grained materials. The selection criteria for the soil/bentonite mixture is based on the following:

- Low permeability
- Compatibility with contaminants
- Constructability, stability, and quality control
- Cost effectiveness

In order for a slurry wall to control groundwater migration, a groundwater removal system is generally installed in conjunction with the slurry wall. For example, if a slurry wall surrounds a given site, the hydraulic controls associated with a groundwater removal system maintain a negative pressure head to ensure that any groundwater movement runs from the outside of the slurry wall system to the inside. The extracted groundwater is transported to the nearest wastewater treatment facility for treatment. The groundwater removal system is designed based on site-specific conditions, and the extraction well system is designed to be flexible in meeting increased or decreased pumping demands. The location and pumping rates for the containment cell are selected based on modeling so that the required hydraulic gradient may be established and maintained.

The mixing of bentonite and water to form the slurry requires a mixing plant to adequately control and monitor the generation of the slurry, a storage pond or pit to store the slurry before it is pumped into the trench, and a covered storage area for the bentonite powder. The pond is necessary because the slurry must be mixed on a batch basis even though it is pumped into the excavated trench on a nearly continuous basis as the trench is excavated. A pug mill is also required to mix the soils with bentonite for use as slurry wall backfill.

Appendix A presents the action-specific ARARs governing the installation of a slurry wall around untreated materials. The ARARs primarily consist of regulations related to groundwater removal as part of hydraulic controls.

Table 6.3-1 lists the costs for installation of a slurry wall. The operating cost for installing a slurry wall is governed by the depth of the slurry wall, which in turn dictates the equipment to be used. The cost for installation of a 20- to 65-ft-deep slurry wall is $47.22/SY of the face of the slurry wall; in this case, an extended reach arm is required on the excavation equipment. For slurry walls less than 20 ft deep, the unit cost is approximately $33.41/SY, and the cost of slurry walls deeper than 65 ft is estimated to be $99.56/SY of the face of the slurry wall since a clamshell would be required for excavation and the wall would be wider than 3 ft. In addition,

the installation of a dewatering system and the annual long-term operation of the dewatering system are estimated on a subgroup-specific basis in accordance with Sections 5 and 14.

6.3.2 Process Performance

The slurry wall containment system is implementable with standard equipment and personnel with experience and knowledge of the process are available to perform the work. The containment system reduces the migration of contaminants and isolates contaminated media to reduce the possibility of human and biota exposure. The process does not provide reduction in toxicity and volume of contaminants.

As with the clay/soil cap, the major limitations of the effectiveness of a slurry wall are irregularities and defects in the wall that could lead to leakage. The installation of the slurry wall is closely monitored to ensure that it is installed to the design depth and that the materials used are as specified in the design.

6.4 COMPOSITE CAP

This section describes a composite cap which both reduces the migration of hazardous substances into the surrounding environment by minimizing infiltration through the contaminated soil and reduces the potential exposure of contamination to both humans and biota by direct contact. Additionally, some hazardous organic contaminants may possibly naturally degrade to nonhazardous compounds during the life of the composite cap. The composite cap alternative will be utilized in the Basin F Wastepile. Currently as part of the IRA the Basin F Wastepile has a clay/soil cover in place. This clay/soil cover will be removed and will be replaced with a composite cap meeting the Resource Conservation and Recovery Act (RCRA) requirements.

6.4.1 Alternative Components

The composite cap consists of seven layers, with the uppermost layer essentially the same as the soil/clay cover described in Section 6.1.1. From top to bottom, the composite cap consists of the following:

- A soil/vegetation layer consisting of clean borrow material capable of supporting vegetation to minimize erosion and promote drainage underlain by a geotextile

- A biota barrier layer made up of cobbles to protect the underlying layers from burrowing animal intrusion underlain by a geotextile

- A drainage layer consisting of a high permeability sand which is used to convey any infiltration to the collection pond to minimize the amount of leachate generated

- A geomembrane is placed between the drainage layer and the low permeability soil layer to reduce infiltration and leachate generation

- Low-Permeability Soil Layer to reduce infiltration and leachate generation, and to impede the flow of any infiltration from the overlying geomembrane

- A geonet gas-transmission layer placed on a geotextile is placed directly over the contaminated soil for gas collection

A detail of the composite cap is shown in Figure 6.4-1. The soil/vegetation layer of the composite cap will consist of clean borrow material capable of sustaining plant species to minimize erosion. The borrow material available near the wastepile consists of fine- to medium-grained, noncohesive soils. These materials are capable of supporting native vegetation.

The soil/vegetation layer is also required to prevent freezing and thawing from damaging the underlying low-permeability soil layer. The compacted low-permeability soil layer must be

located entirely below the maximum depth of frost penetration to prevent damage from freeze/thaw cycles. In the Denver area the maximum depth of frost penetration is approximately 42 inches. Therefore, the 4-ft soil/vegetation layer is adequate to prevent damage to the compacted low permeability soil layer.

The uppermost 2 ft of the existing clay/soil cover will be removed and stockpiled prior to augmenting the wastepile cap. These stockpiled materials will be incorporated into the soil/vegetative cover. To prevent ponding on the surface of the cap the cap will be constructed with a slope of 1.5 to 3 percent. Areas to be capped which have existing slopes within this range will not require additional fill. However, areas with existing slopes of less than 1.5 percent will be graded and filled in order to achieve the desired crown and 1.5 percent slope. Compaction of the soil/vegetation layer will be minimal to facilitate root development and allow sufficient infiltration to maintain root development through dry periods.

The vegetation types used on the soil/vegetation layer will be capable of surviving with little or no maintenance. The vegetation used will be locally-adapted perennial grasses and low growing plants which are resistant to drought and temperature extremes. The grasses and plants will be selected to impede erosion, but allow surface runoff from major storm events. The plant density should minimize top layer erosion to no more than 2 tons per acre per year (0.011 inch per acre per year) calculated using the USDA Universal Soil Loss equation according to EPA guidance on caps and landfill covers (EPA 1989).

A geotextile is placed between the protective soil layer and the biota barrier to minimize the intermixing of the soil with the cobbles. The grasses and low growing plants used for vegetation will have a shallow root system which will not fully penetrate the soil layer. Therefore the geotextile will not be impacted by the vegetation. A second geotextile will be placed between the biota barrier layer and the underlying drainage layer to prevent intermixing of the two layers.

The biota layer is provided as a barrier to burrowing animals. The biota barrier consists of a layer of cobbles which will prevent the intrusion of burrowing animals thus protecting the lower layers of the cap. The biota layer will be 12 inches thick and will consist of large, tightly packed cobbles with gravel filling the voids within the cobble layer. Debris from demolished structures could be used for the biota barrier depending on the alternatives selected for structures.

The drainage layer will consist of 12 inches of a high-permeability soil. The purpose of the drainage layer is to intercept water that percolates through the upper layers of the cap and transport the water out of the cover. The permeability of the drainage layer soils should have a minimum value of 10^{-2} cm/sec. The drainage layer will slope to an exit drain which will allow the water to be efficiently removed by gravity flow.

A 60-mil flexible membrane liner (FML), or geomembrane, is placed below the drainage layer to minimize infiltration. A low-permeability soil layer is directly below the FML. This layer provides long-term minimization of infiltration into the contaminated soil. The minimum acceptable level of hydraulic conductivity of the soil layer is no greater than 1×10^{-7} cm/sec. The low-permeability soil will be compacted and will be a minimum of 24 inches thick as specified by the EPA for hazardous waste cap design (EPA 1989). The thickness is based upon constructability considerations and the ability to provide a uniform overall permeability. The low permeability soil will be installed in 6 inch lifts to allow any localized inconsistencies in one lift to be "sealed" by another. To attain the lowest permeability of the soil layer, the lifts should be compacted a few percent wet of the optimum moisture content of the soil

The specific design of the low-permeability soil layer will be dependent on the properties and engineering characteristics of the soil being compacted. However, the preferred soil material will have low to medium plasticity and a liquid limit of less than 50.

A geonet placed overtop of a geotextile is placed directly above the contaminated soil to act as a gas collection system. Gas is produced due to chemical reactions and the decomposition of

organic wastes. The gas produced must be vented out of the cap. The gas will collect in the gas collection pipes located within the cap. These pipes will connect into header pipes which will be vented to the atmosphere after passing through a treatment system to remove organic vapors.

The action-specific ARARs governing the monitoring of a composite cap over untreated materials are presented in Appendix A. These ARARs include several design considerations regarding promoting drainage and minimizing erosion.

The costs for installing and monitoring a composite cap are presented in Table 6.4-1. The top 2 ft of the existing IRA cap at the Basin F Wastepile will be removed prior to placement of the composite cap. The top six inches of soil removed will be stockpiled and used as topsoil for the composite cap with the remaining 1.5 ft of soil being stockpiled and used for soil cover. After removal of the existing cap some areas of the Basin F Wastepile will need to backfilled to bring the existing grade of the cap to 1.5 percent. Therefore, additional costs due to removal of the existing cap and grading operations may be incurred. The operating costs for installing a composite cap are estimated at $36.04/SY. The operating costs include hauling the additional 2 ft of cover materials from a borrow area; placing the soil, cobble and geosynthetic layers; and placing the stockpiled topsoil. The long-term monitoring costs are estimated at $1.23/SY per year including anticipated erosion damage, maintenance and reviews.

6.4.2 Factors Determining Alternative Performance

The composite cap is implementable with standard equipment, and personnel are available with experience and knowledge of the process. The composite cap isolates the contaminated material from possible human and biota exposure and it also reduces the migration of contaminants. The process does not provide extensive reduction in toxicity and volume of contaminants. However, natural degradation/attenuation will reduce the toxicity and volume of contaminants in the soil. Access restrictions, biota relocation, maintenance, and 5-year reviews will be implemented to ensure the integrity of the cap. The cobble barrier will assist in preventing exposure of burrowing animals.

The effectiveness of the composite cap is contingent upon proper installation procedures being implemented. Uniform compaction of the low permeability soil is necessary to attain a low hydraulic conductivity. To avoid any installation anomalies QA/QC during construction is essential. Installation of the composite cap should be monitored to ensure that the layers are uniform and damage free, the materials for each layer are as specified and that each layer is constructed as specified.

6.5 ON-POST LANDFILL

Under alternatives selected for the soils and structures media, an on-post landfill is used for disposal of contaminated soils/debris. The on-post landfill may consist of several cells depending on the amount of contaminated materials to be disposed. The construction of individual cells may also differ depending on the waste classification of the materials, which is determined by the contaminant concentrations and the leachability of the contaminants.

Landfill cells may be constructed and thus classified based on their cover and liner systems and the types of wastes that are to be disposed in them. Depending on the concentrations and leachability of contaminants, contaminated soil may be placed in either a hazardous waste landfill cell, which is constructed according to RCRA requirements, or in a solid waste landfill cell. An on-post landfill would likely contain both hazardous waste cells and solid waste cells, but the hazardous waste and solid waste cells would be separated from each other within the facility.

Appendix A presents the action-specific ARARs governing the siting, design, and performance of both a hazardous waste and a solid waste landfill. The ARARs governing the hazardous waste landfill are more stringent; therefore, a landfill facility containing both hazardous waste and nonhazardous waste landfill cells is sited on the basis of the hazardous waste landfill ARARs.

The on-post hazardous and on-post nonhazardous waste landfill process options are used primarily for the disposal of untreated soils and debris, but may also be used for the disposal of treated debris and soil/debris mixtures. Alternatives utilizing these processes were retained in

the DSA for the soils medium groups within the biota and human health exceedance categories and for the No Future Use, Manufacturing History and No Future Use, Agent History Medium Groups within the structure medium. In addition, oversize materials removed during materials handling activities for soils and structures direct treatment alternatives require placement in an on-post landfill.

In order to estimate the size of the on-post landfill, the largest potential volumes of material to be placed in the landfill for each medium group were considered. For most soils medium subgroups, the maximum volume of material to be landfilled is the volume of untreated soil under Alternatives 3 and B3. The maximum potential volumes of structural debris and soils to be placed in the on-post landfill is approximately 6.0 million CY.

The following sections discuss the on-post hazardous waste cells and on-post nonhazardous (solid waste) cells separately due to the differences in the siting and performance requirements, although the on-post landfill contains both types of cells. Figure 6.5-1 provides the general location for a centralized landfill based on locating a hazardous waste landfill. Section 6.5.1 describes the components and performance of a hazardous waste landfill cell, and Section 6.5.2 describes the same for a solid waste landfill. Section 6.5.3 describes the construction of the overall on-post landfill facility.

6.5.1 On-Post Hazardous Waste Landfill

A RCRA hazardous waste landfill cell is constructed using at least two synthetic liners and two low-permeability soil liners. This system also contains leachate collection and leak detection systems. The cover system for the hazardous waste landfill cell is constructed with a synthetic and low-permeability soil barrier, an infiltration drainage system, a gas collection system, and a topsoil and soil cover layer.

6.5.1.1 Process Description

This section provides more detailed information on the major system components of an on-post hazardous waste landfill. A hazardous waste cell is constructed according to RCRA requirements. The components of the hazardous waste landfill cell (Figure 6.5-2) include the following major components:

- Cover system, including a gas collection system
- Liner system, including both a leachate detection and collection/removal system

Cover System

The cover system acts as an impermeable cap above the waste to isolate the contaminated material from the surface environment. The cover is designed to accommodate any settlement or subsidence within or below the cell. This is achieved by employing flexible materials to construct the cover and by controlling waste placement to achieve adequate compaction to minimize differential settlement.

The cover consists of several individual layers (Figure 6.5-3). These layers include the following (listed from top to bottom):

- Soil/vegetation layer of common soil and topsoil
- Biota barrier layer
- Drainage layer
- Composite low-permeability layer of a geomembrane and low-permeability soil layers
- Gas collection and transmission layer

The soil/vegetation layer is capable of sustaining plant life. The vegetation (shallow-rooted plants) is capable of surviving and functioning with little or no maintenance. The types of vegetation are locally adapted perennial grasses and plants selected to impede erosion as they allow surface runoff from major storm events.

Clean fill material available at RMA or locally (off post) is used for the vegetation/upper soil layer. Topsoil is obtained off post to provide an upper 6-inch layer for plant growth. The remaining 18 inches of borrow material consists of medium-grained soil that is capable of supporting native vegetation. Since the maximum depth of frost penetration in the Denver Area is approximately 42 inches, the 4-ft-thick soil/vegetation layer is more than adequate to prevent freeze/thaw damage to the low-permeability soil layer of the cap. The 4-ft thickness of the upper layer accommodates vegetation root systems and attenuates infiltration of rainfall to the low-permeability soil layer. As discussed in Section 6.1, the upper slopes of the cover should be sloped from 1.5 to 3 percent. The slope of the landfill cover prevents ponding of rainwater due to irregularities in the upper soil layer, and compaction of the soil/vegetation layer is minimal to facilitate plant growth.

The biota barrier is composed of a layer of cobbles to prevent the intrusion of burrowing animals into the lower layers of the cap and to prohibit the penetration of deep-rooted plants. The barrier is 12 inches thick and consists of large, tightly packed cobbles. The cobble layer is overlain and underlain by a geosynthetic filter to prevent movement of soil into the biota layer or cobbles into the drainage layer.

The drainage layer intercepts water that percolates through the upper layers of the cap and transports the water out of the cover. A 12-inch drainage layer is typically used to allow sufficient cross-sectional area for transport of water. The permeability of the drainage layer soils should have a minimum value of 10^{-2} cm/sec. The drainage layer slopes to an exit drain, allowing the water to be efficiently removed by gravity flow.

The composite low-permeability layer provides long-term minimization of surface water infiltration into the landfill cell. This layer is composed of an FML and a low-permeability soil layer. According to EPA guidance on covers (EPA 1989), FMLs should be more than 20 mils (0.020 inch) thick. The FMLs to be used in the on-post landfill are 60 mil thick and are placed in direct contact with the underlying low-permeability soil layer. The low-permeability soil layer

tends to impede the flow of any leakage through an imperfection in the upper FML. Thus, each component tends to back the other in the event that either one fails. The low-permeability soil layer is constructed with a permeability of less than 1×10^{-7} cm/sec and is a minimum of 24 inches thick as specified by the EPA for hazardous waste cover design (EPA 1989). This thickness is based upon constructability considerations and the ability to provide a uniform overall permeability. The specific design of the low-permeability soil layer is dependent on the properties and engineering characteristics of the clay being compacted.

The gas collection system provides control of gases released from wastes buried in the landfill cell. Any gas produced must be vented to avoid a buildup of internal pressure that can damage the integrity of the cell. Accordingly, the gas vent layer has a gas collection and venting system constructed of high-density polyethylene (HDPE) geonet or granular fill and perforated HDPE pipe surrounded by a filter fabric blanket (Figure 6.5-3). Gas collection pipes run the length of the cell and are connected to a header pipe located on the high end of the cell (Figure 6.5-2). The collected gases are vented to the atmosphere after passing through a treatment system to remove organic vapors. The treatment system may include direct venting to the atmosphere, carbon adsorption, catalytic oxidation, or incineration. The spacing of the collection pipes and the treatment system design is based on the estimated amount of gas to be vented.

Controlling hazardous gas formation may be accomplished through waste control, whereby waste-to-waste incompatibilities are eliminated and uncontrolled decomposition is minimized. Proper waste control prevents commingling of incompatible wastes that can generate hazardous gases.

Liner System

The cell liner system consists of a double composite liner system that isolates the contaminated soil and leachate from the underlying subsurface environment (Figure 6.5-4). The layers of the composite liner typically consist of two synthetic FMLs and two low-permeability soil liners. The synthetic liners must be chemically compatible with the waste contaminants and any leachate generated. Commonly used geomembrane materials include HDPE, chlorinated polyethylene

(CPE), chlorosulfonated polyethylene (CSPE) and PVC. The low-permeability soil liner is commonly constructed of natural soils amended with bentonite or other admixtures. The soil liners are constructed such that the permeability of the liner is less than 1 x 10^{-7} cm/sec. The 3-ft thickness of each soil liner is sufficient to maintain low permeability and provide a stable base for the landfill cell.

The leachate collection and leak detection system is an integral part of the liner system (Figure 6.5-4). Preventing the accumulation of free water within the waste cell is achieved by designing the cover so that surface water runoff is effectively managed and by controlling the water content of the waste as it is placed within the cells. As necessary, the free water in the waste is absorbed with a solidification agent prior to disposal.

The leachate collection and removal system is located inside the landfill cell directly above the primary liner. The system includes either granular material or geonet, geotextiles, and perforated collection pipes placed on approximate 50-ft centers that run the length of the landfill cell. The collection pipes are sloped a minimum of a 1.5 percent to allow gravity flow of the leachate to a series of sumps. The leachate collected in the sumps is removed and transported to an on-post wastewater treatment facility for treatment. A leak detection layer is located below the primary (upper) composite liner to ensure that leachate does not migrate below the secondary (lower) composite liner.

Table 6.5-1 presents an itemization of the capital costs and operating costs for a hazardous waste landfill cell and for the overall landfill facility. The cost of constructing the associated facilities for a 6-million-CY landfill with 4 cells is $14.0 million, which results in a cost of $2.33/CY. The estimated cost to construct the liner for each 1.5-million-CY hazardous waste landfill cell is $5.1 million and the capital costs of closing the cell and installing the cover is $5.7 million for each cell. Therefore, the total capital cost for a 7.5-million-CY on-post hazardous waste landfill is $57 million or $9.52/CY. The cost of placing contaminated soil in the cell once the soil has been transported to the landfill is $4.07/CY, and the annual long-term monitoring cost

is $0.13/CY. The unit cost for placing structural debris in the landfill would be higher than the cost listed for soils.

6.5.1.2 Process Performance

The performance of landfill cells is dependent on their physical properties. The objective of the cell is to provide containment and prevent contaminant migration. To provide waste containment, the waste cell separates the waste from the environment and reduces the possibility of human and biota exposure. To prevent contaminant migration, the waste cell totally encapsulates the waste and provides a means to control leachate and gas generated, and to confirm the performance of the cell, a site monitoring program is developed, scheduled, and implemented. A hazardous waste landfill could be constructed and operated at RMA in accordance with the action-specific ARARs listed in Appendix A.

The major concern regarding the effectiveness of both the landfill liner and cap is that the layers might not be installed as designed or that the layer might not be uniform. Therefore, QA/QC during construction is essential. The installation of the liner and cap layers should be monitored to ensure that the layers are uniform and free from damage, the materials for each layer are as specified, and that each layer is constructed as specified.

6.5.2 Solid Waste Landfill Cell

The solid waste landfill cell is constructed similarly to the RCRA cell (but under less stringent requirements because the materials being disposed are less toxic or less mobile) and is classified as nonhazardous (i.e., non-RCRA characteristic or non-listed RCRA wastes). A solid waste or nonhazardous waste landfill cell includes a bottom composite liner and a cover with a low-permeability soil layer.

6.5.2.1 Process Description

The bottom liner system for the solid waste cell consists of a composite liner (Figure 6.5-5). The layers of the composite liner consist of a single FML and a low-permeability soil liner. The

FML must be chemically compatible with the soil contaminants and any leachate generated. Commonly used FMLs for solid waste are the same as those used in the construction of RCRA cells (HDPE, CPE, CSPE, and PVC). The low-permeability soil liner for the solid waste cell is constructed such that the overall permeability throughout the liner is less than 10^{-7} cm/sec. The thickness of the low-permeability soil liner is a minimum of 2 ft in order to maintain uniform overall low permeability and to provide a stable base for the landfill cell.

The cover system consists of several layers that isolates the wastes from the surface environment (Figure 6.5-6). It consists of the following layers (listed from top to bottom):

- Soil/vegetation cover layer
- Biota barrier layer
- Drainage layer
- Low-permeability soil layer
- Gas collection, transmission, and venting system

The soil/vegetation layer is constructed to the same specifications as listed for the RCRA cell. The vegetation consists of shallow-rooted plants that minimize erosion and that are capable of surviving and functioning with little or no maintenance. The types of vegetation used are locally adapted perennial grasses and plants selected to impede erosion as they allow surface runoff from a major storm event.

Similarly to the RCRA cell, clean borrow material available at RMA and topsoil available locally (off post) are used to construct the soil cover layer. The 4-ft-thick cover layer, in conjunction with the biota barrier, provides sufficient protection of the low-permeability soil layer against freeze/thaw stresses.

The biota barrier consists of 12 inches of large, tightly packed cobbles to prevent the intrusion of burrowing animals into the lower layers of the cap, and the drainage layer consists of a 12-inch layer of soils with a minimum permeability of 10^{-2} cm/sec. This drainage layer intercepts

any water that percolates through the upper layers of the cap and transports the water to an exit drain by gravity flow. The low-permeability layer, which minimizes surface water percolation into the landfill cell, is a minimum of 24 inches thick and is constructed to achieve a maximum permeability of 1 x 10^{-7} cm/sec. Geotextiles are used to prevent migration of materials between layers as discussed for the hazardous waste landfill cell. The gas collection system utilized to control gases generated from burned waste is installed as discussed for the hazardous waste landfill.

Table 6.5-2 presents an itemization of the capital costs and operating costs for a solid waste landfill cell and for the overall landfill facility. The cost of constructing the associated facilities for a 6.0-million-CY landfill with four cells is $14 million, which results in a cost per cubic yard of $2.33/CY. The estimated cost to construct the liner for each 1.5-million-CY solid waste landfill cell is $2.7 million, and the capital costs for closing each cell and installing the cover is $5.7 million. Therefore, the total capital cost for a 6.0 million CY on-post nonhazardous waste landfill is $23 million or $8.02/CY. The cost of placing soil in the cell once the soil has been transported to the landfill is $4.07/CY, and the annual long-term monitoring cost is $0.13/CY. The unit cost for placing structural debris in the landfill is higher than the cost listed for soils.

6.5.2.2 Process Performance

The performance of the landfill cells is dependent on their physical properties. The objective of the cell is to provide containment, and prevent contaminant migration. To provide waste containment, the waste cell separates the waste from the environment and reduces the possibility of human and biota exposure. To prevent contaminant migration, the waste cell totally encapsulates the waste and provides a means to control leachate and gas generated, and to confirm the performance of the cell, a site monitoring program is developed, scheduled, and implemented. A solid waste landfill could be constructed at RMA in accordance with the action-specific ARARs outlined in Appendix A.

The major concern regarding the effectiveness of both the landfill liner and cap is that the layers might not be installed as designed or that the layer might not be uniform. Therefore, QA/QC during construction is essential. The installation of the liner and cap layers should be monitored to ensure that the layers are uniform and free from damage and the materials for each layer are as specified.

6.5.3 Construction of On-Post Landfill Facility

The Task 27 Landfill Study (EBASCO 1988/RIC#89026R01) evaluated the construction of eleven cells for a total volume of 16 million-CY (Figure 6.5-8). As discussed above, the largest volumes of material potentially to be placed in the landfill for each medium group were considered in order to determine the sizing requirements of a landfill. The maximum volume of structural debris and soils that might be placed in the on-post landfill is approximately 6.0-million-CY. Therefore, the first four cells evaluated in the Task 27 Landfill Study are to be constructed as shown in Figure 6.5-7.

The maximum volume used to determine the number of cells is a "worst-case" estimate of materials to be placed in the landfill. The actual volumes placed in the landfill will be based on the preferred alternatives selected, and the required number of cells may be reduced. The previous descriptions presented the differences between solid waste and hazardous waste landfills, but most contaminated materials will probably be placed in hazardous waste landfill cells due to the slightly higher cost but superior performance of a hazardous waste landfill cell. However, most contaminated soils and debris to be placed in the landfill are not considered RCRA hazardous waste, and the materials could be placed in a solid waste landfill cell.

6.6 OFF-POST LANDFILL

The process of disposing materials at an off-post landfill consists of transporting the materials to a commercial landfill. Landfilling hazardous or nonhazardous materials at a commercial facility is becoming increasingly more difficult due to restrictions on landfilling certain chemicals, restrictions on transportation of hazardous wastes (particularly across state lines), and

the high costs charged by commercial disposal facilities to accept wastes. Based on the DSA screening process, off-post landfilling was retained for the disposal of structural debris only.

6.6.1 Process Description

Under alternatives evaluated for the structures medium, the structural debris from building demolition at RMA is transferred via a loading facility into rail cars or trucks and shipped to an off-post disposal facility. The loading facility is sized to allow for an 8-hour storage capacity of debris. Trucks haul the debris from on-post locations to the central loading facility, which is collocated with the debris shredding facility. The trucks empty their loads into the shredding mill, and loaders move the shredded debris to a conveyor where it is transferred into rail cars or trucks for transport to an off-post facility. The debris is then landfilled at the contracted off-post facility after meeting all required RCRA disposal requirements.

Depending on the chosen off-post landfill facility and transportation option, pre-treatment of the debris may be required. The debris is sized to aid in the loading of either rail cars or trucks. If the debris is hauled by truck, the debris should be sized to allow for unattended unloading. Since debris is hauled to an off-post landfill facility, post-treatment of the debris is not necessary and no sidestreams are generated.

Appendix A lists the action-specific ARARs governing the use of a loading/unloading facility. These action-specific ARARs primarily address air emissions and worker protection during operation. Separate descriptions are presented for off-post hazardous waste and off-post solid (nonhazardous) waste landfills due to the differences in waste acceptance criteria and costs.

6.6.1.1 Hazardous Waste Landfill

Four RCRA hazardous waste disposal facilities are presented below as examples. One of the facilities is located in Colorado, and was used to develop unit costs for disposal of structural debris. The other three are within the Rocky Mountain Region.

- Highway 36 Land Development Company (Highway 36) - The Highway 36 facility is located in Last Chance, Colorado, approximately 70 miles east of RMA. It has a total permitted capacity of 2.5 million CY. Disposal costs for hazardous debris is $76/CY.

- U.S. Pollution Control, Inc. (USPCI) – USPCI is located in Lakepoint, Utah, approximately 600 miles from RMA. The facility has a RCRA Part B permit and has a substantial landfill capacity. Disposal costs for hazardous debris are $128/CY.

- Envirosafe Services of Idaho, Inc. (Envirosafe) – The Envirosafe facility is located in Boise, Idaho, approximately 800 miles from RMA. The facility has a RCRA Part B permit and has a land disposal capacity of 2.7 million CY. Disposal costs for hazardous debris are $125/CY.

- U.S. Ecology, Inc. (Ecology) – The Ecology facility is located in Beatty, Nevada, approximately 900 miles from RMA. The facility has a RCRA Part B permit and has a land disposal capacity of 1.5 million CY. Disposal costs for hazardous debris are $72/CY.

The capital and operating costs for off-post landfilling of hazardous structural debris are developed from vendor quotations. The capital cost for the central loading terminal is estimated to be $0.24/CY with operating costs of $0.41/CY. Off-post disposal costs and transportation costs at the Highway 36 facility are $76/CY and $0.19/CY per loaded mile for hazardous debris.

6.6.1.2 Nonhazardous Waste Landfill

Currently, four nonhazardous landfills located near RMA are capable of receiving structural debris. A brief description of these landfills includes the following:

- Browning Ferris Industries (BFI) - BFI has a landfill at 88th Avenue and Tower Road in Commerce City, 10 miles from RMA. The landfill has a current capacity of 475 acres. Disposal cost for nonhazardous construction debris is $4.50/CY.

- Denver Arapahoe Disposal Service, Inc. (DADS) – The DADS landfill is located approximately 20 miles east of RMA. The landfill has a current capacity of 200 acres and has been permitted to expand up to 2,680 acres. Disposal cost for nonhazardous construction debris is $4.70/CY.

- Central Weld County Landfill – The Central Weld County Landfill is located near Greeley, Colorado, approximately 50 miles from RMA. The landfill has a current capacity of 1.5 million CY.

- Conservation Services, Inc. (CSI) – The CSI landfill is located approximately 10 miles from RMA. The landfill has a current capacity of 3 million CY.

In addition to these landfills, the hazardous waste landfills identified in Section 6.6.1.1 accept nonhazardous waste.

Cost

The capital and operating costs for off-post landfilling of nonhazardous structural debris are developed from vendor quotations. The current capital cost for the loading facility is estimated to be $0.24/CY, with operating costs of $0.41/CY. Off-post disposal costs and transportation costs at the BFI facility are $4.50/CY and $0.13/CY per loaded mile for nonhazardous debris.

6.6.2 Process Performance

Off-post landfilling is an effective method for disposal of structural debris providing the debris meets the disposal requirements of the contracted landfill.

Results using RMA structural debris have not been developed to date, although a pilot-scale structural treatment and demolition study is currently ongoing. The contaminated structures may go through a chosen treatment process in order to release the structures from Army jurisdiction.

There are three limitations to the off-post landfill disposal option: restrictions on landfilling certain contaminants; restrictions on transportation of hazardous waste, as described in Section 4; and high transportation and disposal costs charged by commercial disposal facilities to accept wastes.

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EPA (U.S. Environmental Protection Agency). 1989. Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundment EPA1530-SW-89-047.

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Table 6.1-1 Determination of Capital and Operating Costs for Clay/Soil Cover

Cost Category	Cost Item	Cost Estimate	Description
Operating Costs	Preparation of Subgrade	$0.06/SY	Source: 1
	Installation of Soil Backfill	$5.90/SY	Source: 1 Based on $5.06/CY and thickness of 3.5 ft with Level D PPE
	Installation of Topsoil	$3.24/SY	Source: 1 Based on purchase of topsoil and installation; $19.44/CY and thickness of 0.5 ft
	Cover Subtotal	$9.14/SY	
	Revegetation	$0.18/SY	Source: 1
Long-Term Operating Costs	Cover Maintenance	$0.38/SY annually	Source: 1 Costs for annual replacement of any eroded soil and annual inspection of cover

Sources:

1) Means Heavy Construction Cost Data, 1993, 7th Annual Edition.

CY Cubic Yards
SY Square Yards
ft Feet or foot

Table 6.2-1 Determination of Capital and Operating Costs for Clay/Soil Cap

Cost Category	Cost Item	Cost Estimate	Description
Operating Costs	Preparation of Subgrade	$0.06/SY	Source: 1
	Installation of Low-Permeability Soil Layer	$4.52/SY	Source: 1 Based on $7.67/CY and thickness of 2 ft with Level C PPE for installation of base courses
	Installation of Biota Barrier	$9.64/SY	Source: 1 Based on $28.91/CY and thickness of 1.0 ft
	Installation of Soil Backfill	$5.90/SY	Source: 1 Based on $5.06/CY and thickness of 3.5 ft
	Installation of Topsoil	$3.24/SY	Source: 1 Based on purchase of topsoil and installation; $19.44/CY and thickness of 0.5 ft
	Cap Subtotal	$23.30/SY	
	Revegetation	$0.18/SY	Source: 1
Long-Term Operating Costs	Cover Maintenance	$0.80/SY annually	Source: 1 Costs for annual replacement of any eroded soil, and annual inspection of cover

Sources:

1) Means Heavy Construction Cost Data, 1993, 7th Annual Edition.

CY Cubic Yards
SY Square Yards
ft Feet or foot

Table 6.3-1 Determination of Capital and Operating Costs for Slurry Wall

Cost Category	Cost Item	Cost Estimate	Description
Operating Cost	Excavation and Installation of Slurry Wall	$47.22/SY (slurry wall face)	Source: 1 Based on 3 ft width, depth between 20 and 75 ft, and soil/bentonite slurry mixture
	Dewatering System	Variable	Installation of 8 dewatering systems based on hydraulic controls in Section 5.
Long-Term Operating Costs	Maintenance Operations/Dewatering	Variable	Operations of dewatering systems based on hydraulic controls in Section 5 and water treatment costs in Section 14.

Sources:

1) Vendor Quotes for Slurry Wall Installation.

LS Lump Sum
SY Square Yards

Table 6.4-1 Determination of Capital and Operating Costs for Composite Cap

Cost Category	Cost Item	Cost Estimate	Description
Operating Costs	Preparation of Subgrade	$0.06/SY	Source: 1
	Installation of Geotextile	$1.40/SY	Source: 1 Based on $.16/SF
	Installation of Geonet	$1.71/SY	Source: 1 Based on $.19/SF
	Installation of Low-Permeability Soil Layer	$5.11/SY	Source: 1 Based on $7.67/CY and thickness of 2 ft.
	Installation of Geomembrane	$3.29/SY	Source: 1 Based on $.37/SF for 60 mil geomembrane
	Installation of Sand	$4.06/SY	Source: 1 Based on $12.19/CY thickness of 1 ft.
	Installation of Biota Barrier	$9.64/SY	Source: 1 Based on $28.91/CY and thickness of 1.0 ft.
	Installation of Geotextile	$1.40/SY	Source: 1 Based on $.16/SF
	Installation of Soil Backfill	$3.37/SY	Source: 1 Based on $5.06/CY and thickness of 2.0 ft.
	Removal, Stockpile, Installation of Existing Cover	$4.66/SY	Source: 1 Based on removal of uppermost 2 ft of soil cover, stockpilling during cap installation and placement; $14.08/CY and thickness of 0.5 ft.
	Cap Subtotal	$36.04/SY	
	Revegetation	$0.17/SY	Source: 1
Long-term Operating Costs	Cover Maintenance	$1.23/SY annual	Source: 1 Costs for annual replacement of any eroded soil and annual inspection of cover

Sources:

1) Means Heavy Construction Cost Data, 1993, 7th Annual Edition.

CY Cubic Yards
ft Feet or Foot
SF Square Foot
SY Square Yard

Table 6.5-1 Determination of Capital and Operating Costs for Hazardous Waste Landfill

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost for On-Post Landfill Facility	Site Preparation and Support Buildings and Facilities	$14,000,000 LS	Source: 1 Based on earthwork and support facilities for cells each containing 1.5 million CY sized from facility with 11 cells.
Capital Cost for Hazardous Liner	Hazardous Waste Liner	$20,000,000 LS	Source: 2 Based on 4 cells at $5,100,000 per cell with leachate collection and detection, 2 geomembranes, and low-permeability soil layers.
Capital Cost for Cover	Hazardous Waste Cover	$23,000,000 LS	Source: 2 Based on 4 cells at $5,700,000 per cell with low-permeability soil, drainage, geomembrane, biota barrier, and cover soil layers.
	Subtotal Capital Costs	$57,000,000 LS	Based on 4 cells each sized for 1.5 million CY.
Operating Costs	Placement of Materials	$4.07/CY	Source: 2 Based on transportation, sampling, placement of daily soil covers and required dust controls for 5-year build out.
Long-Term O&M for Facility	Post-Closure Monitoring and Maintenance	$0.13/CY annually	Source: 2 Based on annual monitoring and maintenance for facility.

Sources:

1) Hazardous Waste Land Disposal Facility Assessment, EBASCO 1988/RIC#89026R01.
2) Means Heavy Construction Cost Data, 1993, 7th Annual Edition.

CY Cubic Yards
LS Lump Sum

Table 6.5-2 Determination of Capital and Operating Costs for Solid Waste Landfill

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost for On-Post Landfill Facility	Site Preparation and Support Buildings and Facilities	$14,000,000 LS	Source: 1 Based on earthwork and support facilities for 4 cells each containing 1.5 million CY sized from facility with 11 cells.
Capital Cost for Cell Liner	Solid Waste Liner	$11,000,000 LS	Source: 1 Based on 4 cells at $2.7 million per cell with leachate collection, geomembrane and low-permeability soil layers.
Capital Cost for Cell Cover	Solid Waste Cover	$22,000,000 LS	Source: 2 Based on 4 cells at $5.6 million per cell with low-permeability soil, drainage, biota barrier and cover soil layers.
	Subtotal Capital Costs	$48,000,000	Based on 4 cells each sized for 1.5 million CY.
Operating Costs	Placement of Materials	$4.07/CY	Source: 2 Based on transportation, sampling, placement of daily soil covers, and required dust controls for 5-year build out.
Long-Term O&M for Facility	Post-Closure Monitoring and Maintenance	$0.13/CY annually	Source: 2 Based on annual monitoring and maintenance for facility.

Sources:

1) Hazardous Waste Land Disposal Facility Assessment, EBASCO 1988/RIC#89026R01.
2) Means Heavy Construction Cost Data, 1993, 7th Annual Edition.

CY Cubic Yards
LS Lump Sum

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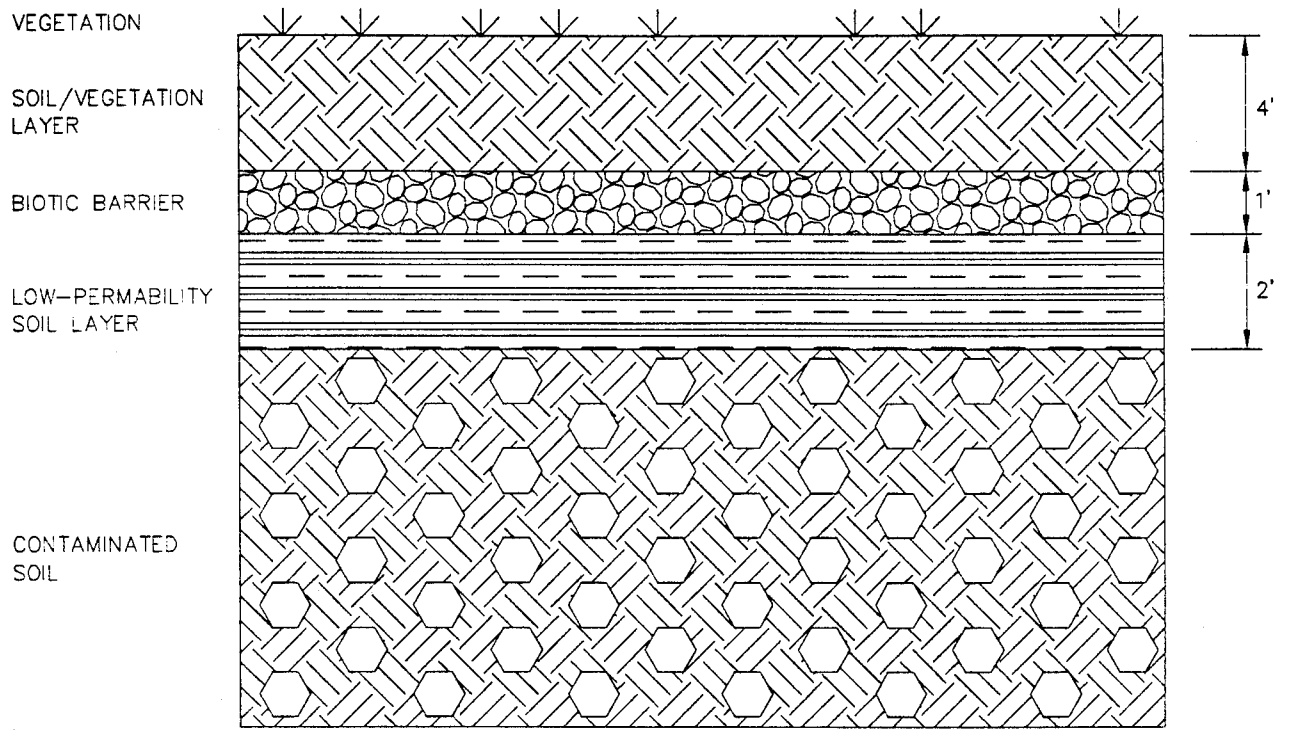

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Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared November 1992

Figure 6.2-1

Clay/Soil Cap Detail

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

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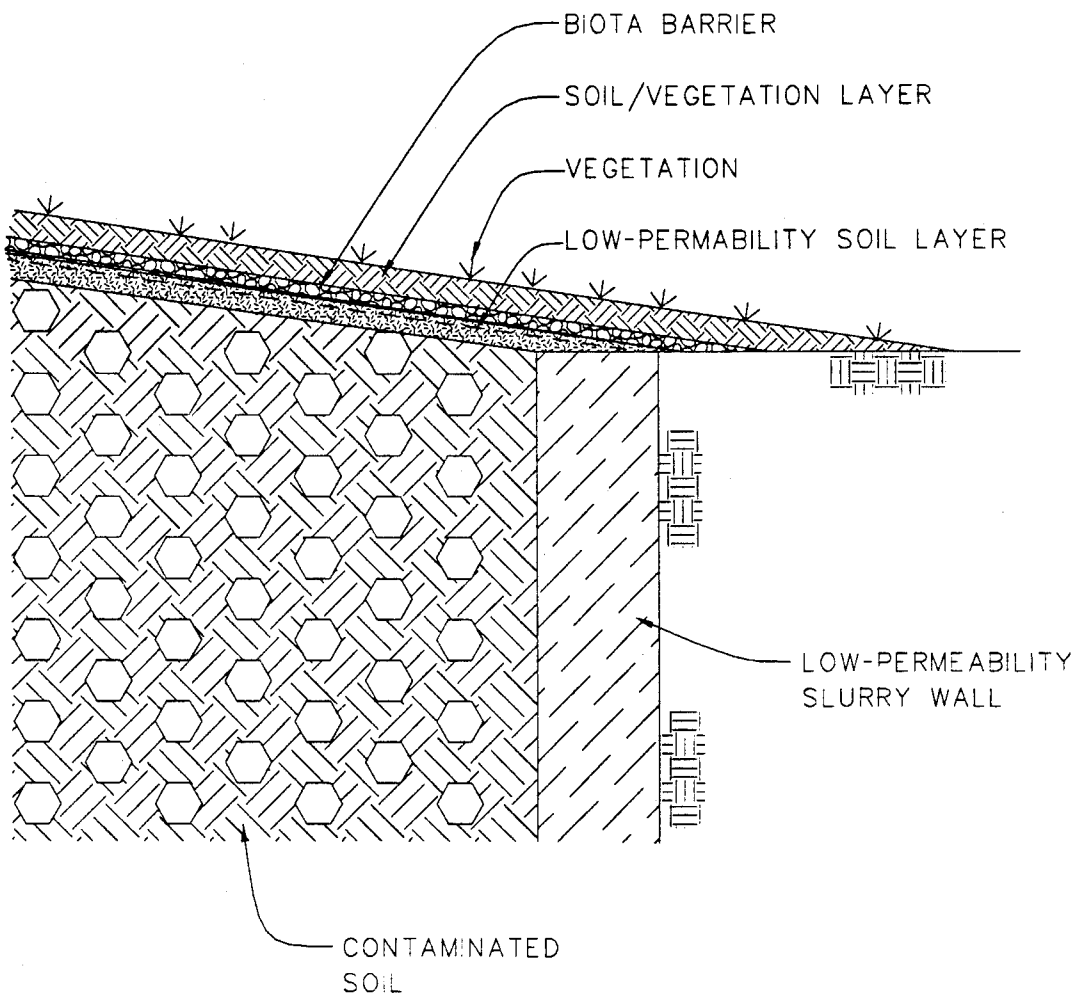

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U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared November 1992

Figure 6.3-1

Clay/Soil cap and Slurry
Wall Edge Configuration Detail

Rocky Mountain Arsenal
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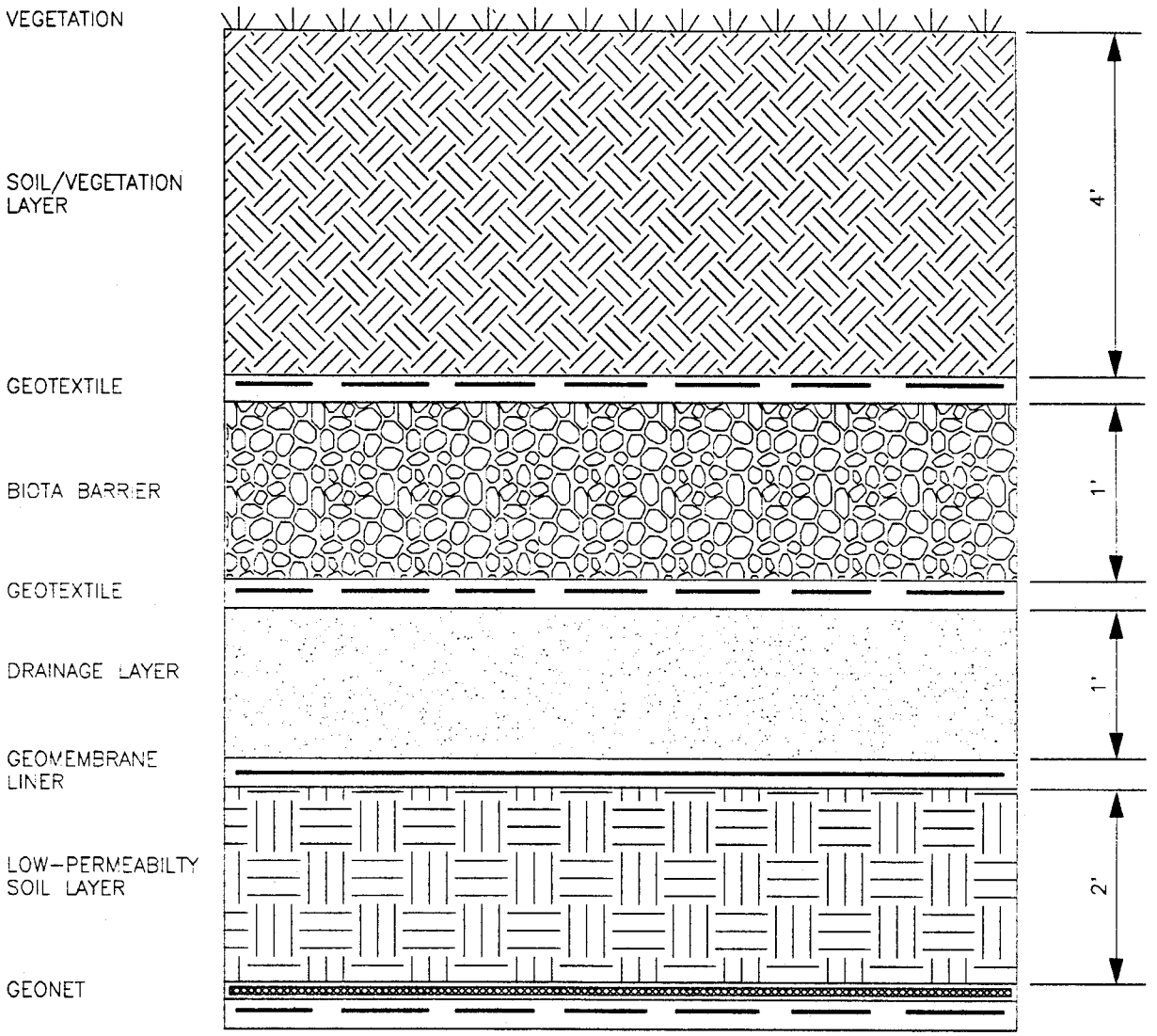

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Prepared July 1992

Figure 6.4-1

Composite Cap Detail

Rocky Mountain Arsenal.
Prepared by: Ebasco Services Incorporated

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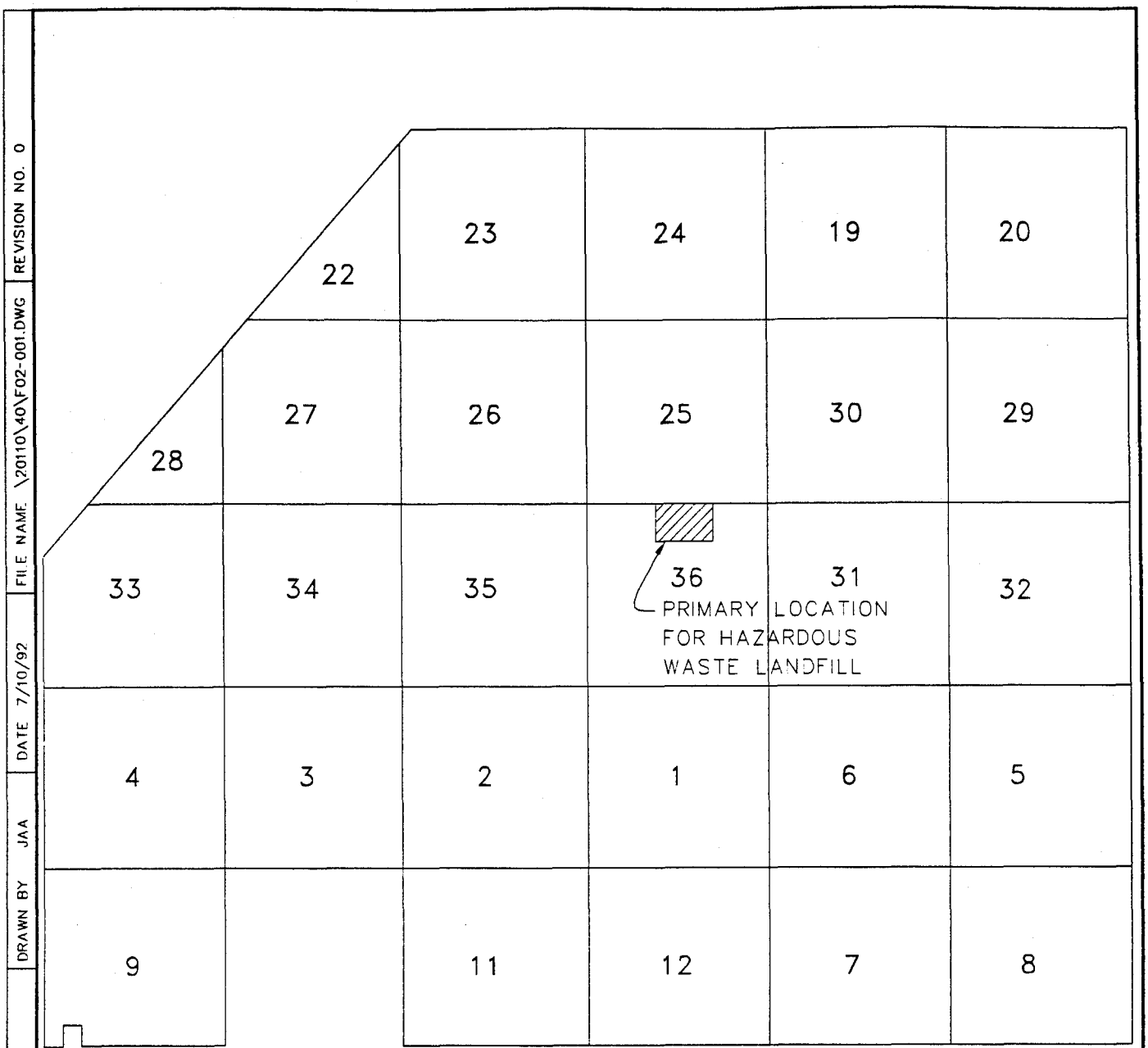

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Figure 6.5-1

Location of Primary Site for
Hazardous Waste Landfill

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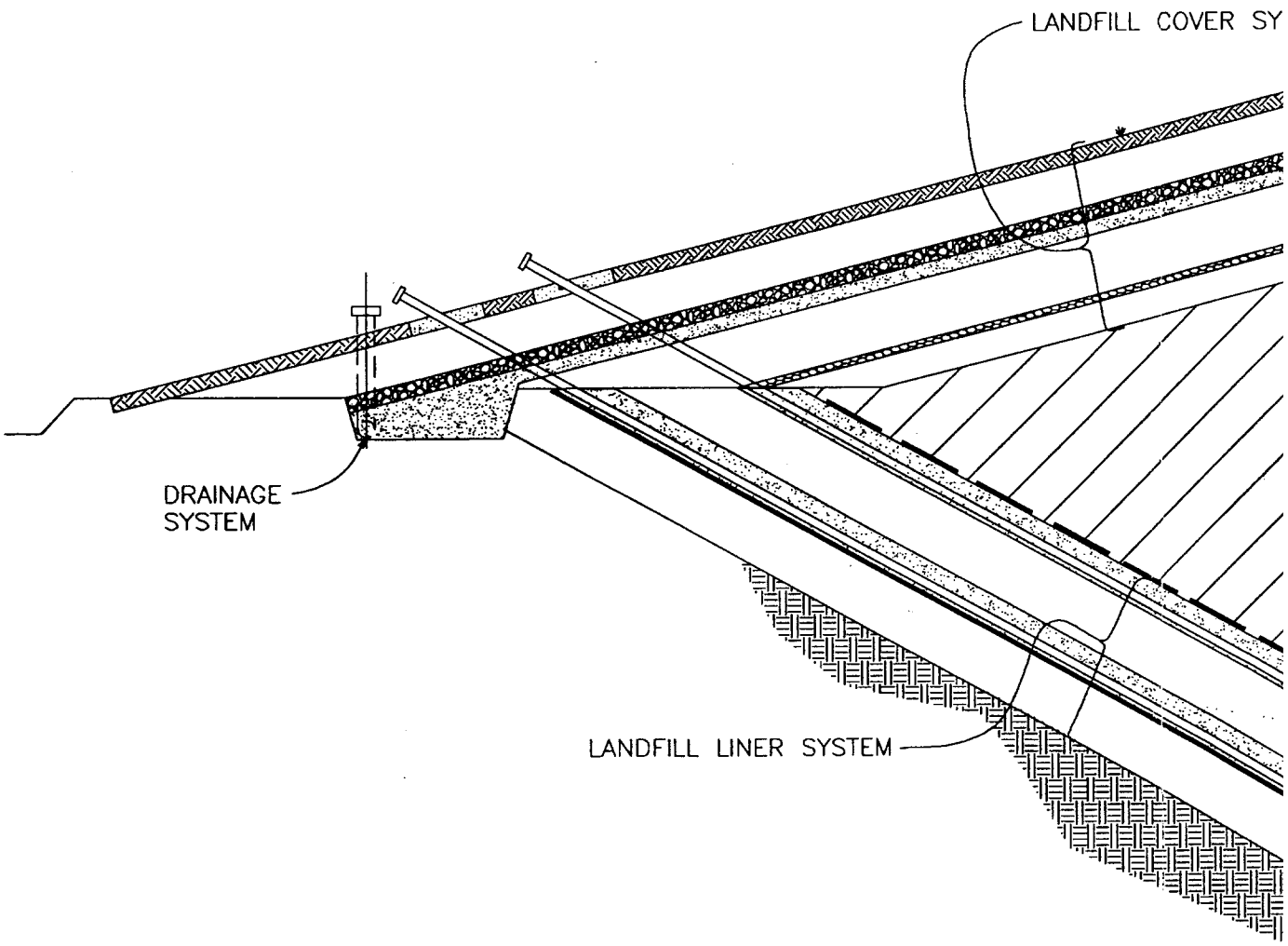

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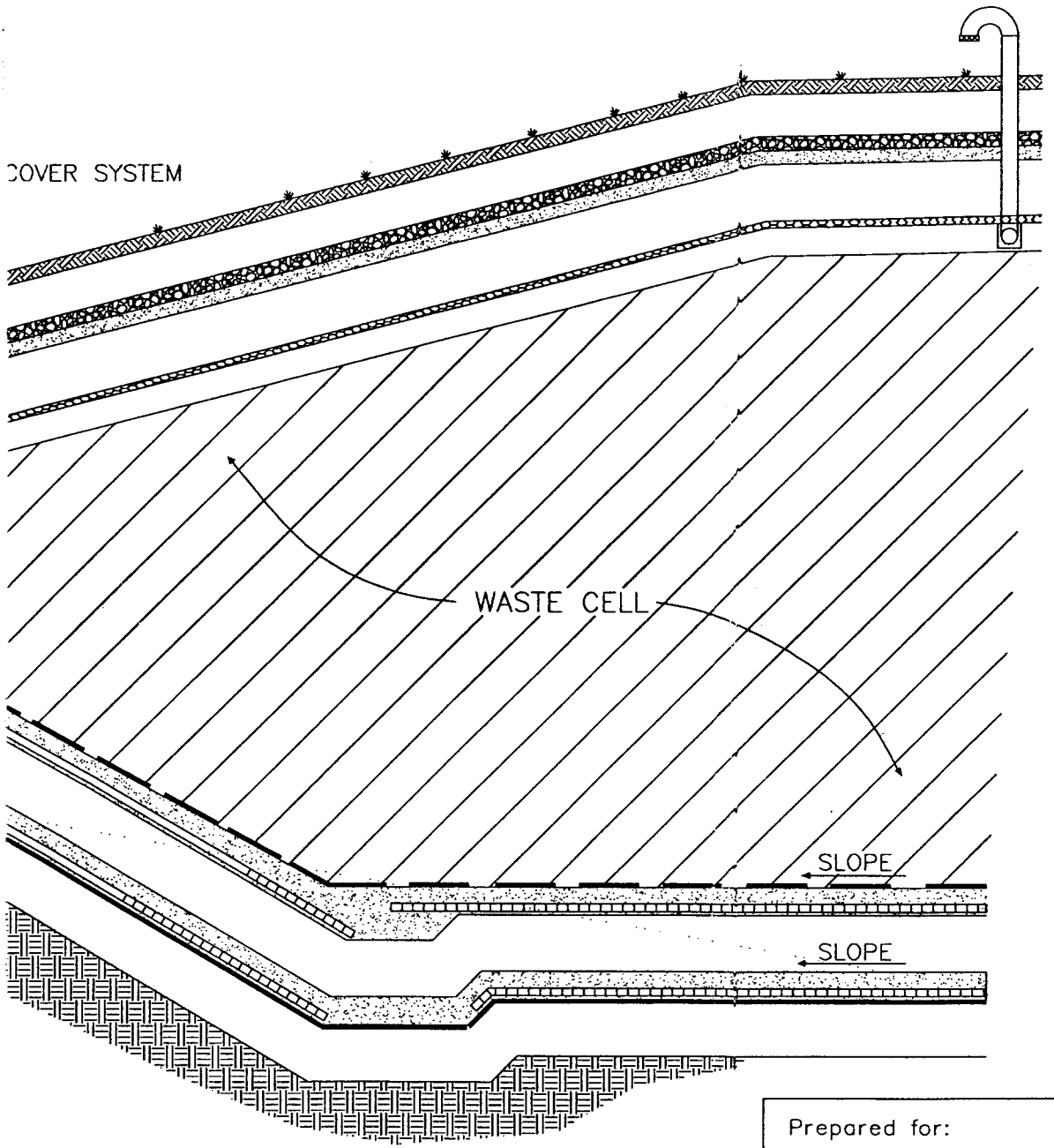

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Figure 6.5–2

Typical Cross Section
of RCRA Landfill Cell

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Rocky Mountain Arsenal.
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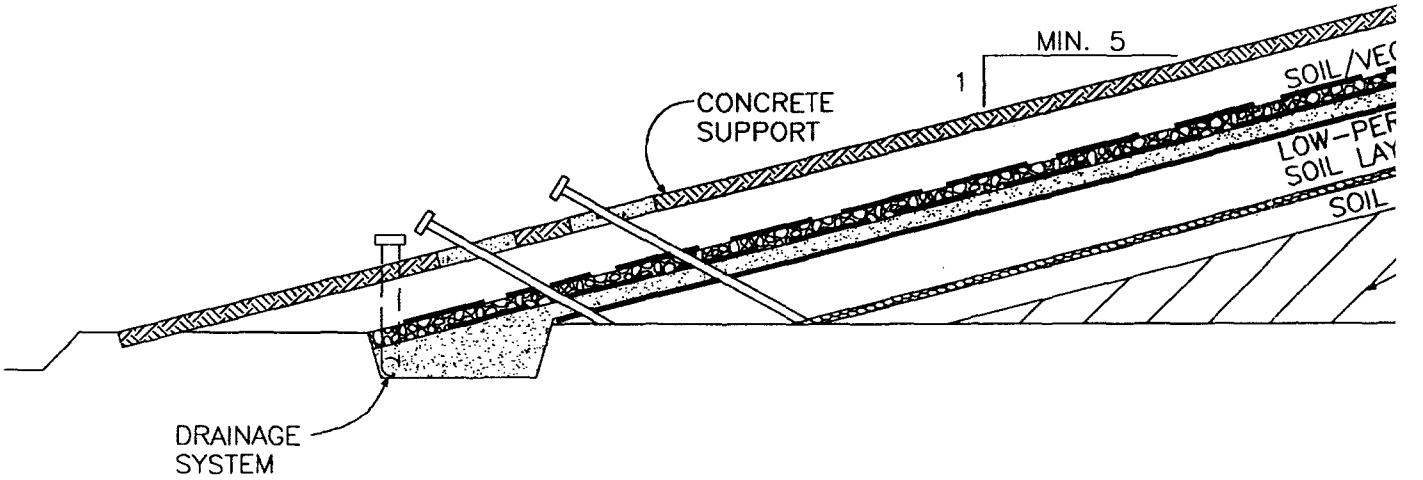

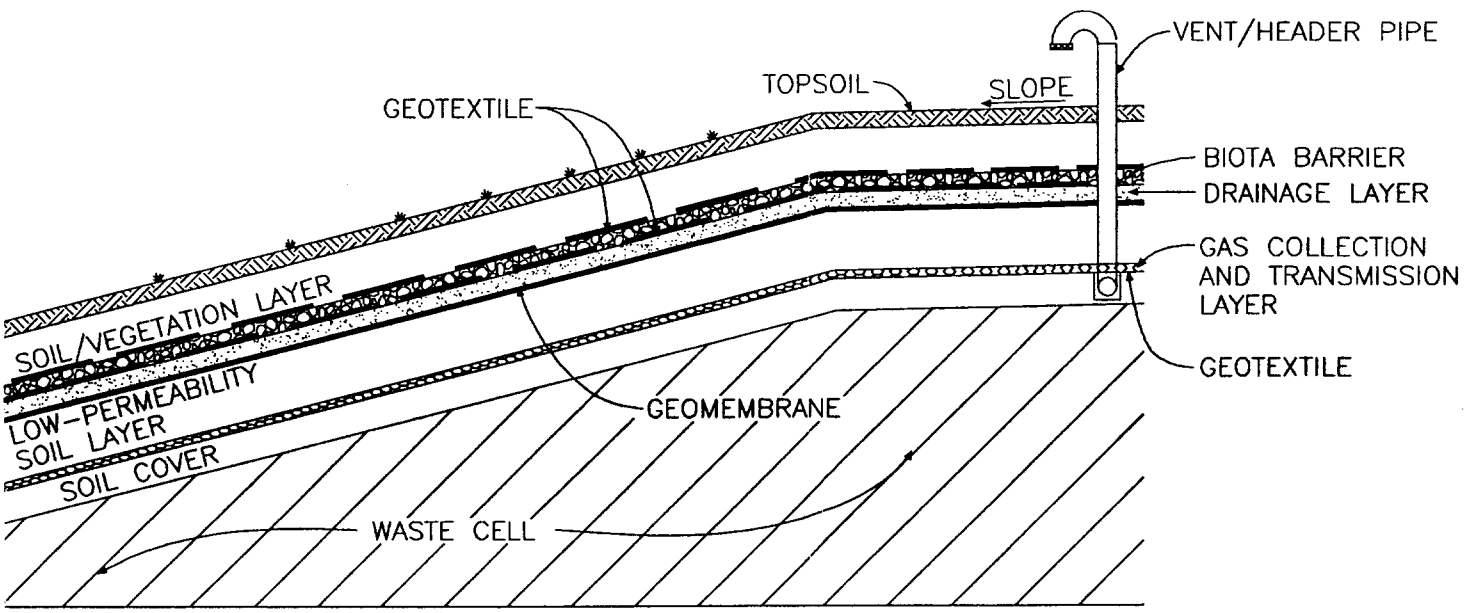

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Figure 6.5–3

Schematic of Typical RCRA
Landfill Cover

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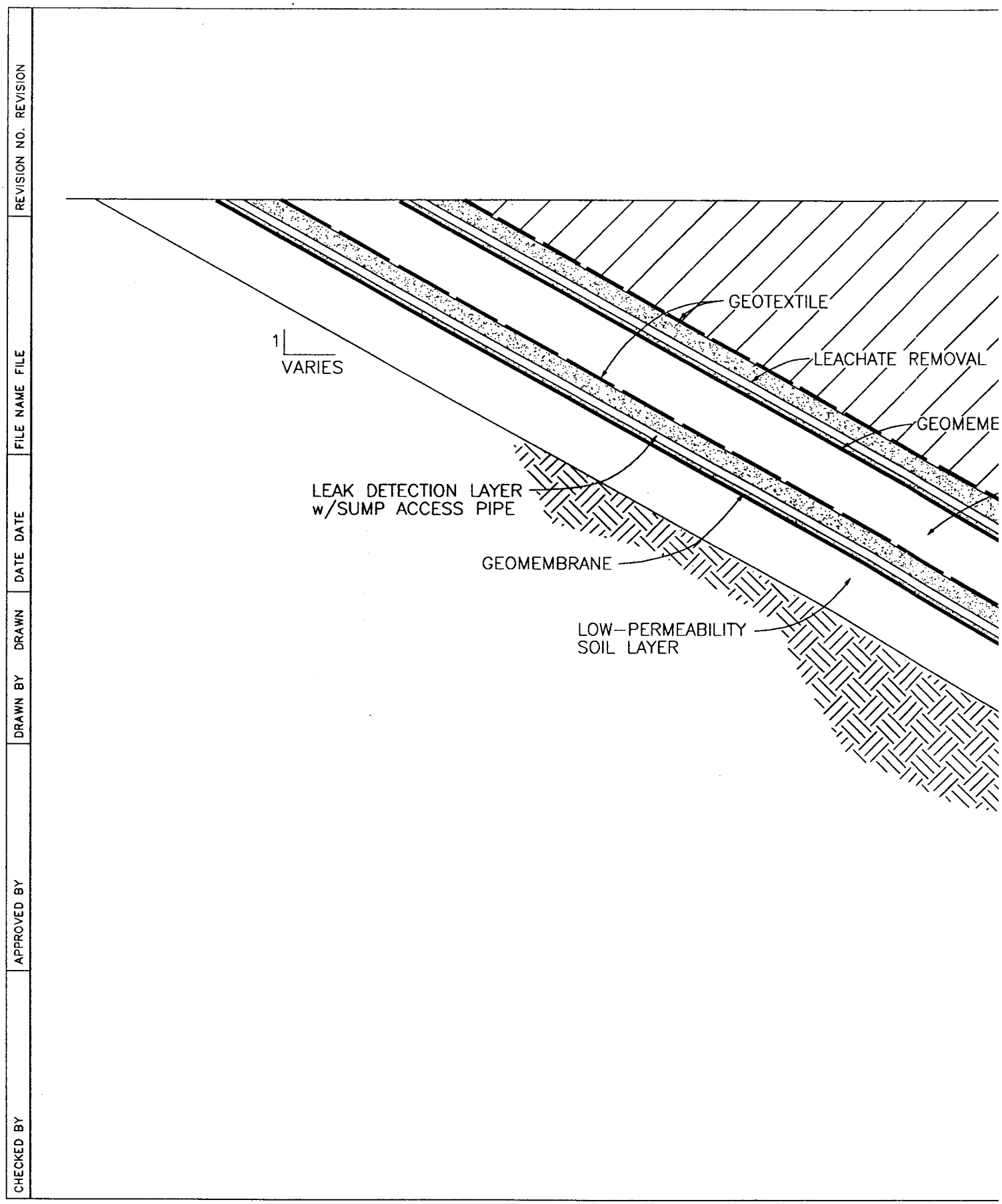
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SOIL LAYER

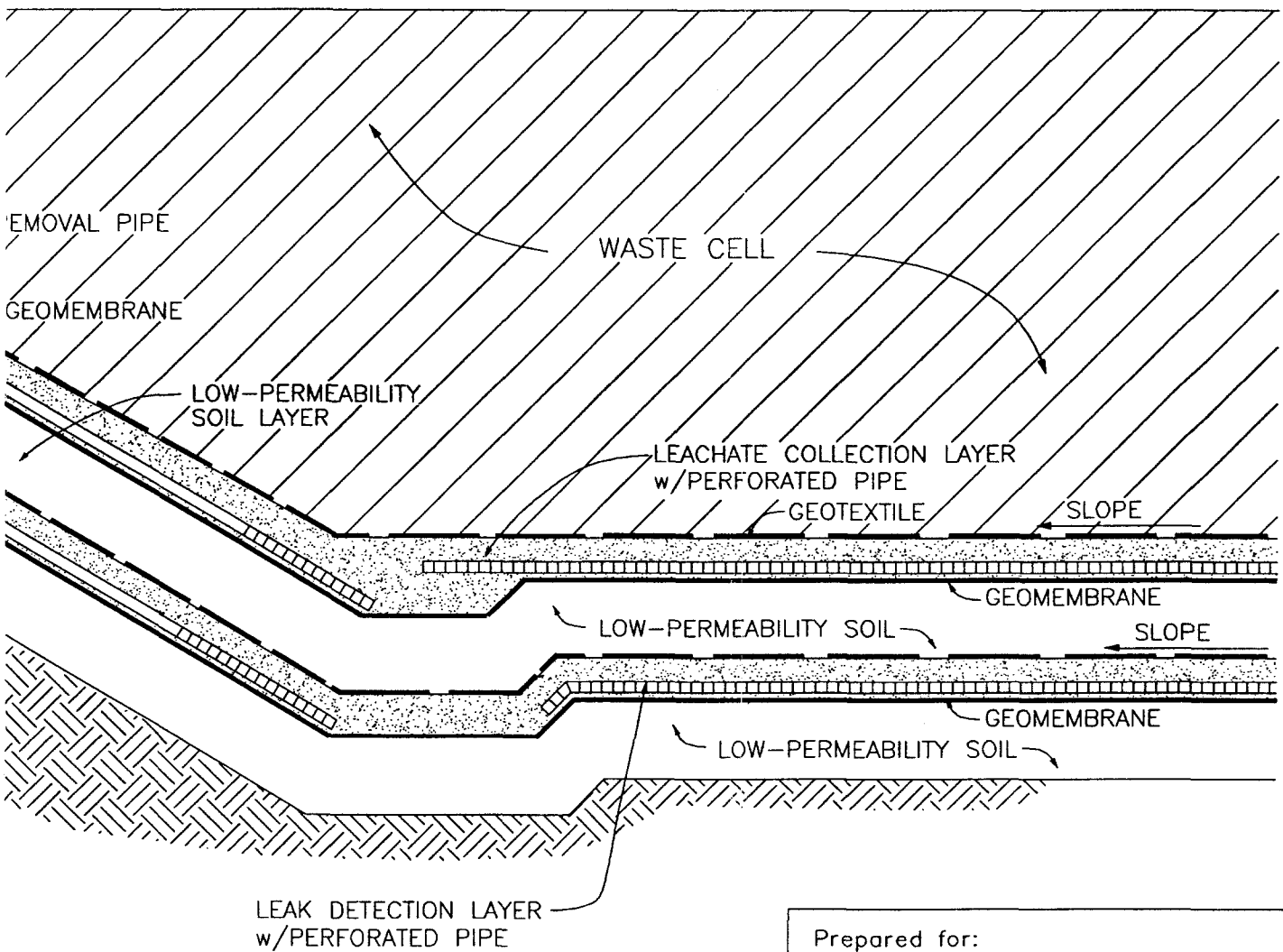

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Figure 6.5-4

Schematic of Typical RCRA
Landfill Liner

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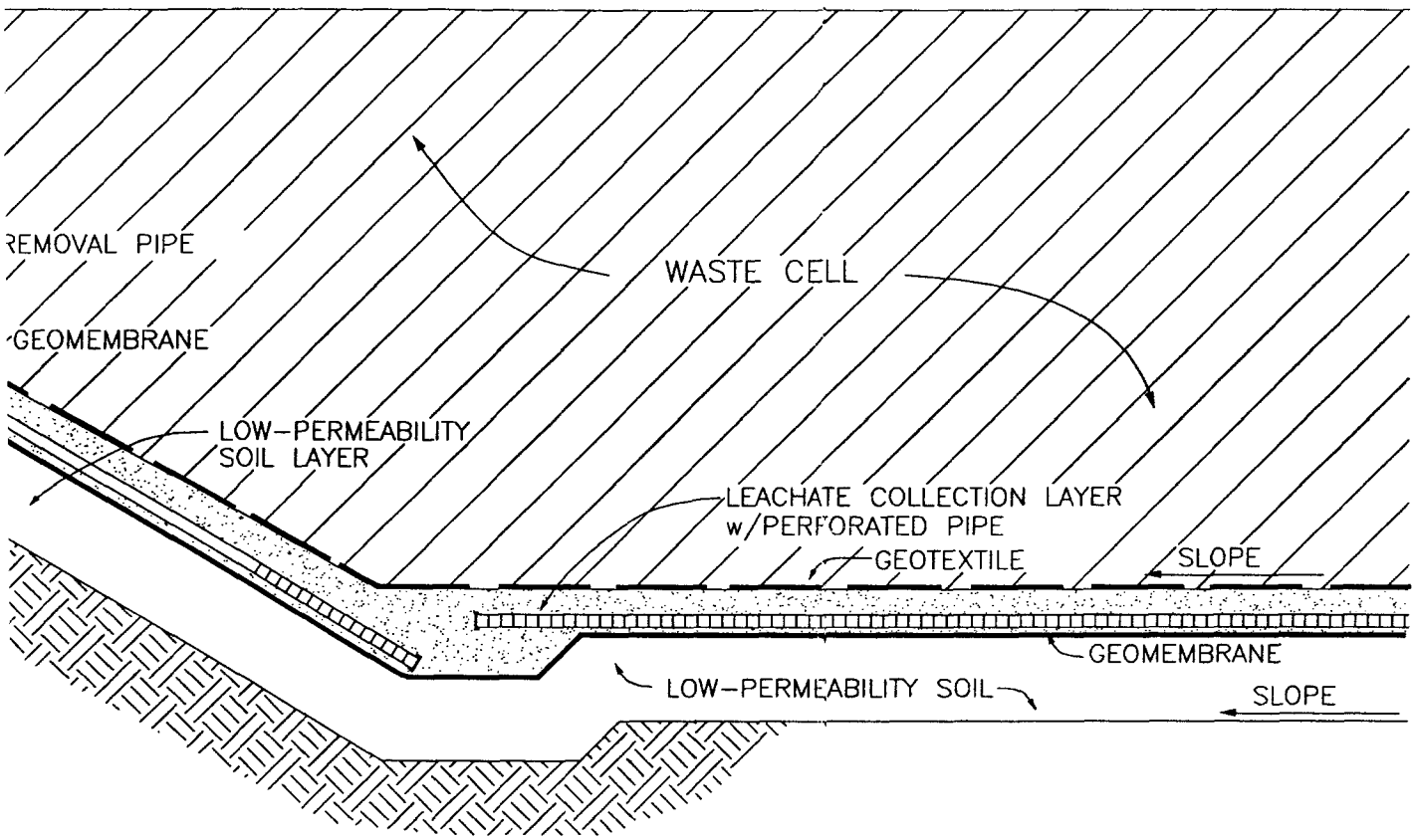

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared July 1992

Figure 6.5-5

Detail of Solid Waste Landfill Liner

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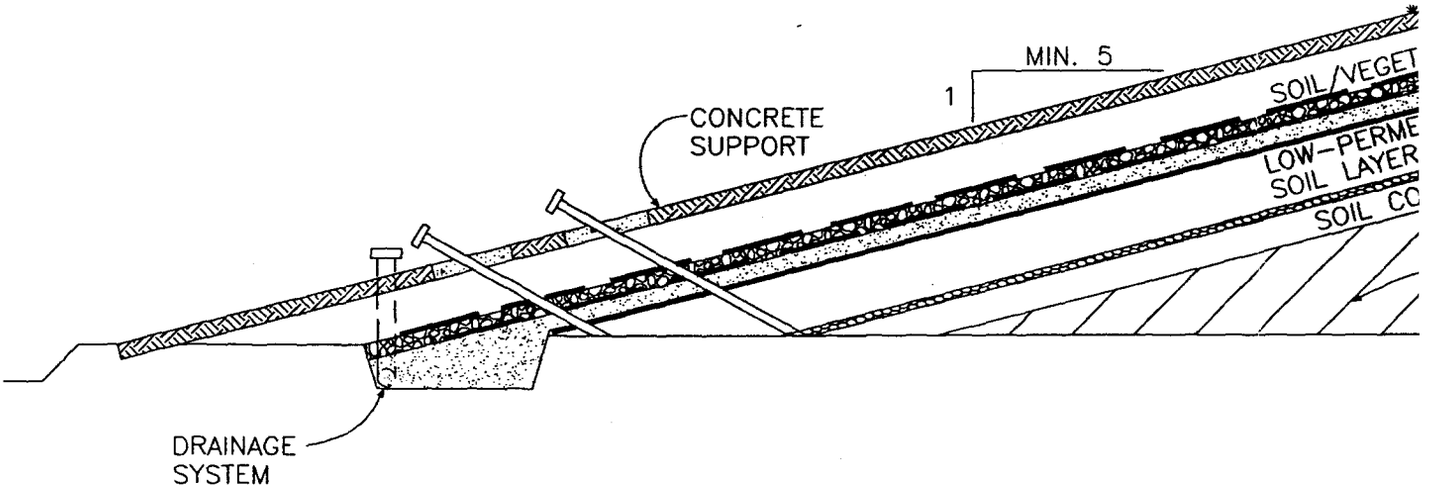

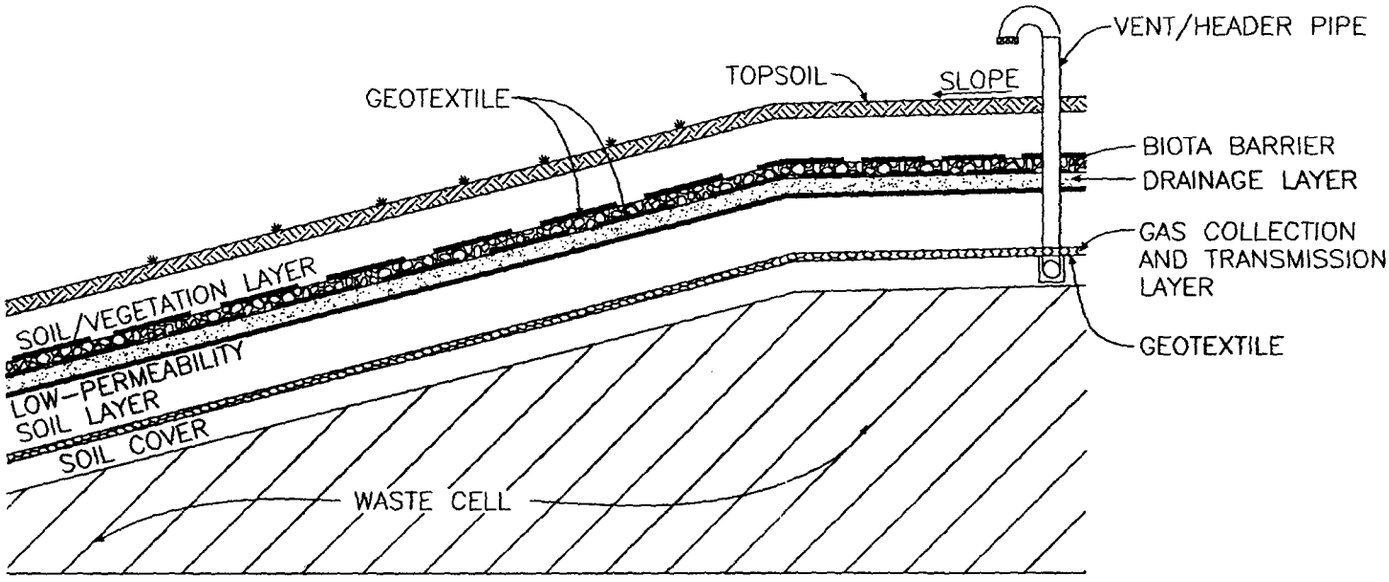

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Figure 6.5-6

Schematic of Typical Solid Waste Landfill Cover

NOT TO SCALE

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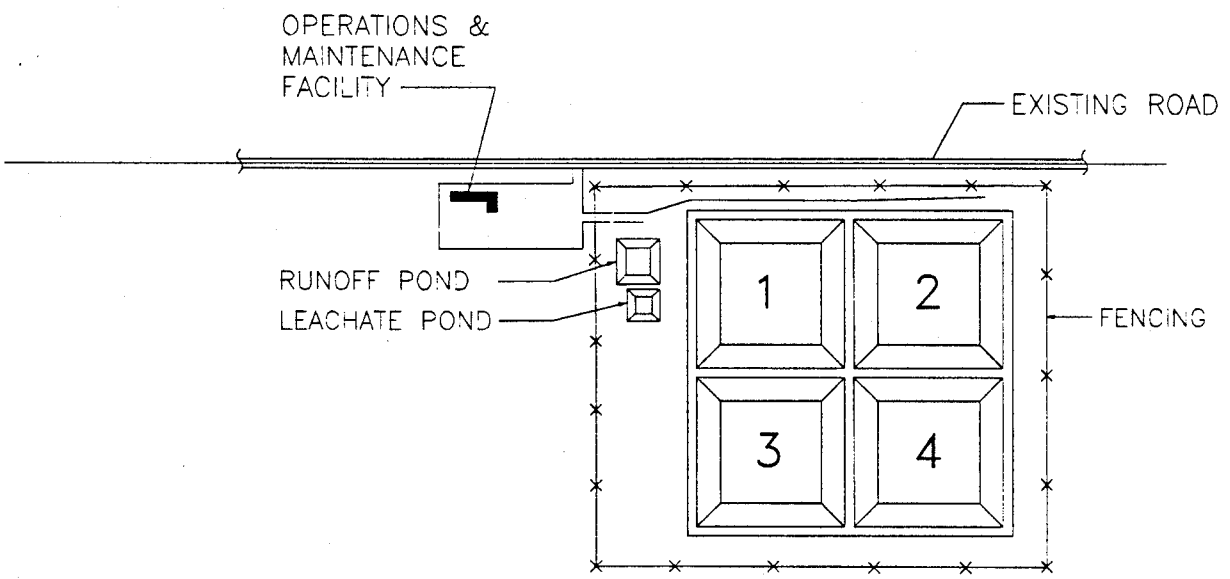
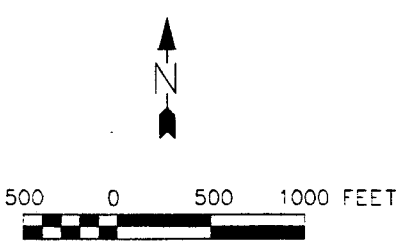
SEC. 25

1 = FILL PROGRESSION OF CELLS



SEC. 36

(4) 1,500,000 CY CELLS = 6,000,000 CY



Prepared for:

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for Rocky Mountain Arsenal

Prepared November 1992

Figure 6.5-7

Facility Layout for Hazardous and Nonhazardous Landfill Cells

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7.0 DIRECT THERMAL TREATMENT

The Direct Thermal Treatment General Response Action Category consists of several process options that involve heating contaminated soils, sediments, sludges, or structural debris in a thermal treatment unit either on or off post. VOCs and semivolatile organic compounds (SVOCs) are vaporized from the solid phase and either recovered or destroyed, depending on the operating temperature of the unit. At temperatures below 540 degrees Celcius (°C) organic contaminants are generally volatilized with little decomposition; this technology type is called thermal desorption. As the operating temperature is raised above 540°C, contaminants are increasingly oxidized or decomposed to other species; this technology type is called incineration/pyrolysis. Section 7.1 describes the thermal desorption technology type, which is represented by the direct-fired process option. Sections 7.2 and 7.3 describe the rotary kiln incineration and off-post incineration process options, respectively, both of which fall within the incineration/pyrolysis technology type.

7.1 THERMAL DESORPTION

Thermal desorption includes any of a number of processes that use heat to volatilize organic compounds from soil, sediment, sludge, and debris. Thermal desorption can also be achieved in an indirect-fired chamber, but direct thermal desorption was selected as an RPO in the DSA because of its higher operating temperatures and greater efficiency. It is used as a stand-alone treatment in alternatives developed for the soils medium Alternative 13 and Alternative 1a (Thermal Desorption of Principal Threat Volume; No Additional Action) and is combined with other RPOs in Alternative 9a (Direct Soil Washing; Direct Thermal Desorption) and in Alternative 20 (In Situ Thermal Treatment; Direct Thermal Desorption; Direct Solidification/Stabilization). Based on the DSA screening process, direct thermal desorption was retained for evaluation in the DAA for nearly all of the RMA biota and human health exceedance medium groups.

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 (SCC) may destroy them. Bench-scale treatability studies conducted with RMA soils indicate that thermal desorption is effective in reducing the concentrations of all of the VOCs and SVOCs of concern to less than detectable levels. 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.

7.1.1 Process Description

The desorption process can be accomplished using several types of equipment, depending on whether the contaminants are to be recovered or destroyed, including indirect-fired, direct-fired, transportable, or site-constructed equipment. Indirect heating was not selected as an RPO during the DSA because it is less efficient than direct heating. Contaminant destruction options generally use direct-fired equipment similar to aggregate dryers, with the contaminant-laden desorber off gas fed to an afterburner or secondary combustion chamber. Direct heating is generally accomplished using the sensible heat of the combustion gases and the radiant heat of the burner flame.

Direct-fired rotary dryers are the basis of design for most transportable thermal desorption units. Depending on the moisture content of the feedstock and the volatility of the contaminants, the rated throughput for most transportable desorbers is between 15 and 50 tons/hour. For higher processing capacities, it is necessary to use multiple desorber units or site-constructed facilities. The following paragraphs list some examples of current transportable unit capabilities:

- Canonie Environmental/Low-Temperature Thermal Aeration (LTTA): Direct-fired rotary kiln desorber with secondary combustion chamber for the destruction of vaporized organics. Full-scale capacity is 25 to 50 tons/hour. Off-gas treatment consists of a partial quench, baghouse, and venturi scrubber. The quench blowdown stream is treated with

GAC. The unit may also be configured with a secondary combustion chamber between the rotary kiln and the partial quench.

- SoilTech Anaerobic Thermal Processor (ATP): Zoned rotary multichamber desorber with condensation of vaporized organics. Full-scale capacity is 8 to 10 tons/hour. Off-gas treatment consists of a quench tower, baghouse, and an activated carbon system. Organics are quenched, scrubbed, and condensed out of the retort zone vapor stream and require further treatment or disposal.

- Williams Mobile Thermal Desorber: Direct-fired rotary dryer with secondary combustion of vaporized organics. Full-scale capacity is 20 to 30 tons/hour. Off-gas treatment consists of a baghouse, a secondary combustion chamber, a quench tower, and an acid gas scrubber.

- Halliburton/Ecotechniek Thermal Treatment System (ETTS): Direct-fired rotary kiln desorber with secondary combustion chamber for the destruction of vaporized organics. Full-scale capacity is 30 to 50 tons per hour. Off-gas treatment consists of a gas-to-gas heat exchanger, baghouse, and wet scrubber.

It is likely that the standard carbon steel construction of most transportable units is compatible with most RMA soils. However, some soils near the basins are expected to have high salt content. Accordingly, the desorber used at RMA may require corrosion-resistant alloys or refractory liners. Based on the large volume of soil to be treated at RMA and the requirement for corrosion resistance, an on-site desorber is anticipated to be technically superior and less costly than a transportable unit. The DAA therefore evaluated a central thermal desorption facility built at RMA.

Given the scale of the remediation implied by RMA soil volumes, an alternative using thermal desorption requires the high processing capacity and relative operating simplicity of direct-fired rotary equipment. Thermal desorption treatability studies were performed on RMA soils and a preliminary conceptual design was developed by Weston (Weston 1992a, 1992b). The Weston study was used as guidance for design and costing throughout the DAA. This preliminary conceptual design calls for two 37 ton/hour rotary kiln desorbers operating with a 65 percent on-stream factor for a period of 10 years.

During direct thermal desorption, the soils or sludges are excavated and moved to the desorber unit or to a central processing area (in accordance with the process options discussed in Section 4.0), where they are prepared as feedstock for the thermal desorber. Figure 7.1-1 presents a block diagram for the direct thermal desorption process, including the soil handling system, which is discussed in the following sections. Preparation steps reduce the physical variability of the material entering the desorber and include drying, size reduction, scrap metal removal, and solids blending. Typically, large objects (greater than 1.5 to 2.0 inches) are screened from the feedstock and rejected as oversize. The feed material is then delivered by gravity, conveyor, or screw augers to the desorber feed hopper.

The feed pre-treatment area requires a fully enclosed building with storage capacity for 3 to 5 days worth of feed material. The building encloses the contaminated soil handling, sizing and mixing equipment, and the desorber feed hoppers. Based on the preliminary conceptual design and standard industry procedures, feed pre-treatment equipment might consist of a feed hopper, magnetic separator, primary shredder, disc classifier, and final shredder to reduce the largest clay soil lumps to 1.5 to 2.0 inches.

According to the preliminary conceptual design, a central thermal desorption facility requires two direct-fired, inclined, rotary dryers (10 ft in diameter and 52 ft long) operating under induced draft at 300°C. The total soil processing rate at 20 percent moisture is 74 tons/hour. The main burner is located on the soil-feed end of the dryer drum so that the highest flame temperatures and highest heat release occur where soil moisture levels are highest and where the soil particles are protected by a film of vaporizing water. Soil and combustion products flow in the same direction so that particulates that entrain in the flue gas are heated to the required desorption temperature before they exit the kiln. Overall soil residence time is 50 minutes.

Off-gas from the desorber passes through a cyclone separator before entering the SCC. Depending upon the partitioning of metal contaminants between the soil and the entrained fines,

the particulates removed by the cyclone are recombined with the treated soil or treated separately to immobilize the metals.

Off-gas treatment involves the removal of the acid gases formed in the SCC oxidation reactions and the particulates carried over from the desorber off-gas cyclone. The preliminary conceptual design includes a spray tower for adiabatic gas cooling, a baghouse for particulate removal, and a caustic quench step to remove acid gases with a venturi scrubber for additional particulate removal (Figure 7.1-1). The sequence can be modified to include off gas to stack gas heat recovery and spray drying of the caustic quench blowdown stream. The technology is sufficiently proven that the off-gas treatment system is expected to meet air emissions standards without any extraordinary measures. Optimization of the treatment sequence is undertaken after final engineering studies.

The conceptual design employs a secondary combustion chamber operating at 1,200°C and a residence time of 2.5 seconds to destroy the organic components of the desorber off gas. With thorough mixing, this temperature and residence time destroys all of the organic contaminants, including any dioxins or furans created during the thermal desorption of the pesticides (Focus 1992). Given the extensive experience with incinerator off-gas treatment, proven technology is available to achieve particulate and acid gas emission requirements for stack gas standards. Depending on the sequence of unit operations, the solids from particulates removal and the brine from acid gas neutralization may exit the off-gas treatment train as a combined stream or as separate wastes.

In the conceptual design, the particulates and metal salts recovered from the off-gas exit the system at several points. The necessity of solidifying some or all of these sidestreams depends on the extent of metal partitioning between the two streams. If the soil feed is high in volatile metals, the particulate sidestream may require solidification to immobilize inorganics prior to disposal in the on-post landfill (Section 6.5).

Byproduct acid gases such as hydrochloric acid (HCI), hydrogen bromide (HBr), and hydrofluoric acid (HF) are neutralized and scrubbed from the desorber off-gas stream in a caustic quench step. The resulting sodium chloride brine stream is evaporated and centrifuged to a wet cake with a solids content of 80 percent. The salt cake is placed in the on-post landfill and the evaporated water recycled to the off-gas treatment system.

The soil discharged from the thermal desorber is cooled and rehumidified by water sprays to minimize fugitive dust emissions. Depending on the final metals content, the treated soil is returned to the original excavation if the inorganic levels are below human health and biota preliminary remediation goals (PRGs). The treated soils with elevated inorganics are solidified to immobilize metals and returned to the original excavation unless the layout of the excavation area precludes backfilling the solidified soils. In this case, the solidified soils are placed in a soil consolidation/containment area or a solid waste landfill cell as discussed in Section 6.5.

Since the conceptual design uses a SCC to achieve the required contaminant destruction levels, the ARARs identified for the thermal desorption technology are essentially the same siting, design, and performance requirements associated with incineration/pyrolysis. Like an incinerator, the facility cannot be sited in a wetland area or 100-year floodplain. The unit must substantively comply with RCRA performance standards for hazardous waste incinerators (40 CFR 264, Subpart O) and achieve a minimum destruction and removal efficiency (DRE) of 99.99 percent for all organic hazardous constituents. Since RMA is in a nonattainment area, the off-gas treatment system must meet federal and Colorado primary ambient air quality standards of performance for new emissions sources. The ARARs governing the use of low-temperature thermal desorption and its associated off-gas treatment train are found in Appendix A.

The capital and operating cost for the thermal desorption technology are taken from Weston (1992b). The order-of-magnitude estimate includes the cost of off-gas treatment and brine concentration, and excludes the cost of soil excavation, soil transport, soil backfill, and waste sidestream disposal. Weston estimated the present day capital cost for a central desorber facility

to be $53 million, with ongoing operating and maintenance costs of $22.5 million per year for 10 years. Total soil volume processed over the 10-year period is 3,100,000 bank cubic yards (BCY).

For costing in the DAA, Weston's estimated capital and operating costs were unburdened of construction indirect, engineering, startup, and contingency costs. In addition, the volume processed in 10 years was adjusted from 3,100,000 BCY to 3,000,000 BCY based on a more typical soil density of 105 lb/CF rather than 100 lb/CF. Table 7.1-1 shows the remaining cost components that make up the RMA thermal desorption capital and operating costs.

The unburdened capital cost of thermal desorption is $42.5 million. For the 3,000,000 BCY cleanup, the unit capital cost for thermal desorption is $14.17/BCY. Depending on the soil moisture level, the operating cost of thermal desorption varies from $49.13/BCY for a dry soil (10 percent moisture) to $128.48/BCY for a semisludge (40 percent moisture). The base cost of (20 percent moisture) is $73.64/BCY.

7.1.2 Process Performance

The applicability and effectiveness of the thermal desorption process are strongly dependent on soil moisture content. The energy expended in vaporizing soil moisture can be a high fraction of the total desorber heating requirement. For example, as soil moisture content increases from 5 to 20 percent of the feedstock weight, the heat load associated with vaporizing water increases from 35 to 70 percent of total fuel fired. Direct-fired desorbers have maximum firing rates; therefore, high soil moisture levels reduce the energy available to bring the soil to the required desorption temperature for the required exposure time. For any given thermal desorber, the soil processing rate decreases as the soil moisture content increases.

Three soil moisture levels were evaluated in the Weston conceptual design report (1992b). The base case assumed an average soil moisture level of 20 percent and proposed a design capacity of 74 tons/hour (52 BCY/hour at 105 pounds per cubic foot [pcf]). This is considered a saturated

soil. For a dry soil (average soil moisture content of 10 percent), the processing rate of the proposed thermal desorption facility increases to 80 tons/hour (56 BCY/hour at 105 pcf). For wet sediments (40 percent moisture), the processing rate for the two-train central desorption facility drops to 41 tons/hour.

As feed moisture levels continue to increase, handling and placement difficulties begin to limit the practicality of using direct thermal desorption as a treatment approach. The contaminated medium must contain between 20 to 30 percent solids to be processable. Sludges or dredged spoil may require dewatering or blending with drier material to meet the solids content requirement.

Soil structure and gradation may also limit the application of thermal desorption. For example, a high fraction of fine silt or clay can produce dusting in the dryer and increased particulates carryover into the off-gas treatment train. In another instance, soils that are tightly aggregated or have high clay content can result in poor processing performance because of caking. Caked material may enclose some of the contaminants and prevent their escape into the vapor phase, and may also cling to or coat dryer internals and inhibit solid/vapor mixing patterns. As with soil moisture content, the caking phenomenon may reduce the soil processing rate for the desorber or actually prevent the achievement of the required DREs.

The presence of VOCs and volatile soil components can complicate the design and operation of the thermal desorber. High levels of salts expected in some of the basins' soils add to the generation of acid gases in the thermal desorption step. The thermal desorber and secondary combustion chamber need to be fabricated with materials capable of withstanding these acid gases. Gas scrubbing equipment also needs to be employed to remove the acid gases from the gas stream prior to atmospheric release.

Thermal desorption has been demonstrated to be effective by treatability testing at bench- or pilot-scale for the removal of halogenated and nonhalogenated volatile organics, halogenated and

nonhalogenated SVOCs, PCBs, pesticides, dioxins, and furans from soil matrices (Weston 1992a). It is potentially effective for these same organic contaminant groups in sludges, although processing problems arise with high moisture levels as described above. The technology also removes volatile metals such as mercury and lead from soils, although the technology is ineffective for most inorganic contaminants. Any volatilized metals need to be removed in the off-gas control system.

Thermal desorption is the selected remedy for one or more operable units at fourteen Superfund sites. Canonie Environmental has extensive performance data for its LTTA system at full-scale operation (15 to 45 tons/hour) (Canonie 1992). The LTTA system is based on a transportable, direct-fired, rotary aggregate dryer and is limited by its construction materials to operating temperatures at or below 425°C. The unit has been demonstrated at full scale at the McKin (Maine), Ottati & Goss (New Hampshire), and Cannon Engineering Corp. (Massachusetts) Superfund sites on soils contaminated with VOCs and polynuclear aromatic hydrocarbons (PAHs). The LTTA system is currently remediating pesticide-contaminated soils at the Litchfield Airport Site near Phoenix, Arizona. Operating information for the Phoenix site is not yet available, but bench-scale testing indicates removal of pesticides, including dichlorodiphenyltrichloroethane (DDT) and dichlorodiphenylethane (DDE), to slightly above detectable levels at an operating temperature of 315°C to 340°C.

Shell Development Company conducted a laboratory-scale treatability study of thermal desorption in 1989 using static tray and tube test apparatus. The study showed that organochlorine pesticides (OCPs) present in soils from Basins A and F at total concentration levels of several hundred to several thousand parts per million (ppm) were reduced to less than 50 parts per billion (ppb) at temperatures as low as 250°C (Farmayan et al. 1989).

International Technology (IT) Corporation conducted a bench-scale treatability study with Basin F soils in 1990 for Morrison-Knudson using a rotary thermal apparatus. The study showed reductions of OCP concentration levels from approximately 800 ppm to below detection levels

(32 ppb) at temperatures as low as 300°C. Virtually all of the mercury and between 20 to 30 percent of the arsenic were volatilized and subsequently removed by the off-gas stream (IT Corporation 1990). Other inorganics in the form of alkali chlorides and sulfates were also present in RMA soil samples. Bench-scale testing indicated that very little salt decomposition took place at the 300°C test temperature, so acid gas formation is not likely to be a major problem in the off-gas treatment train under similar conditions.

IT Corporation conducted an expanded bench-scale treatability study for Weston using RMA soil samples representative of the South Plants, Secondary Basins, and the Undifferentiated Medium Groups. The preliminary results from the study show that all of the RMA organic contaminants of concern can be desorbed to 10^{-4} biological worker PRGs at 250°C. To achieve 10^{-6} biological worker PRGs, the desorber operating temperature must be raised to the 300°C to 400°C range.

Since a 300°C soil discharge temperature is well above the boiling point of water, the desorber operation is analogous to commercial aggregate drying. Upon discharge, the treated soil is completely desiccated, some of the natural organic carbon is partially oxidized, the organic contaminants are desorbed to levels below their detection limits, and some volatile metal contaminants are vaporized into the sweep gas stream. Other than the loss of some humic material, the physical properties of the treated soil are essentially the same as those of the untreated material.

Based on the bench-scale testing discussed above and the full-scale performance of thermal desorbers at other sites, the concentrations of organic contaminants in RMA soils should be reduced to below their levels of detection by low-temperature thermal desorption. Based on commercial incinerator performance, the secondary combustion chamber can be operated at a residence time and temperature sufficient to achieve a 99.99 percent minimum DRE for all of the RMA organic contaminants of concern. Table 7.1-2 summarizes the performance information for thermal desorption of pesticide-contaminated soils.

7.2 INCINERATION/PYROLYSIS

Rotary kiln incineration is a high-temperature process that uses either indirect or direct heat exchange to alter or destroy organic contaminants in soil, sediment, sludge, and debris. It is used as a stand-alone treatment in Alternatives A4 and 14 (soils medium) and may be combined with other alternatives where Army chemical agent is encountered during remediation. Based on the DSA screening process, rotary kiln incineration was retained for evaluation during the DAA for sites in the Agent Storage and Disposal Trenches Medium Groups. Rotary kiln incineration was retained for the No Future Use, Manufacturing History and No Future Use, Agent History Structures Medium Groups. If ongoing treatability studies indicate that thermal desorption does not achieve adequate DREs, rotary kiln incineration will be reconsidered for application to other medium groups. Rotary kiln incineration was also considered for those portions of the Basin A, Sewer Systems, Lime Basins, South Plants, and Undifferentiated Medium Groups that are found to contain agent-contaminated soils. Rotary kilns are also utilized in the on-post demilitarization of UXO, which is discussed separately in Section 9.1.

In general, the operating temperature of the incinerator (540°C to 1,000°C) is high enough to destroy the organic contaminants by oxidation or pyrolysis. Based on bench-scale treatability studies conducted with RMA soils, incineration provides temperatures high enough to remove all of the VOCs and SVOCs of concern to less than detectable levels. The high operating temperatures of incineration are required for unrestricted releases of agent-contaminated materials as discussed in Section 9.5. Incineration will remove, but not destroy, volatile metals such as mercury and arsenic. Mercury is almost entirely volatilized at temperatures greater than 540°C, but arsenic and lead are only partially removed.

7.2.1 Process Description

Except for the operating temperature of the kiln, the process flow diagram and equipment sequence for rotary kiln incineration is nearly identical to that for thermal desorption. Figure 7.2-1 presents a block diagram for rotary kiln incineration. The soils, sludges, or structural debris are first excavated and moved to the mobile incinerator unit or to a central

processing area where they are prepared as feedstock. Preparation steps reduce the physical variability of the material entering the incinerator and may include drying, size reduction, scrap metal removal, and solids blending. Typically, large objects (greater than 1.5 to 2.0 inches) are screened from the feedstock and rejected as oversize. Structural debris may be no larger than 1 ft by 1 ft. All reinforcing steel bars are removed from concrete. The feed material is then delivered by gravity, conveyor, or screw auger to the incinerator feed hopper.

At the central processing area the feed pre-treatment area requires a fully enclosed building with storage capacity for 3 to 5 days feed. The building encloses the sizing and mixing equipment and the incinerator feed hoppers and provides shelter for contaminated soil and structural debris handling activities. The incinerator feed pre-treatment sequence would consist of the same steps described under thermal desorption: feed hopper, magnetic separator, primary shredder, disc classifier, and final shredder.

Based on operating conditions proposed in the Task 17 conceptual design (EBASCO 1988), the incinerator is a direct-fired, inclined, rotary kiln operating under induced draft at a discharge temperature of 760°C. For ease of costing, the incinerator facility employs the same process sequence as Weston's thermal desorption facility. Soil preparation and off-gas treatment equipment are identical in size and cost, but the rotary kiln incinerator is roughly 50 percent larger in diameter than the rotary kiln thermal desorber. Because the soil discharges from the incinerator at a higher temperature (760°C) than from a thermal desorber (400°C), fuel requirements are higher per ton of soil processed. The resulting higher volume of flue gas forces an increase in the diameter of the rotary kiln incinerator in order to maintain the same design space velocity as that used in Weston's thermal desorber and an increase in sizing of the off-gas treatment system for the same soil processing rate.

For the purposes of the DAA, Weston's conceptual design for thermal desorption was adapted to the operating temperatures required in rotary kiln incineration. The volume of gas sent to off-gas treatment is identical in both cases, so the same combustion calculations were used to

establish the quantity of incinerated soil that is consistent with that volume. For the incinerator operating at 760°C, the off-gas treatment equipment in the Weston report limits the soil processing rate (at 20 percent moisture) to 56 tons/hour using two rotary kiln incinerators.

The main burner is located on the soil feed end of the kiln so that the highest flame temperatures and highest heat release occur where soil moisture levels are highest. Soil and combustion products flow in the same direction so that particulates that entrain in the flue gas are heated to the required incineration temperature before they exit the kiln. Overall soil residence time is 30 minutes.

As with thermal desorption, off-gas from the incinerator passes through a cyclone separator before entering the SCC. Depending on metals content, the particulates removed by the cyclone are combined with the treated soil discharge stream or solidified to immobilize inorganics and disposed in the on-post landfill. Residual organic contaminants in the cyclone off gas are destroyed in the SCC at the proposed operating temperature of 1,200°C and residence time of 2.5 seconds.

The off-gas treatment sequence following the SCC employs a spray tower for adiabatic gas cooling, a baghouse for particulate removal, and a caustic quench step to remove acid gases with a venturi scrubber for additional particulate removal. The sequence can be modified to include off gas to stack gas heat recovery and spray drying of the caustic quench blowdown stream. The technology is sufficiently proven in commercial incinerator installations such that the off-gas treatment system is expected to meet air emissions standards without any extraordinary measures. Optimization of the treatment sequence will be undertaken after final engineering studies.

Direct-fired rotary kilns are also available in both transportable and fixed facility versions, and several remediation firms offer transportable versions on a contractual basis. Compared to the bare metal construction of thermal desorbers, the higher operating temperatures of incineration require a refractory lining. A rotary kiln incinerator has no internal lifting flights for solids

processing, so it is generally inclined at a steeper angle than a thermal desorber to encourage solids movement. Depending on the moisture content of the feedstock and the volatility of the contaminants, the rated throughput for the transportable incinerators is between 5 and 44 tons/hour. Examples of current transportable unit capabilities includes the following:

- Weston Transportable Incineration System (TIS): Direct-fired rotary kiln with secondary combustion chamber for the final destruction of vaporized organics. Full-scale capacity is 6 tons/hour. Modular off-gas treatment consists of a spray tower, baghouse, and recirculated quench tower. The quench blowdown stream treatment is unspecified (Weston Services, undated).

- Detoxco Transportable Incinerators: Direct-fired rotary kiln with secondary combustion chamber for the final destruction of vaporized organics. Full-scale capacity of three available models is 7, 22, or 44 tons/hour. Modular off-gas treatment consists of a quench tower, baghouse, and acid scrubber. Scrubber blowdown requires further treatment (Detoxco Inc., undated).

- Rust Remedial Services Transportable Incinerator System (PYROX 8200): Direct-fired rotary kiln with secondary combustion chamber for the final destruction of vaporized organics. Full-scale capacity is 10 to 15 tons/hour. Modular off-gas treatment consists of a quench tower, baghouse, and acid scrubber. Scrubber brine stream requires further treatment.

Depending on the final volume of soil requiring incineration, transportable units may have sufficient processing capacity to be considered for part of the final RMA remedy. For the purposes of the DAA, potential soil volumes are still large enough to favor the higher throughput of a site-constructed incineration facility.

Rotary kiln incinerators are available from several heavy equipment fabricators in the United States. Combustion Engineering; Ford, Bacon, and Davis; and Allis Mineral Systems are three possible sources of detailed mechanical design and equipment fabrication. These same fabricators can supply the SCC and the associated off-gas treatment equipment.

Both site-constructed and transportable incinerators require some form of off-gas treatment system. As already discussed, alternatives developed for the DAA use the same off-gas treatment

sequence for thermal desorption and incineration. The off gas from the incinerator is sent to an SCC operating at 1,200°C with a residence time of 2.5 seconds to destroy the partially oxidized organic components exiting the rotary kiln. Given the extensive experience with commercial hazardous waste incinerator off-gas treatment, proven technology is available to achieve particulate and acid gas emission requirements for stack gas standards. Depending on the sequence of off-gas treatment operations, the solids from particulates removal and the brine from acid gas neutralization may exit the off-gas treatment train as a combined stream or as separate wastes.

Particulates and metal salts recovered from the off gas exit the system from several points. The necessity of solidifying some or all of these sidestreams depends on the extent of metal partitioning between the two streams. If the soil feed is high in volatile metals, the particulate sidestream may require solidification to immobilize inorganics prior to disposal in a soil consolidation/containment area or an on-post landfill (Section 6.5).

Byproduct acid gases such as HCl, HBr, and HF are neutralized and scrubbed out of the desorber off-gas stream in a caustic quench step. The resulting sodium chloride brine stream is evaporated and centrifuged to a wet cake with a solids content of 80 percent. The salt cake is placed in the on-post landfill and the evaporated water recycled to the off-gas treatment system.

Incineration causes irreversible chemical and physical changes to the treated soil, generating an ash. Natural organic material is burned out of the soil matrix. The clay and silt fractions tend to disappear as the smaller particles form sand-sized aggregates. The pH of the soil increases with the loss of hydroxyl groups from the clay minerals and the conversion of carbonate minerals to their oxide forms. Since metal oxides tend to be more soluble than the carbonates, incineration tends to increase the extractability of metal constituents over that of the untreated soil. Depending on the metal content of the contaminated soil, the particulates from the incinerator off-gas treatment system, and possibly the treated soil, may require solidification before they are placed in the on-post landfill.

The soil/ash discharged from the incinerator is cooled and rehumidified by water sprays to minimize fugitive dust emissions. Depending on the analysis of residual inorganic contaminants, the treated soil/ash is either solidified to immobilize metals and then placed in the on-post landfill or is placed in the on-post landfill without solidification. Section 10.1 presents the process of direct cement-based solidification that would be utilized.

RCRA specifies extensive siting, design, and performance requirements for treatment facilities using incineration/pyrolysis technology. Like the thermal desorber, the facility cannot be sited in a wetland area or 100-year floodplain. The unit must substantively comply with RCRA performance standards for hazardous waste incinerators (40 CFR 264, Subpart O) and achieve a minimum DRE of 99.99 percent for all organic hazardous constituents. Since RMA is in a nonattainment area, the off-gas treatment system must meet federal and Colorado primary ambient air quality standards of performance for new emissions sources. The ARARs governing the use of incineration/pyrolysis and its associated off-gas treatment train are found in Appendix A.

The capital and operating cost for the incineration/pyrolysis technology are adapted from those developed for the draft thermal desorption conceptual design proposed by Weston (1992b). The order-of-magnitude estimate includes the cost of off-gas treatment and brine concentration, and excludes the cost of soil excavation, soil transport, soil backfill, and waste sidestream disposal. The current capital cost for a single-train rotary kiln incinerator facility with modular feed preparation and off-gas treatment equipment on the Weston model is estimated to be $21.8 million, with ongoing operating and maintenance costs of $11.0 million/year. The volume of contaminated soil processed by this unit is 600,000 BCY over a 6-year period.

As with thermal desorption, capital and operating costs for incineration are not burdened with construction indirects, engineering, and contingency costs. Table 7.2-1 shows the cost components that makeup the RMA incineration capital and operating costs. The unburdened

capital cost of incineration is $21.8 million. For the 600,000 BCY cleanup, the unit capital cost for incineration is $36.37/BCY.

7.2.2 Process Performance

The fuel requirement per ton of soil treated is typically more than 50 percent higher for a rotary kiln incinerator than a direct-fired desorber because the soil, water vapor, and combustion gases must be raised to the higher operating temperature of the incinerator. The higher operating temperature also increases the specific volume of the off-gas so that gas volume per ton of soil is almost three times higher for incineration than for thermal desorption. As a result, a rotary kiln incinerator operating at 760°C has about one-third the soil processing rate of a similarly sized thermal desorber operating at 315°C, assuming similar waste content in the feed soil.

The energy expended in vaporizing soil moisture is a lower fraction of the incineration heating requirement when compared to thermal desorption. For example, as soil moisture content increases from 5 to 20 percent of the feedstock weight, the heat load associated with vaporizing water increases from 10 to 40 percent of total fuel fired compared to an increase from 30 to 70 percent for the same moisture range in thermal desorption. Changes in moisture content have less impact on the soil processing rate.

As feed moisture levels increase, handling and placement difficulties begin to limit the practicality of using rotary kiln incineration as a treatment approach. The contaminated medium must contain between 20 to 30 percent solids to be processable. Sludges or dredged soils may require dewatering or blending with a drier material to meet the solids content requirement.

As with thermal desorption, a high fraction of fine silt or clay can produce dusting in the kiln and increased particulates carryover into the off-gas treatment train. The presence of VOCs and natural organic compounds present in the soils can complicate the operation of the incinerator. High levels of salts in some soils near the basins add to the generation of acid gases in the incineration desorption step. The salts may adhere to rotary kiln refractory lining or remain as

slag in the SCC. Structure debris are more abrasive than soil and will increase wear of the refractory lining and contact parts of the incinerator.

Incineration has been demonstrated to be effective at commercial facilities for the destruction of halogenated and nonhalogenated VOCs, halogenated and nonhalogenated SVOCs, PCBs, pesticides, dioxins, and furans from soil matrices. It is potentially effective for these same organic contaminant groups in sludges, but treatability study information is not as extensive as the information for soils. The technology volatizes metals such as mercury from soils and removes volatilized inorganics in the off-gas treatment system.

Transportable incinerators have been successfully used to remediate PCB-contaminated soils at several Superfund sites. Weston has extensive performance information for its TIS at full-scale operation (5 to 6 tons/hour). The TIS system consists of a transportable, direct-fired, rotary calciner operating between 650°C and 1,200°C. The associated SCC, bag house, and acid gas scrubber are also transportable. The unit has been demonstrated at full scale at the Lauder Salvage Yard (Illinois) where it achieved a DRE of 99.9999 percent for PCBs. In another instance, EPA operated a transportable rotary kiln incinerator (EPA-1) at Denny Farms (Missouri) to remediate soils contaminated with chlorinated organic compounds including aldrin, chlordane, and Silvex. Again, demonstrated DREs were 99.9999 percent.

EBASCO conducted two bench-scale incineration treatability studies on RMA soils in 1988 using a two-reactor incineration test apparatus. The study showed that OCPs present in Basin A and F soils at total concentration levels of several hundred to several thousand ppm could be removed from the soil matrix at temperatures as low as 400°C, but that overall destruction depended on the operating temperature of the second reactor being at least 800°C.

Some of the volatile metal contaminants are also volatilized at incinerator operating temperatures. Virtually all of the mercury and more than 20 to 30 percent of the arsenic are likely to be

removed with the off-gas stream. The chemical and physical characteristics of the soil are changed by incineration so that residual inorganic contaminants may be more leachable.

Other inorganics in the form of alkali chlorides and sulfates are also present in RMA soil samples. Bench-scale testing indicates that large fractions of the sodium and potassium salts may be removed from the soil matrix and add to the potential slagging problem in the SCC and to general corrosion problems in the off-gas treatment equipment.

Based on the performance of RCRA-permitted commercial incinerators, the concentrations of organic contaminants in RMA soils should be reduced below their detection levels by rotary kiln incineration. DREs of 99.99 percent have been demonstrated in bench-scale treatability studies of RMA soils containing a wide range of contaminants including volatile halogenated organics (VHOs) and pesticides, and commercial units regularly achieve DREs of 99.9999 percent with PCB- and dioxin-contaminated soils. Table 7.2-2 summarizes performance information for incineration of pesticide-contaminated soils.

7.3 OFF-POST INCINERATION OF STRUCTURAL DEBRIS

Off-post incineration of structural debris involves the use of direct-fired equipment to destroy organic contaminants in the debris. Debris is loaded at RMA for rail or truck transport to an off-post facility where it is incinerated in a rotary kiln incinerator. The off-post incineration facility is responsible for disposal of all sidestreams. Based on the DSA screening process, off-post incineration was retained for treatment of structural debris only.

7.3.1 Process Description

Off-post incineration of structural debris is performed by a facility that is responsible for incineration as well as disposal or treatment of all sidestreams generated from the debris. Section 4.0 discusses the transportation of structural debris to the off-post incineration facility in detail.

The feed pre-treatment area at the selected facility requires a fully enclosed building. The building encloses the contaminated material handling, sizing, and mixing equipment and the incinerator feed hoppers. The incinerator feed pre-treatment sequence might consist of the same steps described under thermal desorption: feed hopper, magnetic separator, primary shredder, disc classifier, and final shredder.

Acceptance of the structural debris is predicated on the incineration contractor's review and acceptance of the waste material data sheet that profiles the waste and their examination of a representative sample. It was assumed that structural debris is acceptable, although subject to the following restrictions:

- Concrete may not contain reinforcing steel bars and must be small enough to be handled manually
- Steel pieces cannot be larger than 6 inches and must be packed in 30-gallon poly drums
- Wood must be shredded into small pieces

Waste tracking by the contracted incineration facility is an integral part of this treatment process. Each container of waste is tracked by a bar code labeling system that contains pertinent information about the material. Records are maintained on a computer database, which allows instant status tracking. The bar code is used to record the location of the waste when moves occur and to generate a certificate of disposal upon incineration.

Given the scale of the remediation implied by RMA structural volumes, off-post incineration requires a high processing capacity incineration facility. Examples of off-post facilities capable of treating structural debris include the following:

- Environmental Systems Company (ENSCO), El Dorado, Arkansas: Three direct-fired rotary kiln incinerators are available. Full-scale capacity is 18.2 tons/hour if the British thermal unit (BTU) content of the waste stream does not exceed 218.4 million British thermal units(MMBTU)/hour.

- U.S. Pollution Control, Inc. (USPCI), Houston, Texas: Two direct-fired rotary kiln incinerators are available. Full-scale capacity is 14.6 tons/hour if the BTU content of the waste stream does not exceed 182 MMBTU per hour.

All sidestreams and post-treatment requirements for incineration of structural debris are the sole responsibility of the contracted incineration facility. Once the structural debris is accepted by the contracted facility, RMA relinquishes any further responsibility.

Appendix A presents the action-specific ARARs governing the performance of incineration. Adherence to ARARs and other applicable regulations is the sole responsibility of the contracting off-post incineration facility. Section 4.0 discusses the ARARs related to off-post transportation.

As shown in Table 7.3-1, the capital and operating cost for off-post incineration are taken from a compilation of vendor quotations. These costs are based on the assumption that as part of the off-post incineration technology, structural debris is shredded prior to leaving RMA. It was also assumed that the sized structural debris consists of the following proportions: 50 percent concrete, 20 percent brick/tile, 20 percent wood, and 10 percent steel. The unit cost for shredding is $0.31/CY (capital) and $13.32/CY (operations). The unit cost for a transfer facility is $0.24/CY (capital) and $0.41/CY (operations). Off-post incineration and disposal of all sidestreams costs $0.89/CY (capital) and $4,110/CY (operations), and includes the cost of transportation.

7.3.2 Process Performance

Based on specifications of the contracted incineration facility, structural debris may require pre-treatment. Concrete from the structures demolition may not contain reinforcing steel bars that must be removed from the concrete and sized down to pieces not to exceed 6 inches prior to treatment. The remaining concrete must be small enough to be handled manually. In addition, all wood must be shredded.

Off-post incineration of structural debris is an effective means of treating debris. Once the debris is accepted by the contracted facility, RMA relinquishes all responsibility for the debris. The contracted facility must follow all appropriate regulatory requirements for treatment and disposal of generated sidestreams form the incineration process.

Results from RMA and other sites are not applicable to this technology. Destruction efficiencies, volume reduction, and sidestream disposal information can be obtained from the contracted incineration facility. Facility specifications and operating performance standards can also be obtained from the contracted incineration facility.

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Table 7.1-2 Performance Information on Thermal Desorption of Pesticide-Contaminated Soils

Year	Source	Location	Scale	Results
1989	Shell Development Company	West Hollow Research Center Houston, TX	Laboratory Scale	RMA soils from Basins A, C, and F with total OCP levels of 300 to 20,000 ppm were heated in tube and box furnaces at temperatures between 250°and 650°C for periods of 30 to 150 minutes. Even at the lowest temperature, total OCP levels were reduced to between 1 and 50 ppb.
1990	Morrison-Knudsen Environmental Services	IT Corporation Technology Development Center Knoxville, TN	Bench Scale	Basin F soil with a total OCP level of 780 ppm was heated in a rotary thermal apparatus at temperatures between 300° and 650°C for periods of 15 to 60 minutes. Even at the lowest temperature and shortest time, total OCP levels were reduced to below detectable levels.
1992	Roy F. Weston, Inc.	IT Corporation Technology Development Center Knoxville, TN	Laboratory and Bench Scale	Soils composited from Basins A, C, and F and from South Plant sites with total OCP levels were heated in a rotary thermal apparatus at temperatures between 200°C and 350°C for periods of 5 to 50 minutes.
1992	Canonie Environmental	Litchfield Airport Superfund Site Avondale, AZ	Full Scale	Underway for remediation of pesticides, including DDE and DDT.

DDE Dichlorodiphenylethane
DDT Dichlorodiphenyltricloroethane
OCP Organochlorine Pesticides

Table 7.2-2 Performance Information on the Incineration of Pesticide-Contaminated Soils

Year	Source	Location	Scale	Results
1988	EBASCO	Hittman-Ebasco Laboratory Columbia, MD	Bench Scale	RMA soils from Basin F were heated in a bench-scale incineration unit at primary reactor temperatures between 650°and 900°C and secondary reactor temperatures between 650° and 1,200°C. OCPs were removed from the soil at even the lowest primary operating temperature, but overall DREs of 99.99 percent required a minimum of 800°C in the secondary combustion chamber.
1988	EBASCO	Hittman-Ebasco Laboratory Columbia, MD	Bench Scale	RMA soils from Section 36 (Basin A) were heated in a bench-scale incineration unit at primary reactor temperatures between 450° and 900°C and a secondary reactor temperature of 1,200°C. Results confirmed Basin F testing and suggested that low-temperature thermal desorption might be tried in place of the primary incinerator. Metals partitioning results were inconclusive.

OCP Organochlorine Pesticides

Table 7.1-1 Capital and Operating Costs for Direct Thermal Desorption

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost	Site Preparation	$ 830,000	Source: 1
	Soil Pre-treatment	2,170,000	
	Thermal Desorption	12,820,000	Based on two thermal treatment trains with a common
	Brine Concentration	5,109,000	feed preparation building. Total soil feed rate at 20%
	Spare Parts	2,000,000	moisture is 74 tons/hour. Onstream time is 5,700 hours
	Buildings	7,308,000	per year.
	Piping	2,790,000	
	Electrical & Instrumentation	3,005,000	
	Startup, Shakedown, and Test	4,240,000	
	Field Indirects	486,000	
	Field Staff	1,750,000	
	Total Facility (74 tons/hour)	$42,508,000	
Operating Costs	Operations & Maintenance Labor	$ 5,585,000	Source: 1
	Maintenance Materials	550,000	
	Analytical	580,000	
	Utilities	12,750,000	
	Chemicals	1,120,000	
	Consumables	1,250,000	
Total Operating		$21,835,000	

Sources:

1) Weston, Roy F., Concept Engineering Study Report for Thermal Desorption Systems for Rocky Mountain Arsenal Soils, August 1992 (Weston 1992b).

Table 7.2-1 Capital and Operating Costs for Direct Incineration/Pyrolysis

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost	Site Preparation	$ 830,000	Source: 1
	Soil Pre-treatment	2,170,000	
	Incineration	13,960,000	Based on two incinerator trains with a common feed
	Brine Concentration	5,109,000	preparation building. Total soil feed rate at 20% moisture is
	Spare Parts	2,000,000	56 tons/hour. Onstream time is 5,700 hours per year (65%).
	Buildings	7,308,000	
	Piping	2,790,000	
	Electrical and Instrumentation	3,005,000	
	Startup, Shakedown, and Test	4,240,000	
	Total Facility (56 tons/hour)	$43,648,000	
	Single Train (28 tons/hour)	$21,824,000	
Operating Costs	Operations & Maintenance Labor	$ 2,793,000	Source: 1
	Maintenance Materials	550,000	
	Analytical	290,000	Adjusted for EBASCO Task 17 operating conditions, but
	Utilities	6,113,000	without the use of 40% supplemental oxygen in the kiln and
	Chemicals	424,000	the SCC. Weston figures divided by 2 for single-train
	Consumables	625,000	facilities. Utilities, chemicals, and brine disposal adjusted for reduced throughput.
Total Operating		$10,794,000	

Sources:

1) Weston, Roy F., Concept Engineering Study Report for Thermal Desorption Systems for Rocky Mountain Arsenal Soils, August 1992 (Weston 1992b).

2) EBASCO, Full-Scale Incineration System Conceptual Design for Basin F Wastes, Task 17, September 1988 (EBASCO 1988).

Table 7.3-1 Capital and Operating Costs for Off-Post Incineration of Structural Debris

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost	Transfer Facility	$0.24/CY	Vendor Quote
	Shredder	$0.31/CY	"
	Off-Post Incineration	$0.89/CY	"
Operating Cost	Transfer Facility	$0.41/CY	Vendor Quote
	Shredder	$13.32/CY	"
	Off-Post Incineration	$4,110/CY	"

CY Cubic Yards

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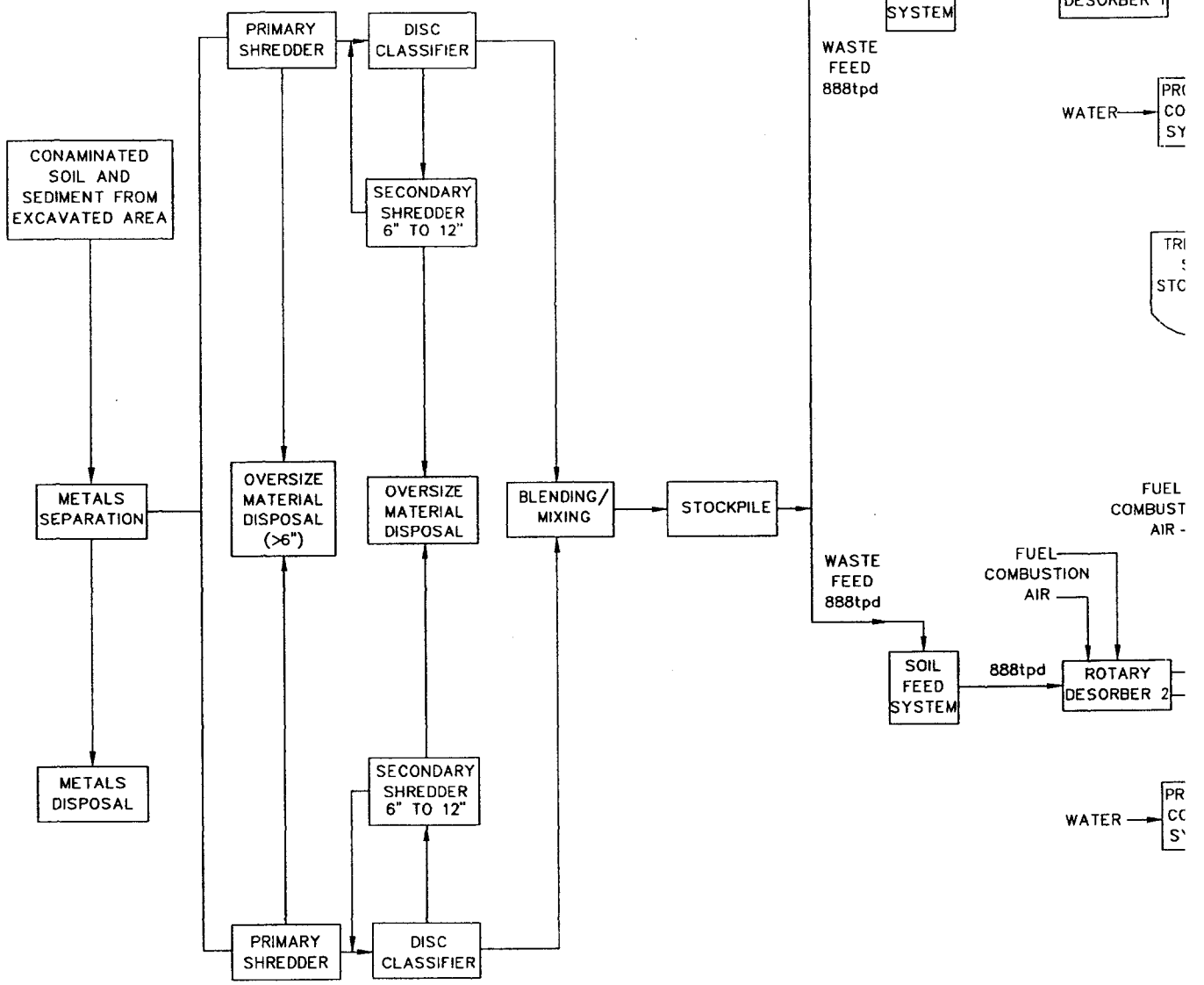
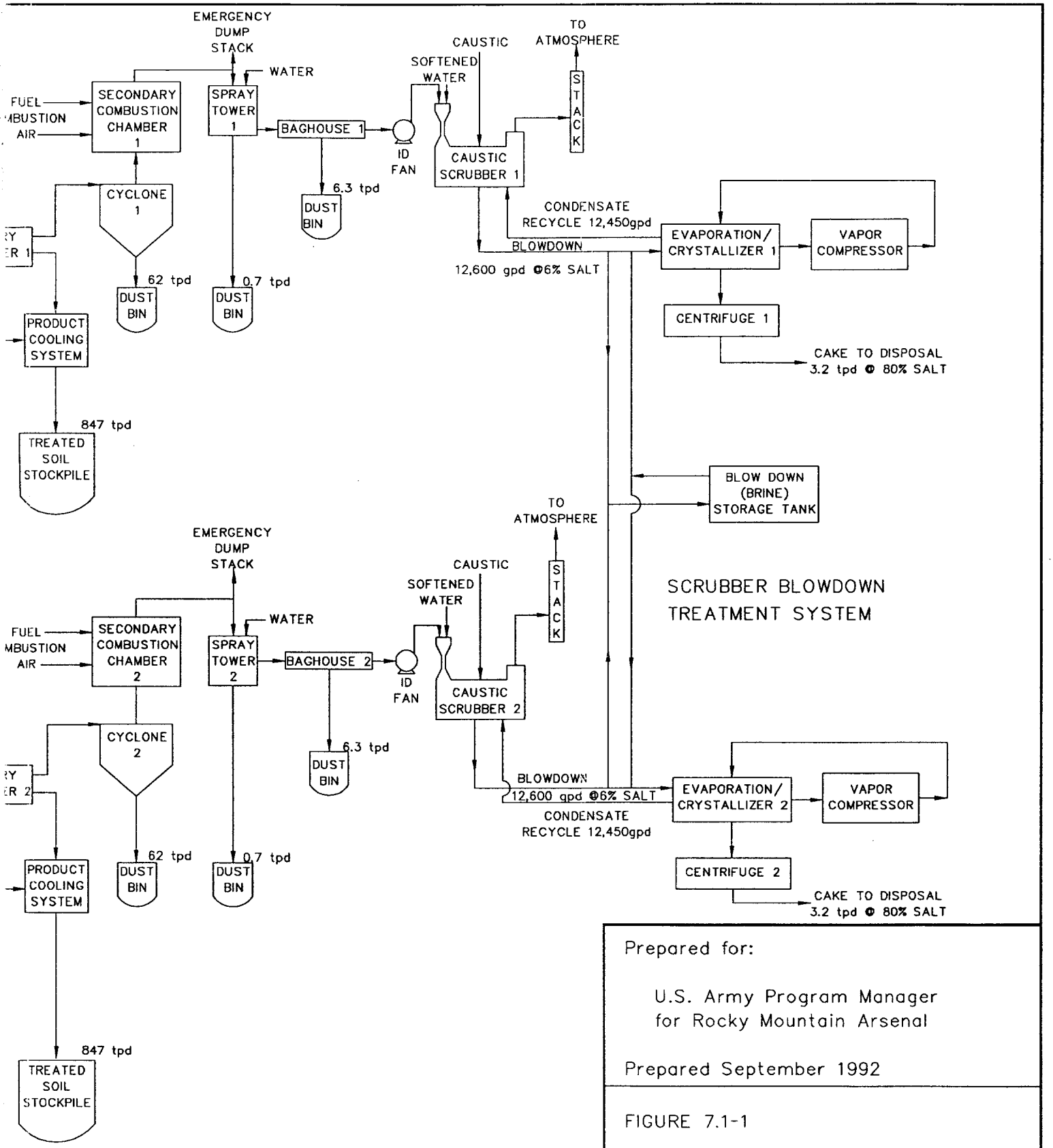


SOIL HANDLING AND PRE-TREATMENT SYSTEM

THERMAL



MAL DESORPTION TREATMENT SYSTEM

Prepared for:

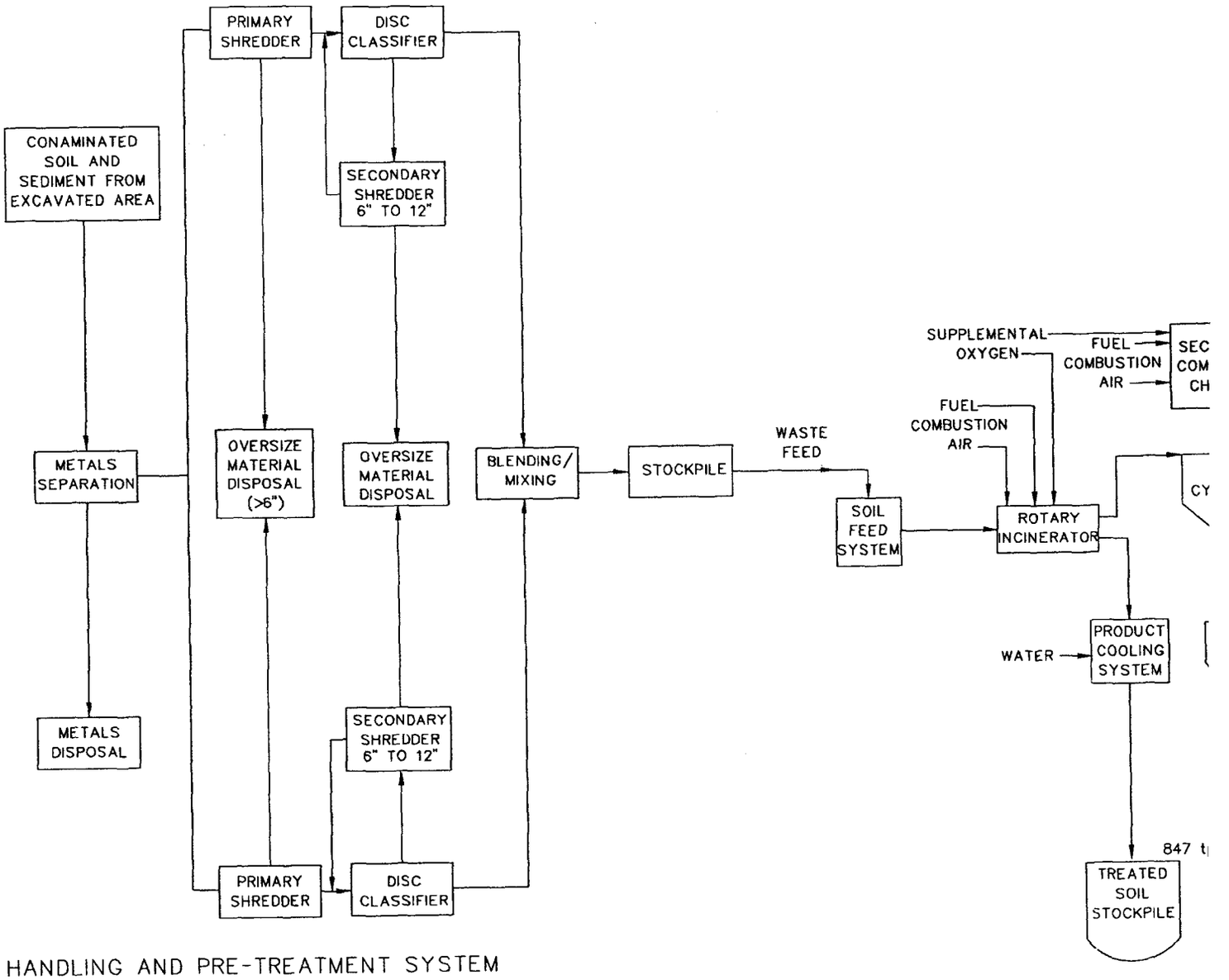
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared September 1992

FIGURE 7.1-1

BLOCK FLOW DIAGRAM FOR
THERMAL DESORPTION

Rocky Mountain Arsenal.
Prepared by: Ebasco Services Incorporated



SOIL HANDLING AND PRE-TREATMENT SYSTEM

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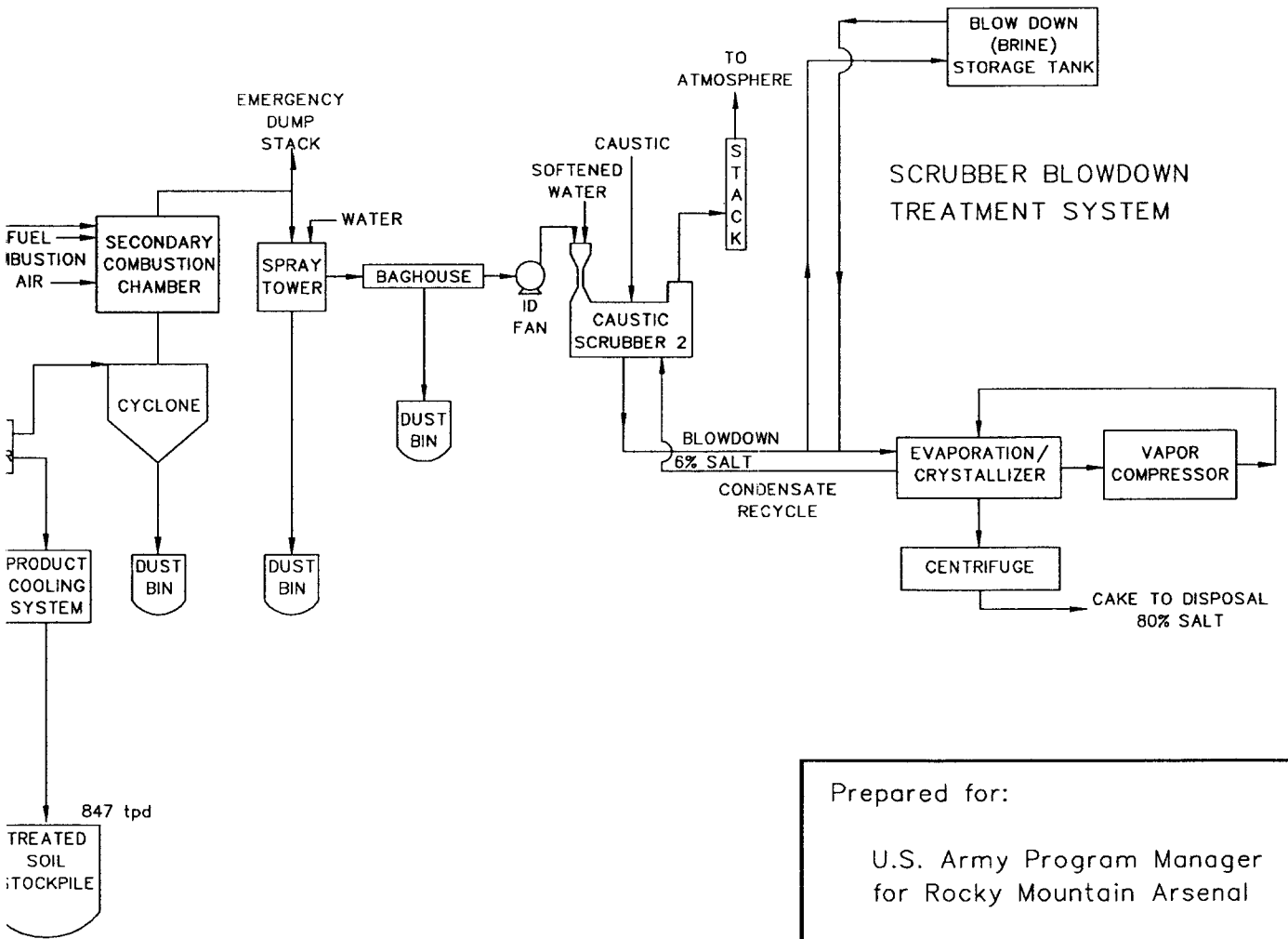

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared September 1992

FIGURE 7.2-1

ROTARY KILN INCINERATION

Rocky Mountain Arsenal.
Prepared by: Ebasco Services Incorporated

8.0 IN SITU THERMAL TREATMENT

In situ thermal treatment involves the in-place heating of contaminated soils, sediments, sludges, and structures. VOCs and SVOCs are vaporized from the solid phase and either recovered or destroyed by the off-gas treatment system. In most of these in situ processes, water vaporizes before the less volatile organic compounds, and the energy required to drive off the soil moisture may represent a sizable percentage of the total energy usage. As the operating temperature of the process is raised, more of the natural organic content of the soil accompanies the heavy organic contaminants. Elevated treatment temperatures produce irreversible physical and chemical changes in the soil, and extreme treatment temperatures induce melting and fusion of the soil matrix.

Sections 8.1, 8.2, and 8.3 describe the surface soil heating, subsurface soil heating, and in situ vitrification process options for treating soils, respectively. Section 8.4 describes the specialized process option of hot gas decontamination of structures and debris.

8.1 SURFACE SOIL HEATING

The surface soil heating process, or enhanced surface soil vapor extraction process (ESSVEP), heats soil within 12 inches of the surface to temperatures at which the contaminants of concern are readily volatilized, collected, and treated. The process consists of a hooded grid of electrical resistance heating elements, an induced draft fan, and off-gas treatment system. The process is most effective at removing surface or near-surface SVOCs such as aldrin, dieldrin, and endrin. This technology is used as a stand-alone treatment in alternatives developed for the soils medium as follows: Alternative B11 (In Situ Thermal Treatment) and as part of Alternative 20 (In Situ Thermal Treatment; Direct Thermal Desorption; Direct Solidification/Stabilization) and Alternative B11b: In Situ Thermal Treatment (Surface Soil Heating, Radio Frequency [RF] Heating).

After the successful laboratory demonstration of thermal desorption of OCPs from RMA soils, an ESSVEP pilot-scale test module was developed for use on surficial soil contamination at

RMA. The technology was demonstrated during pilot-scale testing in Basin C where ESSVEP reduced SVOC concentrations in RMA soil to levels less than 10 ppb in the top 12 inches of soil. The heating duration was 36 hours and the soil was heated to approximately 200°C to a depth of 12 inches.

Based on the DSA screening process, surface soil heating was retained for evaluation in the DAA for one of the human health medium groups (South Plants) and one of the biota medium groups (Surficial Soils). Surface soil heating is also used as part of treatment alternatives developed for the Basin A, Secondary Basins, Lime Basins, South Plants, Buried Sediments/Ditches, and Undifferentiated Medium Groups.

8.1.1 Process Description

The ESSVEP process (Figure 8.1-1) allows the concepts of traditional soil vapor extraction to be extended to SVOC contaminants and is capable of reducing their concentrations to very low levels. A heater is used to raise the soil temperature in the treatment zone to a level at which the contaminants of concern are more readily volatilized. The process is made up of several different components: soil heating assembly, heater support structure, insulation, impermeable cover, vapor collection system, vapor treatment unit, and power supply. The soil heating assembly and impermeable cover can be designed such that the entire unit can be moved quickly from one site to another. The vapor collection system ensures that the contaminants released from the soil flow to a vapor treatment system where they are collected or destroyed.

The soil heating assembly consists of separate heating modules connected mechanically and electrically. Each module contains heating elements that have the potential to be operated up to temperatures of 1,000°C with a design power rating of 70 kilowatts (kW). Power to the soil heater assembly is supplied from a 200 kW, diesel-powered generator. A rigid stainless steel hood is placed over the heater assembly. The hood is designed so that the central vent pipe is connected to a vacuum line and vapor treatment system. To ensure that the system operates under negative pressure, a flexible skirting made out of temperature-resistant silicone rubber is

attached to the perimeter of the hood to provide a seal between the ground surface and the hood (Figure 8.1-2).

During heating, vapors are collected from beneath the soil heating assembly to prevent vaporized contaminants from escaping to the atmosphere or moving to the surrounding soil. Several vapor treatment options are available to use in conjunction with surface soil heating including GAC, catalytic oxidation, and incineration. GAC is widely used for vapor control because it is applicable to a wide variety of organic contaminants, concentrations, and flow rates. This technology is most cost effective where vapor concentrations and flow rates are low. For high flow rates and concentrations, carbon regeneration costs become excessive.

Surface soil heating produces three sidestreams: wastewater, treated off gas, and spent carbon. The wastewater is transferred to a nearby water treatment facility. Spent carbon from the GAC units is regenerated off post, and the treated off gas is released to the atmosphere via a stack after meeting appropriate regulatory requirements.

Surface soil heating is a site-specific technology currently being developed by Shell Oil Company (Shell). The technology has progressed through pilot-scale testing, although full-scale implementation has yet to be completed. Given the scale of the remediation that is required by RMA soil volumes, several modular units will be necessary to achieve effective treatment in a timely manner.

Projections of full-scale implementation by Shell include construction of 50- by 50-ft modules capable of treating the first 12 inches of surface soil to the operating temperature of 250°C. The heating elements are similar to those demonstrated during the treatability test described above, although the type of electrical connections, heater spacing, and heater length may be altered to change the heating density where necessary. Treatment rates for surface soil heating can vary depending on the configuration of the heating assembly, capacity of the process equipment, and the geology of the treatment site, but a 50- by 50-ft unit can generally treat 3.5 acres annually.

Post-treatment of the soil is required, as is revegetation to restore the site to its original condition. Fertilizers and native humic material to effectively maintain a vegetative cover must be used to supplement the organic and moisture content of the treated soil.

Since RMA is in a nonattainment area, the off-gas treatment system must meet federal and Colorado primary ambient air quality standards of performance for new emissions sources. The action-specific ARARs governing the use of surface soil heating and its associated off-gas treatment train are found in Appendix A. These action-specific ARARs primarily address discharge of untreated or treated wastewater, air emissions during operation, and worker protection during operation.

The capital and operating cost for the ESSVEP technology are taken from the draft pilot-scale field test report (Shell 1991). Projected economics are dependent on the operating parameter assumptions used to evaluate the process. For the purpose of this analysis, it was assumed that the top 12 inches of soil can be remediated by using ESSVEP over a 48-hour heating period. At the end of the heating period, the soil heating assembly is allowed to remain in place for an approximate 40-hour cooling period. At the end of the cooling period, an 8-hour period is required to relocate the process equipment to the next site. The ESSVEP apparatus was assumed to require one full-time operator on a time-averaged basis. During heating and cooling, one operator is able to take care of several sets of equipment, but during relocation, several operators are necessary. The current capital cost for a full-scale ESSVEP unit is estimated to be $951,200, with ongoing operating and maintenance costs of $27.30/CY (Table 8.1-1).

8.1.2 Process Performance

As demonstrated in the pilot-scale test at RMA, uniform heating of the soil is difficult to achieve due to varying soil structure and gradation and moisture content (Shell 1991); thus the success and treatment rate of surface soil heating depends upon site-specific conditions. For example, if the area to be treated contains both sandy and dense clay layers, the tendency for "baking"

portions of the soil greatly increases energy requirements and changes the composition of the original soil.

Surface soil heating has not been demonstrated at full scale, so no information on the operability of the units exists. The heating units are constructed of readily available materials, but commercial vendors do not currently exist.

The ESSVEP was demonstrated during a pilot-scale study on RMA soils using a 10- by 10-ft soil heating assembly. The primary objective was to demonstrate a reduction of SVOC contaminants in the top 6 inches of soil to potential cleanup levels by heating the topsoil to at least 250°C. The test was performed in the Shell Plot Test Area in Basin C. The soil at the test site initially contained approximately 9,000 ppb of total OCPs (i.e., aldrin, dieldrin, endrin, and isodrin) in the top 6 inches and 200 ppb in the 6- to 12-inch depth interval.

The test was completed after 36 hours of operation. While the heating elements performed well, the vapor flow was lower than expected due to a partially obstructed vapor collection pipe. The 6-inch soil temperatures reached maximum values of 445°C in the middle of the plot and 338°C at the edge of the plot. The 12-inch soil temperatures reached maximum values of 206°C in the middle of the plot and 164°C at the edge of the plot.

Post-test soil sampling showed that OCPs were removed to concentrations of less than 16 ppb in the 0- to 6-inch and the 6- to 12-inch depth intervals. No significant downward movement of contaminants was indicated by the results. Only small amounts of OCPs were detected in the vapor leaving the soil and in the vapor treatment system, suggesting that OCPs may have been destroyed during soil heating or degraded into byproducts. Soil organic matter was degraded as the soil was heated, producing elevated total hydrocarbon concentrations in the vapor stream. Metals in the soil were relatively unaffected by the process as compared to the organic reduction. However, there was a slight reduction of mercury and arsenic, which indicates that the inorganic elements vaporized into gaseous fumes. These gaseous inorganics may have exited the system

with the volatized organic contaminants. Additional off-gas treatment is necessary to remove these inorganics from the off-gas stream.

Surface soil heating using ESSVEP has only been demonstrated in a pilot study on RMA soils. Two sets of soil samples were composited by depth for this demonstration. The first was taken from the inner 6-ft by 6-ft region called the "core" region. The other set was taken along a line one foot from the edge of the heater, the "edge" region. The core region was intended to be the basis of the calculation of an overall removal efficiency, whereas the edge region was intended for detection of any large edge effects. Table 8.1-2 shows the OCPs analytical results of the pre- and post-test soil sampling.

For both the core and edge regions of the treated area, the OCPs concentrations were reduced to levels nondetectable by EPA Method 8080 in the top 6 inches and the 6- to 12-inch soil interval. Since the treatment temperature target was reached in the edge region, there are no significant differences in treatment effectiveness for the OCP removal between the core and edge regions. The OCP removal efficiency was greater than 99.95 percent in the top 6 inches and greater than 96 percent in the 6- to 12-inch soil interval.

8.2 SUBSURFACE SOIL HEATING

Two processes are being considered for subsurface soil heating: Radio frequency (RF) heating and Shell's enhanced deep soil vapor extraction process (EDSVEP). RF heating converts electrical energy to an electromagnetic form that dissipates in the soil mass as heat. The soil is heated much as food is heated in a microwave oven, and the heat desorbs VOCs and SVOCs from the soil mass. EDSVEP heats the soil by introducing heated air through injection vents. The hot air thermally desorbs the contaminants, which are then removed from the soil via extraction vents. Both processes employ a pattern of borings to inject heat into the soil and extract vapors from the soil mass. Both are innovative technologies and have been demonstrated in the field on RMA soils.

Subsurface soil heating is combined with cement-based solidification for the following alternatives evaluated for the soils medium: Alternative 19 (In Situ Thermal Treatment; In Situ Solidification/Stabilization) and as a sole treatment for Alternative 19a (In Situ Thermal Treatment). These in situ heating processes are designed to remove only organic contaminants; they are not intended to be effective in removing or stabilizing inorganic contaminants. Hence, in situ cement-based solidification follows the thermal treatment step to stabilize inorganic contaminants in the soil matrix, if required.

Based on pilot-scale treatability studies conducted with RMA soils, RF heating is effective in reducing the concentrations of VOCs and SVOCs of concern to or below PRGs. The vapors produced during heating are treated in a vapor treatment system that removes or destroys the VOCs and SVOCs.

Currently, a treatability study is being conducted on RMA soils to evaluate the effectiveness of EDSVEP (Shell 1992). Although the test has not been completed and a detailed final analysis of the results performed, it appears that EDSVEP may be an effective in situ alternative for the remediation of subsurface soils contaminated with low-volatility compounds. However, further analysis of the data generated during the treatability study must be performed to better define the range of soil types and contaminants for which EDSVEP may be effectively used.

Based on the DSA screening process, subsurface soil heating is retained for the Basin A, Secondary Basins, Lime Basins, South Plants, Buried Sediment/Ditches, and Undifferentiated Medium Groups.

8.2.1 Radio Frequency Heating

RF heating is a process for heating large volumes of soil using electromagnetic energy. An array of electrodes is inserted into the ground in rows and the soil between the electrode rows is volumetrically heated. The mechanism of heat generation is similar to that of a microwave oven,

and it does not rely on the thermal conductivity of the soil matrix. Vapors extracted from the soil are treated in a vapor treatment system.

8.2.1.1 Process Description

This process involves the desorption and collection of organic compounds through the placement of electrodes into a grid of boreholes. The soil moisture and solids absorb the electromagnetic energy produced by these electrodes and convert the energy to heat as a result of dipole rotation and molecular vibration. The organics in the soil material are mobilized by vaporization or steam stripping or are thermally decomposed. The mobilized contaminants are then collected at the surface in a hood and drawn into an off-gas treatment system. The process equipment includes a radio frequency generator, a vapor collection and containment system, and a vapor treatment system.

RF heating is implemented by inserting electrodes in the ground and heating the soil to drive off organic contaminants. Power is applied to the exciter electrodes and is transmitted to the ground electrodes. The outer rows of electrodes limit the field boundary of the energy input to the system, and the depth of the electrodes defines the depth of soil to be treated. As the soil is heated, volatilized contaminants and steam are collected from the soil through perforated electrodes that serve as vacuum extraction vents.

The ground surface of the heated soil and/or area surrounding it are covered with a vapor barrier that consists of an insulated, fiberglass-reinforced, silicone rubber sheet. The barrier is secured under the soil berm surrounding the area to be treated. The vapor barrier has four functions: to help maintain a vacuum in the soil for vapor collection, to prevent fugitive emissions from the heated surface, to control infiltration of air into the heated zone and thus into the vapor treatment system, and to prevent condensation of vapors exiting the soil.

The vapor containment and collection system collects the subsurface vapors, steam, and volatilized constituents and transports them to the vapor treatment system. By applying a vacuum

to the perforated electrodes under the vapor barrier, steam and vapor are drawn from the heated soil. The vapor collection manifold and pipes leading to the collection points are heat-traced and covered with fiberglass insulation to prevent condensation of the vapors prior to entering the vapor treatment system (Weston 1992).

Several options are available for the vapor treatment system including GAC, catalytic oxidation, and incineration. Based on the types of organic contaminants, concentrations, and flow rates, the thermal incinerator was selected as the vapor treatment system for the scale-up design for RMA (Weston 1992).

In the incineration process, hot gases collected from the heated blocks of soil are destroyed in the incineration chamber. Depending upon the concentration of the organic contaminants in the collected gases entering the incinerator, additional fuel may have to be added to the incinerator. The vent gases are scrubbed to remove hydrochloric acid formed during incineration and then quenched.

RF heating produces two sidestreams: wastewater and off gas. The wastewater is transferred to a nearby water treatment facility, and the treated off gas is released to the atmosphere via a stack after meeting appropriate regulatory requirements.

RF heating is a site-specific technology that has progressed through several pilot-scale tests, including several at RMA and at Volk Air National Guard Base. Given the scale of the remediation required by RMA soil volumes, RF heating will require several modular units operated simultaneously to achieve effective treatment in a timely manner.

Projections of full-scale implementation at RMA include construction of a depth-dependent modular unit. The treatment system design is based on a vertical electrode placement on a rectangular grid pattern dictated by the depth of the contamination. In general, the proposed full-

scale module design treats a soil block that is 100 ft long by 48 ft wide and 10 ft deep (Weston 1992).

The electrodes are made from 3-inch schedule 40 threaded aluminum pipe. All electrodes are slotted and perforated and the gases and vapors formed in the soil are collected by applying a vacuum to the electrodes. In addition, two horizontal, perforated gas collection lines, connected to the vacuum system, are placed on the soil surface adjacent to the two outer sheet piling ground rows. These lines are used to collect gases rising to the surface.

Post-treatment of the soil after RF heating is required. Due to the heating of the soil matrix, revegetation is necessary to restore the site to its original condition. The soil organic content and moisture content need to be supplemented with fertilizers and native humic material to effectively maintain a vegetative cover.

Since RMA is in a nonattainment area, the off-gas treatment system must meet federal and Colorado primary ambient air quality standards of performance for new emissions sources. The action-specific ARARs governing the use of RF heating and its associated off-gas treatment train are found in Appendix A. These action-specific ARARs primarily address discharge of untreated or treated wastewater, air emissions during operation, and worker protection during operation.

The capital and operating cost for the RF heating technology are taken from the draft conceptual design proposed by Roy F. Weston (Weston 1992). The current capital cost for a full-scale RF unit is estimated to be $7,066,000 (Table 8.2-1). Operating and maintenance costs will vary depending upon the depth of treatment and the moisture content of the soil.

8.2.1.2 Process Performance

As demonstrated in the pilot-scale test at RMA, uniform heating of the soil is difficult to achieve due to varying soil structure, gradation, and moisture content; therefore, the success and treatment rate of RF heating will be very site-specific. For example, if the area to be treated contains both

sandy and dense clay layers, the tendency for "baking" portions of the soil greatly increases, thus increasing energy requirements as well as changing the composition of the original soil.

The Basin F soil tested at RMA caused corrosion and destruction of the electrodes and support equipment. Based on site-specific conditions, the materials of construction could be varied to ensure the structural integrity of the unit as the composition of contaminants in the soil changes. This could lead to either construction of several different types of units to treat varying soil compositions or high costs to maintain existing units.

Condensation of vapors under the vapor blanket also reduces the efficiency of the electrodes and increases energy requirements. The loss of energy by heat transfer through the vapor blanket and from the tent to the surrounding air proved to be a limiting factor during the pilot-test at RMA. The use of RF heating could also be limited by the proximity of RMA sites to the Denver airport. Specific radio frequencies may be restricted to avoid interference with airport operations, although the impact of potential restrictions is unknown at this time.

RF heating has been demonstrated to reduce concentrations of VOCs and SVOCs as well as individual OCPs and organophosphorus compounds during pilot-scale tests. The proven effectiveness of RF heating for a particular site or contaminant does not ensure that the treatment efficiencies achieved can be attained at other RMA sites.

In the treatability study at RMA, the soil initially had up to 5,700 ppm of individual OCPs (Weston 1992). Although contaminant concentrations varied greatly within the test plot, which measured approximately 14 ft by 9 ft by 13 ft deep, the pilot-scale treatment unit generally reduced contaminant concentrations.

A field test performed at the Volk Air National Guard Base in Wisconsin by IIT Research Institute (IITRI) was successful in decontaminating a former fire training pit in which sandy soil had been contaminated with jet fuel to a depth of about 13 ft (Dev 1990). A vertical array of

electrodes was installed in a 6- by 2-ft area to a depth of 7 ft. Over a 9-day treatment period, approximately 500 cubic feet of contaminated soil were heated to 160 degrees °C at an average power input of 30 kW. Results indicated contaminant removal rates in soil of 99.3 percent for volatile aliphatics, 99.6 percent for volatile aromatics, 94.3 percent for semivolatile aliphatics, and 99.1 percent for semivolatile aromatics. In addition, migration of contaminants into the heated zone from the untreated perimeter was observed through the injection of halon tracers.

The pilot-scale test demonstrated the ability of the RF heating technology to heat Basin F soil to more than 250°C, and in the process reduce the OCP concentrations to near or below PRGs. Endrin was reduced to concentrations below the 10^{-6} biological worker PRG. Aldrin, dieldrin, and isodrin were removed to below the 10^{-4} PRGs, but not the 10^{-6} PRGs. OCP removal efficiencies in the soil heated to 250°C or higher ranged from 97 to 99.9 percent. Inorganic removal rates were not analyzed as part of the pilot-scale test demonstration. Upon heating, some of the mercury and arsenic may volatize into gaseous forms and exit the system with the off-gas stream.

8.3 IN SITU VITRIFICATION

In situ vitrification uses electrodes to melt contaminated soil and debris into a vitreous mass. Contaminants are either destroyed by pyrolysis (organic contaminants) bound up in the melt mass (organic and inorganic contaminants) or driven off and captured in an off-gas treatment system (organic and inorganic contaminants). This technology is used as a stand-alone treatment in Alternative 21 (In Situ Vitrification), which was developed for the soils medium.

This technology is marketed exclusively by Geosafe Corporation. A treatability test performed by Geosafe using this technology on arsenic-, mercury-, and pesticide-contaminated soil and sludge from the M-1 Basin was considered successful (Geosafe 1989). Based on the DSA screening process, in situ vitrification was retained for only one of the soils medium groups—the Lime Basins Medium Group—specifically for the Buried M-1 Pits Subgroup.

8.3.1 Process Description

In situ vitrification uses electrical energy to melt soils and sludges for the purpose of thermochemically treating organic and inorganic contaminants present within the treatment volume. Most in situ vitrification applications involve melting of natural soils; however, other naturally occurring or process residual chemicals may be treated. Organic and volatile inorganic contaminants that are not destroyed by the vitrification process are driven out of the soil, collected, and treated in a vapor treatment system. In situ vitrification equipment consists of the electrode array, power source, off-gas hood, and vapor treatment system. Figure 8.3-1 illustrates a sequential staging of in situ vitrification.

In situ vitrification is currently being developed by Geosafe Corporation. The technology has progressed through 90 tests and demonstrations that ranged from bench- to full-scale tests. Pilot-scale tests on soil volumes ranging from 10 to 50 tons have been performed at sites such as Hanford, Oak Ridge National Laboratory, and Idaho National Engineering Laboratory. Large-scale tests treating a soil volume of approximately 1,000 tons have also been performed at the Hanford site. These tests have indicated that organic, inorganic, and radioactive contaminants have been effectively treated and are suitable for this technology. The DREs for both arsenic and mercury from the off-gas system is expected to be 99.97 percent (Woodward Clyde 1992/RIC 92051R02). However, in situ vitrification has not been used for commercial applications to date.

Geosafe has designed a full-scale system capable of treating an area with dimensions of 30 ft by 30 ft and a maximum depth of 30 ft. The total mass of soil that can be treated by this system is estimated to range from 800 to 1,000 tons. During operation, the process is able to treat 4 to 6 tons of soil per hour and requires 0.3 to 0.5 kilowatt hour (kWh) per pound of soil. Electric power is supplied to the electrode array through flexible conductors. Because the soil typically does not have sufficient electrical conductivity to allow initiation of the process, a conductive mixture of graphite and glass frit is placed on the surface between the electrodes to serve as an initial conductive starter. As electrical potential is applied between the electrodes, current flows

through the starter path, heating it and the adjacent soil to temperatures above 1,600°C. Upon melting, typical soils become electrically conductive and act as the primary conducting medium, allowing the process to continue beyond startup. The full-scale process takes place at temperatures ranging from 1,600°C to 2,000°C.

The electrodes consist of 2-inch-diameter molybdenum rods surrounded by a 12-inch-diameter graphite collar. The electrodes are placed in the soil by driving or vibrating the casings into place, placing the electrodes into the casings, and extracting the casings through vibration. The maximum spacing between electrodes is about 18 ft, which allows formation of a maximum soil melt width of about 30 ft. Electric power is supplied to the array of electrodes through a utility distribution system at typical transmission voltages of 12,500 or 13,800 volts; alternatively the power may be generated on site by a diesel generator.

The processing area is covered by an octagonal-shaped off-gas collection hood 55 ft across. The large distance between the edge of the hood and edge of the melt ensures off-gas containment. Flow of air through the hood is controlled to maintain a negative pressure relative to atmospheric pressure. Since the process occurs at temperatures well above combustion minimums, an ample supply of air is provided to ensure excess oxygen is available for combustion of pyrolysis products and organic vapors, if any exist. The off gases, combustion products, and air are drawn from the hood via an induced draft blower into the off-gas treatment system.

In order to ensure compliance with air emissions standards, the off-gas treatment system includes the following processes: quenching, pH-controlled scrubbing, demisting, heating (temperature and dew point control), particulate filtration, and activated carbon adsorption. A self-contained glycol cooling system cools the quenching/scrubbing solution, eliminating the need for an on-site cooling water supply.

Typically, the volume of gases evolving from the melt present less than 1 percent of the total volume of air processed by the off-gas treatment system. The off gas contains sweep air,

pyrolysis and combustion products, and some amount of particulate material. A substantial fraction of the off-gas contaminants are removed from the vapor stream at the initial quenching and scrubbing stages. The filters and carbon adsorption columns are utilized as polishing stages to ensure safe air emissions.

In situ vitrification produces three sidestreams: wastewater, treated off gas, and spent carbon. The wastewater is generated at a rate of approximately 1 gallon/CY of soil treated and is transferred to a nearby water treatment facility. The spent carbon from the GAC units is generated at a rate of three canisters per 1,000 CY of soil processed and is regenerated off post. The treated off gas is released to the atmosphere via a stack after meeting the appropriate regulatory requirements. Under maximum design conditions, off-gas flow is 1,800 cubic feet per minute (cfm) at 260°F, with water vapor comprising approximately one-half of the gas flow.

Site preparation of the treatment site is required. Groundwater in the soil treatment zone slows the vitrification process since the process requires that this water be vaporized prior to the melt progressing downward. Therefore, a sheet pile wall may be installed to cut off groundwater flow into the area during in situ vitrification. Any vegetative growth and any surface debris also must be cleared from the site.

Site restoration includes backfilling the site with clean soil, surface grading as necessary, removal of sheet piles, and revegetation. A soil volume reduction of 28 percent is anticipated from in situ vitrification, since the original soil porosity is eliminated during melting.

Since RMA is a nonattainment area, the off-gas treatment system must meet federal and Colorado primary ambient air quality standards of performance for new emissions sources. The action-specific ARARs governing the use of in situ vitrification and its associated off-gas treatment train can be found in Appendix A. These action-specific ARARs primarily address air emissions during operation and worker protection during operation.

The capital and operating cost for in situ vitrification technology are taken from the design analysis for the M-1 Settling Basins at RMA (Woodward-Clyde 1992/RIC 92051R02). Projected economics are dependent on the design assumptions used to evaluate the process. For the purpose of this analysis, it was assumed that one module is constructed to treat an approximate area of 30 ft by 30 ft down to a depth of 10 ft. This module processes soil at a rate ranging from 4 to 6 tons of soil/hour assuming a soil density of 0.84 tons/CY and a moisture content not to exceed 50 percent. The current capital cost for in situ vitrification is estimated to be $791,582 with ongoing operating and maintenance costs at $860.25/BCY per ton of soil treated (Table 8.3-1).

8.3.2 Process Performance

In situ vitrification was tested on a sample of soil and sludge from the M-1 Settling Basins at RMA (Geosafe 1989). Processing results from the bench-scale treatability test demonstrated the feasibility of using in situ vitrification to process the subject contaminated soil/sludge into an environmentally stable and compact glass product. Approximately 81 to 86 percent of the arsenic was immobilized in the melt, and the remaining arsenic was volatilized and released as off gas. All of the mercury is anticipated to be volatilized. The vitrified material passed the Toxicity Characteristic Leaching Procedure (TCLP) requirements, the leachate solution showing levels of 0.91 miligram per liter (mg/l) for arsenic and 0.0001 mg/l for mercury. Destruction efficiencies in the melted material were 98.3 percent for dieldrin and 96.6 percent for aldrin. Combining these efficiencies with the removal efficiency for the off-gas treatment system results in a total DRE of 99.99+ percent for aldrin and dieldrin.

Prior to vitrification, groundwater must be driven off by system heat since a higher soil moisture content slows the vitrification process, thereby increasing costs. To dewater the soil prior to treatment, groundwater extraction wells or groundwater barriers may be used. Groundwater is present at shallow depths at the M-1 Basins. It was assumed that dewatering of the site prior to in situ vitrification treatment is required, so the current system design is based on the installation of groundwater barriers.

Buried metals greater than 5 to 15 percent of the melt weight between the electrodes can lead to a conductive path within the treatment plot that may short circuit the electrodes. Electrodes that are to be fed into the treatment plot as melting progresses may have to be designed to control this phenomenon. In addition, loosely packed rubbish or other combustible material may cause an underground fire; sheet piling or another type of subsurface barrier will help prevent this problem.

The process is potentially effective in destroying or immobilizing contaminants as a result of the melting process. However, it is suspected that during the in situ vitrification process contaminants may be driven into the surrounding soil of the inert mass causing additional contaminant migration. At a minimum, bench-scale treatability studies are required to establish the effectiveness of this technology.

8.4 HOT GAS DECONTAMINATION OF STRUCTURES AND STRUCTURAL DEBRIS

Hot gas decontamination is a thermal process designed to release VOCs and SVOCs from structural materials. The materials are heated to temperatures of 400°C, releasing adsorbed contaminants and directing them to an off-gas treatment system. To control energy costs, standing structures are sealed and insulated, and structural debris is treated in an enclosure. Based on the DSA screening process, hot gas decontamination was retained for treatment of both standing structures and structural debris.

Based on pilot-scale tests, hot gas decontamination has been proven effective in removing mustard contamination from structural materials (Battelle 1987). These results indicate that this technology is applicable to treatment of VOCs and SVOCs as well as Army chemical agent.

8.4.1 Process Description

The in situ hot gas decontamination process includes preparing the structure, heating the structure, and treating the off gases collected from the structure. It may also be applied ex situ to structure demolition debris within a suitable containment building. For in situ applications,

structure preparation involves sealing and insulating the building (or portions thereof) to be treated. To ensure air-tightness of the structure, all cracks are filled with high-temperature caulk or furnace cement, window glass is replaced with metal, and rubber seals are replaced with high-temperature caulk. Wooden structural members must also be removed or protected. The next step is to cover the outside of the structure with 2-inch insulation with an exterior aluminum foil seal. The aluminum both protects the insulation from the weather and helps seal the structure.

During the decontamination process, a burner with a heating capacity of 4 million BTU/hour is located outside of the structure and heats the air inside the structure to approximately 400°C. After the outside surface of the structure has reached and maintained 150°C for more than 1 hour, the treatment is considered complete. The air inside the structure is routed to an off-gas treatment system.

The gases and volatilized compounds that exit the structure can be treated using vapor-phase GAC units or by passing the gases through an afterburner. If carbon adsorption is used, the off gases must be cooled to below 90°C. Off-gas treatment is based on the modular process equipment commercially available for modular incineration units.

Hot gas decontamination is currently being developed at the pilot-scale level. Full-scale implementation of this technology has yet to be achieved. Given the scale of the structures to be treated at RMA, the use of multiple heating modules will be necessary to achieve an effective treatment in a timely manner. Projections of full-scale implementation by Battelle (1987) include the construction of a heating module with a capacity to treat 2,670 SF of structural material during a treatment cycle. The treatment cycle includes sealing the area, heating to operating temperatures, and allowing the structure to cool down. At a minimum, airflow through the structure would be 1,000 ambient cfm.

Dependent upon the selected off-gas treatment system, hot gas decontamination may produce two sidestreams: treated off gas and spent GAC. The spent carbon from the GAC units is disposed

in an on-post landfill, and treated off gas is released to the atmosphere via a stack after treatment to meet appropriate regulatory requirements. Figure 8.4-1 presents a diagram of a hot gas decontamination system.

Since RMA is within an air quality nonattainment area, the off-gas treatment system must meet federal and Colorado primary ambient air quality standards of performance for new emissions sources. The action-specific ARARs governing the use of hot gas decontamination and its associated off-gas treatment train can be found in Appendix A. These action-specific ARARs primarily address air emissions during operation and worker protection during operation.

The capital and operating costs for the hot gas decontamination technology are based on the results of a large-scale pilot test conducted at Dugway Proving Grounds on structures containing Army chemical agent (Battelle 1987). The agent of concern in the pilot-scale test was distilled mustard, and the following costs are based on decontaminating structures contaminated with mustard. For the purpose of this economic analysis, it was assumed that one decontamination module with a capacity to treat 2,670 SF of structural material during a treatment cycle is constructed. The off-gas treatment system consists of an afterburner, necessary blowers, and stack. Use of vapor-phase GAC may result in lower costs. The current capital cost for hot gas decontamination is estimated to be $151,000, or $0.81/SF, with operating and maintenance costs of $12.49/SF of material surface for manufacturing structures and $15.96/SF for agent structures (Table 8.4-1).

8.4.2 Process Performance

Hot gas decontamination is only applicable to nonflammable structures contaminated with VOCs and SVOCs. Other treatment technologies would be necessary to reduce nonvolatile inorganic contaminant concentrations or to treat combustible structural materials.

Pre-treatment requirements for hot gas treatment of the structure may not be achievable. Thorough sealing of the structure to be treated may be impossible to achieve because of

deteriorated structure conditions. Air leakage into the structure during heating results in excessive energy requirements and significantly reduce the efficiency and effectiveness of the technology.

Structures contaminated with agent and agent degradation products must be remediated per Army Materiel Command (AMC)-R 385-131. Hot gas decontamination at 400°C has not yet been proven in the field as effective enough to release the structure from Army control (i.e., to decontaminate the material to the 5X level).

In pilot-scale testing, the process was effective in removing mustard contamination from structure materials to below detection levels. These results indicate that the process could potentially be effective for other VOCs and SVOCs. Based on the pilot-scale test at Dugway Proving Grounds, a DRE of 90 to 100 percent was achieved for mustard contamination (Battelle 1987).

This technology has not yet been applied to RMA structures. A pilot-scale test is being planned for the mustard transfer pit in Building 537 at RMA.

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Table 8.1-1 Capital and Operating Costs for Enhanced Surface Soil Vapor Extraction Process

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost	Blanket and Canopy	$632,500	Source: 1
	Power Controllers	110,000	Based on construction of one 50-ft by 50-ft
	Vapor Treatment System	154,000	heating module.
	Transformers	29,700	
	Electrical Lines	25,000	
Total Capital Cost		$951,200	
Operating Costs	Electricity	$4.63/SY	Source: 1
	Operating Labor	4.97/SY	Based on treating 2,500 cubic ft of soil in a
	Maintenance	8.40/SY	94-hour operating period or 50,000 CF
	Analytical	4.65/SY	annually.
	Crane Usage	4.65/SY	
Total Operating Cost		$27.30/SY	

Sources:
1) Draft Enhanced Soil Vacuum Extraction Process Pilot Scale Field Demonstration Report (Shell 1991).

DAA Technology Descriptions

SY Square Yard
CF Cubic foot

RMA.DAA 6/93 pf

Table 8.1-2 ESSVEP Pilot Test Soil Sampling Results

Contaminants Tested	Pre-Test Sampling (ppb)	Post-Test Sampling (ppb)	Removal Efficiency (%)	Pre-Test Sampling (ppb)	Post-Test Sampling (ppb)	Removal Efficiency (%)
	Core Region			Edge Region		
0-6" Depth						
Aldrin	1,800	<8	>99.98	1,400	<8	99.98
Dieldrin	6,100	<16	99.95	6,300	<16	99.95
Isodrin	ND	<8	NA	ND	<8	NA
Endrin	1,300	<16	>99.98	1,200	<16	>99.95
Total	9,200	ND	>99.96	8,900	ND	>99.95
	Core Region			Edge Region		
6-12" Depth						
Aldrin	25	<8	>98.80	21	<8	98.10
Dieldrin	200	<16	95.65	150	<16	97.00
Isodrin	ND	<8	NA	ND	<8	NA
Endrin	23	<16	>98.70	ND	<16	NA
Total	248	ND	>96.13	171	ND	>96.61

NA Not Applicable
ND Not Detected
ppb Parts Per Billion

RMA.DAA 6/93 pf

Table 8.2-1 Capital and Operating Costs for RF Heating

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs			
	Electrical Substation	$670,000	Source: 1
	RF Power Source	3,553,000	Based on construction of two modules.
	RF Shield	288,000	
	Matching Network	372,000	
	Dummy Load	40,000	
	Vapor Collection System	168,000	
	Vapor Treatment System	1,600,000	
	Liquid Sidestream Treatment	150,000	
	Office/Safety Equip./Storage/Decon/Trailer	75,000	
	Gas Monit/Therm. Instru.	150,000	
Total Capital Cost		$7,066,000	
Operating Costs			
Deep Zone	AC Power	$31.96/BCY	Source: 1
	Labor	24.35/BCY	Based on treatment of deep zone only
	Block Installation	53.17/BCY	assuming 12-percent moisture content and
	Vapor Treatment System	42.03/BCY	105 lb/CF soil density.
	Materials	27.92/BCY	
	Liquid Sidestream Treatment	2.66/BCY	
	Miscellaneous	16.56/BCY	
Total Operating Cost		$198.66/BCY	
Operating Costs			
Shallow Zone	AC Power	$35.11/BCY	Source: 1
	Labor	26.69/BCY	Based on treatment of shallow zone only
	Block Installation	68.39/BCY	assuming 12-percent moisture content and
	Vapor Treatment System	28.44/BCY	105 lb/CF soil density.
	Materials	37.97/BCY	
	Liquid Sidestream Treatment	2.92/BCY	
	Miscellaneous	18.14/BCY	
Total Operating Cost		$217.67/BCY	
Operating Costs			

1) Weston 1992

BCY Bank Cubic Yards
lb/CF Pound Per Cubic Foot

RMA/DAA 7/93 tlm

Cost Category	Cost Item	Cost Estimate	Description
Deep/Saturated Zone	AC Power	$46.49/BCY	Based on treatment of deep zone only
	Labor	33.44/BCY	assuming 20-percent moisture content and
	Block Installation	53.17/BCY	105 lb/CF soil density.
	Vapor Treatment System	42.03/BCY	
	Materials	27.87/BCY	
	Liquid Sidestream Treatment	3.67/BCY	
	Miscellaneous	22.74/BCY	
Total Operating Cost		$229.41/BCY	
Operating Costs			
Shallow Saturated Zone	AC Power	$51.17/BCY	Based on treatment of shallow zone only
	Labor	36.67/BCY	assuming 20 percent moisture content and
	Block Installation	68.39/BCY	105 lb/CF soil density.
	Vapor Treatment System	28.44/BCY	
	Materials	37.97/BCY	
	Liquid Sidestream Treatment	4.01/BCY	
	Miscellaneous	24.93/BCY	
Total Operating Costs		$251.59/BCY	

1) Weston 1992

BCY Bank Cubic Yards
lb/CF Pound Per Cubic Foot

Table 8.3-1 Capital and Operating Costs for In Situ Vitrification

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs	Backfill and Grade	$131,858	Source: 1
	Safety Fence	30,342	Based on vitrification of M-1 Settling Pits at
	Stairs	4,024	RMA. Total volume to be treated is 10,200
	Tank and Foundation	18,561	CY and depth of treatment is 10 ft.
	Mechanical Work	113,019	
	Electrical Work	40,563	
	Mobilization	206,857	
	Demobilization	214,636	
	Removal of Support Items	31,722	
Total Capital Cost		$791,582	
Operating Costs	Vitrification	$677.66/BCY	Source: 1
	Sampling and Analysis	62.65/BCY	Based on vitrification of M-1 Settling Pits at
	Stack Sampling	25.21/BCY	RMA. Total volume to be treated is 10,200
	Sit Administration	94.72/BCY	CY and depth of treatment is 10 ft.
Total Operating Cost		$860.25/BCY	

Sources:

1) Final Implementation Document, Version 3.1, In Situ Vitrification, M-1 Settling Basins (Woodward Clyde Consultants 1992).

CY Cubic Yards

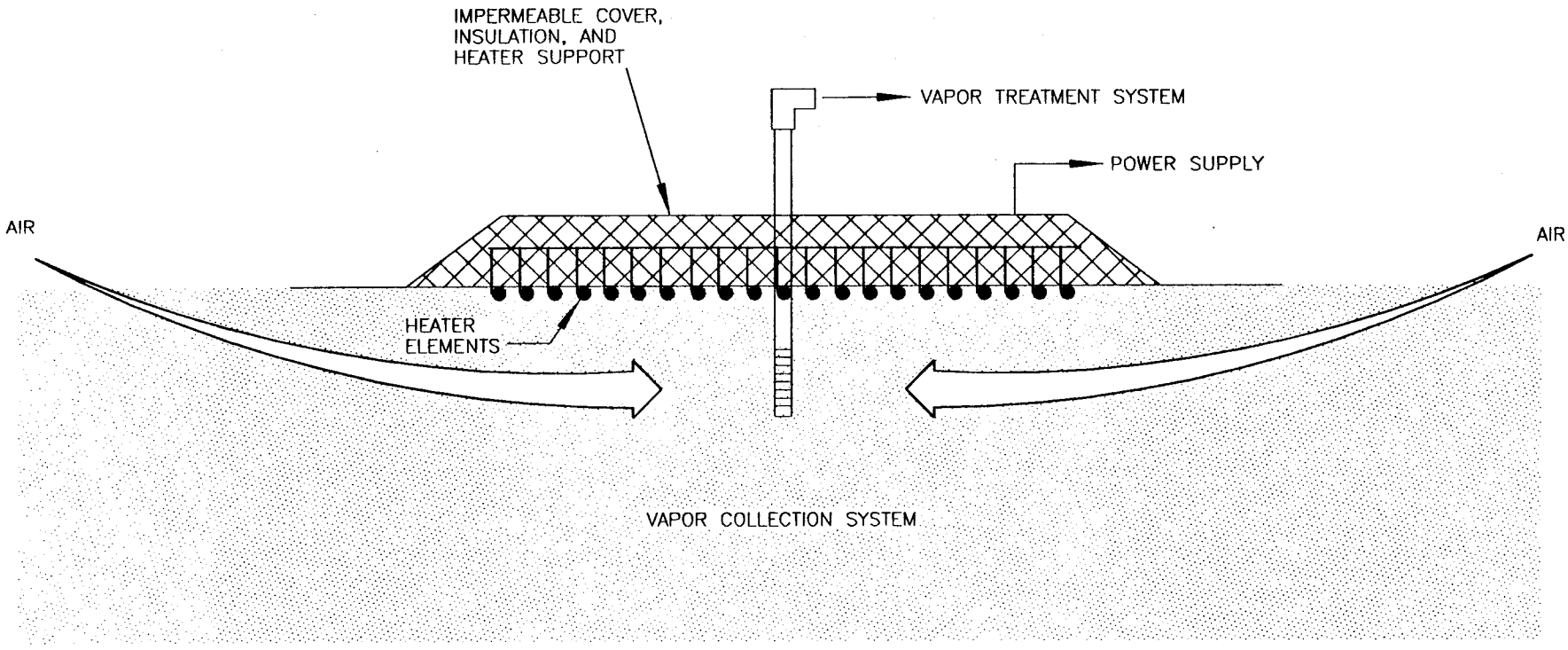
Table 8.4-1 Capital and Operating Costs for Hot Gas Decontamination

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs		System Cost:	Source: 1
	Burner Assembly	$31,000	Based on the construction of one heating
	Air Circulation Assembly	88,000	system capable of treating 2,679 SF
	Mobile Monitoring Station	32,000	System can be used for 75 repeated operations.
	Total	$151,000	
		Unit Cost:	75 repeated operations
		$151,000	
		$0.81/SF	
Operating Costs	Manufacturing Structures	$12.49/SF	Source: 1
	Agent Structures	15.96/SF	Based on the construction of one heating system capable of treating 2,670 SF System can be used for repeated operations.
Total Unit Cost	Manufacturing Structures	$13.30/SF	
	Agent Structures	16.77/SF	

Sources:

1) Preliminary cost estimates for the application of the Hot Gas Decontaminaiotn System to Field Operations (Battelle 1989).

SF Square foot

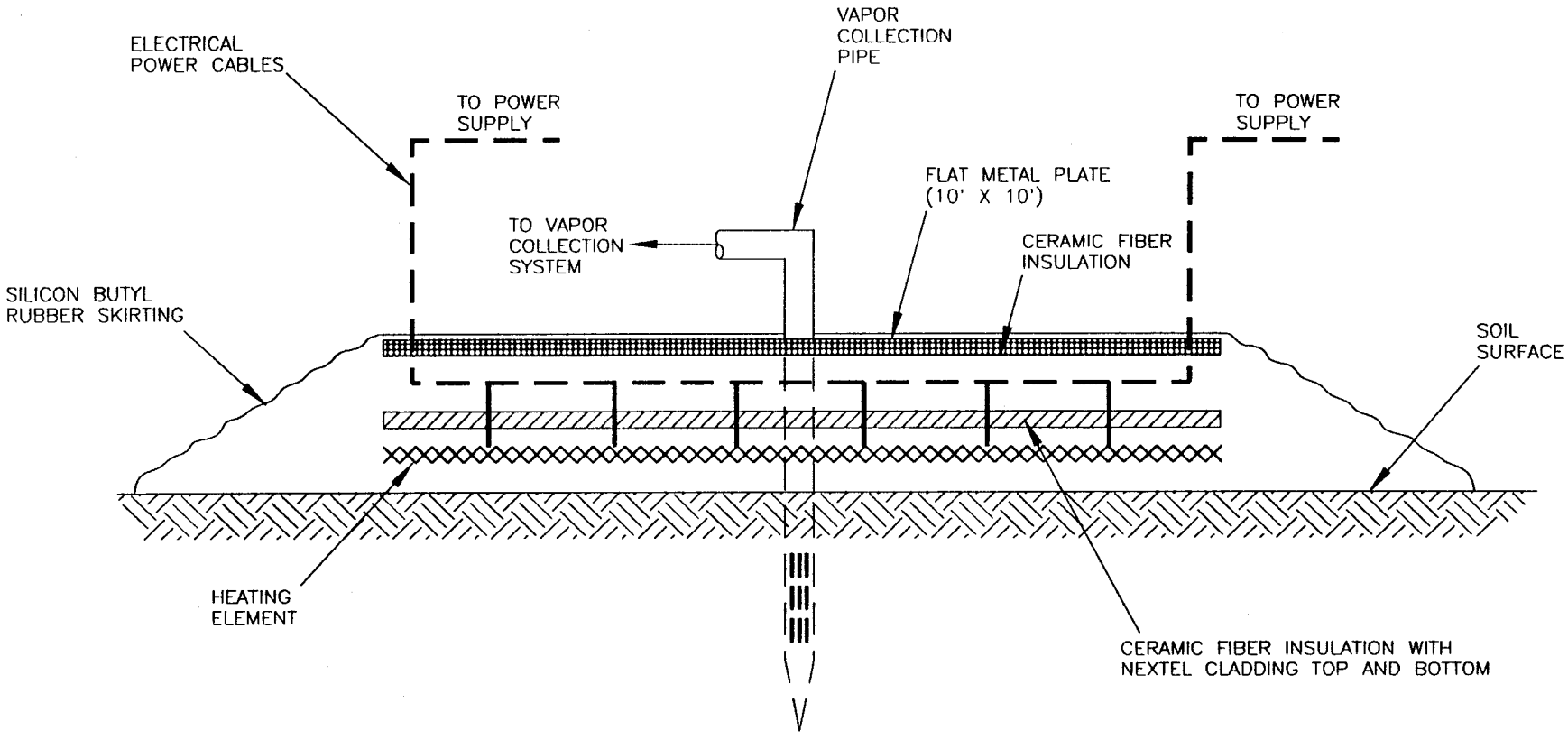


Prepared for:
Office of the Program Manager
for Rocky Mountain Arsenal

FIGURE 8.1–1

Schematic of Enhanced Surface Soil
Vapor Extraction Process

Prepared by:
EBASCO SERVICES INCORPORATED

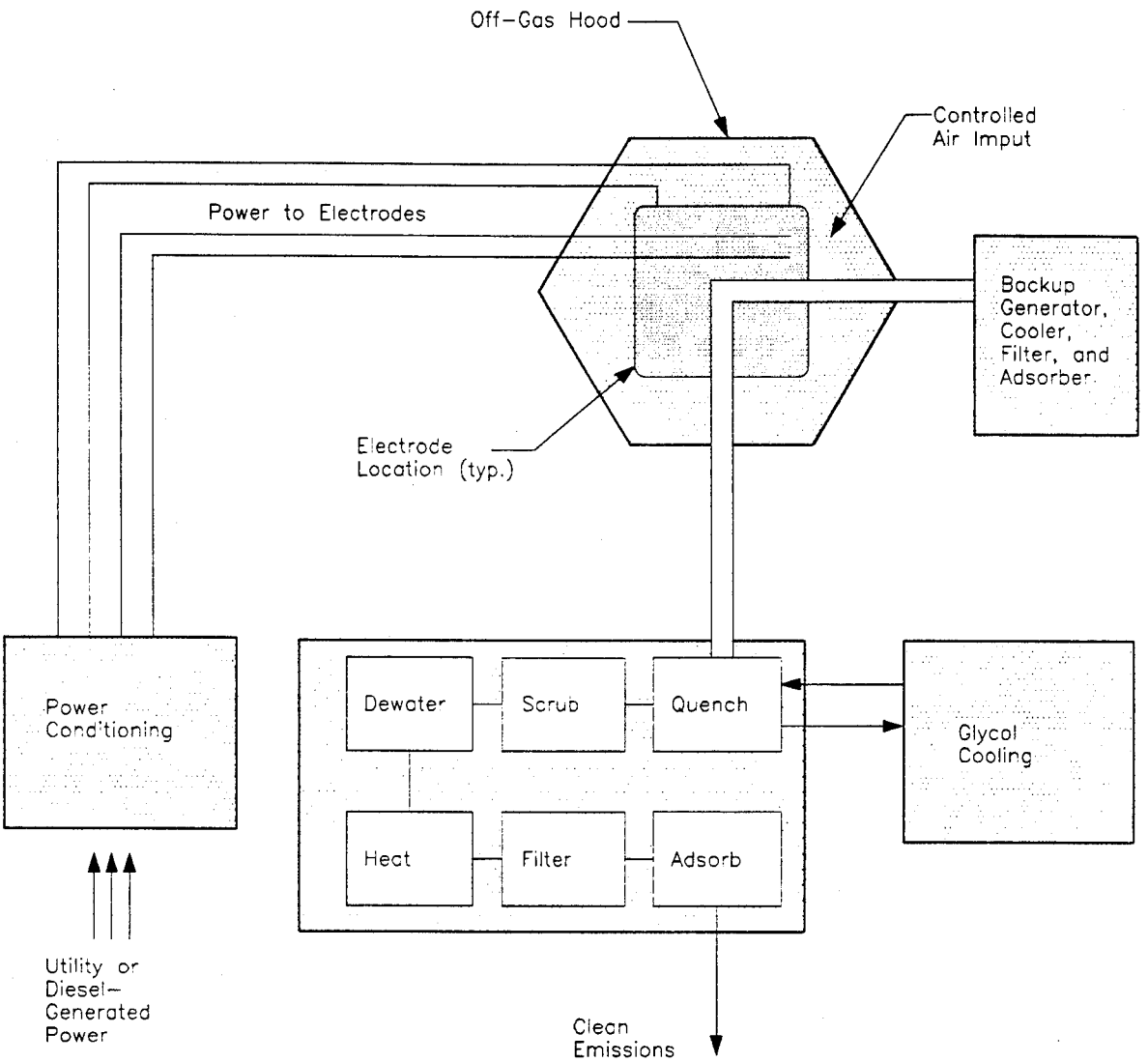


Prepared for:
Office of the Program Manager
for Rocky Mountain Arsenal

FIGURE 8.1-2

ESSVEP
Soil Heating Assembly Configuration Diagram

Prepared by:
EBASCO SERVICES INCORPORATED



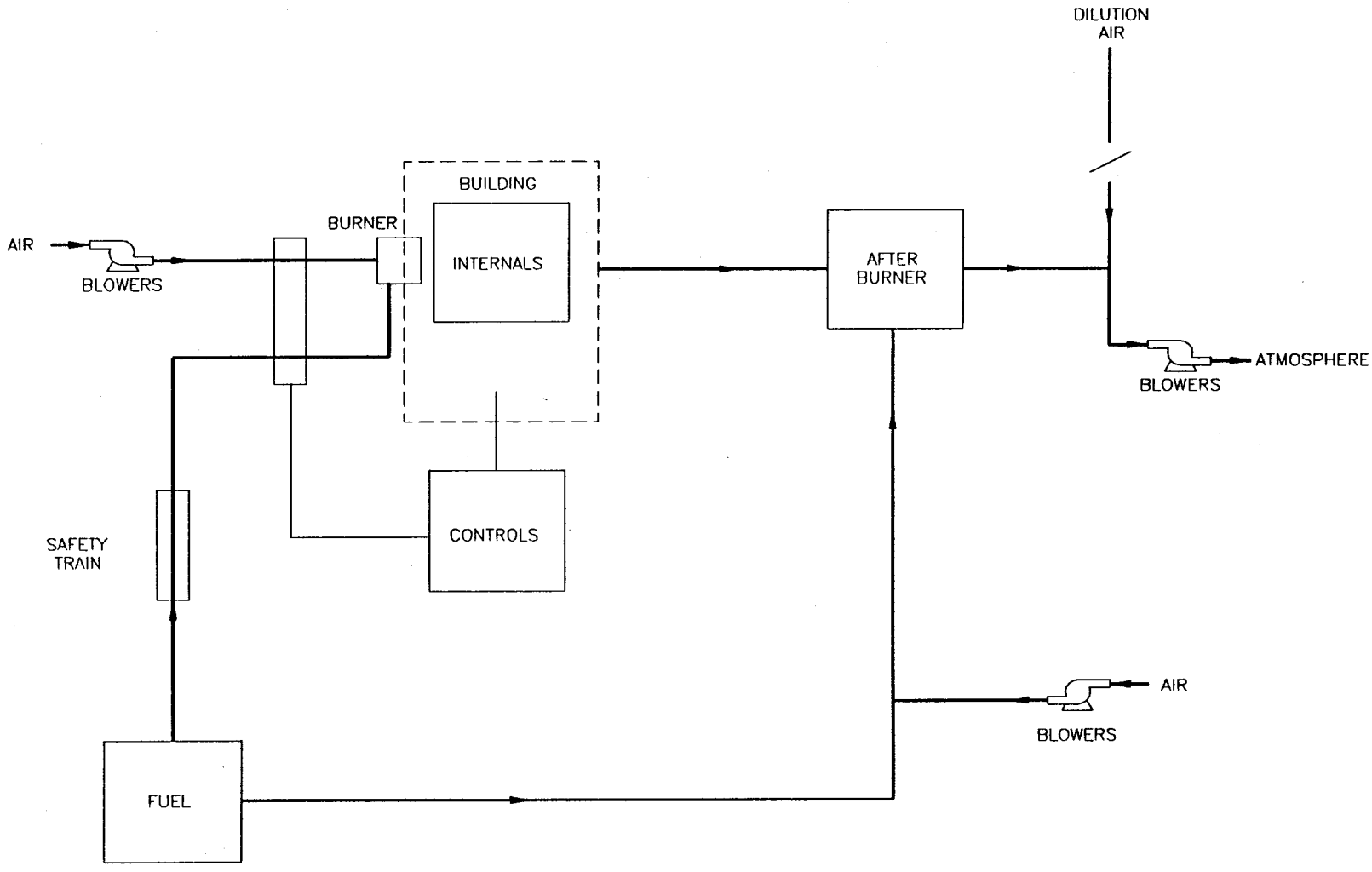
(Geosafe 1987)

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

FIGURE 8.3-1

In Situ Vitrification System

Prepared by:
EBASCO SERVICES INCORPORATED



Source: Battelle, 1989

Prepared for:	FIGURE 8.4-1	Prepared by:
Office for the Program Manager for Rocky Mountain Arsenal	Hot Gas Decontamination System	Ebasco Services Incorporated

9.0 AGENT/UXO TREATMENT

This section describes several processes for the demilitarization of agent or non-agent filled or contaminated UXO and soils. Section 9.1 presents the demilitarization of on-post UXO through detonation and incineration, Section 9.2 discusses the off-post demilitarization of UXO, Section 9.3 presents the neutralization of agent in soil through caustic washing, Section 9.4 discusses the neutralization of agent through solvent extraction/caustic washing, and Section 9.5 describes the treatment of agent-contaminated and structural debris soils through rotary kiln incineration. All of these processes are governed by Department of Defense (DOD) regulations, which are referenced in the following sections.

The following methods were evaluated for the treatment of UXO: incineration utilizing a rotary kiln and incineration off post. UXO includes rounds or munitions that have not been detonated. UXO is typically found in test sites, soils beneath firing ranges, and munitions disposal locations, all of which describe sites within the Munitions Testing Medium Group. UXO may also occur sporadically in other medium groups (e.g., Basin A).

Munitions tested and disposed at RMA primarily include M76 incendiary bombs that were detonated and burned on the ground surface and 4.2-inch mortar. Examples of munitions that were manufactured at RMA include M34 cluster bombs, 105 millimeter (mm) and 155 mm projectiles, and M55 rockets. Other munitions with documented history at RMA include rocket motors, rocket propellants, and miscellaneous explosives. Although only high-explosive (HE) UXO is mentioned in historical descriptions for the Munitions Testing Medium Group, there is a possibility that agent-filled UXO could be encountered during the remediation of areas within the Basin A, Disposal Trenches, and Undifferentiated Medium Groups. For that reason, provisions for dealing with both HE and agent-filled UXO are included in the discussions of on- and off-post incineration.

The U.S. Army originally established RMA to manufacture agents and agent-filled munitions. The Army manufactured Levinstein Mustard and Lewisite, which are classified as vesicant or

blister agents. Phosgene, although not manufactured, was handled at RMA. The Army also demilitarized bombs containing cyanogen chloride. Isopropylmethylphosphonosfluoridate (GB) and white phosphorous were loaded into bombs and ethyl s-dimethyl aminoethyl methylphospho nothiolate nerve agent (VX) was handled at RMA. The technologies considered for treating agent-contaminated soils and structural debris are caustic washing, caustic washing/solvent extraction, and incineration utilizing a rotary kiln.

These two processes primarily focus on treating soils from the Agent Storage Medium Group because potential presence of agent is the only exceedance for these sites. However, these processes also apply to portions of the Basin A, Sewer Systems, Disposal Trenches, Lime Basins, South Plants, and Undifferentiated Medium Groups that may contain agent. In addition, this process addresses structural debris from the structures medium groups with the potential presence of agent.

9.1 ON-POST UXO DEMILITARIZATION

On-post demilitarization consists of detonating and incinerating UXO. This process addresses any UXO identified in the Munitions Testing Medium Group and in portions of several other soils medium groups with the potential presence of UXO.

Agent UXO includes all military lethal or incapacitating chemical agents. They can be in the form of solid, liquid, or contained gases. Agent materials must be decontaminated to the 5X level if the material is to be released from government control without precautions or restrictions in accordance with AMC-R 385-131. UXO containing agent materials at RMA will be decontaminated to this level. To achieve this level, UXO containing agent must be subjected to temperatures above 540 °C for at least 15 minutes. Longer times may be required if the material is unable to be disassembled.

UXO containing chemical surety material as defined in AR50-6 (Surety UXO) are described as one of two categories: those that pose an immediate hazard and cannot be transported and

require emergency disposal action, and those that do not pose immediate hazard and can be transported to the closest facility for demilitarization. If UXO requires emergency disposal action, options are limited to the application of the explosive ordnance disposal (EOD) render safe procedures (detonation) by trained EOD personnel (AMC-R 385-131 and AR 75-15).

9.1.1 Process Description

After clearance procedures and UXO removal, the agent will be removed by the drill, drain, and detoxify procedures per AMC-R 385-131. The burster and fuse will be removed and destroyed by demolition methods. The empty casing and fragments will be processed through a rotary kiln incinerator at 1,000°F for 15 minutes. The brine from the agent neutralization will be stopped and later injected into the secondary chamber of the rotary kiln using a liquid nozzle. The rotary kiln operates at a temperature above the 1,000°F minimum (AMC-R 385-131) required for 5X decontamination. Since appropriate air pollution control equipment (baghouse and scrubbers) are utilized during the incineration process, decontamination of the UXO casing with a caustic solution is not necessary prior to incineration (AMC-R 385-31). A complete description of the rotary kiln incineration process, including the off-gas system, is contained in Section 7.2.

Operation of the rotary kiln system for UXO demilitarization results in several residual streams:

- Debris from explosive components detonation
- Debris/slag from incineration
- Ash from agent incineration treatment
- Dust from the particulate control system
- Process and scrubber waste water
- Clean off gas

The debris from the detonation of the agent-filled UXO explosive components that have been treated to the 5X level of decontamination can be collected from the detonation site using conventional equipment and then salvaged. The metal debris/slag from the incineration process are considered clean and are released from government control without precautions or restrictions.

Therefore, the metal debris/slag can be sold as salvage or be disposed at a nonhazardous waste landfill. The incinerator ash is analyzed for organics and inorganics according to TCLP requirements prior to on-post disposal. If the ash does not pass TCLP requirements, it is disposed in a hazardous waste cell (Section 6.5). Dust collected from the particulate control systems is analyzed for carryover contamination (i.e., metals) and is sampled prior to on-post disposal (Section 6.5). Off gas is caustic and is scrubbed to neutralize the acid gases. The resulting brine is concentrated by evaporation and the recovered water is returned to the process. Salt cake from the concentration step is analyzed and placed in the on-post landfill. Treated off gas is monitored and released to the atmosphere.

UXO can also be of the HE type which do not contain agent. Treatment for HE UXO consists of open air detonation. The area selected for detonation should be well-packed earth with no vegetative growth, rocks, or cracks to reduce fire hazards and the lodging of the UXO in the ground. The site should be located in relation to the prevailing winds to prevent movement of any sparks generated toward explosives storage areas. Detonation should occur at the maximum practicable distance from all magazines, inhabited buildings, public traffic routes, and operating buildings. The distance should not be less than 2,400 ft unless pits or similar aids are used to limit the range of fragments and debris. When trials prove that fragments and debris are limited to lesser ranges, the appropriate inhabited building distances may be used (AMC-R 385-100). Site ESA-4b is a bermed site that has been used for detonation and that could be used again for on-site detonation of HE UXO (Site 29-4 Phase I Contamination Assessment Report [CAR], ESE 1988/RIC #88103R04).

The quantities used to cost the UXO remedial activities were incorporated based on two assumptions: that UXO is found in 0.1 percent of the total soil area in which UXO might occur and assuming a 2-foot a depth there is one UXO per CY of this remaining volume (therefore 1 CY equals one UXO). The first step in addressing the UXO on a site is to perform a clearance of the area using geophysics (magnetometric survey) to identify their location at a cost of $0.85/SY.

The unit cost for detonation of the agent-filled UXO explosive components and incineration of the agent and agent-contaminated debris is estimated to be $216.80/CY. One of the most complex processes associated with agent-filled UXO is handling and packaging the UXO for transportation; this was assumed to be directed by the Army's Technical Escort at a cost of $1,012/CY for on-post handling of the UXO. This handling includes the removal of the explosive devices from the agent-filled UXO and the packaging and transportation of the agent-filled and explosive parts of the UXO. Table 9.1-1 presents a breakdown of the unit costs for on-post demilitarization of agent filled UXOs. After all the UXO has been removed (both HE and agent), a 1-ft layer of soil is excavated from the ground surface at a cost of $0.24/CY. The purpose of this step is to remove the excess UXO debris remaining on the surface. The unit cost for detonation of the UXO is estimated to be $46.75/CY which includes the collection, transportation, and detonation of the HE UXO on post. It is anticipated that work would be directed by the Army's EOD personnel. Table 9.1-2 presents a breakdown of the unit costs for on-post detonation of HE UXOs.

Appendix A lists action-specific ARARs.

9.1.2 Process Performance

The results from Supplement B Project Eagle - Phase II Demilitarization and Disposal of the M34GB Cluster at Rocky Mountain Arsenal Final Plan (February 1974) indicated that the incinerator stack emission concentrations of GB were less than 0.00003 milligrams per centimeter (mg/cm^3) for all trials. The agent-filled UXO was first stripped of external hardware, drained of all agent, placed in decontaminating solution and then thermally decontaminated in a decontaminating furnace. The UXO was then incinerated at 1,000°F for 15 minutes to achieve a 5X level of decontamination (AMC-R 385-131). Prior to incineration, the ton containers (a ton container is a heavy-duty welded steel vessel containing an average of 1,500 pounds of GB) were washed with a caustic solution (18 percent sodium hydroxide [NaOH]) to neutralize the agent residue. However, two of the incineration trials used ton containers that had not been chemically decontaminated before being placed in the incinerator. There was no significant difference in

the results from the trials using chemically decontaminated containers versus the containers that had not been nonchemically decontaminated. This indicates that caustic washing of the ton containers prior to incineration does not affect results.

9.2 OFF-POST DEMILITARIZATION OF UXO

Off-post demilitarization of UXO involves transportation of the UXO to the appropriate Army facility for demilitarization. This process, applicable to any UXO identified in the Munitions Testing Medium Group and for portions of other soils medium groups with the potential presence of UXO, involves shipping agent-filled UXO that is safe or rendered safe to an Army facility specially designed for UXO demilitarization. HE bombs are transported to an Army-approved facility such as Fort Carson Army base in Colorado Springs, Colorado, where they are demilitarized.

The Army's current chemical weapons disposal program involves total containment, robotics, and machine disassembly of the chemical weapons as appropriate for each specific munitions. The various waste materials from disassembly are incinerated separately. There is an incinerator for the liquid chemical agent and process liquid waste; a rotary kiln furnace for the destruction of explosives and propellants, with an accompanying heated discharge conveyor to remove leftover materials; a metal parts furnace to decontaminate by incineration the empty bulk containers, shells, and bombs; and an incinerator for the combustion of waste packaging consisting of wooden pallets and crates that may be contaminated with agent (OTA-BP-0-95). Transportation requirements are outlined in AMC-R 385-131 for agent-filled UXO. UXO incineration at the specially designed off-post facility is completed to render the UXO nonhazardous. All residual streams from the incineration process are controlled and managed by the off-post facility.

9.2.1 Process Description

Agent-filled UXO that is safe or rendered safe for transport are prepared for shipment by military aircraft to the appropriate Army facility. As specified in AR 50-6 military air craft is the preferred mode for moving chemical surety material. Other modes of shipment are authorized

only when they are determined to be safer, more economical, or more practical than military aircraft. HE bombs safe for transport are prepared for shipment by truck, rail, or aircraft to the appropriate Army facility.

The movement of agent-filled UXO will be accomplished by using U.S. miliary-owned and military-operated aircraft, or leased aircraft. Technical escort personnel will accompany all military off-site movements of agent UXO except as indicated for emergencies in AR 75-15. Personnel will be Chemical Personnel Reliability Program (CPRP) certified and armed (AR 50-6). Category Va quantities of chemical surety material will be accompanied by at least two DOD personnel knowledgeable in safety, security, custody, and accountability procedures. Costs for agent UXO examinations are estimated to be $70.57/CY and agent UXO transportation is $2,200.00/CY to an approved off-site Army facility such as Tooele Army Depot. Table 9.2-1 presents a breakdown of the costs for off-post agent UXO demilitarization.

Off-post movement of HE UXOs will be accomplished using U.S. military-owned and military-operated vehicles, or leased vehicles. Trained EOD personnel will accompany all military off-site movements of HE UXOs. All motor vehicle shipments of explosive materials on public highways are governed by DOT regulations and any additional state and municipal regulations. Costs for HE UXO examination are estimated to be $70.57/CY and HE UXO transportation is $59.50/CY (this cost includes collection, transportation, and detonation of the HE UXO). Table 9.2-2 presents a breakdown of the costs for off-post HE UXO demilitarization.

ARARs governing off-post transportation are contained in Appendix A, and discussed in Section 4.0.

All agent-filled UXO shipments must be escorted in accordance with AR 50-6 and AR 740.32. Shipping routes are selected to avoid congested areas and peak traffic periods. Periodic inspection of shipment to ensure no leakage is occurring should be performed.

9.2.2 Process Performance

Off-post incineration reduces the TMV of UXO. All the UXO evaluated as safe for transport is sent off post for demilitarization and destruction. The amount of agent-filled UXO present is expected to be small; it was assumed that only 0.1 percent of the total soil volume of sites with the potential for UXO presence actually contains UXO, and that there is only one UXO per CY of this volume. Therefore, releases to the environment due to detonation of agent-filled UXO that are unsafe for transport is limited because the overall amount of agent-filled UXO present is small.

9.3 CAUSTIC WASHING OF AGENT-CONTAMINATED SOILS OR STRUCTURAL DEBRIS

Caustic washing is a physical/chemical treatment process option in which agent-contaminated soil or structural debris are excavated, mixed with caustic wash fluids in an aboveground unit to degrade agent, and then separated from the wash water. The process is applicable to agent-contaminated soil sites in the soils medium groups, in particular the Agent Storage Medium Group, as well as to agent-contaminated structural debris from the structures medium group sites. The process of conducting soil washing on agent-contaminated soil is performed with four wash cycles. Four washes were used for this evaluation. Washing agent-contaminated structural debris is performed in one cycle. The soil or structural debris is treated to a 3X decontamination level, which requires that the materials have been surface decontaminated and tested (AMC-R 385-131). As a result, they would have to be placed in the on-post landfill (Section 6.5).

9.3.1 Process Description

The basic principle behind caustic washing of agent-contaminated materials is that the caustic solution neutralizes agent that is present. Neutralization may not necessarily destroy all agent present in the materials; therefore, the process is classified as a 3X decontamination level of treatment. Caustic washing is accomplished using alkaline hydrolysis, which is the reaction of water with a chemical, using a base catalyst to produce compounds of greatly reduced toxicity. Alkaline hydrolysis could be a means of chemically neutralizing GB, VX, Lewisite (L), and mustard. GB has been successfully neutralized using a NaOH solution in a large-scale

application, and both VX and mustard neutralization have been demonstrated in a small scale application.

The caustic washing of agent-contaminated soils consists of contacting a caustic solution with the contaminated soils to neutralize the agent through hydrolysis. An 18-percent NaOH solution is used to neutralize GB. The soils are placed in a reactor and mixed with a NaOH solution at a ration of 5:1 solution/soil. The slurry is then mixed to ensure contact of the caustic solution with any agent present inside the pore spaces of the soil. The solution is then recycled in the reactor, a 15% make-up solution added, and another cycle is initiated. The contaminated soils are processed through four wash cycles. The total residence time in the reactor is 30 minutes. Similar concentrations are used for treatment of structural debris. In this instance, a specially designed rolloff container filled with debris is flooded and allowed to stand for 30 minutes.

An 18-percent NaOH solution was used at RMA to neutralize bulk agent in Project-Eagle-Phase II. For soils treatment, a portion of the caustic is degraded in each wash cycle, and the solution withdrawn from the reactor will be recycled and then treated through spray drying after the cycle is completed. A 15% make-up of caustic solution will be added between washes 2, 3, and 4. For structural debris treatment, the caustic is recycled until it is not effective and then treated by spray drying.

The pH of an 18-percent NaOH solution is approximately 12. The pH of the treated materials approaches 12 following the four wash cycles. The treated materials are neutralized to lower the pH, if required and placed in a solid waste landfill cell (Section 6.5). Soils containing elevated levels of inorganics requires solidification prior to disposal. Any solidification activities are to be performed in accordance with the direct cement-based solidification process described in Section 10.1.

The equipment used for the caustic washing of soil is the same as that described for soils unique processes (Section 12.0). However, the process is different because the soil is not separated into coarse- and fine-grained soil fractions and it uses a caustic wash.

Two waste streams from the soil washing activities is generated: the washed soil and the process water. The caustic solution used in the washing cannot be recycled for use in the subsequent washings; therefore, a large volume of process water is generated. The water, which consists of a brine, is evaporated by spray drying. Spray drying is the process of heating the brine with an infrared lamp to remove the gross amount of water and them completing the drying in an oven at 110 °C (Edgewood Arsenal Technical Report, February 1977/RIC #85155R02). Remaining salts are analyzed and landfilled. Washed soil, which has been treated to a 3X level of decontamination, is also analyzed and landfilled (Section 6.5).

The ARARS governing the performance of caustic washing are the same as those for solution washing, which is presented in Section 12.1. Appendix A lists these ARARs, which primarily address worker protection, air emissions during treatment, and discharge requirements for the treated solutions.

To identify agent contamination in soils, areas of interest are screened in the field and then further verified by analysis at the RMA laboratory. The cost for this screening is $0.10/SY. The capital cost for caustic washing of soils is similar to solution washing, but the operating cost is higher due to the use of the caustic solution. The estimated capital cost of the soil caustic washer is $76.95/CY which is based upon an 8-month rental of the required caustic washing equipment amortized over a 10-year period, with an operating cost of $212.30/CY. The estimated cost for the spray drying equipment is broken down as a capital cost of $245.00/CY and an operating cost of $17.80/CY. All structural debris potentially contaminated with agent will be screened for agent, and those costs are built into the demolition process. It was assumed that 5 percent of the debris does not pass screening and needs to be treated. The estimated capital cost for caustic

treatment of structural debris is $2.60/CY and the estimated operating cost is $80.43/CY. Table 9.3-1 presents a breakdown of the unit cost for caustic washing.

9.3.2 Process Performance

Project Eagle-Phase II has successfully neutralized agent using an 18-percent NaOH solution. In Project Eagle, it was shown that GB, at a temperature of 30°C and in a neutral environment (pH of 7), has a half-life of 146 hours. However, at a pH of 9, the half-life decreases to 0.4 hour. After conducting the caustic washing test the Army found that there were problems with the process: the caustics that were used to neutralize the chemical agent had to be handled safely in bulk quantities, the agent itself had to be properly handled and stored until it was neutralized, and the rate of neutralization of the chemical agent was much slower than predicted (which could be due to incomplete mixing of the organic material and the aqueous NaOH).

For the test conducted at the RMA, using an excess of caustic, 2.6 pounds of salt were formed to neutralize 1 pound of agent. Re-formation of GB during the spray-drying of the brine solution, noted during the test, could be avoided by adjusting the pH and brine flow rate and by reducing the operating temperature of the drying process. Some difficulties were also encountered in confirming that the brine was free from agent. At RMA, the neutralization brine was considered free from agent if a 5-percent excess NaOH level was achieved. However, agent emissions during the brine spraying at RMA often exceeded the action level (0.0003 milligrams per cubic meter [mg/m^3]) and, occasionally, the shutdown level (0.003 mg/m^3) promulgated by the Department of Health and Human Services (DHHS) and the Army's Surgeon General (Project Eagle).

9.4 CAUSTIC WASHING/SOLVENT EXTRACTION OF AGENT-CONTAMINATED SOILS

Caustic washing is a physical/chemical treatment process option in which agent-contaminated soil or structural debris are excavated, mixed with caustic wash fluids in an aboveground unit to degrade agent, and then separated from the wash water. The process is applicable to agent-contaminated soil sites in the soils medium groups, in particular the Agent Storage Medium

Group, as well as to agent-contaminated structural debris from the structures medium group sites. The process is similar to the solvent extraction process described in Section 12.4. For the agent-contaminated materials the pH is raised to 12 rather than 11 (as described for the solvent washing). This process is preferable to simple caustic washing in that it removes organic contaminants as well as destroys Army chemical agent. The soil or structural debris is treated to a 3X decontamination level, which requires that the materials have been surface decontaminated and tested (AMC-R 385-131). As a result, they would have to be placed in the on-post landfill (Section 6.5).

9.4.1 Process Description

The solvent extraction process is discussed in Section 12.4. The issues of caustic destruction of Army chemical agent are discussed below. The basic principle behind caustic destruction of agent-contaminated materials is that the caustic solution neutralizes agent that is present. Neutralization may not necessarily destroy all agent present in the materials; therefore, the process is classified as a 3X decontamination level of treatment. Caustic washing is accomplished using alkaline hydrolysis, which is the reaction of water with a chemical, using a base catalyst to produce compounds of greatly reduced toxicity. Alkaline hydrolysis could be a means of chemically neutralizing GB, VX, L, and mustard. GB has been successfully neutralized using a NaOH solution in a large-scale application, and both VX and mustard neutralization have been demonstrated in a small-scale application.

The process will consist of screening and crushing the feed materials to a size of less than 1/2 inch. The feed will be placed in the washer/dryer vessel and triethylamine (EA) solvent and NaOH solution will be added to produce a slurry with a pH of 12. Subsequent extraction steps will proceed as described in Section 12.4. If necessary, additional NaOH will be added during the subsequent extractions to keep the pH at 12.

Following extraction and pH readjustment to lower the pH, the soils will be placed in a solid waste landfill cell (Section 6.5). Soils containing elevated levels of inorganics require

solidification prior to disposal. Any solidification activities are to be performed in accordance with the direct cement-based solidification process described in Section 10.1.

The ARARs governing the performance of caustic washing are the same as those for solution washing, which is presented in Section 12.1. Appendix A lists these ARARs, which primarily address worker protection, air emissions during treatment, and discharge requirements for the treated solutions.

The capital cost for caustic washing/solvent extraction of soils is similar to solvent extraction. Costs are somewhat higher due to an assumed smaller volume of soil, greater PPE requirements, and increased equipment wear due to the higher pH. The estimated capital cost is $32.55/CY. The operating cost is $248.53/CY. Table 9.4-1 presents a breakdown of the unit cost for caustic washing.

9.4.2 Process Performance

Project Eagle-Phase II has successfully neutralized agent using an 18-percent NaOH solution. In Project Eagle, it was shown that GB, at a temperature of 30°C and in a neutral environment (pH of 7), has a half-life of 146 hours. However, at a pH of 9, the half-life decreases to 0.4 hour. After conducting the caustic washing test the Army found that there were problems with the process: the caustics that were used to neutralize the chemical agent had to be handled safely in bulk quantities, the agent itself had to be properly handled and stored until it was neutralized, and the rate of neutralization of the chemical agent was much slower than predicted (which could be due to incomplete mixing of the organic material with the aqueous NaOH).

For the test conducted at RMA, using an excess of caustic, 2.6 pounds of salt were formed to neutralize 1 pound of agent. Re-formation of GB during the spray-drying of the brine solution, noted during the test, could be avoided by adjusting the pH and brine flow rate and by reducing the operating temperature of the drying process. Some difficulties were also encountered in confirming that the brine was free from agent. At RMA, the neutralization brine was considered

free from agent if a 5-percent excess NaOH level was achieved. However, agent emissions during the brine spraying at RMA often exceeded the action level (0.0003 mg/m^3) and, occasionally, the shutdown level (0.003 mg/m^3) promulgated by the DHHS and the Army's Surgeon General (Project Eagle).

Process performance in the presence of a solvent such as TEA has not been demonstrated. However, the high pH, substantial agitation, and high removal of the aqueous phase would suggest that the process would be effective. Additionally, the Basic Extraction Sludge Treatment (BEST) process is isolated from the atmosphere due to the flamable nature of TEA. This would minimize atmospheric emissions, but does present a safety issue if the TEA did catch on fire prior to destruction of the agent. Treatability studies would need to be performed to confirm the effectiveness of the process.

9.5 INCINERATION OF AGENT-CONTAMINATED SOIL

Rotary kiln incineration is commonly used for hazardous waste incineration, and incineration using specifically designed incinerators is the preferred method of disposal for agent-contaminated wastes (AMC-R 385-131). The process is applicable to agent-contaminated soils from the Agent Storage Medium Group and from portions of other soils medium groups with the potential presence of agent and to agent-contaminated structural debris. Rotary kiln incinerators are capable of attaining 5X decontamination levels, the required level for remediated agent materials to be released from Army control (AMC-R 385-131). Rotary kiln incineration involves two-stage combustion of waste materials, with primary combustion occurring in the rotary kiln followed by secondary combustion of off gas in an afterburner.

9.5.1 Process Description

Rotary kiln incineration begins with pre-treatment of wastes to increase the destruction efficiency of the kiln and to preserve the working life of the kiln. Pre-treatment includes size reduction of soil/waste and neutralization of corrosive soil/wastes as discussed in Section 7.2. The soil/waste materials, following pre-treatment, are fed into the inclined rotary kiln. Waste materials flow

through the kiln as a consequence of the rotation and the angle of inclination of the kiln. Rotation of the kiln enhances mixing of the soil/waste with combustion air and provides continuously renewed contact between waste material and the hot walls of the kiln. The flow rate (residence time) of the waste in the kiln is regulated by the feed rate, angle of kiln inclination, kiln rotation (revolutions per hour), internal baffles, and kiln size. As incineration of the waste progresses, the ash flows to the bottom of the kiln and is conveyed to the ash recovery unit. Gaseous combustion byproducts are exhausted to the afterburner for secondary combustion. The products from the afterburner are then passed through heat recovery and air pollution control systems. Refer to Section 7.2 for a detailed description of the rotary kiln incineration process and associated air treatment technologies.

The rotary kiln system oxidizes or volatilizes all the organic waste constituents in the soil matrix for subsequent oxidation in the afterburner. To achieve a 5X level of decontamination, the rotary kiln is operated at a temperature of at least 1,000°F for 15 minutes to ensure complete volatilization of all agent constituents (AMC-R 385-131). The ash recovery system cools the ash in a fluidized-bed cooler; it can then be analyzed for organics and inorganics to determine the appropriate disposal methods (see Section 6.5).

Off gas from the rotary kiln is fed to the afterburner for destruction of the volatilized organics. The afterburner operates at temperatures up to 2,250°F and must be able to withstand the high corrosivity of acid gases and iron compounds (EBASCO 1988/RIC #88286R02). Excess air added to the afterburner to ensure destruction of 99.99 percent of the remaining organics present. Section 7.2 describes the off-gas control system for a rotary kiln incinerator.

Flue gas from the afterburner, which includes particulate materials and acid gases, is further processed by air pollution control equipment as discussed in Section 7.2. The incinerator byproducts are handled as described in Section 7.2. The costs for rotary kiln incineration of agent-contaminated soils is presented in Table 9.5-1.

9.5.2 Process Performance

The most significant screening criterion for a thermal treatment process is the operating temperature. The waste/soil being treated must be subjected to a temperature of 1,000°F for 15 minutes to achieve a 5X level of decontamination (AMC-R 385-131). Rotary kiln incineration is, therefore, an effective treatment process because temperatures above the 1000°F range are typically achieved in the primary chamber. Moreover, because of pre-treatment (e.g., size reduction and neutralization), the kiln can effectively treat a wide variety of soils with variable particle size, clay and salt content, and moisture content. Depending on the required feed rate, a design capacity can be selected to treat the contaminated soil within an appropriate time frame. Unit costs are based on treatment trains capable of treating 40 tons per day (tpd).

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Table 9.1-1 Capital and Operating Costs for Agent-filled UXO Incineration/Pyrolysis, On-Post

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost	UXO Clearance	$0.85/SY	Source: 1 Based upon a complete surface sweep for UXO by geophysical survey.
	UXO Detonation/Incineration	$36.37/CY	This is the capital cost to construct the on-post rotary kiln as presented in Table 7.2-1.
Operating Costs	UXO Removal	$70.57/CY	Source: 1 Based upon the special precautions to remove the UXO from the soil.
	UXO Transportation	$1,012.00/CY	Source: 2 Based upon the costs for the Army's Technical Escort to handle, package, transport the UXO with appropriate safeguards to the on-post rotary kiln.
	UXO Detonation	$216.80/CY	Source: 3 Based upon the cost to detonate the fuses prior to incinerating the UXO and agent plus the cost to incinerate the de-fused UXO and agent at the on-post rotary kiln.

Sources:

1) Decontamination Assessment for Land and Facilities at RMA Draft Final Report, RIC#84034R01 (USATHAMA 1984).
2) Phone conversations with Army's Technical Escort.
3) Source 1 above and information in Section 7.2 and costing data on Table 7.2-1.

CY Cubic Yards
UXO Unexploded Ordnance

Table 9.1-2 Capital and Operating Costs for HE-filled UXO Demilitarization, On-Post

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost	UXO Clearance	$ 0.85/SY	Source: 1 Based upon a complete sweep for UXO by geographical survey.
Operating Costs	UXO Removal	$70.57/CY	Sources: 1 and 2 Based upon the special precautions to remove the UXO from the soil.
	UXO Transportation and Detonation	$46.75/CY	Sources: 3 and 4 Based on the costs for the Army's EOD to handle, package, transport the UXO with the appropriate safeguards to the on-post detonation site, then perform the UXO detonations with appropriate safeguards.

Sources:

1) Decontamination Assessment for Land and Facilities at RMA Draft Final Report, RIC#84034R01 (USATHAMA 1984).
2) MEANS, 1993; cost for test pits plus cost factor for personal protective equipment.
3) Phone conversations with Army's Technical Escort.
4) Phone conversations with Fort Carson EOD

EOD Explosive Ordance Division
UXO Unexploded Ordnance
CY Cubic Yard
SY Square Yard

Table 9.2-1 Capital and Operating Costs for Agent-filled UXO, Off-Post

Cost Category	Cost Item	Cost Estimate	Description
Capital Cost	UXO Clearance	$0.85/SY	Source: 1 Based upon a complete surface sweep for UXO by geophysical survey.
Operating Costs	UXO Removal	$70.57/CY	Source: 1 Based upon the special precautions to remove the UXO from the soil.
	UXO Transportation	$2,200/CY	Source: 2 Based upon the costs for the Army's Technical Escort to handle, package, transport the UXO with appropriate safeguards to the off-post Army facility (Tooele Army Depot).

Sources:

1) Decontamination Assessment for Land and Facilities at RMA Draft Final Report, RIC#84034R01 (USATHAMA 1984).
2) MEANS, 1993; Cost for Test Pits plus Cost Factor for personal protective equipment.
3) Phone conversations with Army's Technical Escort.
4) Phone conversation with Fort Carson EOD.

CY Cubic Yards
UXO Unexploded Ordnance

Table 9.2-2 Capital and Operating Costs for HE-filled UXO Demilitarization, Off-Post

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs	UXO Clearance	$ 0.85/SY	Source: 1 Based upon a complete sweep for UXO by geophysical survey.
Operating Costs	UXO Removal	$70.57/CY	Sources: 1 and 2 Based upon the special precautions to remove the UXO from the soil.
	UXO Transportation	$59.50/CY	Sources: 3 and 4 Based on the costs for the Army's EOD to handle, package, transport the UXO with the appropriate safeguards to the off-post detonation site, then perform the UXO detonation with appropriate safeguards.

Sources:

1) Decontamination Assessment for Land and Facilities at RMA Draft Final Report, RIC#84034R01 (USATHAMA 1984).
2) MEANS, 1993; Cost for Test Pits plus Cost Factor for personal protective equipment.
3) Phone conversations with Army's Technical Escort.
4) Phone conversation with Fort Carson EOD.

CY Cubic Yards
UXO Unexploded Ordnance

Table 9.3-1 Capital and Operating Costs for Agent Solution Washing

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs	Agent Screening	$0.10/SY	Source: 1 Based upon using drilling and field and analytical screening for agent-contaminated soils.
	Caustic Washer	$76.95/CY	Source: 2 Based upon an 8-month rental of the caustic washing equipment (20 ton/hr unit) amortized over a 10-year period.
	Spray Drying System	$245.00/CY	Source: 3 Based upon spray drying unit large enough to treat the four nonrecyclable washings from the caustic washer within an 8- to 10-month period.
Operating Costs for Caustic Washing	Material handling/feeding	$0.31/CY	Source: 3 Based upon a 24-hour-per-day operation with a 20-ton/hour unit using an 18% caustic solution and four nonrecyclable washes.
	Operation Labor	$13.71/CY	
	Surfactant and flocculants	$12.00/CY	
	Caustic (773 lb NaOH/cy)	$177.17/CY	
	Utilities	$3.83/CY	
	Maintenance and supplies	$1.46/CY	
	Unit mod., repair and replace	$2.09/CY	
	Laboratory analysis	$1.73/CY	
	Total Unit Cost	$212.30	
Operation Costs for Spray Drying Unit	Material handling/feeding	$0.31/CY	Source: 3 Based upon a 24-hour-per-day operation with a unit large enough to spray dry the total solution generated by the caustic washing in an 8- to 12-month period.
	Operation labor	$8.31/CY	
	Utilities	$3.90/CY	
	Maintenance and supplies	$1.46/CY	
	Unit mod., repair and replace	$2.09/CY	
	Laboratory analysis	$1.73/CY	
	Total Unit Cost	$17.80/CY	

Sources:

1) EBASCO, Soil Volume Refinement Program, 1992.
2) Biotrol Systems, Economic Analysis, EPA/540/A5.91/003.
3) Information provided through discussions with Selch Process Systems, Boulder, Colorado.

Table 9.4-1 Capital and Operating Costs for Agent Caustic Washing/Solvent Extraction

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs	Pre-treatment	$0.55/CY	From Section 7.3 Size Reduction
	Solvent Extraction	$32.00/CY	From Resource Conservation Company (RCC) costs presented in April 1993 HLA Treatability Study Report
	Total Capital Costs	$32.55/CY	
Operating Costs	Pre-treatment	$13.73/CY	From Section 7.3 Size Reduction
	Solvent Extraction	$224/CY	From RCC costs presented in April 1993 HLA Treatability Study Report
	Sidestream Treatment	$10.80/CY	From vendor quote for off-site destruction
	Total Operating Costs	$248.53/CY	

Table 9.5-1 Capital and Operating Costs for the Incineration of Agent-Contaminated Soils

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs	Agent Screening	$0.10/BCY	Source: 1 Based upon using drilling field and analytical screening for agent-contaminated soils.
	Incineration/Pyrolysis:		Source: 2 Based on two incinerator trains with a common feed preparation building. Total soil feed rate at 20% moisture is 56 tons/hour. Onstream time is 5,700 hours per year (65%).
	Site Preparation	$ 830,000	
	Soil Pretreatment	2,170,000	
	Incineration	13,960,000	
	Brine Concentration	5,109,000	
	Spare Parts	2,000,000	
	Buildings	7,308,000	
	Piping	2,790,000	
	Electrical & Instrumentation	3,005,000	
	Startup, Shakedown, and Test	4,240,000	
	Total Facility (56 tons/hour)	$43,648,000	
	Single Train (28 tons/hour)	$21,824,000	
Operating Costs	Operating & Maintenance Labor	2,793,000	Source: 2 Adjusted for EBASCO Task 17 operating conditions, but without the use of 40% supplemental oxygen in the kiln and the SCC. Weston figures divided by 2 for single-train facilities.
	Maintenance Materials	550,000	
	Analytical	290,000	
	Utilities	6,113,000	
	Chemicals	424,000	
	Consumable	625,000	
	Total	$10,794,000	

Sources:

1) EBASCO, Soil Volume Refinement Program, 1992.
2) Weston, Roy F., Concept Engineering Study Report for Thermal Desorption Systems for Rocky Mountain Arsenal Soils, August 1992 (Weston 1992).
3) EBASCO, Full-Scale Incineration System Conceptual Design for Basin F Wastes, Task 17, September 1988, RIC#88286R02 (EBASCO 1988).

BCY Bank Cubic Yards
SCC Secondary Combustion Chamber
SY Square Yards

10.0 SOLIDIFICATION/STABILIZATION

This section describes both direct and in situ solidification/stabilization processes using both generic and proprietary binders. The terms solidification and stabilization, generally used together because the process additives employed usually perform both functions, are also sometimes referred to as immobilization, fixation, or encapsulation. In the narrow sense, solidification changes the physical properties of the soil or waste matrix, e.g., eliminating free liquids. Stabilization changes the physical or chemical properties of the contaminants, e.g., converting metal salts to their insoluble hydroxide forms. For simplicity in the following discussion, the term solidification/stabilization is referred to as solidification.

While solidification has historically addressed inorganic contamination, the technology can be applied to media contaminated with both organic and inorganic compounds. In general, the proprietary binders and additives are aimed at incorporating organic contaminants into the soil/binder matrix or at least preventing the organics from interfering with the solidification reactions. For RMA, however, direct and in situ solidification processes are evaluated for the treatment of soils, sludges, and semisolid byproduct sidestreams contaminated primarily with inorganic compounds.

This section is organized as follows: Section 10.1 describes direct cement-based solidification, Section 10.2 describes direct solidification using proprietary additives, Section 10.3 describes in situ cement-based solidification, and Section 10.4 describes in situ solidification using proprietary additives.

10.1 DIRECT CEMENT-BASED SOLIDIFICATION

The most widely used solidification agent for hazardous wastes is Portland cement. It is widely available as a uniform product in several types, including two with moderate to high sulfate resistance. Portland cement may be used alone as the binding agent or formulated with fly ash, lime, soluble silicates, clay, or other materials to enhance processing or improve the properties of the final product. It is available in bag or bulk quantities and has a successful performance

record for use in the solidification of radioactive wastes as well as other inorganic and organic contaminants (EPA 1986).

Cement-based solidification often includes the use of non-proprietary, inorganic binders that are combined with Portland cement to address specific problem interactions between the contaminants and the cement binder. For example, certain contaminants can interfere with cement hydration or solidification to disrupt the matrix or retard the setting time. In general, interference problems are more commonly caused by organic compounds than by inorganic compounds. Some common additives for cement-based binders are as follows:

- Pozzolans: Insoluble silicates in the form of fly ash, blast furnace slag, and cement kiln dust that react with the calcium hydroxide released by cement hydration to form additional cementitious compounds. Pozzolanic additives generally improve the strength and reduce the porosity of the final product if they are not consumed in competing reactions with the contaminants. Pozzolans can be added tc adsorb metals, organics, and excess water.

- Soluble Silicates: The liquid forms of sodium and potassium silicates that react with the calcium hydroxide released by cement hydration. Soluble silicates form a gel structure that prevents solids from settling out of aqueous wastes before the cement sets and hardens. They also encapsulate contaminants that adsorb to cement particle surfaces. The resulting solid may be weaker than Portland cement alone.

- Lime: Calcium oxide or calcium hydroxide (hydrated lime) accelerates cement hydration by providing additional calcium hydroxide for the hydration reactions. It is also added to prevent destruction of the cement structure by acidic contaminants.

- Clay: Selected clays such as bentonite absorb free liquids and bind specific anions and cations.

Direct solidification is utilized as a treatment alternative for the Buried M-1 Pits and Burial Trenches Subgroups in Alternative 10 (Solidification/Stabilization). Direct cement-based solidification is also utilized in treating soils and byproducts (i.e., particulates from off gas) for several of the human health exceedance medium groups that may contain excess concentrations of inorganics.

10.1.1 Process Description

The solidification process starts with the mixing of the contaminated soil with Portland cement. Fresh water supplements moisture within the soil to promote the hydration reactions that bond the cement-soil-contaminant matrix together. Calcium hydroxide, cement gel, and other compounds form during the hydration process and bind the soil particles and contaminants into the crystalline lattice of the cement matrix (Figure 10.1-1). The final product varies from a granular, soil-like material to a cohesive solid depending on the amount of binder added and the contaminants present in the soil. As hydration proceeds and the crystallinity of the matrix increases, the porosity and internal surface area decrease. The final product is much less permeable than the contaminated soil, and the contaminants are physically incorporated and sometimes chemically bonded to the cement matrix. The overall effect is to inhibit the leaching of contaminants from the solidified/stabilized mass.

In direct solidification, the soil material is removed by conventional earth-moving equipment and conveyed or otherwise transported to the solidification equipment as discussed in Section 4.0. Depending on the type of mixing equipment used, the contaminated feed stream may require coarse screening as a pre-treatment step. As the soil and binder is mixed with a pugmill, oversize material is "entombed" in the processed material leaving the mixer. Metering and thorough mixing of the ingredients are essential for achieving consistent solid properties, but any mechanical equipment that uniformly mixes the soil and additives is satisfactory. In general, however, a pug mill is the best choice for soil and binder mixing.

Solidification requires equipment for chemical storage, materials handling, materials mixing, and materials control. Dry binder ingredients, such as Portland cement, fly ash, and lime, are usually delivered in bulk transport trailers and stored in elevated metal storage silos. Liquid ingredients, such as hydrated lime and soluble silicates, are delivered in both bulk and drummed shipments and are stored in tanks or buildings. Storage tanks and buildings may require protection from extreme heat or cold for year-round operations.

The determination of binder ratios and additive levels is site- and soil-specific. The soil-to-binder ratio is controlled on a weight or volume basis using weigh batchers or screw feeders available from the concrete batch plant industry. Preliminary results from the treatability studies conducted by the Waterways Experimental Station (WES) indicate that a binder-to-soil ratio of 0.2 (weight basis) is generally optimum for RMA soils (Bricka 1992).

For RMA soils, pre-treatment consists of screening debris and metal fragments and reducing the size of clay lumps in the feed. Size reduction increases the homogeneity of the feed and improves mixing control. For thermally treated soils and sidestreams, moisture adjustment is likely to be the only pre-treatment requirement.

Oversize materials, debris, and metal fragments from feed pre-treatment are likely to be the only sidestream from a direct solidification process. If contaminated, these materials are placed in the on-post landfill. If uncontaminated, the pre-treatment sidestream is returned to the original excavation and embedded in the treated soil mass. Since solidification requires the handling and mixing of fine-grained soils and finely divided binder ingredients, control of volatile organic emissions and fugitive dusts is necessary during the loading, blending, and discharge operations.

Because of the interferences provided by the presence of fine soil particles and the contaminants themselves, the setting time of the cemented soil is prolonged. This slow set allows time for the transport and placement of the mixture either in the original excavation or in another location such as a landfill. Post-treatment of the processed soil is limited to backfilling in the original excavation or placing the processed soil in the on-post landfill.

In general, solidified soils are backfilled in the original excavation as a pumpable material. Solidified soils are placed in the original excavation and a soil/clay cover provides weather protection for the treated material after it has been allowed to cure, as discussed in Section 6.1. In some cases, the configuration of the site or depth of the excavation may preclude backfilling all of the processed material, so the excess soils are placed in the on-post landfill. The solidified

materials are placed in forms and allowed to cure for a few days. The forms are then removed and the "monoliths" placed in the landfill.

A volume increase usually accompanies the solidification process. In most cases of cement solidification, the volume of the final mixture is 20 to 50 percent greater than the original in-place volume of the contaminated soil. To return the processed soil to the original area of excavation, it must accommodate the increased volume of the solidified mixture and its final protective soil cover layer.

The ARARs identified for the cement-based solidification process option (Appendix A) are similar to the siring, operation, monitoring, and closure requirements for miscellaneous treatment, storage, and disposal units under RCRA (40 CFR 264, Subpart X). Although a solidification unit does not produce an off-gas sidestream, fugitive dust emissions from soil and binder mixing operations must be mitigated.

The capital and operating costs for direct cement-based solidification are developed from the SITE Program applications analysis report for the Hazcon Solidification Process (EPA 1989a). Although the Hazcon process uses a proprietary additive, it is basically a cement-based technology using transportable batch plant equipment. The cost breakdown (Table 10.1-1) allows the subtraction of the proprietary ingredient costs from the total. The cost of the cement binder in the Hazcon economic summary is further adjusted to reflect the low binder usage observed by the WES in the preliminary solidification screening studies on RMA soils. The resulting order-of-magnitude estimate does not include the cost of soil excavation, transport, or backfill. The unit capital cost of cement-based solidification is $3.35/BCY of soil solidified. The cost of the single shift operation of a transportable batch mixing plant and associated bulk storage is estimated to be $70.10/BCY of soil solidified.

10.1.2 Process Performance

Portland cement has been used very successfully in the solidification of metals contaminants, including arsenic and mercury. The cement neutralizes excess acidity and typically converts metals to their hydroxides, which are much less soluble than other ionic species of most metals. The effectiveness of solidification depends upon the level of contamination and the oxidation state of the metal. For example, only low concentrations of mercury can be successfully stabilized. For lead, the Ph of a pure cement binder is higher than optimum for minimum hydroxide solubility. An insoluble silicate, such as fly ash, can be added to the cement binder to lower the mix pH.

Certain organic waste constituents can interfere with the cement hydration reactions. Chlorinated hydrocarbons adsorb on cement surfaces or retard hydration and interfere with cement matrix formation (Andaska 1992). Portland cement has been successfully used to solidify low levels of organic contaminants, including PCBs, oils, and oily sludges, but high levels of organic contaminants require additional binder ingredients (EPA 1989b). The solidification study by WES indicates that the organics present in the M-1 Pits do not interfere with the binding processes (Bricka 1992).

Processed soil must be protected from the effects of weathering. Exposure of the matrix to the elements, particularly freeze/thaw cycles, may produce an increase in the leachability of the immobilized constituents. If the processed soils are returned to the original excavation, the backfilled mass requires a soil cover layer for freeze/thaw protection as well as successful revegetation as discussed in Section 6.1.

Direct solidification involves the excavation of the contaminated soil for treatment. Its placement after treatment may be subject to RCRA land disposal restrictions (LDRs) if the material is a characteristic hazardous waste under RCRA or is a RCRA-listed waste. In these cases, the LDRs may prohibit the disposal of the solidified mixture in anything but a RCRA-type landfill unless a waiver of LDRs is obtained. This problem is avoided by the use of in situ techniques.

Portland cement is seldom used alone for direct hazardous waste solidification because most sites contain a mix of inorganic and organic contaminants. Even metal compounds can sometimes interfere with the cement reactions, and other cementitious materials such as fly ash or lime kiln dust are blended in to increase binder effectiveness. Cement has been used alone to immobilize inorganic contaminants at the Independent Nail site, and the solidified material was subsequently delisted as a RCRA hazardous waste (EPA 1989b).

Treatability studies are now underway at WES using soils from four representative RMA sites. The site include clayey and sandy-silty soil samples from South Plants, the M-1 Pits, Basin A, and the burn site at NCSA-1e. Initial screening results indicate that a Portland cement/lime kiln dust binder at a loading of 20 percent of the soil mass adequately solidifies the RMA soils and immobilizes the organic and inorganic contaminants such that the material passes TCLP requirements.

Solidification does not destroy organic or inorganic contaminants, but it does reduce their mobility by chemical reaction or physical encapsulation. The immobilization efficiency of the process is measured by comparing the leachability of the contaminants before and after solidification via the TCLP or other leach testing. Based on the WES study, the immobilization efficiencies are greater than 90 percent.

10.2 DIRECT PROPRIETARY AGENT SOLIDIFICATION

Many vendors offer solidification services that employ proprietary additives in the binder formulation. In most cases, the basic binder is still Portland cement (EPA 1989a) or Portland cement and fly ash (EPA 1990b). Some vendors avoid Portland cement and use alumino-silicates (Bates et al. 1992) or calcium silicates (EPA 1991a) in conjunction with other patented additives instead. In most cases, the proprietary ingredients are intended to improve the stabilization of organic contaminants and reduce the impact of organic and inorganic contaminants on the cement reaction.

10.2.1 Process Description

Proprietary solidification uses the same process sequence as cement-based solidification (Section 10.1). After excavation and preliminary sizing, the soil is fed to the pug mill where the proprietary ingredient(s) are added. Bulk solid and/or liquid proprietary ingredients may be premixed or added to the incoming soil as individual streams.

As with direct cement-based methods, direct proprietary solidification depends upon equipment similar to that used for asphalt and cement batch plants. Most vendors offer complete solidification support including treatability studies, materials handling and mixing equipment, operating labor or labor training, and analytical support. Chemfix builds and leases transportable equipment for use with their proprietary solidification additives, Chemset I-20 and Chemset I-220 (EPA 1991a). On the other hand, Emtech (formerly Hazcon) used conventional transportable cement mixing equipment to add their proprietary additive, Chloranan (EPA 1989a).

Aside from additional storage tanks or silos for the proprietary additive(s), the equipment is the same as that already described under cement-based solidification. The equipment illustrated with dotted lines in Figure 10.1-1 indicates additional storage for proprietary ingredients.

The materials handling and feed pre-treatment and backfill requirements of direct proprietary agent solidification are the same as those for direct cement-based solidification (Section 10.1). In addition, the ARARs are the same for the two processes.

The capital and operating costs (Table 10.2-1) for direct proprietary solidification are developed from the SITE Program applications analysis report for the Hazcon solidification process (EPA 1989a). Although the Hazcon process used a proprietary additive, it is basically a cement-based technology using transportable batch plant equipment. The cost of the cement binder in the Hazcon economic summary is adjusted to reflect the results obtained by the WES in the preliminary solidification screening studies on RMA soils. The unit cost of the proprietary additive Chloranan is further adjusted to yield the same cement-to-additive ratio as that used in

the Douglassville site demonstration. The resulting order-of-magnitude estimate does not include the cost of soil excavation, transport, or backfill. The cost of operating a small, transportable batch mixing plant and associated bulk storage is estimated to be $77.12/BCY of soil solidified.

At present, there is no information from WES on proprietary binder formulations. Therefore, there is no way to adjust the Hazcon cement-to-additive ratio from the Douglassville site demonstration to RMA soils. Since the cost of binder ingredients represents 20 percent of the unit soil solidification cost, treatability studies are required to define additive levels for RMA applications. If cement alone can achieve the immobilization, there is no economic justification for the use of proprietary additives.

10.2.2 Process Performance

Proprietary additives are employed to improve the effectiveness of more conventional cement and pozzolanic binders in the immobilization of organic contaminants. A large number are aimed at the immobilization of PCBs, which behave similarly to pesticides in their interference with the cementation reactions. However, the performance of additives is highly soil- and contaminant-specific and cannot be extrapolated from the SITE Program demonstrations to RMA applications.

Proprietary additives are selected to avoid or suppress the chemical interferences that most organic and some inorganic compounds have on cement lattice formation. The same process limitations associated with direct cement-based solidification (weather protection, volume increase of treated soil, and potential LDRs) apply to proprietary additives.

Binder formulations are specific to the site and contaminant. Each vendor of proprietary agents is capable of conducting treatability studies to determine the appropriate binder formulations for site soils and contaminants. In terms of applicability to RMA soils and contaminants, the literature suggests several possible candidates:

- Silicate Technology Corporation (STC) used alumino-silicate compounds (Soil Sorb P-4 and P-27) to stabilize soils contaminated with pentachlorophenol (PCP) and chromated-copper-arsenate (CCA) from the Selma Pressure Treating site in Selma,

California. Maximum concentrations of PCP, arsenic, chromium, and copper were 10,000, 2,700, 2,200, and 1,300 ppm, respectively. The treatment successfully immobilized the inorganics, adsorbed and microencapsulated the PCP, and produced a material with unconfined compressive strengths well above landfill solidification standards. At a binder-to-soil loading of 75 percent, soil volume increased on average by 68 percent. The treatment cost approached $200/CY (Bates 1992).

- Chemfix Technologies, Inc. used polysilicates and dry, calcium-containing reagents (Chemset I-20 and C-220) to stabilize soils containing PCBs, lead, and copper at the Portable Equipment Salvage Company site in Clackamas County, Oregon. Maximum concentrations of PCBs, lead, and copper were 500, 140,000, and 33,000 ppm, respectively. The treatment successfully immobilized the inorganics and produced a suitable end product, but the immobilization of PCB could not be confirmed. At a binder-to-soil loading of 20 percent, soil volume increased by 20 to 50 percent. The treatment cost approached $73/CY (EPA 1991a).

- EmTech (formerly Hazcon Engineering, Inc.) used Portland cement and additive called Chloranan to stabilize soils containing oil and grease up to 25 percent by weight, lead up to 2.3 percent by weight, VOCs up to 150 ppm, and SVOCs up to 500 ppm at the Douglassville, Pennsylvania Superfund site. The treatment successfully immobilized the inorganics and produced a suitable end product, but the immobilization of VOCs and SVOCs was not confirmed. At a binder-to-soil loading of 100 percent, soil volume increased by 120 percent. The treatment cost approached $235/CY (EPA 1989a).

The metals are generally immobilized, but the success with chlorinated organics has been mixed.

Treatability studies are not available for direct proprietary solidification of RMA soils. WES plans a survey of solidification vendors to determine whether any look more promising than the results already obtained with cement binders.

10.3 IN SITU CEMENT-BASED SOLIDIFICATION

Soils can be solidified/stabilized in place using conventional excavation or drilling equipment. If the contaminants are less than 2 ft deep, conventional earth-moving or land-farming equipment can be used for the mixing step. Mixing is unconfined, however, and tends to generate fugitive dust emissions. For deeper contamination, or where the contaminant volatilization or fugitive dusts must be avoided, specialized hollow-stem auger drilling equipment can deliver the binding

agent to levels as deep as 150 ft. An overlapping drilling pattern is used to obtain complete contact with the contaminated soil volume.

In situ cement-based solidification is used in conjunction with the in situ heating processes described in Alternative 19. This alternative was retained in the DSA for several of the human health exceedance category medium groups.

10.3.1 Process Description

The major difference between direct and in situ solidification is the absence of the excavation and backfill steps required by direct processes (Figure 10.3-1). The mixing equipment is based on powerful drilling rigs rather than cement batch plants, but the solid and liquid binder constituents still require on-site storage and handling.

The binder formulation for in situ work is the same as that used in the direct treatment method discussed above. Because of the difficulty of monitoring the binder-to-soil ratio in the in situ approach, binder consumption tends to be higher than direct treatment. Some of the increase comes from the overlapping pattern of binder application, but most is due to the necessity of erring on the high side of the target formulation.

The equipment for in situ soil mixing comes from specialty foundation and cutoff wall construction. Instead of the soil being brought to the mixer, the mixing equipment is moved through the volume of soil to be remediated. The equipment takes two forms: a fully tracked modified drilling rig such as that developed by Millgard Environmental Corporation (MecTool) or Noraterra (Detoxifier), or a mobile crane-supported auger such as that developed by Geo-Con, Inc. (Deep Soil Mixer and Shallow Soil Mixer). Both types of equipment can drill as deep as 150 ft. Depending on the soil type and the depth of boring required, the size of the MecTool boring/mixing head ranges in diameter from 4 to 12 ft. The Geo-Con Deep Soil Mixer uses a pilot-scale 3-ft-diameter single auger and a commercial-scale four-auger rig with mixing heads that can treat 27 SF at each setup. Each type of mixer is supported by cement slurry storage and

transfer equipment, and the binder ingredients are metered into the hollow-stem auger or kelly bar and injected into the soil column. The MecTool and the Detoxifier are equipped with a shroud that can be used for vapor collection if volatile contaminants are expected. In situ cement-based solidification uses the same cement/soil ratio as direct cement-based solidification, but consumes more binder because of the overlapping drilling pattern.

The only pre-treatment step for in situ solidification that is required is to adjust abrupt grade changes so that the mobile mixing rigs stand on a relatively flat surface. In situ solidification results in a volume expansion of the treated soil. Depending on the required binder ratio, the expansion may range between 10 and 25 percent. Post-treatment may involve recontouring of the expanded soil in place, or removal of the unacceptable volume to Basin A or the on-post landfill.

Other than the fugitive dust emissions associated with bulk solids transfer, in situ solidification does not produce any sidestreams. The process involves the injection of a cement slurry into the mixed soil column, so dusting is not likely at the mixing head. Volatile organics may be released from the soil as mixing proceeds, so the drill rig must be provided with a vapor collection hood if volatiles are anticipated.

In situ solidification is a miscellaneous treatment operation and falls under the siring, operation, monitoring, and closure requirements of RCRA regulations (40 CFR 264, Subpart X). The ARARs listed in Appendix A deal with fugitive dust and volatile organics emissions.

The operating costs for in situ cement-based solidification are developed from a quotation for a year-long program of shallow soil solidification at RMA supplied by Millgard Environmental Corp (MEC 1992). Other than mobilization and demobilization costs, there are no capital costs associated with the process since Millgard operates and maintains the equipment as a lease (Table 10.3-1). The quotation assumed the use of one MecTool drill rig for 5 days a week and 10 hours per day as well as operating and maintenance support. Processing capacity is estimated

to be 600 BCY of soil per day. Binder costs are based on $65/ton for bulk cement delivered to the site and a mix ratio of 0.2 tons of cement per ton of soil as suggested by the WES screening experiments on RMA soils. The Millgard quotation includes all operating and maintenance labor, including living expenses and all process utilities. As with direct solidification, a supply of clean water is required for cement slurry preparation and equipment washdown. The cost of in situ cement-based solidification using the MecTool process is estimated to be $60.38/BCY of soil treated.

10.3.2 Process Performance

If the cement slurry is intimately mixed with the soil, in situ cement-based solidification should be as effective in immobilizing contaminants as direct solidification methods. Uniform contact with all of the soil, however, is more difficult with in situ methods. The solution is to overlap the drilled columns to reduce the possibility of missing some of the soil section. In the overlap pattern, some of the mixed soil is remixed and additional binder is consumed.

As with direct methods, a volume increase that ranges between 10 and 25 percent takes place during the in situ processing of the soil. To protect the solidified mass from weathering, the site requires a soil cover layer for freeze/thaw protection as well as successful revegetation.

In situ cement-based solidification has been used successfully to solidify soils contaminated with heavy metals, but is seldom used alone when soils are also contaminated with chlorinated organic compounds such as PCBs and pesticides (EPA 1989b).

Treatability studies are not available for in situ cement-based solidification of RMA soils. However, the difference between direct and in situ solidification is in the mixing equipment rather than the binder formulation required. Since the preliminary screening tests from WES indicate that Portland cement successfully immobilizes RMA soil contaminants, a cement binder should prove adequate in an in situ application.

10.4 IN SITU PROPRIETARY AGENT SOLIDIFICATION

In general, in situ proprietary methods indicate a joint offering from an equipment vendor and a binder formulation vendor. For example, one solidification demonstration in EPA's SITE Program involved a proprietary formulation from International Waste Technologies (IWT) and a deep soil mixing rig from Geo-Con. Equipment setup, mixing patterns, and binder injection were all analogous to those used for cement-based in situ solidification. As with direct proprietary methods, a significant portion of the treatment cost is associated with the special additives.

In situ proprietary agent solidification was used in the DSA as part of Alternative 16 in conjunction with in situ vapor extraction. The volatile organics, which are generally not immobilized during solidification, are removed with in situ vapor extraction before the remaining inorganics and SVOCs are solidified. This alternative was retained for the South Plants Medium Group in the DSA.

10.4.1 Process Description

In situ proprietary solidification uses the same soil mixing equipment as that described under in situ cement-based methods. The equipment illustrated in dotted lines in Figure 10.3-1 indicates additional storage for proprietary ingredients. The need for a soil/clay cover and potentially for regrading is the same for in situ proprietary agent solidification as for in situ cement-based solidification (Section 10.3). In addition, the ARARs are also the same for these two processes.

The operating costs for in situ proprietary solidification are developed from the Millgard MecTool quotation for cement-based solidification. In place of the pure cement binder, a proprietary binder formulation was taken from the SITE Program applications analysis report for the IWT/Geo-Con in situ solidification process (EPA 1990a). The IWT binder uses a proprietary formulation of organophilic clays and sodium silicate. The binder usage of the IWT/Geo-Con summary is based on the pilot-scale demonstration at a Hilaleah, Florida site contaminated with low levels of PCBs. Operating and maintenance labor are included in the Millgard quote. The

cost of operating an in situ proprietary solidification process based on the MecTool equipment is estimated to be $79.28/BCY of soil treated (Table 10.4-1).

10.4.2 Process Performance

Proprietary additives are selected to avoid or suppress the chemical interferences that most organic and some inorganic compounds have on cement lattice formation. If the binder formulation is intimately mixed with the soil, in situ proprietary solidification should be as effective in immobilizing contaminants as the same formulation used in a direct mode.

In situ proprietary solidification has been used successfully to solidify soils contaminated with heavy metals and chlorinated organic compounds such as PCBs and pesticides (EPA 1989b). The immobilization efficiency of the binder formulation is specific to individual soil types and contaminants, however, so the results cannot be confidently extrapolated to RMA soils.

Treatability studies for in situ proprietary solidification are not available for RMA soils. The Waterways Experiment Station (WES) plans a survey of solidification vendors to determine whether any proprietary formulations look more promising than the results already obtained with cement binders. Those that prove adequate for direct treatment methods should prove adequate for in situ methods.

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Table 10.1-1 Capital and Operating Costs for Direct Cement-Based Solidification

Cost Category	Cost Item	Cost Estimate	Description
Fixed Costs	Mixing Unit	$ 110,000	Source: 1 Based on single-shift operation with a 5 day week (260 days/year).
	Batch Plant	90,000	
	Total Capital (65 tons/day)	$ 200,000	$3.35/BCY over a 5-year service life.
Operating Costs	Operating Labor	$23.46/ton	Source: 1 With variable costs adjusted for single shift operation.
	Consumables	2.25/ton	
	Analytical	5.65/ton	
	Utilities	1.11/ton	
	Maintenance and Spares	0.68/ton	
	Water truck rental	2.00/ton	
Binder	Cement at 20 percent of soil	$ 14.30/ton	Source: 2 With 10% waste factor.
Total		$ 49.45/ton	$70.10/BCY at 105 1b/CF

Sources:

1) EPA/540/A5-89/001, Hazcon Solidification Process, Douglassville, PA, SITE Applications Analysis Report, May, 1989 with costs escalated to January 1, 1993.

2) Personal communication, July 20, 1992, Mark Bricka of Waterways Experimental Station to Norman Scheaffer of Applied Environmental, preliminary screening tests on RMA soils.

BCY Bank Cubic Yards

Table 10.2-1 Capital and Operating Costs for Direct Proprietary Agent Solidification

Cost Category	Cost Item	Cost Estimate	Description
Fixed Costs	Mixing Unit	$ 110,000	Source: 1 Based on single-shift operation with a
	Batch Plant	90,000	5 day week (260 days/year).
	Total Capital (65 tons/day)	$ 200,000	$3.35/BCY over a 5-year service life.
Operating Costs	Operating Labor	$23.46/ton	Source: 1 With variable costs adjusted for single
	Consumables	2.25/ton	shift operation.
	Analytical	5.65/ton	
	Utilities	1.11/ton	
	Maintenance and Spares	0.68/ton	
	Water truck rental	2.00/ton	
Binder	Cement at 20 percent of soil	$ 14.30/ton	Source: 2 With 10% waste factor.
	Chloranan at $3.00/gallon	13.25/ton	Source: 1 Cement/chloranan ratio.
Total		$ 62.70/ton	$77.12/BCY at 105 pounds per cubic foot

Sources:

1) EPA/540/A5-89/001, Hazcon Solidification Process, Douglassville, PA, SITE Applications Analysis Report, May, 1989 with costs escalated to January 1, 1993 (EPA 1989a)

2) Personal communication, July 20, 1992, Mark Bricka of Waterways Experimental Station to Norman Scheaffer of Applied Environmental, preliminary screening tests on RMA soils.

BCY Bank Cubic Yards

Table 10.3-1 Capital and Operating Costs for In Situ Cement-Based Solidification

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs	None	$ 0.00/ton	Source: 1 Equipment is proprietary and operation is a service of the developer.
Operating Costs	Equipment Lease, Operating and Maintenance Labor, and Utilities	$ 17.64/ton	Source: 1 Operations are based on one 10-hour shift per day with a 5 day week.
	Cement Storage Facilities	.18/ton	Source: 2 Consumables and analytical costs taken as the same as direct solidification.
	Consumables	6.35/ton	
	Analytical	1.41/ton	
	Water Truck and Driver	.68/ton	
Binder	Cement at 20 percent of soil ($65/ton) and water at 50% of soil ($0.80/1,000 gal)	$ 16.35/ton	Source: 3 With 25% waste factor for overlapping boring pattern.
Total		$ 42.61/ton	$ 60.38/BCY at 105 pounds per cubic foot.

Sources:

1) Millgard Environmental Corp., vendor quotation of 12/23/92, for shallow mixing (10 to 15 ft) of silty clay soils at RMA using one MecTool Remediation Delivery System for a period of one year.

2) EPA/540/A5-89/001, Hazcon Solidification Process, Douglassville, PA, SITE Applications Analysis Report, May, 1989 (EPA 1989a).

3) Personal communication, July 20, 1992, Mark Bricka of Waterways Experimental Station to Norman Scheaffer of Applied Environmental, preliminary screening tests on RMA soils.

BCY Bank Cubic Yards

Table 10.4-1 Capital and Operating Costs for In Situ Proprietary Solidification

Cost Category	Cost Item	Cost Estimate	Description
Fixed Costs	None	$ 0.00/ton	Source: 1 Equipment is proprietary and operation is a service of the developer.
Operating Costs	Equipment Lease, Operating and Maintenance Labor, and Utilities	$ 17.64/ton	Source: 1 Operations are based on one 10-hour shift per day.
	Cement Storage Facilities	0.18/ton	Source: 2 Consumables and analytical costs taken as the same as direct solidification.
	Consumables	6.35/to	
	Analytical	1.41/ton	
	Water Trucks and Drivers	.68/ton	
Binder	Cement at 20 percent of soil and water at 50% of soil ($.80/1,000 gallon)	$ 16.35/ton	Source: 3 With 1.25 waste factor. Source: 2 Cement/Chloranan ratio.
	Chloranan at $ 3.00/gal	13.33/ton	
Total		$ 55.94/ton	$ 79.28/BCY at 105 lb/CF

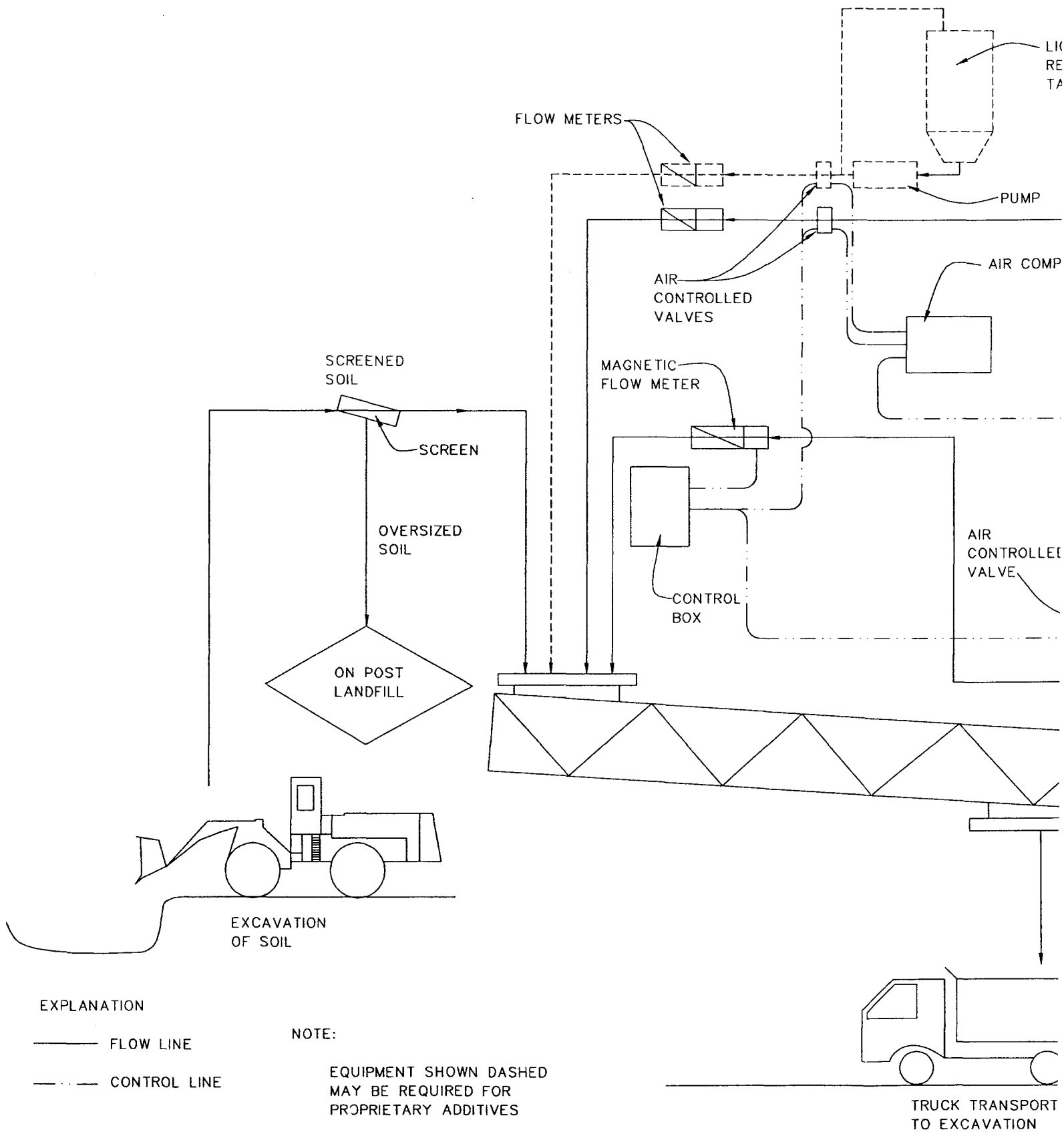
Sources:

1) Millgard Environmental Corp., vendor quotation of 12/23/92, for shallow mixing (10 to 15 ft) of silty clay soils at RMA using one MecTool Remediation Delivery System for a period of one year.

2) EPA/540/A5-89/001, Hazcon Solidification Process, Douglassville, PA, SITE Applications Analysis Report, May 1989 (EPA 1989a).

3) Personal communication, July 20, 1992, Mark Bricka of Waterways Experimental Station to Norman Scheaffer of Applied Environmental, preliminary screening tests on RMA soils.

BCY Bank Cubic Yards


FLOW METERS
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NOTE:
EQUIPMENT SHOWN DASHED
MAY BE REQUIRED FOR
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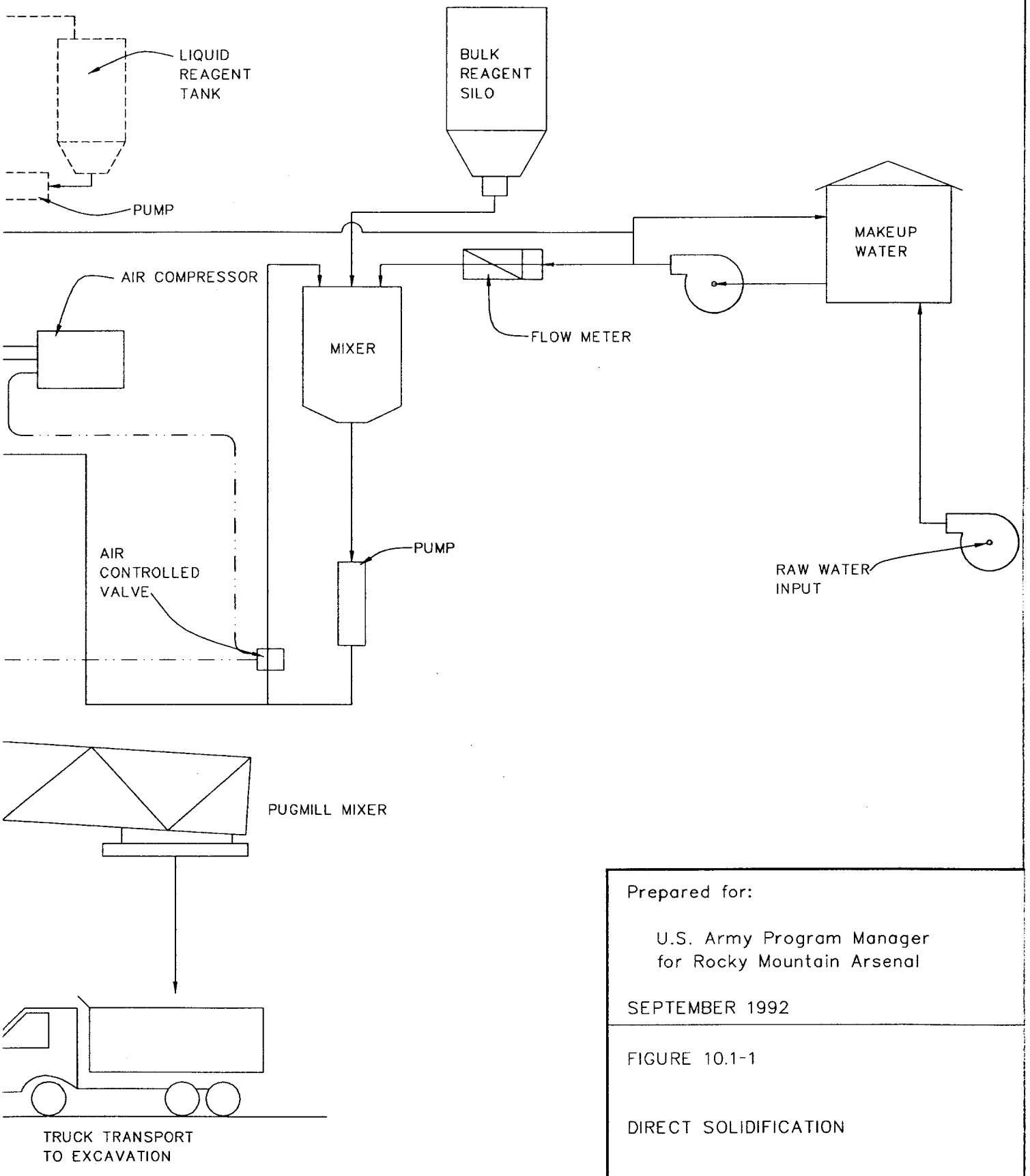

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

SEPTEMBER 1992

FIGURE 10.1-1

DIRECT SOLIDIFICATION

Rocky Mountain Arsenal.
Prepared by: Ebasco Services Incorporated

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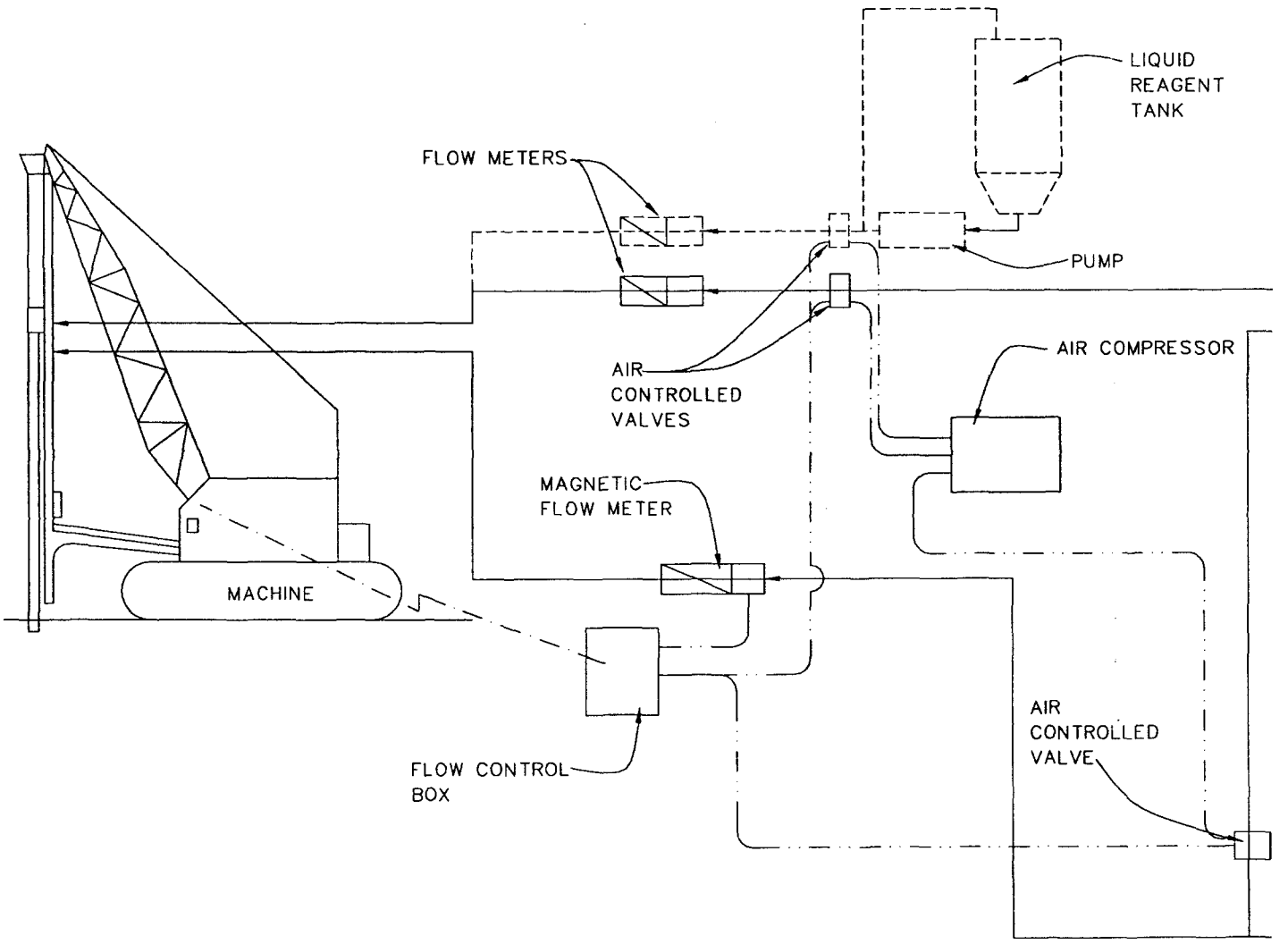


EXPLANATION

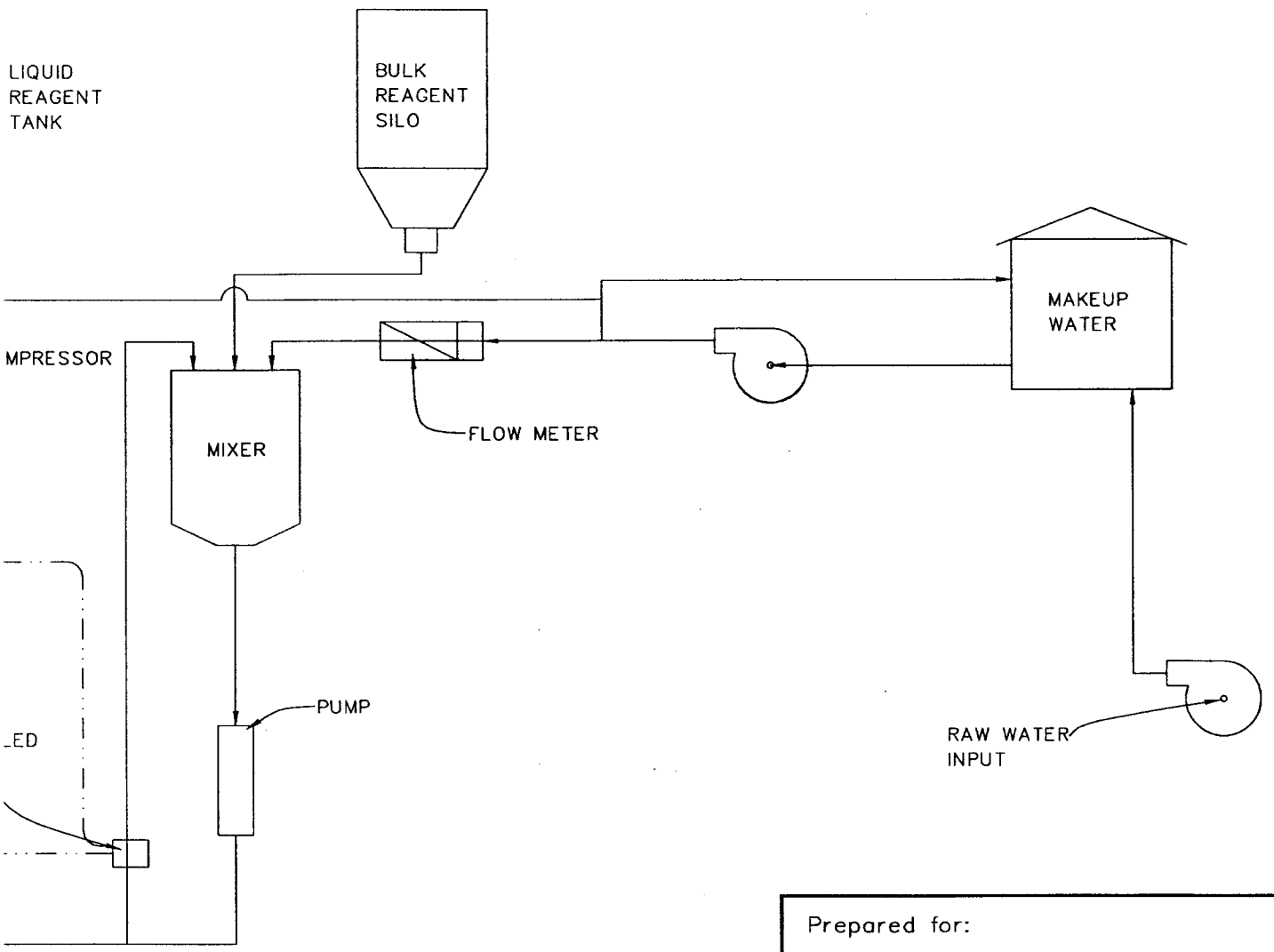
——— FLOW LINE

—·—·— CONTROL LINE

– – – – COMMUNICATION LINE

NOTE:

EQUIPMENT SHOWN DASHED MAY BE REQUIRED FOR PROPRIETARY ADDITIVES



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

SEPTEMBER 1992

FIGURE 10.3-1

IN SITU SOLIDIFICATION

Rocky Mountain Arsenal.
Prepared by: Ebasco Services Incorporated

11.0 BIOLOGICAL TREATMENT

The technologies discussed in Section 11 consist of treating of chlorinated pesticides (such as dieldrin) in surface soils via agricultural practices (landfarming), treating aromatic hydrocarbons (such as benzene) in groundwater using bioreactors or in situ biotreatment, and treating chlorinated pesticides in lake sediments using in situ biodegradation. Chlorinated pesticides are found in some soil and lake sediments at RMA, and aromatic hydrocarbons are found in groundwater primarily south of the South Plants Tank Farm.

Agricultural practices/landfarming was considered for pesticide-contaminated soils to promote contaminant loss, to reduce the potential for the exposure of receptors to contaminants, and to reduce the potential for wind dispersion of contaminants. An associated sidestream of this process may consist of some nitrate runoff due to fertilization.

Both in situ and ex situ biological treatment were considered for treatment of the South Plants Tank Farm groundwater plume. The in situ technology produces no sidestreams, and the ex situ technology produces biomass that must be disposed.

The lake sediments were considered for in situ biological treatment to achieve aldrin and dieldrin degradation. The addition of nutrients and oxygen or other electron acceptors produces biomass and dissolved nutrient sidestreams that would remain in the lake system.

11.1 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- to 1-ft depth interval). The concentrations of pesticides found in soils have been shown to decrease over time when subjected to agricultural practices (Shell 1992/RIC92-304-R03). Many studies have shown that the largest percentage of OCP losses in tilled or farmed soils occur in the first few years, although losses do continue after the first few years (Decker 1965; Freeman 1975; Lichtenstein and Schultz 1959; Lichtenstein et al. 1970; Nash

and Harris 1973). Other studies, however, have shown at least some loss in untilled soils (Nash and Woolson 1967). These studies postulated that there were a number of loss mechanisms involved including photolysis, oxidation, biodegradation, and volatilization. Bowman et al. (1965) and Nash (1983) have demonstrated that volitization is an active loss mechanism, although the contribution of the other loss mechanisms is not well understood. Moreover, the rate of loss, kinetics of loss, and degradation products are not fully defined.

11.1.1 Process Description

Farm Machinery

Landfarming involves tilling soil with farm machinery and seeding it with native grass in a manner consistent with an RMA refuge management plan. Where the ground is initially too hard for a plow to penetrate, a V-ripper with 13- to 20-inch blades is used to open the ground surface. Once the surface is broken, a plow with 6- to 8-inch bottoms overturns the soil and covers the upper 2 inches of contaminated soil with uncontaminated soil from below 0- to 2-inch depth interval. With the contaminated soil covered, dust dispersion and exposure of surface receptors is minimized. Finally, a 32-ft disk is used to break up soil chunks and uniformly mix the soil. To achieve uniform soil mixture, the disking is conducted in three different directions: the first pass is parallel to the plowing direction and the final two passes oppose the original plowing direction in two 45-degree angles. Fertilizer and mulch are applied and a mixture of native grasses is seeded using a pair of 15-ft seed drills. The seeding facilitates development of a stable final grass stand and aids soil conservation and prevention of dust dispersion.

Soil Stabilizer

A number of soil stabilizers that perform soils mixing are currently available. The soil stabilizers have the ability to uniformly mix an 8-ft width of soil to a depth up to 18 inches. They typically come equipped with an internal spray bar that enables water or nutrients to be added during soil mixing. The advantage of using a soil stabilizer compared to farm machinery is that the former requires only one pass to effectively mix the soil, although the results may be less predictable than with the farm machinery because soil reclamation vendors do not typically use this

equipment. A typical soil stabilizer, at a working speed of 30 feet per minute (fpm), can till approximately 2.6 acres in a 10-hour day. Figure 11.1-1 presents a typical soil stabilizer.

Seeding

The RMA vegetative system is very complex, and it cannot be precisely determined which plants need to be seeded in particular areas without a prior assessment of remediation/mitigation goals and an RMA refuge management plan. Prairie species should be seeded in areas desirable for wildlife habitation and less desirable species should be seeded in areas requiring wildlife exclusion. For cost estimating purposes, it was assumed that crested wheat grass at 8 pounds per acre (lbs/acre) and Pubescent grass at 12 lbs/acre can be seeded for a rapidly developing stand (Hastings 1992). In more sensitive areas, native grasses at 5 to 10 lbs/acre and native forbs at 8 to 15 lbs/acre would need to be seeded. Typical costs are approximately $900 per acre.

11.1.2 Process Performance

Mixing surface contamination into 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. The stands of native grasses and forbs to be planted stabilize the soil and provide wildlife habitat. Native grasses and forbs are sensitive plant species and attention to timing, soil moisture, and seeding/mulching technique play an important role in developing the native grasses and forbs.

The landfarming technology does not provide intensive treatment of the contaminants present. It does, however, reduce contaminated dust migration and surface receptor exposure and contaminant loss is expected with time. The primary advantage of this technology is that the treated soil supports growth of native grasses and forbs that will in turn provide wildlife habitat. Other potential remediation technologies, such as thermal treatment, tend to sterilize the soil and remove the organic carbon in the soil. The soil resulting from a thermal treatment process is not a viable growth media for native grasses and forbs.

11.2 FLUIDIZED-BED BIOLOGICAL REACTOR FOR GROUNDWATER TREATMENT

This technology involves treatment of extracted groundwater in a bioreactor. A number of biotechnologies were considered in the DSA for treatment of the hydrocarbons present in the South Tank Farm groundwater plume. These technologies include trickling filters, rotating biological contactors, submerged biological contactors, and suspended growth sequencing batch reactors. Because of the low anticipated contaminant concentrations and the results of the ongoing WES treatability studies (Zappi 1993), a GAC fluidized-bed reactor was selected.

11.2.1 Process Description

The biological reactor system being considered includes an oil/water separator to remove any floating product. Alternately, an in-well skimmer pump may be used to remove the floating product. Floating product removal may not be necessary if current removal efforts are successful. All influent is pumped and transported to a lined tank. This tank is sized as an equalization tank based on the anticipated amount of storage of contaminated groundwater, ensuring continuous and consistent flow to the treatment system so that sharp fluctuations in the concentration of feed water are avoided. The contaminated water is then introduced into the GAC fluidized-bed reactor (Figure 11.2-1). The fluidized-bed reactor consists of an expanding GAC bed to which microorganisms attach. Contaminants are quickly sorbed to the fluidized GAC. Microorganisms growing in and on the carbon subsequently degrade the contaminants, which regenerates the carbon. Water is continuously recycled through the reactor with oxygen from an oxygen generator added during the closed recycle loop, thereby eliminating the production of off gas in the aeration process. A lamella clarifier is used for effluent polishing and iron and manganese removal. The final treatment step consists of removing suspended solids with a sand filter. The primary sidestream consists of biomass and spent carbon from the bioreactor. The biomass is filtered in a multimedia filter and disposed in the on-post landfill. The small amounts of spent carbon is also drummed and disposed in the landfill.

11.2.2 Process Performance

The fluidized-bed biological reactor is being proposed for treatment of water extracted from the South Tank Farm Plume. The dimensions of the plume are approximately 4,000 ft long by 2,000 ft wide. The primary contaminant of concern is benzene, which has a mean concentration of 46,000 micrograms per liter (µg/l). OCPs are also present, but at low levels. For the high concentrations of benzene present, it was assumed that biological treatment is combined with additional treatment to meet the target effluent criteria.

Several factors determine the implementability of biological treatment including pollutant concentration, oxygen concentration, active biomass concentration, temperature, pH, availability of inorganic nutrients, and microbial adaptation. These parameters are currently being investigated by a WES treatability study conducted with highly concentrated water collected from the South Tank Farm Plume. This treatability study is using three suspended-growth reactors to treat water extracted from the South Tank Farm Plume. Preliminary results indicate that good microbial adaptation and removal rates can be maintained at significantly higher concentrations than the estimated influent concentrations for the South Tank Farm Plume.

Dissolved iron and manganese exist in the groundwater at this site and could potentially require pre-treatment to prevent precipitation in the bioreactor or post-treatment to prevent clogging of the discharge system. However, during the preliminary WES treatability study results, these compounds have not required special treatment. Accordingly, this system is designed without pre- or post-treatment for iron and manganese.

11.3 IN SITU AEROBIC BIODEGRADATION

In situ aerobic biodegradation consists of generating conditions within the aquifer that facilitate aerobic biodegradation of the contaminants of concern at an acceptable rate. In this system, nutrients and an oxygen source (hydrogen peroxide) are added to the extracted groundwater, which is then reinjected into the aquifer. The nutrients and hydrogen peroxide enhance the in situ biodegradation process.

11.3.1 Process Description

In situ aerobic biodegradation involves the microbial degradation of organic contaminants in the aquifer. For in situ biodegradation to occur, the following materials or conditions must be present:

- Sufficient quantities of microorganisms capable of degrading the contaminants
- Sufficient oxygen concentration
- Macronutrients
- Micronutrients
- Acceptable pH for the microorganisms
- Acceptable temperature for the microorganisms

The system proposed for treatment of the contaminants present in the South Tank Farm Plume is based on an assumption that indigenous microorganisms degrade the contaminants present at the current pH and temperature under nutrient- and oxygen-enriched conditions.

Oxygen in the form of hydrogen peroxide, along with micronutrients and macronutrients, are expected to be required additives. Optimum concentrations need to be determined through site-specific treatability studies. The oxygen and nutrients are introduced into the subsurface through a series of injection wells. The microorganisms, in the presence of the oxygen and nutrients, degrade the contaminants while the water moves downgradient. Extraction wells remove the treated water, and additional oxygen and nutrients are added prior to reinjection of the treated water. The purpose of reinjecting the treated water is to provide additional treatment opportunity if the water has residual concentrations of contaminants, to use the treated water to aid in flushing sorbed contaminants from the aquifer material, and to reintroduce the suspended acclimated microorganisms. During groundwater recharge, the water table is artificially elevated and contaminants trapped in pore spaces may be resolubilized. A secondary goal of this technology is to remove the contaminants in these pore spaces and subsequently treat them by in situ bioremediation. Figure 11.3-1 presents a diagram of the system.

Hydrogen peroxide produces the highest amount of oxygen per volume of any source and also restricts biogrowth on well screens at the point of groundwater recharge. Accordingly, it will be used as the oxygen source.

The extraction wells proposed for the in situ biodegradation have stainless steel slotted screens with permeable sand packs and a bentonite seal immediately above the sand pack. Grout and cement are placed above the bentonite seal. Additional aquifer and soil properties testing may indicate a need for alternative extraction methods. Trenches utilizing perforated piping could be used in low-permeability, low-flow, shallow aquifers. The injection wells proposed for this technology are designed similarly to the extraction system with the exception of increased size to enhance effluent percolation.

The macronutrients and micronutrients are added along with hydrogen peroxide as an oxygen source prior to reinjection of the water. Mixing takes place in a mixing tank and oxygen concentrations are monitored to ensure desired oxygen concentrations are reached. A storage tank is included to ensure a continuous and consistent volume of reinjection water for in situ treatment.

The in situ aerobic technology would result in a very long remediation time given the high volume of water that needs treatment and given the relatively impermeable aquifer materials present in the South Tank Farm Plume area. Furthermore, the biological mass produced by these high concentrations of benzene could possibly clog the aquifer.

11.3.2 Process Performance

Several factors determine the performance of the biodegradation treatment process including:

- Pollutant concentration
- Microbial adaptation and activity
- Temperature
- pH

- Availability of macronutrients
- Availability of micronutrients
- Oxygen concentration
- Hydrogeologic conditions

Shell reported excellent benzene removal in an activated sludge biological treatment pilot plant (Shell, 1982). Influent concentrations ranged from 40 to 240 mg/l and the effluent concentration was generally less than 0.020 mg/l. These removal efficiencies were achieved at 25°C with a 2-day hydraulic retention time. The unit was biologically seeded with sewage sludge and nitrogen and phosphorus were added in the ratio of the 5-day biological oxygen demand (BOD_5):N:P at 100:5:1. Site-specific treatability studies are needed to demonstrate that the indigenous microorganisms are adapted to degrading the contaminants present, to establish the rate of degradation in situ, and to evaluate the impact of the system on the hydrogeologic properties of the aquifer.

Precipitation of iron and manganese is a concern because the addition of oxygen to RMA groundwater may cause the iron and manganese to precipitate either in the surface reactor or in the aquifer. The precipitates will fill the void space in the aquifer and ultimately reduce the groundwater flow to the point that the treatment system will no longer function. The magnitude of this effect may need to be determined through site-specific treatability studies.

This technology is being proposed for treatment of the South Tank Farm Plume. The main contaminant is benzene, which has a mean concentration of 46,000 µg/l. OCPs are present at low concentrations. It has been reported that benzene concentrations higher than 100 mg/l are inhibitory to microbial growth and that no degradation occurs at benzene concentrations higher than 250 mg/l (Alvarez and Vogel, 1991). A Shell (1982) study confirms this finding, reporting that concentrations up to 240 mg/l did not inhibit microbial growth.

The oxygen supply must be carefully regulated so that the dissolved iron does not precipitate in a quantity that would clog the aquifer and make in situ biotreatment ineffective. Sodium hexametaphosphate may be added as an agent to reduce the precipitation of iron.

The geology of the area varies from sandy siltstone to sandy claystone. The Denver formation, which dominates the South Tank Farm area, has a low primary permeability. However, interconnected fractures in this area provide a much higher effective permeability. The groundwater is located in an unconfined zone of weathered bedrock with a hydraulic conductivity of 2.8×10^{-1} feet per day (ft/day). The bedrock is overlain with unsaturated alluvium with a hydraulic conductivity of 2.6×10^{3} to 1.7×10^{2} ft/day.

11.4 IN SITU BIOTREATMENT OF LAKE SEDIMENTS

The in situ biological treatment of sediments is being considered for the remediation of the southern lakes at RMA. The contaminants of concern are aldrin a high of 27 ppm, dieldrin at a high of 5.1 ppm, and endrin at a high of 0.23 ppm. This technology consists of optimizing conditions within the lake sediments to enhance biodegradation. The primary variables to be optimized are oxygen (or other electron acceptor) concentration and nutrient availability. For this technology to be effective, the contaminants to be treated must be biodegradable. Unfortunately, the primary organic contaminant of concern in the southern lakes, aldrin and dieldrin, have not been shown to biodegrade. However, recent advances in aerobic biodegradation of large chlorinated molecules such as PCBs indicate that in the near future biodegradation of chlorinated pesticides may be viable. Accordingly, this technology was retained for treatment of the southern lakes.

11.4.1 Process Description

An in situ biological treatment system for aerobic biological treatment of sediments consists of a mechanism to add oxygen and a mechanism to add macronutrients and micronutrients. Due to the constant flow of water in the lake over the sediments, the addition of the nutrients must be isolated from the water flow. This is done by placing a physical barrier between the

sediments and the main body of the water, which should prevent eutrophication. When excess nutrients such as nitrogen and phosphorus are added to the lake system, eutrophication, which may occur if nutrient-limited organisms are present, clogs the lake system and subsequently kills larger organisms due to lack of oxygen. The system only treats a small part of each lake at a time so the lake ecosystem system is not destroyed.

In situ biotreatment of the lake sediments is desirable because it does not require destruction of the sediment biosystem to treat the contaminants. Alternative technologies require dredging of the contaminants with subsequent landfill disposal or thermal, chemical, or physical processing to remove the contaminants. These dredging processes make the sediments no longer useful for supporting life in the lakes. However, in the late 1950s, the lake sediments were dredged due to high concentrations of pesticides present and over time the system has rebounded to its current state. Based on field studies done on these lakes, there is a surprising lack of benthic organisms, which makes it difficult to predict the recovery rate if the sediments were grain dredged.

In support of the endangerment assessment (EBASCO 1992 RIC#92275R02), literature searches and field studies were performed to determine whether biodegradation was taking place in soils at RMA and if so, at what rate. The results of the literature studies showed that aldrin and dieldrin are lost from soils over time, although they did not pinpoint mechanisms. Possible mechanisms of this natural attenuation include volatilization, dissolution, and migration with surface water or groundwater, or biodegradation. A number of first-generation degradation products were described in these studies, but no studies showed these contaminants being mineralized, and no studies showed a pathway from the first-generation degradation compounds to relatively nontoxic compounds. The RMA Basin C field studies did not show a loss of aldrin and dieldrin from soils over the several years the study was conducted. Current work is ongoing to identify specific microorganisms and conditions that favor biodegradation.

Assuming a biodegradation mechanism for aldrin and dieldrin could be found, two vendor approaches for remediating lake sediments using bioremediation were identified. Both

approaches isolate the sediments from the surrounding water so that conditions can be controlled to maximize biodegradation. The first approach, performed by OHM Incorporated, was demonstrated in a pilot-scale demonstration on a portion of Hudson River sediments contaminated with PCBs (Harkness et al. 1993). The pilot-scale system used a caisson-enclosed system consisting of a raking mechanism to aerate the sediments along with a submerged blanket to prevent resuspension of the contaminants into the water. Each caisson unit was capable of treating a 2-SY area. Treatment time was approximately 6 weeks per batch.

The second method was suggested by IT Corporation. This method involves adding dense insoluble nutrient and oxygen sources to the lake water where they settle to the bottom and are used by organisms present in the sediment. The oxygen and nutrient supplies aid in multiplying the number of organisms capable of degrading specific contaminants without disturbing the sediment, lessening the possibility of resuspending contaminants.

No vendor capable of providing an aerobic in situ sediments treatment system was located, so a system similar to those used for biotreatment of petroleum sludges was designed. The system consists of a corrugated steel curtain ponded into the lake to isolate approximately 5 percent of early lake (200 ft by 200 ft) and three aerators and three sludge pumps. The sludge pumps pump the sediment from the bottom and create a water/sediment suspension. (Due to the low vapor pressure of aldrin and dieldrin, contaminant losses to air are expected to be minimal.) With the sludge pumps and aerators in place, a nitrogen-phosphorous fertilizer is added to the water/sediment suspension. Seeded microorganisms degrade the contaminants. An 8-week treatment time was assumed.

11.4.2 Process Performance

Once microorganisms capable of degrading aldrin and dieldrin have been identified, this process is expected to remediate the sediments without destroying the biosystem. With the technology at its current level of development (microorganisms not identified), the technology would not be expected to meet PRGs.

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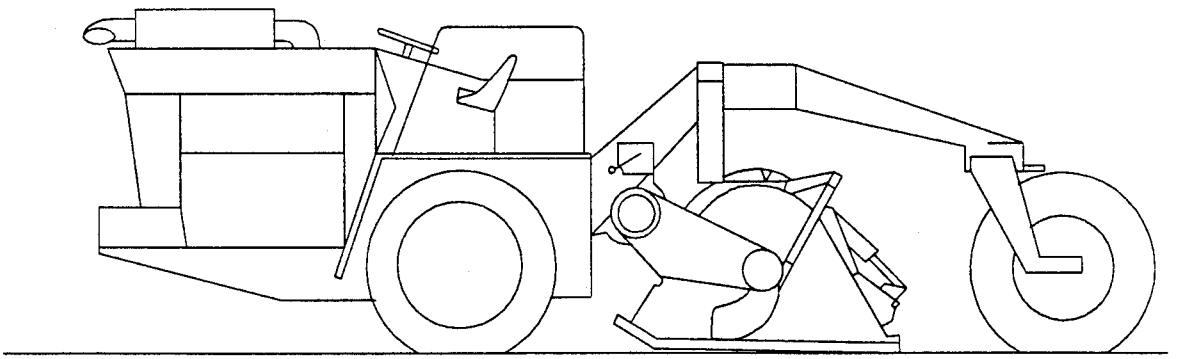

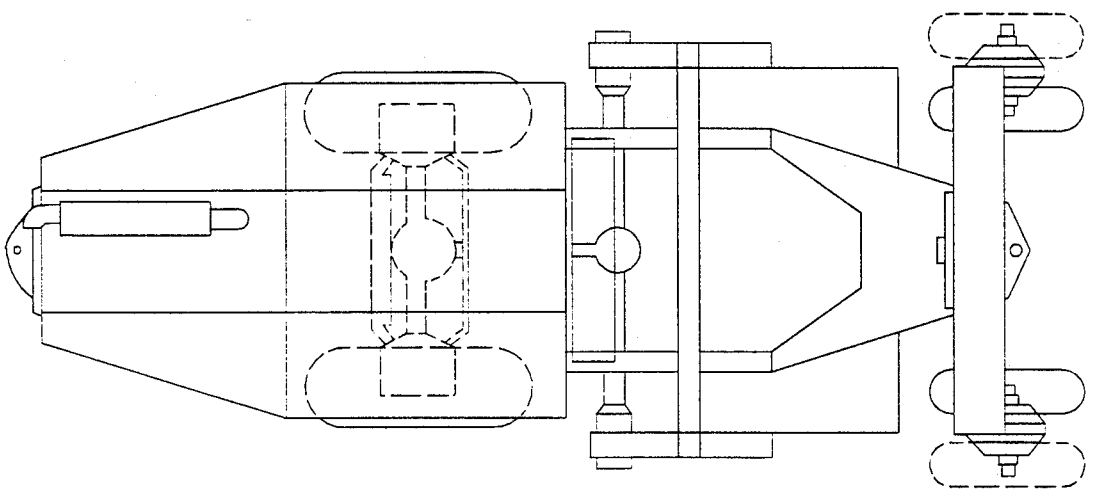

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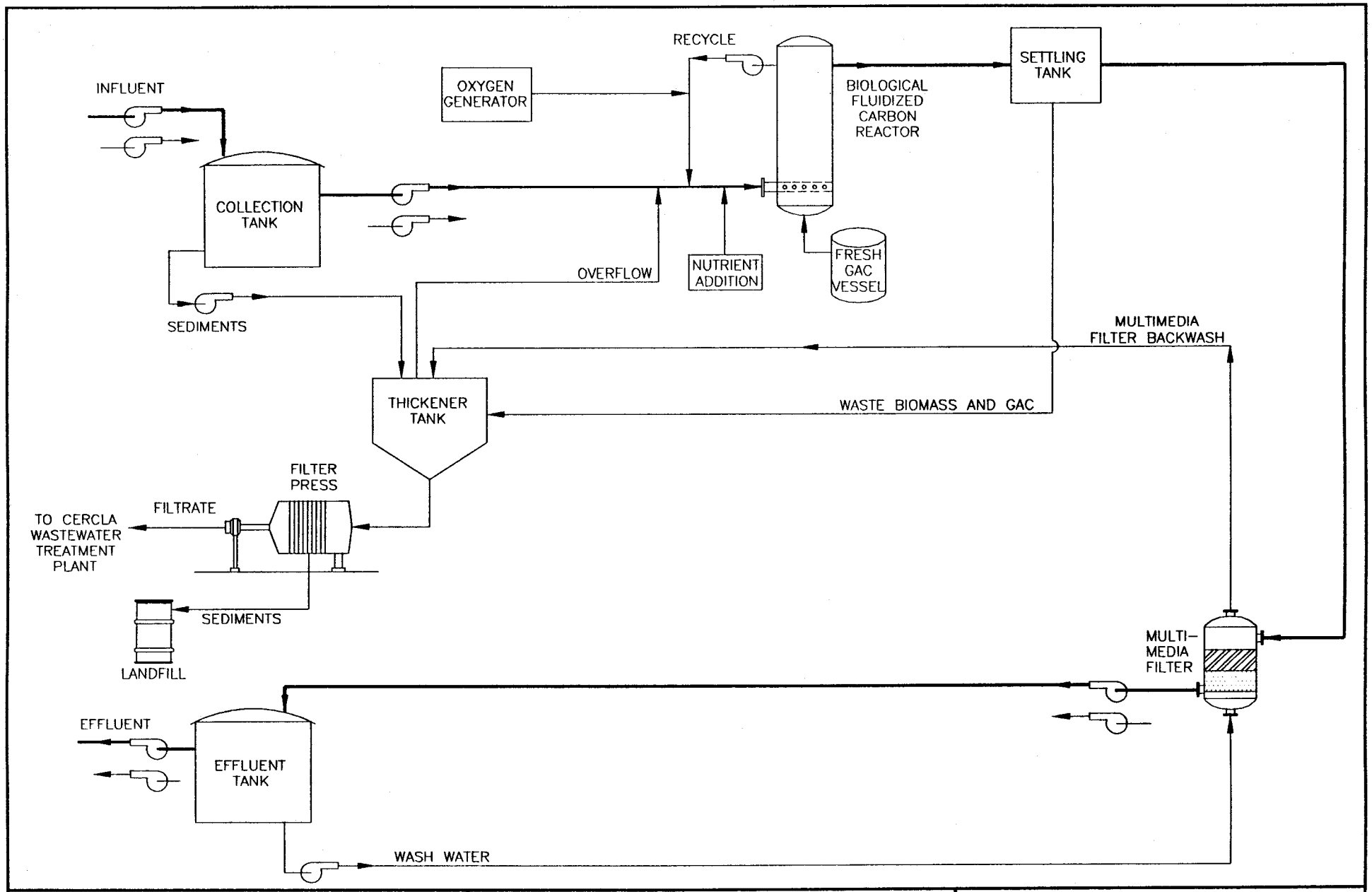
for Rocky Mountain Arsenal

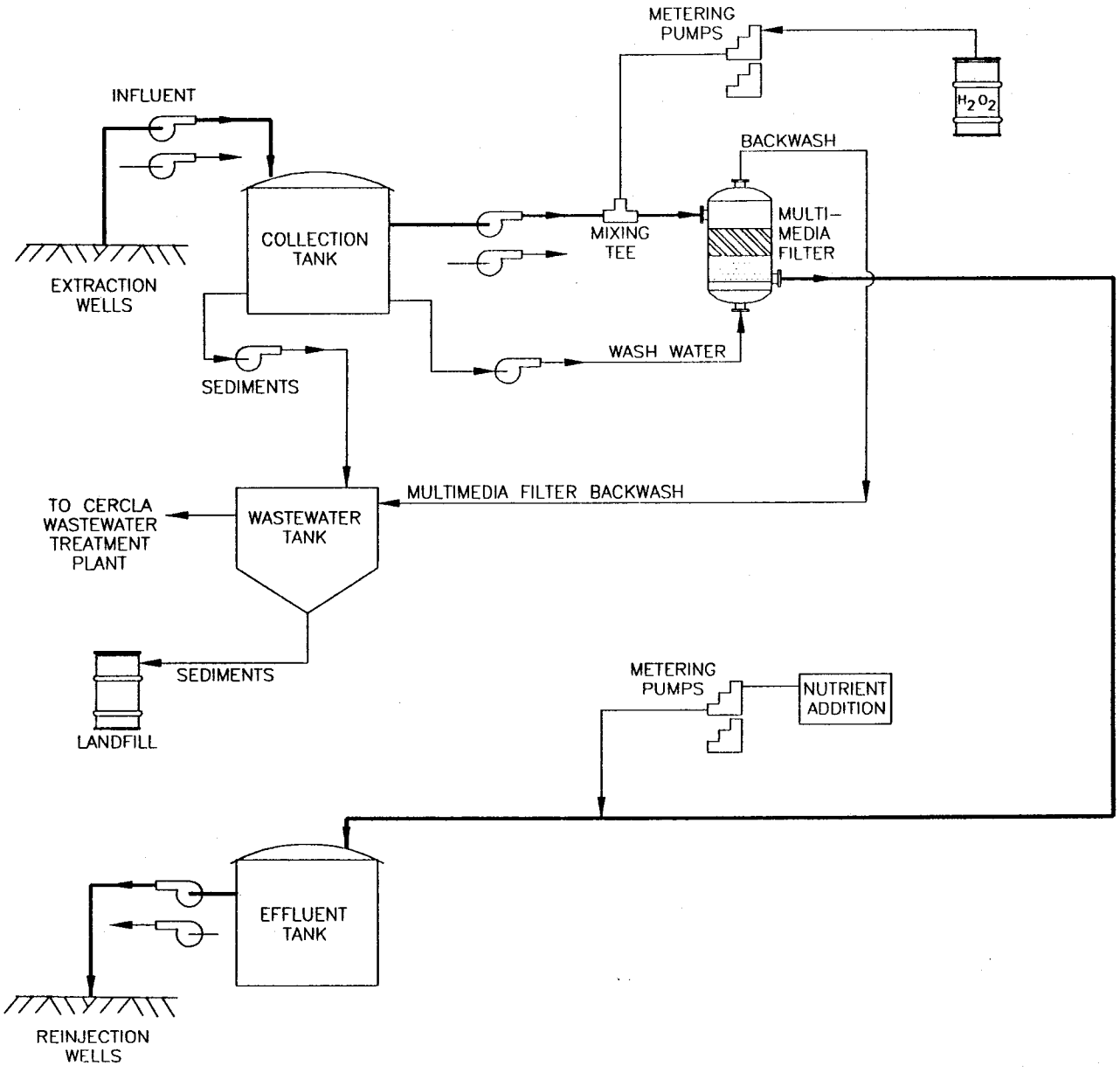
FIGURE 11.1-1

Caterpillar SS-250 Soil Stabilizer

Prepared by:
EBASCO SERVICES INCORPORATED



Prepared for:	FIGURE 11.2-1	Prepared by:
Office for the Program Manager for Rocky Mountain Arsenal	Fluidized Carbon Bed Biological Treatment	Ebasco Services Incorporated



Prepared for:	FIGURE 11.3-1	Prepared by:
Office for the Program Manager for Rocky Mountain Arsenal	In Situ Biodegradation	Ebasco Services Incorporated

12.0 SOILS UNIQUE PROCESSES

Soils unique processes include three process options—direct soil washing, soil flushing, and soil vapor extraction—developed to remediate contaminated soils by physical/chemical processes. Section 12.1 describes direct soil washing, Section 12.2 describes soil flushing, and Section 12.3 describes of soil vapor extraction.

12.1 DIRECT SOIL WASHING (SOLUTION WASHING)

Soil washing is a direct physical/chemical treatment process that uses washing solutions and physical scrubbing to separate soil size fractions and remove organic and inorganic contaminants from the soil. Washing solutions typically consist of water and additives that increase the removal efficiency of the washing processes. Additives may consist of surfactants, chelating agents, oxidizers, or acids or bases. Surfactants are used to increase the removal efficiency of soluble and insoluble organic compounds. Chelating agents, oxidizing agents, and acids or bases are used to aid the removal of metals. Solvent extraction utilizing pure organic solvents typically removes low solubility organic compounds such as OCPs. The washing solution is selected depending on the contaminants to be removed and the removal efficiencies desired.

The soil washing process developed for RMA is designed primarily as a pre-treatment or partial treatment technology, and is to be used in conjunction with other treatment technologies (i.e., thermal desorption) to provide overall soil remediation. This process was developed as a partial treatment technology because treatability studies have shown that soil washing is not effective as a stand-alone technology in cleaning contaminated soils to human health or biota PRGs. Based on the high water solubility of fluoroacetic acid, solution washing is expected to be capable of removing fluoroacetic acid and salts as a partial treatment step to improve the performance of thermal treatment processes. Additionally, if soils containing only fluoroacetic acid are to be treated, direct soil washing may be used as a complete remediation technology.

Soil washing incorporating solvents may be potentially effective in removing organic constituents to required treatment levels. This process was evaluated in the DSA, but it was not retained pending the outcome of an ongoing bench-scale treatability study to support this decision.

The soil washing process considered for the RMA FS was designed as a volume reduction process. The process consists of mixing contaminated soil with the washing solution, scrubbing and agitating the mixture, and classifying the soils by size. Ideally, the process produces a "clean" coarse-grained washed soil that meets PRGs, as well as a contaminated fine-grained soil. The clean soil is backfilled on post, and the contaminated fine-grained soil fraction is subsequently treated by another technology to destroy or solidify/stabilize the contaminants present.

Soil washing has been proposed for three medium groups at RMA: Basin A, Basin F Wastepile, and Secondary Basins. The contaminants of concern at these sites include VOCs, OCPs, fluoroacetic acid, and metals.

12.1.1 Process Description

Figure 12.1-1 provides a schematic of the soil washing process. Excavated soils are screened to remove debris and oversized materials and then mixed with the soil washing solution to form a slurry. The slurry is subjected to a series of intense scrubbing processes to free contaminated fine particles from sand and gravel particles and then is subjected to physical classification steps to separate the clean sand and gravel, the contaminated silt and clay fines, and the process water. The clean soil is backfilled on post, and contaminated fine-grained soil fraction is subjected to subsequent treatment. The process water is treated to remove contaminants and recirculated back into the soil washing process.

The basic principles of the soil washing technology are that organic contaminants adsorb preferentially onto fine-grained soil particles such as silt, clay, and organic matter. Additionally, heavy metal contaminants, including arsenic, mercury, and inductively coupled argon plasma

(ICP) metals, adsorb preferentially onto minerals and organic solids present in silt- and clay-sized fine-grained soils. Contaminants associated with coarse soils are primarily surficial, and this surficial contamination may be removed by solution washing and abrasion.

The removal of fluoroacetic acid and salts is based on the high water solubility of these contaminants. Since they are water soluble, they should readily dissolve in the washing solution. Treatment for these contaminants should not require intense scrubbing or agitation and should not result in a fine-grained soil fraction requiring additional treatment.

The first step in soil washing, screening and size reduction, is initiated by passing the excavated soils through a coarse-mesh sieve to remove rocks and debris greater than two inches. The oversized materials are then passed through size-reduction equipment to reduce the material to a required maximum 2-inch feed size or separated for disposal without soil-washing.

Solution washing is accomplished in multiple-stage scrubbing units. In the scrubbing units, the soil is sprayed with the washing solution and intense scrubbing is initiated. The scrubbing action disintegrates soil aggregates, freeing contaminated fine particles from sand and gravel fractions by the abrasive scouring action of the particles themselves. Contaminants may also be dissolved into the process washing solution.

The soil washing slurry is then segregated through sieves, screens, hydraulic classifiers, cyclones, settling basins, or clarifiers to separate the coarse- and fine-grained soils. The coarse-grained soils are rinsed, dewatered, and analyzed for residual organic and inorganic contaminants to ensure PRGs have been achieved. The remaining volume of fine-grained soils are dewatered and further processed to remove, destroy, or stabilize organic and inorganic contaminants. The contaminated washing fluid is subsequently treated to remove dissolved and suspended contaminants and recycled back into the soil washing process. The wastewater sludge is treated with the soil fines.

The action-specific ARARs governing the design and performance of solution washing are presented in Appendix A. These action-specific ARARs primarily address the discharge of treated waste water, air emissions, and worker protection during processes operation.

Table 12.1-1 presents costing information for soil washing. The total capital cost for soil washing is $6,765,000, and the operating and maintenance cost is $35.31/BCY.

12.1.2 Process Performance

The success of this process in reducing the TMV of contaminants depends predominantly on the distribution of the contamination in the soil matrix (i.e., fine-grained versus coarse-grained soils) and the effectiveness of the washing process in separating the contaminated material from the coarse-grained soil. Treatability studies completed at RMA (French 1993) have evaluated the distribution of pesticides and metals for Basin A and South Plants soils and the effectiveness of two soil washing technologies. Results indicated that in Basin A soil contaminants were not sufficiently concentrated in fine-grained soils (i.e., 22.5 percent of total soils are fine grained and contain 31 percent of the total pesticides along with 46.1 percent of the total metals) to make soil washing effective. For South Plants soils, the contaminants were distributed in the fines to a greater extent (i.e., total fines were 23.6 percent, with 70.2 percent of the total pesticides and 67.7 percent of the total metals). Unfortunately, the soil washing process was only able to reduce the concentration of OCPs present in the coarse-grained soil by 90 percent. Accordingly, this technology would only be applicable if the initial OCP concentrations were within one order of magnitude of the cleanup goal.

These results also indicate that solution washing may be an effective volume reduction treatment for soils similar to South Plants soils, because the soil remaining after fines removal has a much lower contaminant content regardless of the amount of contamination removed by the washing fluid. Basin A soils or other soils at RMA where the pesticides are not concentrated in fine-grained soils will not be significantly affected by the size fractionation portion of the soil washing process.

These results also indicate that soil washing would not achieve PRGs for all of the contaminants of concern. Thus, the process was retained as a pre-treatment step only. Soils with OCPs and metals require additional treatment (i.e., thermal desorption) to achieve PRGs. Soils with fluoroacetic acid exceedances only may not require additional treatment and may be backfilled after soil washing.

Table 12.1-2 provides soil washing performance data from other sites. Removal efficiencies in treatability studies at the Woodbury Chemical and Sand Creek Superfund Sites, which have similar COCs, ranged from 65 to 94 percent at an estimated cost of $148/CY. Removal efficiencies reported in treatability studies performed by the Resource Conservation Company (RCC) using a triethylamine (TEA)-based solvent extraction process ranged from 98 to more than 99 percent. The PRGs for OCPs were met in the treatability study, but required up to nine extraction steps. This large number of extraction steps would make application of the technology at RMA more expensive than application at a typical site (requiring three to five extraction steps).

12.2 SOIL FLUSHING

Soil flushing is an in situ treatment technology designed to remove contaminants from soils by passing extractant solutions through the soils. The process involves the creation of an active leaching field in areas of soil contamination to accelerate percolation and desorption of contaminants from the soil. The flushing solution is sprayed, flooded, or injected over and into the soil area to be treated. As the flushing solution percolates through the treatment zone, it mobilizes contaminants from the soil matrix. The flushing solution then carries the mobilized contaminants through the soil profile until it mixes with the underlying groundwater. The flushing solution and contaminants are collected in downgradient recovery wells or trenches and pumped to a treatment system. Following treatment, the captured groundwater is discharged to the leaching field, forming a closed-loop recovery system.

The effectiveness of a soil flushing system is dependent on the solubility of the contaminants in the flushing solution and the ability to move the flushing solution through the contaminated soil.

Best removal will be achieved in highly permeable, homogeneous soils where the flushing solution is effectively distributed throughout the soil treatment zone. The process is particularly cost effective in the case where pre-existing groundwater contamination requires groundwater recovery and treatment and where the groundwater moves rapidly.

Soil flushing is a proposed technology for the Basin A Medium Group. The COCs at these sites are OCPs, fluoroacetic acid, and metals.

12.2.1 Process Description

Figure 12.2-1 provides a schematic of a soil flushing system. For the Basin A Medium Group, the flushing solution is sprayed over the soil area to be treated. As the flushing solution percolates through the treatment zone, it mobilizes contaminants from the soil matrix and carries the mobilized contaminants through the soil profile to the water table. The solution and contaminants are then collected in downgradient recovery wells at the Basin A Neck and pumped to the Basin A Neck IRA groundwater treatment system. The Basin A Neck IRA system will require expansion if this alternative is selected. Costs to expand the system were included in the estimated costs for this alternative. Much of the captured groundwater is discharged to the leaching field, forming a nearly closed-loop recovery system.

Soil flushing removes contaminants from the soil column by three mechanisms: preferential wetting, solubilization, and emulsification. Preferential wetting may remove residual free-phase contaminants by wetting the soil particle surfaces, thereby partially or completely displacing a residually saturated contaminant or a contaminant adsorbed to the soil organic fraction. Remaining free-phase or adsorbed contaminant removal is accomplished through solubilization (emulsification), in which the contaminant becomes dissolved or dispersed within the flushing solution.

Water can be used for flushing of relatively soluble compounds with a low affinity for soil organic carbon. To mobilize OCPs, surfactants are required; metals require weak acids, reducing

agents, and chelating agents. Even with these additional agents, effectiveness for mobilizing OCPs is anticipated to be poor.

Surfactants improve the ability of an aqueous flushing solution to mobilize strongly adsorbed, low-solubility compounds. Surfactants wet the soil particles and decrease the interfacial tension between the aqueous phase and the solid phase, thereby promoting preferential wetting and solubilization due to the interaction of the surfactant molecules with the contaminant. Surfactants can also enhance the detergency of an aqueous solution by promoting the dispersion of an insoluble organic phase within the aqueous phase, creating an emulsion. Interactions between surfactants, soil media, contaminants, and microbial populations can lead to problems in implementation of soil flushing technologies caused by loss of permeability resulting from enhanced microbial growth or expansion of clays. Surfactants may be lost within the soil or groundwater environment through adsorption on solid surfaces, absorption by partitioning into free-phase contaminants, and biodegradation. Complete removal of surfactants from the environment may not be possible, and surfactant recovery from the waste stream can be difficult (Rixey 1990).

Surfactant requirements are dependent on the solubilization capacity of the particular compounds of interest, contaminant concentrations, desired cleanup level, and sorptive properties of the soil. Of these four parameters, surfactant requirements are most dependant on the solubility of the contaminant (Rixey 1990). OCPs have low solubilities and high organic carbon partition coefficients (i.e., attraction for soil organic carbon), and require high surfactant loadings for even partially effective remediation. Loadings of 20 to 60 pounds of surfactant per ton of soil are commonly used for bench- and field-scale pilot tests (Rixey 1990).

The action-specific ARARs governing the design and performance of soil flushing are presented in Appendix A. These action-specific ARARs primarily address the discharge of treated wastewater, air emissions, and worker protection during process operation.

Table 12.2-1 presents costing information for soil flushing. The total capital cost for soil flushing is $8,113,000, the total operating and maintenance cost is $83.45/BCY.

12.2.2 Process Performance

The success of this alternative in reducing the TMV of contamination depends predominantly on the soil types in which the contaminants are distributed, the physical/chemical properties of the contaminants, and the hydrologic properties of the aquifer below. The soil types present dictate the effectiveness of the soil flushing system in distributing the flushing solution and the contact achieved between the flushing solution and the soil contaminants. Best removal efficiencies are achieved in highly permeable homogenous soils where the flushing solution is effectively distributed throughout the soil treatment zone. EPA has noted that effective remediation by soil flushing is limited to soils with a hydraulic conductivity of at least 1 x 10^{-4} cm/sec (EPA 1985, 1986).

The physical/chemical properties that directly influence the applicability of soil flushing include the following:

- Contaminant solubility
- Organic carbon partition coefficient of the contaminant
- Total organic carbon (TOC) content of the soil

The solubility of a compound is a measure of its ability to enter into solution. Once a contaminant is dissolved, it moves through the soil profile and mixes with the underlying groundwater. Table 12.2-2 presents solubility data of the contaminants of concern in Basin A. The more soluble the compound, the greater the fraction of the mass present that is removed with each flushing volume.

A contaminant's partition coefficient describes its affinity to adsorb to soil organic carbon. Organic compounds are grouped by relative magnitude of their partition coefficients (K_{oc}). Values greater than 4,000 milliliters per gram (ml/g) exhibit a strong affinity for the solid phase

and, therefore, a limited mobility in the aqueous phase or the flushing solution. Moderate K_{oc} values (500 to 4,000 ml/g) indicate a moderate affinity for the solid phase and moderate mobility in the aqueous phase (EBASCO 1991/RIC#91326R02). Table 12.2-2 presents K_{oc} values for the COCs in Basin A.

TOC is a measure of the organic carbon content of soils. The lower the TOC value, the less carbon there is available to hold the organic contaminants in the soil; thus values lower than 1 percent are favorable to soil flushing effectiveness (EPA 1985). The TOC content of RMA soils ranges from 2.6 percent in topsoil and root-zone layers to less than 0.01 percent in aquifer sediments (ESE 1988/RIC#88243R01).

Soil flushing experiments with surfactants were conducted with several RMA COCs. Based on physical/chemical properties, soil flushing with surfactants was found to be applicable for dieldrin at concentrations up to 1,000 milligrams per kilogram (mg/kg), aldrin up to 10 mg/kg, and dicyclopentadiene (DCPD) up to 10 mg/kg (Rixey 1990). Removal efficiencies for PAHs, which have a range of physical/chemical properties similar to dieldrin, aldrin, and DCPD, were approximately 70 percent in a field test of in situ soil flushing (Rixey 1990). Compounds that are more soluble and less strongly adsorbed to soils than aldrin, dieldrin, or DCPD are likely to be removed more efficiently under similar conditions.

Table 12.2-3 provides soil flushing performance data from other sites where it has been used. Removal efficiencies at these sites range from 60 to 95 percent. Contaminants of concern removed included VOCs, PAHs, PCBs, and metals. No soil flushing applications were found for the removal of OCPs.

12.3 SOIL VAPOR EXTRACTION

Soil vapor extraction (SVE) is a treatment technology designed to physically remove organic compounds in situ via vacuum extraction. SVE systems are designed to maximize air flow through the zone of contamination, thereby recovering organic-laden vapors. The system operates

by applying a vacuum to extraction points in the subsurface, resulting in air flow through the pore spaces between soil particles to the extraction points. The extraction points may be vertical wells where contamination is found at depth or horizontal wells or trenches where the water table or contaminants are near the surface. The VOC-laden vapors, collected at the extraction points, are transferred to a surface emission treatment system via a piping system. Typical emission treatment systems are GAC adsorption, catalytic oxidation, or incineration. The specific treatment system is selected on a site-specific basis based on the estimated organic vapor concentrations and air flow rates.

The SVE technology is generally used to remove VOCs from vadose zone (unsaturated) soils. However, if the extraction points are located directly above the water table, the SVE system may also recover dissolved or free-phase VOCs at the top of the water table. The effectiveness of an SVE system design is dependent on contaminant volatility, contaminant concentration and distribution, and the air permeability of the soils.

The SVE technology is proposed for the South Plant Central Processing Area and South Plants Tank Farm Subgroups within the South Plants Medium Group. The contaminants of concern in these subgroups are chloroform, DCPD, and dibromochloropropane (DBCP).

12.3.1 Process Description

Figure 12.3-1 is a schematic of an SVE system designed to remove contaminants from the vadose zone. The system operates by inducing air flow through extraction points in the contaminated area. The location of the extraction points must be selected to ensure adequate vapor flow through the contaminated zone resulting in air/contaminant contact. The SVE system may be designed with air injection wells. Air injection wells may either passively take in atmospheric air or be designed for forced air injection.

The induced air flow through the soil pore spaces between the soil particles entrains contaminated vapors and water to the extraction points. From the extraction points the air stream flows

through a piping system to a vapor/liquid separator. The vapor/liquid separator removes the entrained water and stores it for subsequent treatment. The contaminated vapors are transferred to vapor treatment.

Extraction points are typically vertical wells designed with a vacuum-tight seal near the surface and an extraction zone (e.g., screen) corresponding to the profile of subsurface contamination. A well consists of slotted PVC pipe placed in a borehole surrounded by a permeable sand pack. Air or water inflow to the well from the surface is prevented by sealing the borehole above the slotted screen with bentonite, grout, and cement. In cases where the water table is shallow or the contaminated soil is within 10 to 15 ft of the surface, trenches and perforated pipe rather then vertical wells may be more effective. Well or trench spacing is based on the radius of influence of an individual extraction point, which typically varies from 15 to 100 ft. Air injection wells may also be incorporated into the SVE system to allow air to enter the subsurface at specific points to increase the radius of influence of the well system. For the South Plants Tank Farm Medium Subgroup, the radius of influence was estimated at 30 to 35 ft per vapor extraction well (MK-Environmental 1992).

Header piping systems are usually constructed of PVC and may be installed above or below the ground surface depending on site-specific needs. Belowground installation requires trenching and, therefore, is accompanied by additional costs. The piping system includes ball or butterfly shutoff valves on each extraction point and flow meters to measure air flow rates.

The vapor/liquid separator is a device used to remove entrained moisture that is detrimental to the downstream vacuum blower and vapor treatment system. The separator may be as simple in design as a vertical cylinder or as complex as a centrifugal separator.

Positive displacement blowers, centrifugal blowers, or vacuum pumps are used to create the vacuum that draws ambient air through the soil, stripping and volatilizing contaminants from the soil matrix into the air stream. Blowers ranging from 100 to 6,000 cfm have been used, and

vacuums of 1 to 8 inches of mercury are typical. Individual blowers are selected on a site-specific basis based on the design air flow rate through the soil.

Vapor treatment may include four common options: GAC, catalytic oxidation, internal combustion engines, and incineration. GAC is effective for most volatile contaminants and is cost effective at low flows or low concentrations. Catalytic oxidation is especially effective for nonchlorinated compounds at high concentrations, but it has high capital costs. Internal combustion engines are an inexpensive option, especially if the power produced is used to drive the vapor extraction pumps or blowers, and are appropriate for compounds typically found in fuel products. Incineration destroys a high fraction of the contaminants present, but has high capital and operating expenses. Contaminant concentrations will decrease over time as the contaminants are removed from the subsurface, therefore, the vapor treatment needs may also change over the life of system operation. Catalytic oxidation for the first few months of operation followed by GAC for the remaining months or years is a commonly selected vapor treatment system.

The condensed moisture from the air stream is treated by transferring the liquid to a nearby water treatment facility or to the CERCLA Wastewater Treatment Plant. Separate facilities would not be cost effective because of the small size of this waste stream.

The action-specific ARARS governing the performance of an SVE system are presented in Appendix A. These action-specific ARARs generally govern the air emissions and worker protection during operation.

Table 12.3-1 presents costing information for SVE. The unit capital cost for SVE is $1,053,000. The operating and maintenance costs are $2.97/SY.

12.3.2 Process Performance

The physical/chemical properties of subsurface contaminants and the subsurface soil environment significantly affect the fate and transport of contaminants and, therefore, the applicability of SVE. Physical/chemical properties of the contaminants include volatility, Henry's Law constant, soil sorption coefficient, water solubility, contaminant composition, and weathering.

Contaminant volatility is the most important characteristic affecting SVE. Volatility controls the quantity of contaminant present as vapor in the soil pores. Volatility is described by a contaminant's vapor pressure and Henry's Law constant. The lower limit of vapor pressure for effective removal of a compound by SVE is 1 mm mercury (Hg) (EPA 1991). Contaminants with vapor pressures less than 0.5 mm Hg should not be considered applicable for removal by SVE (EPA 1991a). Table 12.3-2 lists vapor pressures for the contaminants of concern at RMA. The vapor pressures for chloroform, DCPD, and DBCP are 151, 2, and 1, respectively.

Chemicals with a Henry's Law constant above 0.01 atmospheres per cubic meters (atm-m^3) are readily removed by SVE (Curtis et al. 1989) and removal of compounds with constants greater than 0.001 has been demonstrated (EPA 1989). Table 12.3-2 also lists Henry's Law constants for the contaminants of concern to be removed by SVE. Chloroform, DCPD, and DBCP have Henry's Law constants of 0.0029, 0.019, and 0.00031, respectively. Based on the volatility and Henry's Law constant, it appears that chloroform and DCPD may be effectively treated by SVE, whereas DBCP may not be effectively treated.

Compounds with high water solubilities may be removed from arid soils, but the removal efficiency drops in normal soils (i.e., 10 to 20 percent moisture content) because the moisture in the soil acts as a sink for soluble compounds (EPA 1991a). Table 12.3-2 also lists relative water solubilities for the contaminants of concern at RMA. Water solubilities are low to moderate for chloroform, DCPD, and DBCP, indicating that water solubility should not be a limiting factor.

Sorption of compounds to soil particles and organic matter in the soil zone influences the ability of SVE to recover contaminants. TOC content is a measure of the soils' ability to adsorb contaminants. As TOC content increases in soils, the sorption of organic contaminants and difficulty of removing contaminants from the soil increases. Most soils at RMA exhibit TOC values of less than 1 percent, and will not adversely affect SVE.

The rate of removal by SVE depends, in part, on the rate at which air can be circulated through the soil. The air circulation rate depends on the effective air permeability of the soil. The effective air permeability, in turn, depends on the geometric properties of the soil and the moisture content of the soil. Highly permeable, dry, coarse-grained soils are best suited for SVE. If the air permeability is lower than 10^{-10} centimeters squared (cm^2), SVE may not be feasible (EPA 1991). Fracturing low-permeability soils may improve recovery.

Air permeability is generally determined by site-specific tests. Likewise, the radius of influence of a vapor extraction well is determined by site-specific testing, which allows design and costing of the system. The radius of influence is affected by the air permeability, depth to water, depth of the extraction points relative to the surface, and the presence of a surface seal. Air inlet or injection wells can also be used to increase the radius of influence and enhance the movement of air through the subsurface.

Preliminary results of an SVE test conducted by Harding Lawson Associates identified a soil air permeability of 1×10^{-9} cm^2 for Basin F soils (HLA 1992). Studies conducted near the South Tank Farm have estimated an air permeability of 1.9×10^{-7} cm^2 for unsaturated alluvial deposits, and a permeability of 1.4×10^{-9} to 9.3×10^{-10} cm^2 for weathered Denver Formation soils encountered at RMA. Air permeabilities for the Denver Formation are therefore near the lower end of the range for SVE applicability. The treatability study maintained a soil gas extraction flow rate of 40 to 60 cfm, with a radial extent of influence of a single extraction vent of approximately 30- to 35-ft (MK-Environmental 1992).

Table 12.3-3 provides SVE performance data from other sites where it has been used. Removal efficiencies at these sites range from 88 to 99.9 percent, and contaminants of concern removed were primarily VOCs.

12.4 SOLVENT EXTRACTION

Solvent extraction is a direct physical/chemical treatment process that uses solvent solutions to leach hazardous components from contaminated material. The process described here uses organic solvents to leach organic contaminants from contaminated material. The contaminated material is placed in contact with an immiscible solvent for which the contaminants have a high affinity. The contaminants are removed from the contaminated material and concentrated in a solvent solution. The previously contaminated material is now clean which minimizes the amount of contaminated material requiring disposal. The process involves three basic steps: feed pretreatment, solvent washing, and solvent recovery. It produces a sidestream consisting of solvent containing concentrated contaminants that must be further treated.

Solvent extraction was screened out of the selection process in the DSA. It was removed based on the perception that it might not be able to meet PRGs, full-scale equipment was not available, and it was more expensive than other appropriate technologies such as low temperature thermal desorption. After completion of the DSA, the Army performed a treatability study using the Basic Extraction Sludge Treatment (BEST) solvent extraction process. Results of this treatability study showed that PRGs could be met. Additional recent commercial and EPA site program experience by RCC, the vendor that markets the BEST technology, has convinced the Army that this technology is viable at full-scale. Accordingly, solvent extraction using the BEST technology has been reintroduced into the screening process. The following discussion of solvent extraction is based on the BEST process.

The BEST process uses TEA as a solvent. TEA is ineffective as a solvent below a pH of 10.5. To effectively use TEA, the feed material is adjusted to a pH of 11 or greater. This requirement for a high pH makes this technology appropriate for organic-contaminated material that is also

contaminated with Army chemical agent. The high pH hydrolyses the Army agent products in a manner similar to caustic washing.

12.4.1 Process Description

Figure 12.4-1 provides a schematic of the solvent washing process. The process starts by taking excavated soils and screening them to remove debris and oversized materials. The oversized material is fed to a size reduction unit as described in Section 7.3, then back into the feed stream. Maximum size of the feed material is 1/2 inch in diameter. The feed is then mixed and agitated with refrigerated TEA solvent in a washer/dryer mixer vessel. Since TEA can be ionized at a pH of less than 10.5, the pH of the contaminated soil is tested and if necessary sodium hydroxide is added to raise the pH to 11 to prevent ionization of the TEA. In the ionic form, TEA is nonvolatile and cannot be recovered from the soils process product phase.

The washer/dryer is typically a horizontal steam-jacketed vessel with rotating paddles. For the first extraction, organic contaminants and water in the vessel dissolve in the cold TEA, creating a homogeneous single-phase mixture. As the solvent breaks the oil/water/solids bonds in the waste, the solids are released and settle to the bottom of the vessel. The solvent/water mixture is removed. The solvent mixture is heated by applying steam to the vessel jacket. As the temperature increases, the water separates from the TEA solvent, which retains the organics, resulting in a two-phase mixture. The solvent mixture is then decanted. Decanted TEA is sent to a stripping column where the contaminants are separated from the TEA and the TEA is recycled to the washer/dryer mixing vessel. The water is sent to another stripping column to remove any residual TEA. The product water is later added back to the treated soils to return them to their pretreatment moisture content. Subsequent extractions are conducted at elevated temperatures to keep the TEA in the non-water soluble form, which improves the removal of organic contaminants.

Several extractions are necessary to obtain the desired contaminant removal. Once contaminant removal is achieved, product materials are adjusted back to neutral pH and sent for backfill. The

BEST process does not have a residual fine soils fraction, so all fines go back with the treated soil and is used as backfill. The residual TEA with the concentrated contaminants is sent for off-site disposal.

Costs for this technology include feed preparation of screening and size reduction, pH adjustment to basic conditions, solvent extraction, solvent recycle, pH adjustment back to neutral, and product oil side stream treatment. Costs are based on the conservative case of nine extraction steps. Costs were developed by RCC and are based on data from this treatability study, similar treatability studies, and full-scale systems designed by RCC. These costs are based on a scenario of treating 3,000,000 CY of material. Total capital and operating costs are $28.55/BCY and $118.53/BCY, respectively, and are shown in Table 12.4-1.

Due to the proprietary nature of the process, RCC was reluctant to provide detailed cost backup. Results of the BEST EPA Site Program test will be available shortly and will be used to adjust these costs if necessary.

12.4.2 Process Performance

Bench-scale testing conducted at RMA (HLA 1993) evaluated solvent washing utilizing the BEST process. Soils tested were collected from South Plants, Basin A, and Basin F. Analytical results indicate that solvent extraction is an effective treatment process to achieve the PRGs. The PRGs were met with five to nine extraction cycles. Basin A soils required fewer cycles than Basin F and South Plants soils. The removal efficiency of the BEST process for pesticides was typically greater than 99.9 percent.

Contaminant mass balances were calculated for the soils treated. Mass balance closure ranged from 42 to 289 percent. The larger deviations from 100 percent were typically for samples with concentrations near the analytical detection limit for which greater analytical variability would be expected.

Basin A, Basin F, and South Plants soils exhibited similar settling characteristics. The soils settled rapidly during both the cold and hot extraction stages, eliminating the need for centrifugation in the bench-scale study. These results indicated that after centrifuging at full-scale, very little fines material should remain in the product oil.

Residual oil per ton of feed soil was estimated based on an assumption of 100 percent recovery of residual oil from the process stream, a residual oil specific gravity of 0.8 grams per milliliter, no water in the process stream and no solids in the process stream. These calculations resulted in a residual oil of 0.3 gallons for Basin A soils, 0.6 gallons for Basin F soils, and 2.4 gallons for South Plants soils. This residual volume will require further treatment. The proposed treatment is off-site destruction.

Although not tested in the treatability study, the caustic pre-treatment of the feed materials is expected to be an effective mechanism of treating agent-contaminated soils. The pH and materials retention time at that pH can be adjusted to meet Army 3X decontamination procedures. The caustic solution consisting of sodium hydroxide and water will be miscible with the TEA in the first extraction cycle. When the solution is removed from the first extraction cycle, a water soluble products of agents hydrolysis are also expected to be removed. These water soluble products will be separated in the decanter and water stripping column and can receive further treatment if necessary. The remaining feed materials can be subjected to additional solvent extractions to remove remaining organic contaminants.

The system was designed with a step to adjust product materials pH back to neutral. However, it may be desirable to leave the materials somewhat basic if the final disposition of the materials is to be in a secure landfill and not as a growth media. Specifically, if metals are present which have a lower solubility at high pH it may in fact be preferable to leave the product materials at a somewhat higher pH than they were originally.

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Table 12.1-1 Capital and Operating Costs for Soil Washing

Description		Cost
Capital Cost		
Equipment Costs (1-20 ton/hr unit)		
screening equipment		$2,927,000
size reduction equipment		0
soil washing equipment		0
CERCLA Wastewater Treatment Facility		3,838,000
	Total Capital	$6,765,000
Operation & Maintenance Cost		
Soil Washing System Operation (Labor)		13.25/BCY
Consumables		17.29/BCY
Residuals		0.03/BCY
CERCLA treatment		2.91/BCY
Laboratory Analysis		1.83/BCY
	Operation and Maintenance	35.31/BCY

Table 12.1-2 Summary of Soil Washing Results from Other Sites

Source	Primary Contaminants	Process/Scale	Results
Biotrol	chlordane, aldrin, 4,4-DDT, and dieldrin	Woodbury Chemical-Bench Scale Treatability Study	65-70% removal rate in washed soil after scrubbing and size classification. 80-85% removal after gravity separation.
Biotrol	dieldrin, heptachlor, chlordane, 2,4-D, and 4,4-DDT	Sand Creek Superfund Site-Bench Scale Treatability Study	85-94% reduction efficiency in washed soil. Cost estimated at $148 per cubic yard.
Biotrol	pentachlorophenol	Wood Treatment Facility Bench Scale Treatability Study	Removal efficiencies of 83-88% reported. Fines contained <10% of site soils but 50% of original contaminants after treatment
Resource Conservation Company	oily sludge comprised of 25% oil, 20% solids, and 55% water.	General Refining Site cleaned 3,700 tons during EPA Emergency Response Action	Treatment of oily sludges, efficiency over 98% (Best Solvent Extraction Process).
Resource Conservation Company	pesticide- and herbicide-contaminated soil	Bench Scale Test Data	Removal efficiency from 98-99%. (Best Solvent Extraction Process).
Harbauer GMBH	mineral oil, halogenated and aromatic hydrocarbons, PCBs, PAHs, and phenols	Pilot-Scale Test	80% removal efficiency from washed soil. 40% residual sludge volume requiring further treatment.

4,4-DDT
2,4-D
PAH Polynuclear aromatic hydrocarbons
PCB Polychlorinated biphenyl

Table 12.2-1 Capital and Operating Costs for Soil Flushing

Description		Cost
Capital Cost		
Sprinkler system		$222,328/BCY
Groundwater treatment system		$7,891,000/BCY
	Total Capital	$8,113,000/BCY
Operation and Maintenance Cost		
Soil Flushing System Operation (Labor)		$0.84/BCY
Surfactant		76.77/BCY
Maintenance and Supplies		0.02/BCY
Effluent Treatment		5.82/BCY
	Operation and Maintenance	83.45/BCY

Table 12.2-2 Physical Properties Pertaining to Soil Flushing for COCs at RMA

COCs for Soil Flushing	Organic Carbon Partition Coefficient[a] Log (K_{OC})	Solubility[b] (mg/l)
Fluoracetic Acid (FC2A)	NA	Miscible
Organochlorine Pesticides (OCPs)		
Aldrin	4.67 (High)	0.021 (Low)
Chlordane	5.15 (High)	0.13 (Low)
Dichlorodiphenytrichloroethane (DDT)	5.48 (High)	0.002 (Low)
Dieldrin	3.86 (High)	0.084 (Low)
Endrin	3.87 (High)	0.082 (Low)
Isodrin	4.58 (High)	0.17 (Low)
Metals		
Arsenic	–	Insoluble[c]
Chromium	–	Insoluble[c]

COCs identified for Basin A Medium Group

a Low = <2.4 Moderate = 2.4 to 3.6 High = >3.6

b Low = <50 mg/l Moderate = 50 to 10,000 mg/l High = >10,000 mg/l

c Some salts and compounds are soluble

– Information not available

Data from Table RISR E.2-1 (Remedial Investigation Summary Report)

Table 12.2-3 Summary of Soil Flushing Results from Other Sites

Site	Primary Contaminants	Process/Scale	Results
U.S. Aviex Michigan Superfund Site	TCA, TCE, PCE, benzene, toluene, xylenes, and diethyl ether	Record of Decision	Soil flushing of 11,500 cubic feet of soil. No DRE information currently available.
South Cavalade Street Texas Superfund Site	VOCs, BTEX, PAHs, lead, chromium, and arsenic	Record of Decision	Soil flushing of 10,500 cubic yards of soil. No DRE information currently available.
LA Clarke and Sons Superfund Site	benzene and creosote	Record of Decision	Flushing of subsurface soils underlying buildings. No DRE data currently available.
Goose Farm Ocean County, New Jersey Superfund Site	VOCs, SVOCs, and PCBs	Record of Decision	Flushing selected as preferred remedy. No DRE data currently available.
Texas Research Institute	Gasoline	Column and large scale study	80% removal during column study and 60-80% removal during large scale study.
EPA	Crude Oil and PCBs	Column study	Crude oil removal of 79-94% removal. PCBs removal of 60-90%.
CH2M Hill	Creosote	Column and field tests	95% removal during the column test and 67% removal during the field test.
Volk ANG Base[A]	Jet fuel and breakdown products	Column and field tests	Column studies were promising but in situ flushing of fire training pit using surfactants was not successful due to "short-circuiting" of flushing solution.

[A] EPA. 1986. Field Studies of In Situ Soil Washing Prepared by: James H. Nash, Mason and Hanger Silas Mason Co., Inc. Prepared for: Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. 1986.

Table 12.3-1 Capital and Operating Costs for Soil Vapor Extraction

Description	Cost
Capital Cost	
Equipment Costs	
Well installation	$210,000
Blowers	$126,000
Manifold material	$450,000
Trenching and bedding	$145,000
Catalytic oxidizer	$60,000
Installation of equipment	$62,000
Total Capital	$1,053,000
Operation & Maintenance Cost	
SVE System Operation and Maintenance (labor)	$1.26/SY
Catalytic Replacement	$0.07/SY
Utilities	$1.60/SY
Laboratory Analysis	$0.05/SY
Operation and Maintenance	$2.97/SY

Table 12.3-2 Physical Properties Pertaining to Vapor Extraction

RMA COCs	Vapor Pressure (mmHg)[b]	Henry's Law Constant[c]	Water Solubility mg/l[d]	SVE Applicability
Volatile Organic Compounds (VOCs)				
Benzene	95	$5.6x10^{-3}$	1,700 (Moderate)	Yes
Carbon tetrachloride	90	$2.4x10^{-2}$	810 (Moderate)	Yes
Chlorobenzene	12	$3.7x10^{-3}$	450 (Moderate)	Yes
Chloroform	151	$2.9x10^{-3}$	8,300 (Moderate)	Yes
1,2-Dichloroethane	64	$9.8x10^{-4}$	8,600 (Moderate)	Potential
1,1-Dichloroethylene	600	$3.4x10^{-2}$	2,200 (Moderate)	Yes
Dicyclopentadiene (DCPD)	2	$1.9x10^{-2}$	19.4 (Low)	Yes
1,1,2,2-Tetrachloroethane	5	$3.8x10^{-4}$	2,900 (Moderate)	Potential
Methylene chloride	360	$2.0x10^{-3}$	18,000 (High)	Yes
Tetrachloroethane	18	$2.6x10^{-2}$	252 (Moderate)	Yes
Toluene	28	$6.4x10^{-3}$	520 (Moderate)	Yes
Trichloroethylene	58	$9.1x10^{-3}$	950 (Moderate)	Yes
Semivolatile Halogenated Organics (SHOs)				
Hexachlorocyclopentadiene (HCCPD)	$8.0x10^{-2}$	1.4x10-2	1.59 (Low)	No
Dibromochloropropane (DBCP)	1[b]	3.1x10-4	11,000 (High)	Potential
Fluoroacetic Acid (FC2A)	–	8.0x10-2	miscible (High)	Potential
Organosulfur Compounds, Mustard-Agent Related (OSCMs)				
Chloroacetic acid	0.8	–	850,000 (High)	No
Organochlorine Pesticides (OCPs)				
Aldrin	$6.6x10^{-6}$	$1.6x10^{-5}$	0.021 (Low)	No
Chlordane	$1.0x10^{-5}$	$0.6x10^{-6}$	0.13 (Low)	No
Dichlorodiphenyethane (DDE)	$6.5x10^{-6}$	$6.8x10^{-5}$	0.08 (Low)	No
Dichlorodiphenytrichloroethane (DDT)	$5.5x10^{-6}$	$5.1x10^{-4}$	0.002 (Low)	No
Dieldrin	$1.8x10^{-7}$	$4.6x10^{-7}$	0.084 (Low)	No
Endrin	$2.0x10^{-7}$	$4.2x10^{-6}$	0.082 (Low)	No
Isodrin	$<1.0x10^{-4}$	$3.3x10^{-4}$	0.17 (Low)	No

RMA COCs	Vapor Pressure (mmHg)[b]	Henry's Law Constant[c]	Water Solubility mg/l[d]	SVE Applicability
Metals				
Arsenic	–	–	(--) Insoluble[e]	No
Cadmium	–	–	(--) Insoluble[e]	No
Chromium	–	–	(--) Insoluble[e]	No
Lead	–	–	(--) Insoluble[e]	No
Mercury	2.0×10^{-5}	–	(--) Moderate[e]	No

[a] COCs identified for Central Processing and South Tank Farm Subgroups in the South Tank Farm Medium Group.
[b] Compounds with Vapor Pressure above 1 mm Hg applicable to SVE (EPA/540/2-91/006).
[c] Compounds with Henry's Law Constants above 1.0×10^{-3} have a demonstrated removal by SVE (EPA/650AAS-89/003).
[d] Low = <50 mg/l Moderate = 50 to 10,000 mg/l High = >10,000 mg/l (RISR E.2-1 Remedial Investigation Summary Report).
[e] Some salts and compounds are soluble (RISR E.2-1 Remedial Investigation Summary Report).
– Information not available.
Data from Table RISR E.2-1 (Remedial Investigation Summary Report).

Table 12.3-3 Summary of Soil Vapor Extraction Results from Other Sites

Site	Primary Contaminants	Reference	Results
Upjohn Superfund Site Puerto Rico	Carbon Tetrachloride 7,000,000 cu yds Impacted soil and GW	Terra Vac and EPA/540/2-91/006	Recovered up to 800 lbs/day; 80 % of spill volume recovered
Tyson's Superfund Site Pennsylvania	Residual hydrocarbons and solvents from disposal area BTEX, PCE, TCE, and trichloropropane	Terra Vac	Pilot Test removed 150 lbs/day; SVE selected as preferred technology in the ROD; Total Estimated Cost $4,000,000
Groveland Superfund Site Massachusetts	TCE	Terra Vac and EPA/540/2-91/006	Approximately 1,300 lbs of TCE extracted in 56 days during demo test; Removal efficiency estimated at 95.6%
Verona Well Field Superfund Site Michigan	TCE, PCE, and TCA	Terra Vac and EPA/540/2-91/006	Ongoing project; 28,000 lbs removed in 55 days
Sheet Metal Plant Michigan	PCE	EPA/540/2-91/006	Removal efficiency estimated at 99.9%
Prison Construction Site Michigan	TCA	EPA/540/2-91/006	Removal efficiency estimated at 99.7%
Sherwin-Williams Site Ohio	Paint Solvents	EPA/540/2-91/006	Removal efficiency estimated at 99.7%

Table 12.4-1 Capital and Operating Costs for Solvent Washing

Cost Category	Cost Item	Cost Estimate	Description
Capital Costs	Pre-treatment	$0.55/CY	from Section 7.3 Size Reduction
	Solvent Extraction	$28.00/CY	from RCC costs presented in April 1993 HLA Treatability Study Report
	Total Capital Costs	$28.55/CY	
Operating Costs	Pre-treatment	$13.73/CY	from Section 7.3 Size Reduction
	Solvent Extraction	$94.00/CY	from RCC costs presented in April 1993 HLA Treatability Study Report
	Sidestream Treatment	$10.80/CY	from vendor quote for off-site destruction
	Total Operating Costs	$118.53/CY	

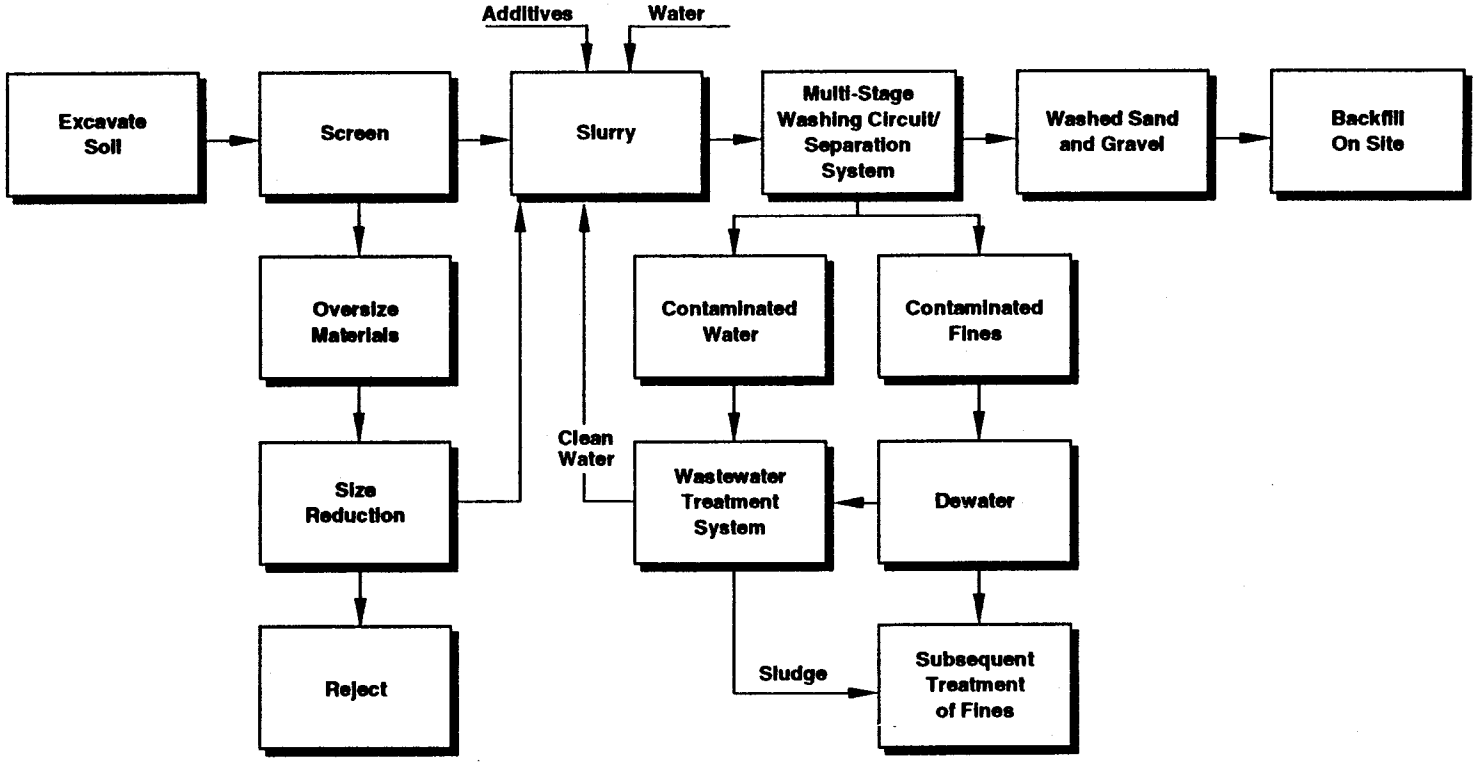

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FIGURE 12.1-1

Schematic of the Soil Wasing Process

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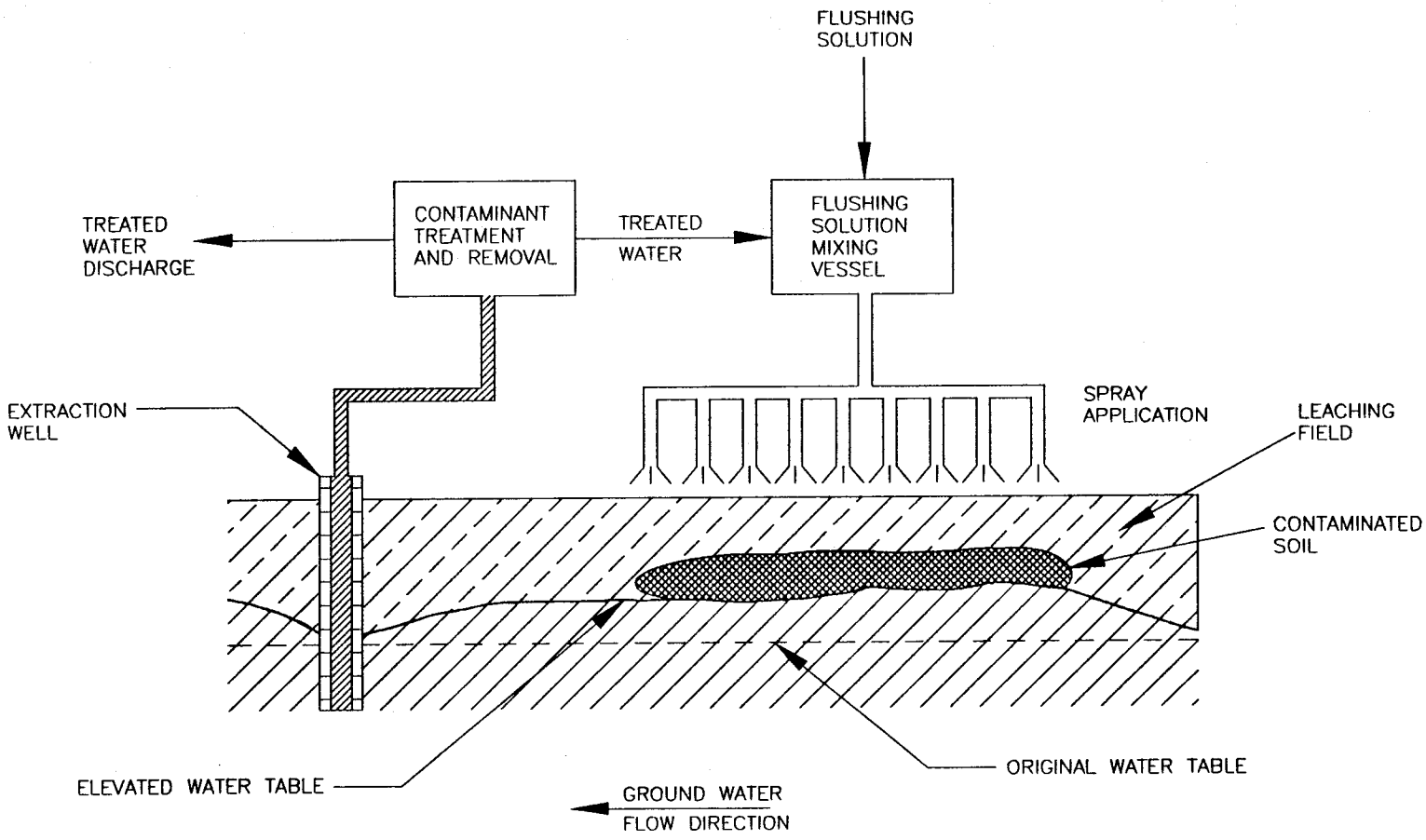

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FIGURE 12.2-1

In Situ Soil Flushing

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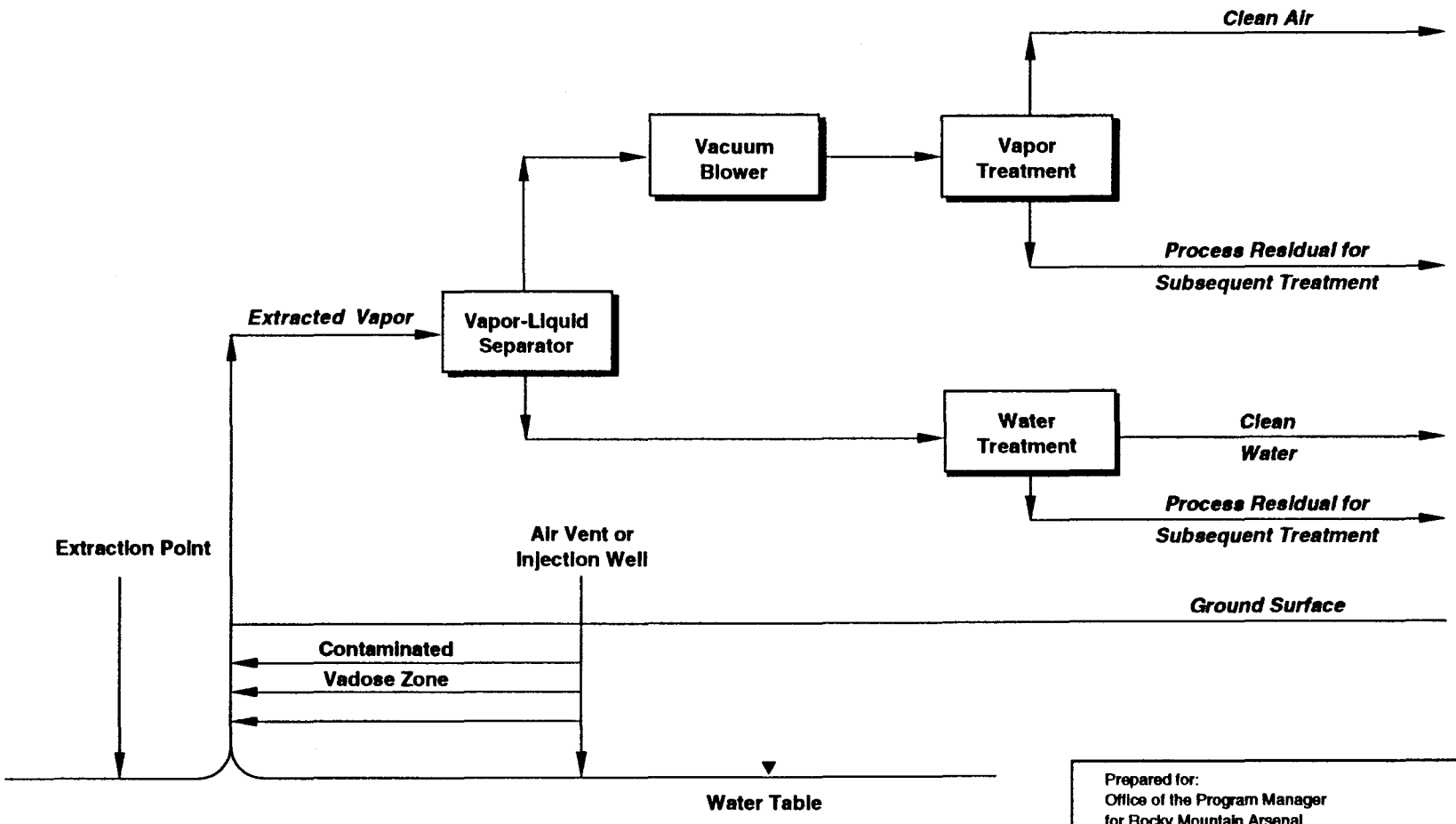

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FIGURE 12.3-1

Generic Soil Vapor Extraction System

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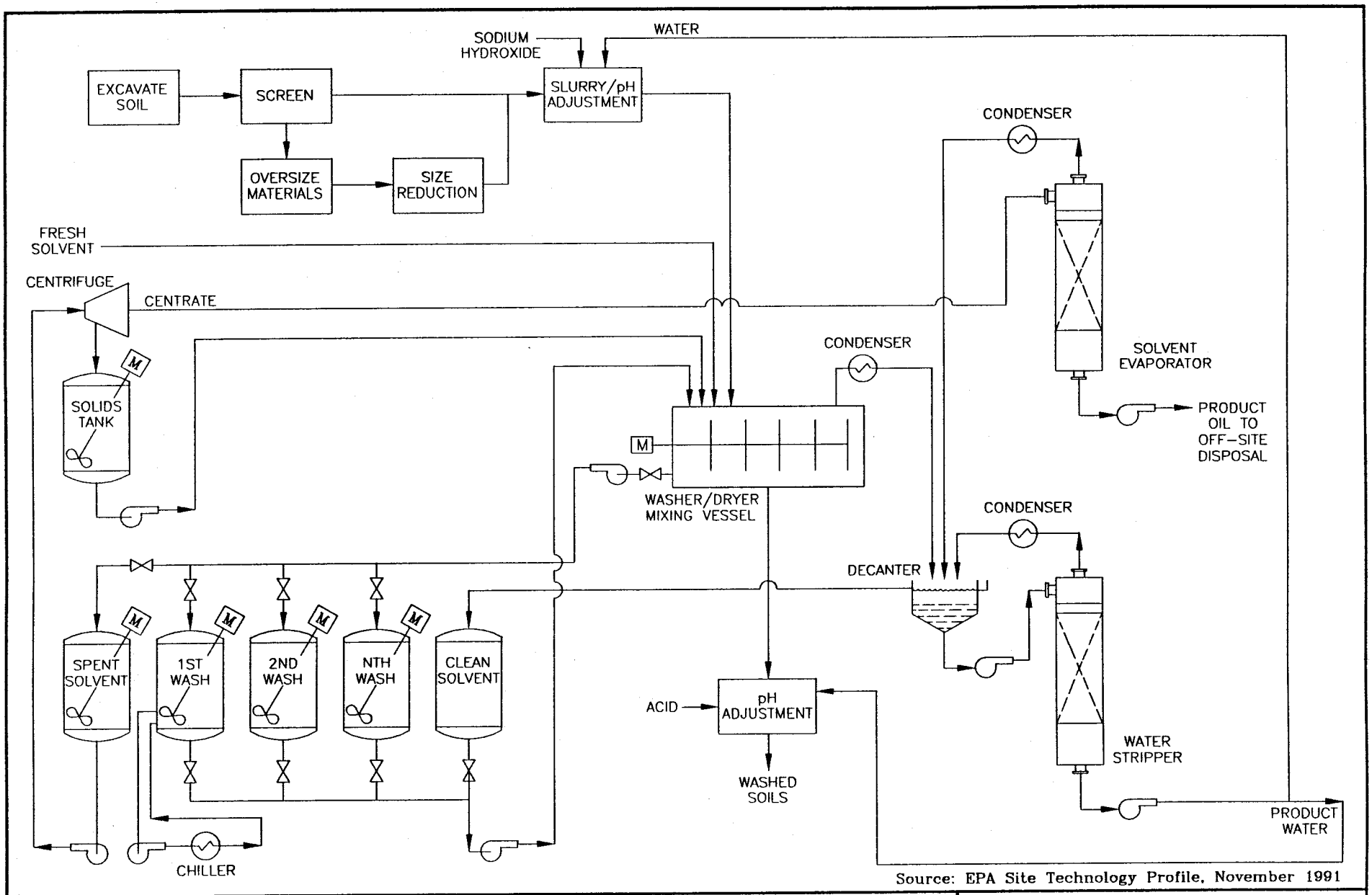

Source: EPA Site Technology Profile, November 1991

Prepared for: Office for the Program Manager for Rocky Mountain Arsenal	FIGURE 12.4-1 Schematic of the TEA-based Solvent Extraction Soil Process	Prepared by: Ebasco Services Incorporated

13.0 STRUCTURES UNIQUE PROCESSES

This section details the technologies that are unique to the structures medium, which include the following:

- Pipe plugging
- Vacuum dusting
- Sand blasting
- Steam cleaning
- Salvage

All of these technologies comprise part of remedial alternatives that were retained in the DSA for further consideration in the DAA. Pipe plugging, discussed in Section 13.1, represents a containment option in which pipes are filled with grout to immobilize contaminants and prevent contaminant migration. Sections 13.2 through 13.4 describe physical, in situ treatments for structural materials that include steam cleaning, sand blasting, and vacuum dusting, respectively. Section 13.5 describes different salvage options for structural materials, piping, and tanks. Salvage provides a means to minimize waste and reduce the cost of disposal. The action-specific ARARs associated with each of these processes is contained in Appendix A of this volume. Process descriptions and cost information were supplemented with vendor contacts and support materials referenced at the end of this section.

13.1 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 place 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- to high-end helps prevent voids from forming.

The process of grouting is widely employed in a variety of construction applications. The most common use is in geotechnical applications to reduce water seepage beneath dams and to enhance the stability of foundation subgrades. Grouting has wide applications in water well construction using similar techniques applied to this process option.

13.1.1 Process Description

The pipe plugging system to be used at RMA is fully portable and self contained. It consists of a gasoline-powered portable grout plant, water tank, wastewater tank, grout hose, valves, and rubber plugs to cap the ends of the treated pipe, cutting tools, electric generator, and movable containment structures (Chem Grout 1992). The grout is a nonshrink Portland cement mix due to its wide applicability and availability (Quikcrete 1992).

The majority of the operation takes place in the vicinity of the pipe to be plugged; activities thus take place within standing buildings under enclosed space conditions. To avoid breathing hazards, the grout plant and the electric generator are operated outside the enclosed space, and health and safety monitoring is performed during draining and placement operations to detect the presence of contaminants.

The containment system, consisting of a 55-gallon drum or larger portable tank in a secondary containment, is set up to catch any overflow from the pipe being worked on. It is sized to contain 1.5 times the pipe volume to allow for complete failure of the pipe or plug once the pipe has been filled with grout. The containment system provides a backup for the pipe draining effort, which collects and contains any residual liquids from the pipe for subsequent treatment at the CERCLA Wastewater Treatment Plant or equivalent on-post-treatment.

This process was retained for the No Future Use, Manufacturing History–Process History Subgroup as part of Alternative 2 in order to isolate specific pipe runs within these structures. There are 365 structures in this subgroup containing approximately 20,106 CY of pluggable piping.

13.1.2 Process Performance

The pipe runs are selected for treatment based on their potential contaminants, which could include acids, bases, pesticides, and herbicides. Pipe plugging is an effective method of reducing the mobility of residual contamination in pipes.

The process is potentially less effective on oils and greases because these substances may interfere with the chemical reaction that causes the pipe plugging material to set or harden (Chamber Process Equipment 1992). Strongly alkaline or acidic environments are also likely to reduce the effectiveness of the process, although plugging material composition can be adjusted to account for some of these conditions.

The pre- and post-treatment requirements for pipe plugging are minimal. Before treatment, the condition of the structure, the pipes, and the physical hazards associated with the structure should be reviewed to ensure the safety of the workers. Also, it may be necessary to brace pipe fittings to support the additional weight of the grout and to drain residual liquids in the pipes prior to plugging operations. Following treatment, the piping runs are monitored and maintained on a regular basis.

Major waste sidestreams include residual liquids drained from pipes, the first bit of grout from the placement process, and pipe valves and other obstructions that are removed because the grout cannot pass. Minor waste sidestreams include water used to clean equipment (grout plant, grout hose, containment structure), and normal PPE and decontamination wastes. No air emissions are expected from this process.

A crew of two can operate the grout plant and prepare the pipe for plugging. With the required health and safety and foreman support, it is generally economical to operate two to four crews at once.

The grout plant used for this example was assumed to be the Chem/Grout Model CG-555 with the L4 pump. This unit mixes and pumps four sacks of grout a minute at a maximum pressure of 225 psi (Chem/Grout 1992), which results in the maximum production rates. The proposed grout mixture consists of 11 pounds of water for every 50-pound sack of grout, which generates 0.45 cubic foot of pipe plugging material (Quikcrete 1992).

The capital costs involved with pipe plugging include transport of the grout plant to the site, purchase of startup materials, labor, and rental of a water tank (Table 13.1-1). Operations and maintenance costs are all costs incurred after the beginning of the operation including rental cost, additional materials cost, labor costs, fuel, maintenance, etc.

13.2 VACUUM DUSTING

Vacuum dusting is the physical removal of dust from a structural surface using air suction. This process can be applied to practically any surface, but only removes contaminants that are associated with the surface dust. This process does not remove any of the structural surface material. Vacuum dusting is most effective when used in conjunction with another in situ treatment process such as sand blasting, which physically loosens surface particulates.

13.2.1 Process Description

The vacuum dusting system selected for use at RMA includes a portable, self-contained vacuum-drum loading system equipped with a dual filtration system that allows three 100-ft hoses to be run off the same vacuum. A high efficiency particulate air (HEPA) filtration system capable of filtering particulates to a 0.3-micron size with 99.97 percent efficiency is used to remove the dust, which is loaded into drums. Fouled primary filters are cleaned using a small amount of water that is treated on post by existing systems. Vacuum dusting with reusable filtration systems has

been effective in the removal of asbestos and contaminated materials from structural surfaces (Vactagon 1993).

Vacuum dusting can be an effective decontamination technique for structural material and equipment at RMA. This process was retained for the No Future Use, Manufacturing History–Process History Subgroup as part of Alternative 9. There are 365 structures in this subgroup containing approximately 519,004 SF of treatable surface.

13.2.2 Process Performance

Vacuum dusting provides an effective, permanent reduction of contamination associated with removable dust on structural surfaces. The major limitation of vacuum dusting is that it only removes particulates not bonded to the structural surface. In addition, contaminants can be released from the surface and escape the vacuuming system. If needed, the process can be modified through water misting as a dust control measure, or by using sand blasting and steam cleaning in conjunction with this process.

A water mist may be needed as pretreatment to control dust emissions from the surface and to allow better removal of contaminants that may physically adhere to the water particles. Once the vacuum dusting is completed, the filters need to be cleaned and the extracted contaminants properly drummed and disposed.

Sidestreams generated by vacuum dusting are fugitive dust and spent filters. The spread of fugitive dust can be minimized closing off the room or structure. Vacuum dusting equipment must be properly decontaminated and the filters and collected materials/contamination/debris drummed to ensure proper disposal of all collected wastes.

Capital costs for the vacuum dusting treatment include the purchase of a vacuum unit, drum loader, two 50-ft-long hoses, and new HEPA filters[1], and operations and maintenance costs include labor, additional filters, additional hose, and sampling (Table 13.2-1).

13.3 SAND BLASTING

Sand blasting is an in situ treatment process consisting of the physical removal of contaminated surfaces via abrasion. This treatment is becoming more common in the hazardous waste remediation industry and is capable of reducing materials waste and operations cost through the use of a recycling system.

Sand blasting (sometimes called gritblasting) is a mechanical-scour surface removal technique in which an abrasive such as sand or steel pellets is used to uniformly remove layers of superficially contaminated structural material (Battelle 1983a). Abrasive materials are propelled at sufficient velocity by a fluid stream or air pressure to scour the surface to be treated. The nature and degree of treatment are controlled by the size of the shot used, operating pressures, and exposure time.

Sand blasting is effective as a surface treatment for a wide range of materials but only at depths less than 1/8 to 1/2 inch (Battelle 1983a). Minimal damage is done to the abrasive material during the process, and it may be reused after decontamination. Because the abrasive is "sprayed," sand blasting is used for many hard-to-reach areas. However, corners may not be sandblasted as effectively as flat surfaces (EPA 1985a). The removed surface and spent abrasive are collected immediately following impact through an integrated vacuum and recycling system. Following the collection of spent abrasive and contaminated debris, composite samples of the product need to be taken to characterize the waste for disposal.

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[1] The recommended vacuum system has a primary filter that is easily cleaned using water; therefore, HEPA filters are changed less often.

Sand blasting is a well known and frequently used technique. It has been used extensively throughout industry since 1870 to remove surface layers from metallic and ceramic surfaces. For example, sand blasting is commonly used to clean the surfaces of old brick and stone buildings, similar to those at RMA (EPA 1985a). Sand blasting may be applied to most materials except glass, transite, and Plexiglas (EPA 1985a). The method may be used for most surface contaminants except asbestos and some highly sensitive explosives.

13.3.1 Process Description

The sand blasting system proposed for RMA includes an air compressor, pressure lines, sand pot, blast gun, abrasive, a recycling system, and HEPA filters. The specific sand blasting units that are recommended for this type of treatment are equipped with a vacuum collection system and a recycling apparatus, which allows reuse of the abrasive after separation from the contaminants within the recycling unit filtration systems. The recycling units are mounted on a trailer for full mobility between sites. A typical recycling sand blasting unit can treat 45 SF/hr (for removal of 0.6 cm), which requires the use of 40 lbs of abrasive per hour to replace the degenerated shot. This produces an estimated 18 cubic inches of concrete debris and abrasive per square foot treated. Used HEPA filters and debris from treatment are considered hazardous and disposed appropriately.

This process was retained for the No Future Use, Manufacturing History–Process History Subgroup as part of Alternative 10. There are 365 structures in this subgroup containing approximately 519,004 sq ft of treatable surface.

13.3.2 Process Performance

Sand blasting provides an effective, permanent reduction of surficial contamination through the removal of the top 1/8 to 1/2 inch of a surface. Residual subsurface contamination may remain if it was initially below the treatable depth limit. Sand blasting with recycling of shot has been routinely performed nationwide on structural materials (LTC 1993). Contaminants have been removed using this technology from concrete, metal, and other structural materials. Removal of

hazardous substances has been demonstrated with pesticides, lead-based paints, petrochemicals, oil, and other related wastes.

Sand blasting is not applicable to wood, glass, transite, and Plexiglas surfaces. Sand blasting is only effective for surface contamination; deep contamination must be treated with a more aggressive method. In addition, the mobility and volume of particulate contaminants may be increased prior to separation/filtration, though this can be addressed using a vacuum recycling system and trained labor to accomplish the treatment task.

Pre-treatment requirements for sand blasting include analysis of contamination or chemical sampling to determine contaminant types, structural material evaluation to ascertain treatability of materials (e.g., wood is untreatable), and the transport of the treatment system to the specific site. Post-treatment requirements may require sampling of the treated structure, a complete check of the sand blasting system filter for fouling, and the replacement of grit degenerated in the scouring process.

The sidestreams generated by sand blasting, which include contaminated aggregate dust and debris, are controlled primarily by a recycling system that vacuums the spent grit and debris and separates the two materials using HEPA filters (0.3 micron, 99.97 percent efficient). Sand blasting equipment that recycles grit minimizes air sidestream contamination.

Capital costs for sand blast systems consist of purchasing the sand blasting units and three 100-ft hoses, and the initial cost of aluminum oxide abrasive. Seven units are required to meet schedule requirements. Operations costs other than labor are based on the materials required to replace degenerated abrasive and rental costs for a 350-cfm compressor. Unit process costs given are based on treatment of 45 SF/hr (Table 13.3-1).

13.4 STEAM CLEANING

Steam cleaning is an in situ, physical removal process that extracts contaminants from building materials, equipment surfaces, and debris using heated water applied under pressure (EPA 1985a). Steam is generated using oil, gas, or electric-fired generators and is applied to the surface through either a manually operated hand-held wand or automated spraying system. The condensate containing the removed contaminants is collected in existing or temporary sumps and is either treated on site and reused or disposed.

Steam cleaning is only effective for surface decontamination (EPA 1985a). Contaminants are removed from the surface by the physical action of the steam or by solubilization of the contaminants into the steam. Systems can be designed to inject sand or other abrasive materials into the water stream to enhance surface removal. In addition, solvents or cleaning solutions can be added to enhance solubilization. The materials to be treated must not have a tendency to absorb water because this causes the contamination to migrate deeper into the material. In general, metal and concrete surfaces are more amenable to steam cleaning than wood.

13.4.1 Process Description

The steam cleaning units proposed for use at RMA are fully self-contained and mobile. The pressure washer, hoses, reel, utilities, and water supply tank are all to be mounted on a trailer that may be easily moved between structures. Discharge from steam cleaning units ranges from 3.5 to 10.2 gallons per minute (gpm). For cost and waste stream estimating purposes it was assumed that the unit discharges approximately 5.2 gpm. Given this rate of discharge, approximately 3 gallons of wastewater is generated per SF of material treated. Assuming 20 percent evaporates, 2.4 gallons need to be collected per SF of surface material treated. Steam cleaning units require 200 to 600 gallons per hour process water. The amount of raw water needed is reduced by approximately 75 percent using a water treatment and recycling system. In general, chemicals added to the steam to enhance removal typically constitute less than 2 percent of the waste stream by volume.

Condensate collection systems need to be designed for each application, although existing sumps are used to the extent possible. The condensate is treated on post using a mobile, trailer-mounted water treatment system. An on-post-treatment system is desirable because it minimizes the amount of water used and the volume of waste created. A typical on-post-treatment system for process water consists of a multimedia filter, polyester cartridge filter (available with retention to 5 microns), and GAC. The treated water is returned to the pressure washer for reuse.

In addition to treating areas of intact structures, steam cleaning can be used for cleaning large sections of structural materials that have been segregated and positioned over a central treatment area. This is most efficient for structures that are thought to have widespread contamination; however, for localized contamination, in situ steam cleaning prior to structural demolition is recommended.

Steam cleaning is considered an effective decontamination technique for structural material at RMA. This process was retained for the No Future Use, Manufacturing History–Process History Subgroup as part of Alternative 9a. There are 365 structures in this subgroup containing approximately 375,609 sq ft of treatable surface.

13.4.2 Process Performance

Steam cleaning is an effective in situ treatment for structural materials providing the materials are not porous enough to allow the steam to drive contaminants deeper into the material. In fact, steam cleaning with detergents on porous materials can reverse the decontamination process and force the contamination deeper into the surface. The use of an on-post water treatment system removes contaminants from the condensate and minimizes the waste stream. Results from other sites substantiate that steam cleaning is a proven, reliable technology (Landa 1992). Equipment is readily available from many manufacturers.

Regular periodic inspections of filtration systems and materials is required in order to ensure that contamination is not spread by fouled filters. The most likely contaminants associated with

structural materials at RMA are pesticide residues and metals, both of which can be removed by steam cleaning. However, an entire structure could not generally be decontaminated using steam cleaning due to the inapplicability of this process to many structural materials.

A condensate collection system must be designed for each application. The condensate is then treated on post using a mobile, trailer-mounted water treatment system. Post-treatment involves disposal of all collected materials as hazardous waste.

The capital and operating costs for steam cleaning (Table 13.4-1) are developed from vendor quotations and are compared with costs from Means (Landa 1992). Capital costs for steam cleaning systems consist of the cost for the treatment system and for each steam cleaning unit. Four units are required to meet schedule goals. Operating costs for this alternative include labor, water, treatment system costs, as well as equipment maintenance and replacement filter costs.

13.5 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 in these alternatives include metal structural materials (rebar, support beams, etc.) and process equipment and piping.

13.5.1 Process Description

On-Post Demolition/Dismantling and Salvage

On-post demolition/dismantling and salvage involves the physical demolition or dismantling, sizing, and separation of scrap metals on post. In addition, salvage includes the recycling of any metal materials that are stockpiled in "boneyards" on post. All metal materials are salvaged through the Defense Reutilization and Marketing Office (DRMO). Metal materials may either be resold to salvage companies, recycled on or off post, or redistributed to Army facilities.

The salvage option was incorporated into all of the alternatives for the No Future Use, Manufacturing History–Non-Process History Subgroups and to a lesser extent tothe No Future Use, Manufacturing History–Process History Subgroup alternatives. There are 788 structures in these subgroups. Various salvage options are applicable to a large fraction of the approximate 146,316 CY of structural materials contained in these subgroups. For the Process History Subgroup it is assumed that all process equipment, piping and tanks are removed from the structures, decontaminated and stockpiled under the ongoing chemical-process-related activities. All of these stockpiled materials will be salvaged. The volume of this material was reduced by 20 percent to account for wasteage. No structural steel is salvage from this subgroup due to the cost of decontaminating the material and the relatively low salvage value. For the Non-Process History Subgroup all metal, including structural steel, is salvaged. The total material volume was reduced by 50 percent to account for wasteage. For the Agent History Subgroup salvage is not applicable due to the high cost of achieving 5X decontamination as required by AR 385-131.

13.5.2 Process Performance

Salvage of metal will minimize transportation, disposal costs, and materials waste streams at RMA, although it requires effort to size and separate the demolition/dismantled materials, which subsequently raises project costs.

Treatment requirements prior to the salvage of structures include disconnection of utilities, removal of any processing equipment, and review of chemical use history or sampling to determine the level of protection required for site workers and the most applicable decontamination treatment.

The salvage option will not generate waste streams because only noncontaminated metals or equipment from Non-Process History structures will be considered salvagable. Aggregate materials will be used as biota barriers only if they are uncontaminated.

Air sidestreams generated by this option exist as a result of demolition, sizing, separation, and transportation activities. This contamination can be addressed through the use of dust suppressants, equipment covers, and enclosure of processes from which dust has a good chance of escaping suppression methods. Air emissions need to be monitored continuously in order to ensure public and worker safety. The current price for scrap metals salvaged through DRMO is $52.61 per ton.

Capital and operations costs for salvage of metal materials at RMA are highly dependent upon the types of equipment, labor, treatment, and salvage options implemented.

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Table 13.1-1 Capital and Operating Costs for Pipe Plugging

Item Description	Capital Cost	O&M Cost	Unit Cost (Units)
Grout Plant[1]			
Rental Cost		$1,460.00/month	$3.66/CY
Fuel and Maintenance		150.00/month	0.38/CY
Transport Cost to RMA and back to Leasor	$700.00		0.05/CY
Truck Rental			
1/2 ton pickup for operations crew			
Rental Cost		850.00/month	2.13/CY
Fuel and Maintenance		100.00/month	0.25/CY
Liquid Containment			
Potable water tank, rental		275.00/month	0.69/CY
Liquid waste tank, purchase	300.00		0.02/CY
Labor Cost[2,3,4]		70.00/hour	
Total Grouting Costs:			
(based on grout and labor cost)			
Pipe Width (inches)			
2			$6,170.00/CY
4			1,800.00/CY
6			995.00/CY
8			715.00/CY
10			581.00/CY
12			510.00/CY
16			530.00/C
18			495.00/CY
24			430.00/CY
36			385.00/CY

Sources:

1) Longyear 1992.
2) Chem Grout 1992.
3) Grout costing is estimated using $5.10 per 50 lb sack[1].
4) Total Cost estimates were based on average costs per pipe size range and the following estimated pipe ratios that were thought to exist at RMA: 5% pipe ≤ 2", 55% pipe > 2" & < 6" and 40% pipe ≥ 6"

CY Cubic Yards
lb Pound
O&M Operations and Maintenance

Item Description	Capital Cost	O&M Cost	Unit Cost (Units)
Cost Averages Used for Estimation of Grouting Pipe Size			
≤ 2"			9,960/CY @5% of total volume
> 2" and < 6"			2,119/CY @55% of total volume
≥ 6"			678/CY @40% of total volume

Sources:
1) Longyear 1992.
2) Chem Grout 1992.
3) Grout costing is estimated using $5.10 per 50 lb sack[1].
4) Total Cost estimates were based on average costs per pipe size range and the following estimated pipe ratios that were thought to exist at RMA: 5% pipe ≤ 2", 55% pipe > 2" & < 6" and 40% pipe ≥ 6"

CY Cubic Yards
lb Pound
O&M Operations and Maintenance

Table 13.2-1 Capital and Operating Costs for Vacuum Dusting

Item Description	Capital Cost	O&M Cost	Unit Cost (Units)
Heavy Duty, HEPA Filter Vacuum	$9,800.00		
Drum Loader for Vacuum Loading Directly to Plastic Bags or Drums	552.00		
Drums		$32,500	
Two 50-ft, 3-in hoses (Max # of Hoses is 4)	720.00		
HEPA Filter, Replacement is Required Approximately 5 Times During the Operation Life of the Unit		$23,500 @ 1 filter per day	
Composite Sampling of Structures Walls and/or Filtered Debris (not factored into unit costs)		$310,000.00	
Labor for Two Workers in Level C Protection		$120,000	
PPE Costs		$42,500	
Total O&M Cost		$528,500	1.02/sq ft
Total Capital Cost	$12,512.00		$0.03/sq ft
Total Unit Based Cost			$1.05/sq ft

Note: Prices based upon vendor quotes.

1) Costs estimated at $650.00/unit for the replacement of reusable HEPA filters.
2) Sampling costs will be factored into the alternative costs because the technology does not meet Best Demonstrated Available Technology standards.
3) Assumed treatment rate of 150 SF/hr.
4) Assumed 774 samples per 100,000 sq ft of treatable surface area.

SF Square Foot
SF/hour Square Foot Per Hour

Table 13.3-1 Capital and Operating Costs for Sand Blasting

Item Description	Capital Cost	O&M Cost	Unit Cost (Units)
Pneumatic Sand Blasting Unit with Vacuum Collection System and 3 100-ft Hoses	$170,380.00		
Aluminum Oxide Abrasive (Initial volumes)	1,050.00		
350 cfm Compressor Rented on a Monthly Basis		$9,450.00/month	
Aluminum Oxide Abrasive		27,105.00/month	
Labor Based Upon One Worker Per Unit in Level C		16.00/worker/hour 19,712.00/month	
Total Capital Cost	$171,500.00		$0.54/sq ft
Total O&M Cost		$56,266.00/month	$2.03/sq ft
Total Unit Based Cost			$2.57/sq ft

Note:

1) Unit cost based on treatment of 45 sq ft/hr for length of project
2) Abrasive replacement rates estimated at 40 lbs/hr.
3) It was assumed that sand blasting treatment requires no sampling because it satisfies Best Demonstrated Available Technology standards.
4) Final O&M cost and capital cost are doubled in the final quote to allow for miscellaneous costs.

lbs/hr Pounds Per Hour
O&M Operations and Maintenance
sq ft/hr Square Foot Per Hour

Table 13.4-1 Capital and Operating Costs for Steam Cleaning

Item Description	Capital Cost	O&M Cost	Unit Cost (Units)	
Pressure Washing Unit (trailer-mounted)	$33,200.00			
Portable Treatment System (will be trailer-mounted)	76,000.00			
Filter Replacement and Media Replacement in the Locten Treatment System		$95.00/cartridge and $1.75/lb activated carbon		
Process Water from On-Site Treatment and Replacement of Lost Water		Cost per 1 million gallons determined by county and total amount of water used.		
Labor Cost of Two Workers in Level C				
Total Capital Cost	$109,200.00		$0.25/SF	
Total O&M Cost		$5,810.00/month	$0.72/SF	
Total Unit Based Cost			$0.97/SF	$419,680.00

Note:

1) Assumed 431,000 sq ft of RMA surfaces treatable by steam cleaning.
2) Sampling costs are excluded because steam cleaning meets Best Demonstrated Available Technology standards for decontamination.
3) Assumed the replacement of filters and/or carbon every 1,750 sq ft.
4) Assumed treating approximately 50 sq ft/hr.

SF Square Foot
SF/hour Square Foot Per Hour
O&M Operations and Maintenance

14.0 WATER/LIQUID SIDESTREAM TREATMENT

Several treatment technologies were retained for treatment of groundwater at RMA. Treatment is needed primarily for VOCs, DBCP, pesticides, and, potentially, inorganics such as fluoride and arsenic. Technology types retained for treatment of organics are phase transfer, sorption, and oxidation and the technology type retained for inorganics treatment is sorption. This section includes descriptions of process options that were chosen to be representative of the technology types. The oxidation technology type is represented by ultraviolet (UV)/ozone/hydrogen peroxide oxidation, which is discussed in Section 14.1. The sorption technology type for organics is represented by GAC, which is discussed in Section 14.2. Air stripping is the process option representing the phase transfer technology type and is discussed in Section 14.3.

14.1 CHEMICAL OXIDATION

The chemical oxidation technology type as it applies to RMA includes advanced oxidation processes (AOPs) that utilize combinations of chemical oxidizers and catalysts to destroy organic contaminants present in groundwater. Such processes can be designed to effectively treat most contaminants present in RMA water. The proper combination of oxidants depends on the chemicals to be treated. Oxidation treatability studies for groundwater from South Plants and Basin A have been conducted for the FS at WES. Oxidation was retained in the DSA for alternatives in the North Boundary, Basin A, and South Plants Plume Groups.

14.1.1 Process Description

By combining UV light and/or different oxidants in AOPs, most organic chemicals, including those found at RMA, can be effectively destroyed by oxidation. The proper combination of oxidants depends on the chemical properties of the compounds to be treated; compounds with absorbance maxima in the UV range are typically treated in a process involving UV light, while other compounds may be more effectively treated with ozone and hydrogen peroxide (Zappi 1993).

Commercial oxidation systems are available for the UV/peroxide, UV/ozone, and UV/ozone/peroxide processes. The peroxide/ozone process is under development and commercial reactors are expected to be available in the near future.

UV/ozone oxidation is a chemical treatment process that uses ozone to oxidize organic contaminants in the presence of UV light provided by low-pressure lamps. The UV radiation converts the ozone into strongly oxidizing hydroxyl radicals. The radicals then complete the oxidation of the organic compounds. Some organic compounds are easily oxidized by ozone while other compounds require UV irradiation to create the stronger oxidizing radicals (Sundstrom et al. 1989). The chemical bonds in some organic compounds are destroyed or weakened by the UV radiation. For UV/ozone oxidation, the contaminated water is treated in a reactor containing UV lamps encased in quartz tubes where ozone is added through an air sparging system. Gaseous ozone emissions are destroyed by an ozone destruction unit prior to release. Typical reaction retention times range from 20 to 40 minutes.

The UV/ozone/peroxide system that is commercially available is basically the same as the system described above, except that peroxide is added to further improve the oxidation. This system also uses the least powerful low-pressure UV lamps, and has an ozone destruction unit for emission control.

The UV/peroxide systems available utilize more powerful, medium-pressure UV lamps that more effectively catalyze the oxidization of UV-sensitive compounds such as chloroform. Hydrogen peroxide is added to the reactor containing the UV lamps. This system has insignificant emission problems compared to an ozone-based system and emission control is typically not required.

The most important factor in the operation of a UV-based system is the UV lamps. These lamps are very sensitive to fouling caused by hardness-causing compounds and iron and manganese precipitation. Pre-treatment may be needed if the levels of such compounds are high. Examples of pre-treatment include extensive filtration and preoxidation/precipitation. Most UV systems

have a washing unit to deal with potential problems. UV lamps are the major cause of operations problems and are the major contributor to operations as well as capital costs of oxidation systems. There is a cost and operational trade off between extensive pre-treatment and allowing some fouling of the UV lamps. Precipitation processes generate large sludge volumes that have to be treated and disposed. It was assumed that extensive prefiltration provides adequate pre-treatment for RMA and that further interference is dealt with through cleaning of the lamps.

Ozone/hydrogen peroxide oxidation (also called peroxone) provides a solution to the lamp fouling problem. The ozone and hydrogen peroxide act on the organics simultaneously. Catalysts such as Fenton's reagent may be added to increase the reaction rate of the ozone/hydrogen peroxide. An ozone/hydrogen peroxide system consists of an ozone generator and a reactor with an ozone diffusion system and a hydrogen peroxide feed unit. Ozone off gas is treated in an ozone destruction unit. Reactor retention times vary according to the required destruction levels and are determined through pilot-scale testing.

Off gas from the UV/ozone or ozone/hydrogen peroxide reactor is a sidestream requiring treatment in an ozone destruction unit and possibly further treatment of volatilized organics. An ozone destruction unit is typically a heated molecular sieve that breaks down the ozone into oxygen before release to the atmosphere. This unit is generally included in the prefabricated oxidation systems sold by oxidation vendors. Some of the volatiles are volatilized rather than oxidized during the oxidation process. Some of the organics may be destroyed thermally in the ozone destruction unit while certain compounds present at high concentrations, such as chloroform, may require further off-gas treatment.

Treatability studies are necessary to determine the applicability of this technology to particular waste streams. The post-treatment requirements that must be considered for an oxidation system are the treatment of unoxidized or partially oxidized species in the effluent gas or liquid stream. For species that oxidize less readily, it may be more cost effective to use additional treatment

such as air stripping or GAC adsorption. This is recommended for the South Tank Farm Plume and Basin A Neck Plume Group. Oxidized water must be filtered prior to reinjection.

Oxidation systems can be designed to meet groundwater and air emissions standards in addition to action-specific ARARs. The action specific ARARs that must be considered for this technology are given in Appendix A.

UV-based oxidation systems require high UV lamp maintenance costs, which can account for 20 to 40 percent of the total operations and maintenance costs for the system. Ozone-based systems require ozone destruction units as well as other emission control for VOCs that may account for as much as 50 percent of the costs.

14.1.2 Process Performance

The effectiveness and limitations of UV/ozone and ozone/hydrogen peroxide oxidation on the groundwater at RMA has been evaluated through recent treatability studies at WES (Zappi 1993). Several other oxidation treatability studies have been conducted at RMA over the years, a summary of which is presented in Table 14.1-1.

Oxidation, under favorable conditions, achieves destruction efficiencies greater than 90 percent for most organics, with some as high as 99.99 percent. Treatability studies conducted with RMA groundwater have shown that hardness, iron, and manganese can impede efficiencies by acting as oxidizer sinks and can cause scaling of the UV lamps. Oxidation is applicable to diisopropylmethyl phosphonate (DIMP), DBCP, VHOs, volatile aromatic organic compounds (VAOs) and volatile hydrocarbon compounds (VHCs), and pesticides in RMA groundwater. For complex contaminant mixtures and high concentration levels, it may be cost effective to partially remove the contaminants using oxidation and complete the treatment with other treatment technologies such as GAC adsorption or air stripping. It is known that incomplete oxidation of organics may result in compounds that are more polar and consequently less adsorbable.

However, if such intermediates are formed, these compounds are typically of much less concern from a health perspective and are much less likely to exceed acceptable levels.

Studies have shown that the ozone diffuser system may strip volatiles from the aqueous stream instead of oxidizing them. It may, therefore, be necessary to add an emission treatment system in addition to the ozone destruction unit. The use of hydrogen peroxide decreases the ozone requirement and reduces the stripping effects of the diffusion system. Also, some compounds may not be completely oxidized and their daughter products may require additional treatment.

Khan and Thompson (1978) evaluated the treatment of DIMP in RMA well 118 groundwater using UV/ozone bench-scale reactors. The water had to be treated with caustic or lime to remove soluble iron and manganese in order to prevent the precipitation of these cations in the reactor. They found that high-intensity lamps proved more effective for DIMP destruction than low-intensity lamps. Treatment times of four hours and an ozone feed rate of 2.5 liters/min were required to bring DIMP concentrations down from 70 ppm to the target level of 0.5 ppm (Zappi 1993). Studies completed by Glaze and Kang (1988) indicate that ozone/hydrogen peroxide oxidation is capable of removing recalcitrant compounds such as trichloroethylene (TCE) at comparable rates to UV/chemical oxidation (Zappi 1993).

Presently, UV/hydrogen peroxide oxidation is being used at the RMA CERCLA Wastewater Treatment Plant. Treatability studies completed prior to design of the system showed that oxidation could be used to effectively destroy some RMA contaminants but that additional treatment would be needed for complex water matrices. Inorganics were not found to be a problem, although reductions in metal ions indicate that some metal oxidation and precipitation took place (Thompson et al. 1989). Zappi et al (1990) studied UV/hydrogen peroxide oxidation of groundwater from different RMA groundwater sources. Water with low concentration levels was effectively treated within 15 minutes. The UV/hydrogen peroxide system did not perform well for South Plants groundwater with high levels of volatiles and high iron content that caused

fouling of the UV lamps. Hydrazine fuels were effectively treated by this sytem but NDMA was not.

Treatability studies were conducted by WES as part of the groundwater FS for RMA. These studies have shown that UV/ozone and ozone/peroxide oxidation are effective in destroying benzene, TCE, and chloroform in the South Plants and Basin A plumes, although problems were encountered with the water in the Basin A plume. The groundwater in this plume contained higher levels of metal ions that interfered with the oxidation process and retarded the oxidation of DBCP. If iron and manganese were pre-treated, the organic contaminants were more easily oxidized. The results of the treatability study showed that ozone/peroxide treatment without the addition of UV light was sufficient to oxidize most contaminants, leading to an operations and maintenance cost savings of up to 40 percent of the cost of oxidation based on savings in maintenance and replacement of the UV lamps and quartz tubes (Zappi 1993). However, the results also showed that 50 to 80 percent of the chloroform is volatilized rather than oxidized in ozone-based systems. Oxidation of chloroform can best be achieved by an oxidation system involving UV lamps; volatilization can be minimized by excluding ozonation. The final system selection for each alternative under consideration depends on the relative concentration and significance of each compound. It is typically more efficient to remove chloroform by air stripping than to treat it in an oxidation reactor.

Peroxone systems that utilize combinations of peroxide and ozone seem to have great promise for a wide range of contaminants that do not require UV light for destruction. Such systems are not yet commercially available and do not have a performance history for hazardous waste applications.

The most efficient UV-based systems are designed with medium-pressure lamps that, although fairly expensive to maintain, are needed to achieve the desired UV destruction in such systems. UV radiation combined with ozone or peroxide oxidation can be an effective means for completely destroying organic groundwater contamination. Several types of oxidation systems

are commercially available. Oxidation effectively reduces the toxicity and volume of organic contamination in groundwater at comparable cost to air stripping with vapor-phase treatment and GAC adsorption. Most of the oxidation systems at RMA are designed as part of an alternative involving additional treatment. The optimal design, therefore, depends on which compounds are most effectively treated by each alternative at a reasonable cost.

14.2 GRANULAR ACTIVATED CARBON ADSORPTION

GAC adsorption, as presented in this section, 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 organics is brought into contact with GAC, onto which the organics 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. For treatment of groundwater at RMA, GAC was retained for alternatives addressing the North Boundary, Basin A, and South Plants Plume Groups.

14.2.1 Process Description

GAC is a well-developed technology that is widely used in the treatment of hazardous waste streams. It is well suited for the removal of a wide range of organic contaminants over broad concentration ranges. In general, the adsorbability of organic compounds is favored by high carbon chain length, high aromaticity, low polarity, low solubility, and low degree of dissociation. Compounds that are readily adsorbed onto GAC include SVOCs such as OCPs, DBCP, and other semivolatile halogenated organics. Volatile halogenated organics and volatile hydrocarbon compounds are not treated as efficiently as the SVOCs, but can be removed by GAC adsorption

at the cost of high carbon consumption. GAC adsorption is commonly used for benzene, ethylbenzene, xylene, and toluene (BTEX) compounds that are fairly well adsorbed.

The major contaminants in RMA groundwater targeted for GAC adsorption are chloroform, benzene, methylene chloride, tetrachloroethylene, DBCP, aldrin, chlordane, dieldrin, endrin, and DDT. Of these, all but the chloroform and methylene chloride can be removed efficiently with GAC.

GAC systems are typically operated as packed beds in continuous flow pressure vessels. The downflow, fixed-bed, in-series configuration has been found to be more cost effective and produces the lowest effluent concentrations compared to other carbon adsorber configurations (e.g., downflow in parallel, moving bed, expanded up-flow). It is, therefore, the recommended configuration for GAC systems at RMA. In this configuration, water enters the lead vessel at the top, is collected in an internal underdrain system at the bottom, and is conveyed to the top of the second vessel. During operation, the pressure drop through the lead vessel may slowly increase as a result of trapped suspended solids or compaction of the bed. When the vessel reaches an unacceptable pressure drop (around 35 psi), it must be taken offline and backwashed to remove the clogging particles or to expand the bed. The bed is backwashed upflow for a duration of 25 to 30 minutes at a rate that is dependent on the vessel size. While one vessel is backwashed, the entire flow is diverted to the other vessel.

Eventually the lead adsorber becomes saturated with contaminants, and target effluent concentrations are exceeded. This condition is commonly referred to as "breakthrough". The lead vessel is taken offline and the spent GAC is replaced with fresh GAC (either virgin or regenerated). Spent GAC is displaced into a receiving container by pressurizing the vessel with utility water, and fresh GAC is transferred as a slurry to the empty adsorber via pressure. After the adsorber has been recharged, it is backflushed to evenly distribute the carbon within the vessel and to remove carbon fines. This vessel is then placed in the second-stage position and

the former second vessel becomes the lead vessel. Spent GAC is thermally regenerated off-post by the carbon vendor. The carbon is then reused.

Some pre-treatment for water may be required for the following reasons: high suspended solids concentrations may lead to clogging of the carbon bed; high iron and manganese concentrations, as well as high hardness in the influent, can result in precipitation of solids on the GAC, which in turn results in clogging and fouling of the carbon surface; and precipitation may result when the equilibrium chemical conditions are changed during pumping and storage, which can happen by exposure to air. However, new GAC systems designed for the FS do not include pre-treatment other than filtration. The iron content of RMA groundwater is high enough to potentially cause precipitation problems, as is the hardness, but GAC systems currently operating at RMA have not required pre-treatment to remove the iron.

Post-treatment is sometimes required to remove suspended solids that can lead to clogging of reinjection wells. Precipitation of iron and manganese in the GAC effluent has caused clogging of reinjection wells at RMA, both due to precipitation onto the well screens and to biological growth associated with the iron and manganese.

14.2.2 Process Performance

GAC can be used for a wide range of water flow rates and concentrations. The size of the adsorbers and the frequency of carbon replacement is determined by the flow rate and the contaminant concentrations. The adsorber vessels must be large enough to provide a minimum hydraulic retention time for the water stream. Carbon consumption is determined by the influent contaminant concentration and the desired extent of removal. The consumption is constant, but the size of the adsorption vessels can be increased to reduce the frequency of carbon replacements.

Contacting vessels are available in sizes that range from small, drum-size units to large tanks that hold 40,000 lbs of carbon. For very large flows, multiple vessels can be connected in parallel to increase capacity.

GAC has been used extensively to treat groundwater at RMA. The NBCS, NWBCS, ICS, South Plants Treatment System, Basin A Neck IRA, and CERCLA Wastewater Treatment Plant all use GAC. Table 14.2-1 describes these treatment systems, the contaminants being removed, and the design flow rates.

All of the boundary systems were reviewed through the IRA program to ensure that they are operating efficiently and achieving treatment goals. As a result, modifications were made primarily to the extraction and injection systems, although some operational modifications were also made to the treatment systems.

Prior to the NBCS Short-Term and Long-Term Improvements IRAs, extracted water from three parts of the aquifer was kept separate so that the most highly contaminated water was treated in one adsorber, the next most contaminated water was treated in another adsorber, and the least contaminated water was treated in the remaining adsorber. After reevaluation the system was modified so that all extracted water is mixed in a single influent sump. The mixed water is then put through two of the adsorbers in series, and the remaining adsorber is available for backup. This results in more efficient use of the carbon.

In addition, the recharge wells at the NWBCS were prone to plugging so that recharge capacity was seriously reduced. It was assumed that the plugging was due to carbon fines in the effluent stream, so recharge trenches were constructed to replace the wells. Recharge was improved, but an investigation of the trenches showed the presence of iron and manganese and associated biological growth, rather than carbon fines, was still causing some plugging of the recharge system. This demonstrated the need to consider inorganics removal for RMA water in the future.

Operation of the NWBCS was reviewed under the Short-Term Improvements IRA. This system was installed in October, 1984 to remove DBCP and dieldrin from groundwater flowing to the northwest in Section 22. Two active adsorbers in parallel and one standby adsorber are used, each of them contain 40,000 pounds (lbs) of carbon. As a result of the IRA, improvements were recommended for the extraction and reinjection systems, but the treatment system remains unchanged.

The ICS was also evaluated under the IRA program. This system was originally built to remove DBCP from groundwater moving under the western boundary of RMA. The treatment system uses two adsorbers, each containing 42,000 lbs of carbon, connected in parallel, with a third adsorber available on standby. The plant capacity has recently been increased from 1,400 gpm to 2,100 gpm by utilizing the standby adsorber. This was needed to accommodate increased flow from the Motor Pool and Rail Yard IRAs, which extract water containing TCE and DBCP, respectively. The ICS original extraction wells are currently turned off. Four newly installed extraction wells southeast of the original system (the east row) are pumping approximately 505 gpm. Five extraction wells in the Rail Classification Yard are pumping approximately 265 gpm, and two extraction wells in the Motor Pool area are pumping approximately 100 gpm. The total system flow rate is approximately 870 gpm.

All of the boundary systems have been shown to remove contaminants to acceptable concentrations through the use of GAC. GAC adsorption is the typical choice for dilute streams containing large organic molecules and for low concentrations of VOCs that are not treated as efficiently by other processes.

14.3 AIR STRIPPING

Air stripping is an effective and proven method for removal of VOCs from water. The process involves the removal of volatile contaminants 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 the gas (vapor) that requires additional treatment. Air

stripping was retained as an alternative in the DSA for the groundwater in the North Boundary, Basin A, and South Plants Plume Groups.

14.3.1 Process Description

The most effective, most commonly used, and most economical air stripping system that is being considered for RMA is the packed tower (CDM 1986). The tower is packed with material that provides a large contact area for mass transfer. Water is introduced at the top of the tower and allowed to trickle through the packing while the air is introduced countercurrent from the bottom of the column using a blower. The air containing the removed contaminants is emitted from the top and is treated in a vapor-phase treatment system, if necessary, to meet air emissions standards. The liquid effluent leaves through the bottom of the tower and is further treated or discharged.

Pre-treatment requirements for air stripping typically include filtration or water softening to remove hardness-causing compounds. Filtration is required to remove any suspended solids. The pH of the water may also increase during air stripping as carbon dioxide is removed from the water along with the contaminants. The increase in pH may cause dissolved metals in the water to precipitate onto the packing material as scale, which can eventually clog the column. This problem can be addressed by mixing carbon dioxide with the air entering the column, thereby reducing the amount of carbon dioxide removed from the water or by periodically rinsing the column packing with an acid or caustic solution to remove the scale buildup. Alternatively, a scaling inhibitor that keeps the scaling-causing compounds in solution may be added to the water upstream of the air stripper.

Air stripping transfers the VOCs in a liquid waste stream to a gaseous stream. If the gaseous stream meets emissions standards, it may be released without further treatment. However, at RMA further treatment is often included. The vapor-phase treatment technologies under consideration are vapor-phase GAC adsorption, thermal oxidation, and catalytic oxidation. Vapor-phase GAC adsorption consists of transferring the contaminants to activated carbon by way

of adsorption. Catalytic oxidation involves the conversion of the contaminants in the air stream to carbon dioxide and water by oxidation in the presence of a catalyst, which allows the reaction to take place quicker at lower temperatures than thermal oxidation. Thermal oxidation is the thermal destruction of organic contaminants in the air stream. Table 14.3-1 presents a summary of possible post-treatment technologies for the gaseous emissions and their requirements.

Catalytic oxidation was chosen as the air treatment for all of the high flow rate emissions under consideration because it offers complete contaminant destruction with no sidestream generation if designed and operated properly. It has higher capital costs, but considerably lower O&M costs when compared to GAC adsorption (Table 14.3-1). At lower flow, vapor-phase GAC adsorption has much lower costs and is also preferable for these low-flow systems due to its ease of implementation.

Air stripping systems can be designed to meet groundwater and air emissions standards. Table 14.3-2 presents a summary of air stripping costs. Action-specific ARARs related this process are listed Appendix A.

14.3.2 Process Performance

Air stripping is commonly used, easily implemented, and widely accepted for removing low levels of VOCs from wastewater and groundwater. It is highly effective for the types of volatile contaminants found in RMA groundwater, and is currently being used to treat groundwater from Basin F at Basin A Neck and at the CERCLA Wastewater Treatment Plant. In addition, it has been successfully used to treat most of the volatile contaminants found at RMA.

The removal efficiencies for organic compounds by air stripping are controlled by the ability of contaminants in the water to migrate to the air/water interface and then by the tendency for the contaminants to transfer into the air from the water phase once they reach the interface. Conveying the contaminants to the interface is determined by the configuration of the contact system, which has been chosen to be a packed tower in this case, and by the air to water flow

ratio. The tendency of a contaminant to transfer from the water phase into the air phase is dependent on the specific system under consideration. A relation that is used to evaluate the affinity of a contaminant for the vapor over the liquid phase is the Henry's Law constant, which is defined as the partial pressure of a contaminant in air over its mole fraction in water when the system is in equilibrium (Kavanaugh and Trussel 1981). Compounds with high Henry's Law constants have a high affinity for air phase, and thus are good candidates for stripping. In general, compounds with dimensionless Henry's Law constants greater than 0.0003 are strippable (EPA 1983). Removal efficiencies range from 90 to 99.9 percent for most volatile compounds. However, the contamination found in much of the water at RMA contains nonvolatiles as well as volatiles. In these cases, it would be necessary to add an additional treatment system to remove the unstrippable compounds. Table 14.3-3 presents the Henry's Law Constants for contaminants of concern at RMA.

The South Plants groundwater treatment pilot plant included an air stripper that provided 96 to 100 percent removal rates for VOCs except for methylisobutyl ketone and carbon tetrachloride (S-R 1983). Testing completed on this unit showed that no advantage was gained from softening the water prior to treatment and that increasing the air-to-water ratio increased the removal of all VOCs (EBASCO 1988).

Air stripping is currently being used as a treatment step at the CERCLA Wastewater Treatment Plant and the Basin A Neck treatment system. The Basin F groundwater treatment system has had problems with calcium carbonate scaling in the stripper. Air stripping at these RMA sites has been effective at removing the VOCs from the influent water streams. Both systems use vapor-phase GAC adsorption to meet vapor-phase emissions requirements.

This technology typically requires that concentrations of iron and manganese be reduced to less than 0.2 ppm and 0.1 ppm, respectively, in the influent water stream. Typically, manganese and iron are present at low ppm levels in RMA groundwater, indicating that pre-treatment for removal of iron, manganese, and hardness-causing compounds may be required.

The iron, manganese, and hardness-causing compounds present in the RMA groundwater may require additional pre-treatment or process modifications, such as inhibitor additions, depending on the specific levels in each water to be treated.

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Table 14.1-1 Past Chemical Oxidation Research Efforts Using RMA Waters

Year	Researcher	Main Concern	Operation Units	Results
1977	Thompson et al.	DIMP, groundwater from Well PW-3.	Ultrox (pilot scale)	1. 99.9 percent removal rate. 2. TOC removal increased with increased UV dosage.
1978	Buhts	Intermediate products of DIMP, $CMPSO_2$, aldrin, dieldrin, DCPD.	UV/ozone	1. Organic acids formed as intermediate products of incomplete oxidation. 2. Organic compounds converted to inorganic phosphates, sulfurs, and carbon dioxide.
1978	Khan and Thompson	Groundwater contaminated with DIMP	UV/ozone (bench scale)	1. Iron and manganese were removed by caustic/lime. 2. High-intensity lamps proved more effective. 3. Four hours were required to achieve target levels (from 70 mg/l to 0.5 mg/l).
1990	Zappi et al.	Contaminated waters; groundwater from NBCS and South Plants Area, wastewater from the hydrazine storage facility, and influent to the South Plants Treatment System.	UV/hydrogen peroxide	1. Low levels of contaminants could be treated in 15 min or less (North Boundary groundwater and NBCS influent). 2. DIMP very reactive to both UV and peroxide. 3. Chlorinated aliphatics difficult to oxidize. 4. Process not effective for VOC removal from the South Plants groundwater. 5. Oxidized iron posed serious fouling problems for the UV lamps. 6. Hydrazine fuels treated effectively, but not effective for NDMA. 7. Longer treatment time required for NDMA.
1990	Jelinek et al.	Wastewater from the hydrazine storage facility.	UV/chemical oxidation (Batch, pilot scale).	1. Hydrazine fuels oxidized with the use of tungsten catalyst within 16 hours at pH less than 3.0. 2. NDMA required 80 hours for destruction.

$FeCL_2$	Iron Chloride
$CMPSO_2$	Chlorophenylmethyl sulfoxide
DCPD	Dicyclopentadiene
DIMP	Diisopropymethyl phosphonate
NBCS	North Boundary Containment System
NDMA	Nitrosodimethyl amine
TOC	Total Organic Carbon
UV	Ultraviolet
VOC	Volatile Organic Compound
WO_3	Tungsten trioxide

Year	Researcher	Main Concern	Operation Units	Results
1990	Kuo and Zappi	Wastewater.	(bench scale).	1. Results agreed with the pilot scale study above. 2. NDMA removed by UV irradiation. Oxidizer produced negative effect due to absorption of UV by oxidizer.
1991	USAE WES	DIMP, North Boundary groundwater.	Chemical oxidation system (bench scale).	1. Hydrogen peroxide alone was not very reactive. 2. Catalysts, $FeCl_2$ or WO_3, caused appreciable oxidation. 3. With UV, complete removal of DIMP occurred within 10 minutes. 4. Cooxidation treatment kinetics were similar to UV. DIMP was removed without UV.
1991	USAE WES	Chloroform and benzene (distilled water solution and North Boundary groundwater).	UV/hydrogen peroxide.	1. Benzene and chloroform in groundwater effectively treated.
1993	USAE WES	Basin A and South Plants groundwater.	UV/hydrogen peroxide, UV/ozone and hydrogen peroxide ozone.	1. DBCP and OCPs effectively treated by hydrogen peroxide/ozone. 2. Chloroform most effectively destroyed in presence of UV light. Significant fraction of chloroform stripped in ozone system.

$FeCL_2$	Iron Chloride
$CMPSO_2$	Chlorophenylmethyl sulfoxide
DCPD	Dicyclopentadiene
DIMP	Diisopropymethyl phosphonate
NBCS	North Boundary Containment System
NDMA	Nitrosodimethyl amine
TOC	Total Organic Carbon
UV	Ultraviolet
VOC	Volatile Organic Compound
WO_3	Tungsten trioxide

Table 14.2-1 GAC Treatment Systems Using RMA Waters

Year	Operator	Operation Units	Main Concern	Design Flow Rate
1981	PMRMA/Shell	North Boundary Containment System	DIMP/$CHCl_3$	450 gpm
1981	PMRMA/Shell	Irondale Containment System	DBCP/TCE	2,100 gpm
	PMRMA/Shell	South Plants Treatment System	Miscellaneous Contaminated Waters	10 gpm
1984	PMRMA/Shell	Northwest Boundary Containment System	DBCP/Dieldrin	1,500 gpm
1990	PMRMA/Shell	Basin A Neck Interim Response Action	VHOs, VAOs, OCPs	15 gpm
1992	PMRMA/Shell	CERCLA Wastewater Treatment System	Miscellaneous Contaminated Waters	20 gpm

Table 14.3-1 Vapor Phase Post-Treatment Technologies for Air Stripping

Technology	Description	Advantages	Disadvantages
Vapor-Phase GAC Adsorption	Contaminants in air stream are adsorbed onto vapor-phase GAC.	1. Highly implementable. 2 Low capital cost ($2,500)	1. Transfers contaminants to solid phase requiring further treatment, regeneration, and/or disposal. 2. High O&M cost ($13,000 to $440,000 per year). 3. High present worth cost ($210,000 to $6,000,000).
Catalytic Oxidation	Chemical process where organics in the exhaust and converted into carbon dioxide and water. Catalyst accelerates the rate and allows for lower reaction temperature.	1. Cost effective for long term air stripping applications. 2. Organic contaminants are completely destroyed. 3. Low O&M costs ($3,000 to $13,000 per year). 4. Low present worth ($108,000 to $300,000 per year).	1. Air stream contaminants could cause catalyst deactivation. 2. High capital cost ($60,000 to $100,000).
Thermal Oxidation	Thermal process whereby organics in the exhaust are incinerated and converted to carbon dioxide and water. High temperatures are required for complete oxidation to take place.	1. Organic contaminants are completely destroyed.	1. High O&M costs due to high heating costs. 2. High capital equipment costs. 3. Operation at high temperatures requires special precautions.

GAC Granular Activated Carbon
O&M Operations and Maintenance

Flow Rate (gpm)	Approximate Concentration	(ug/l)	Unit Size		Unit Cost
10	Benzene	380	Tower Diameter	1 ft	$15,740
	Chloroform	3400	Packing Height	20 ft	
	Dichloroethane	9	Air/Water Ratio		
	Methylene Chloride	72			
	Tetrachloroethylene	98			
	Trichloroethylene	11			
10	Benzene	9600	Tower Diameter	1 ft	$15,740
	Chloroform	260	Packing Height	15 ft	
	Methylene Chloride	13	Air/Water Ratio	30	
	Tetrachloroethylene	6			
5	Benzene	150	Tower Diameter	0.75 ft	$15,740
	Carbon Tetrachloride	17	Packing Height	20 ft	
	Chloroform	850	Air/Water Ratio	30	
	Methylene Chloride	34			
	Tetrachloroethylene	16			
25	Benzene	4100	Tower Diameter	1.5 ft	$17,620
	Carbon Tetrachloride	6	Packing Height	25 ft	
	Chloroform	110	Air/Water Ratio	50	

Contaminant	Henry's Law Constant (atm m^3/mol)	Reference Temperature (°C)	Reference
Aldrin	4.96E-04	25	EPA/600/2-82-001a
Benzene	5.55E-03	25	EPA/600/2-82-001a
Carbon tetrachloride	3.02E-02	25	EPA/600/2-82-001a
Chlordane	4.80E-05	25	EPA/600/2-82-001a
Chlorobenzene	3.93E-03	25	EPA/600/2-82-001a
Chloroform	3.39E-03	25	EPA/600/2-82-001a
Dibromochloropropane	1.47E-04	25	SCR, 1988
1,2-Dichloroethane	1.31E-03	25	Nirmalakhanda & Speece, 1988
1,2-Dichloroethylene	1.50E-02	25	EPA/600/2-82-001a
Dieldrin	5.80E-05	25	EPA/600/2-82-001a
Endrin	5.00E-07	25	EPA/600/2-82-001a
Methylene chloride	3.19E-03	25	EPA/600/2-82-001a
Tetrachloroethylene	2.87E-02	25	EPA/600/2-82-001a
Trichloroethylene	1.17E-02	25	EPA/600/2-82-001a

15.0 AIR TREATMENT

The air treatment processes evaluated in the FS are all secondary treatments associated with emissions generated by remediation technologies used for other media. In most cases, the emission controls are integral parts of the equipment or action implemented under the primary technologies and are, therefore, discussed as part of the technologies with which they are associated. This section summarizes those DAA technologies that emit off gases.

For those technologies that do not include air controls in the equipment package, a number of competitively priced options are available. Air stripping is a good example of a technology that typically does not include integrated air control. Section 15.1 summarizes emission treatment technologies and Section 15.2 analyzes the preferred air treatment for the flow and concentration ranges being considered.

15.1 EMISSION TREATMENT SUMMARY

The technologies that were identified as generating potential air sidestreams (Table 15.1-1) were reviewed during the DAA to determine whether air-related issues were identified and addressed to the extent necessary. Some of these air-related issues included the type and quantity of emissions anticipated, proposed air treatment technology, treatment effectiveness, air ARARs, and costs associated with air treatment.

In most cases, the treatment technologies identify the specific air treatment processes that are included as part of the technology package. In general, the equipment vendors provide a treatment package that specifies compatible air treatment equipment as part of their overall treatment train in order to address the anticipated emissions generated by the primary treatment equipment. In these cases, the air portion of the technology package was reviewed to ensure that all of the anticipated air emissions could be addressed by the specified air treatment, that the air treatment technology could efficiently treat the compounds to satisfy ARARs, and that air treatment costs were included in the overall technology costs.

In cases where air treatment was not built in to the technologies, the potential air emissions were reviewed, and proposed air treatment was evaluated to determine whether it could effectively address these emissions and satisfy ARARs. Overall treatment costs were also reviewed to ensure that costs associated with air treatment or air emission control were included.

15.2 EVALUATION OF TREATMENT TECHNOLOGIES FOR THE TREATMENT OF AIR STRIPPER OFF GAS

Five groundwater alternatives in the DAA include the use of an air stripper whose emissions may exceed ARARs. To select the appropriate emission treatment technology, the contaminant of concern concentrations and flow rates of air emissions from the five different process options were compared (Table 15.2-1). Several technologies are available for the treatment of organic compounds in the off-gas emissions. These technologies, GAC adsorption, biofiltration, thermal oxidation, and catalytic oxidation, are described below.

Vapor-phase GAC adsorption is the most common method for removing VOCs from vapor emissions generated by water treatment systems. Unfortunately, some compounds encountered at RMA, such as chloroform and methylene chloride, are relatively poorly adsorbed and, consequently, require large quantities of GAC. For low flow rates, GAC may be the most practical option; but for the cases presented here, at flow rates greater than 200 standard cubic feet per minute (scfm), GAC usage increase dramatically. Furthermore, the contaminants are not destroyed, but are transferred to GAC, which requires thermal regeneration or disposal. Table 15.2-2 provides estimates of carbon usage and costs when using vapor-phase GAC units that are replaced and regenerated off post by the vendor. In-place regeneration units are also available. These typically use steam or hot nitrogen to desorb the contaminants from the GAC bed. Hot nitrogen applications are generally cost prohibitive and, therefore, limited to highly concentrated industrial streams. Steam regeneration units, on the other hand, could potentially be used for regenerating the GAC at RMA. Success of the technology depends on how effectively the contaminants removed by the steam can be separated from the condensate. It is not expected that the removed contaminants have any resale value, but it might be possible to

use contaminants such as benzene as supplemental fuel for thermal treatment of soil. Table 15.2-3 presents the estimated costs for using vapor-phase GAC with steam regeneration.

Catalytic oxidation is a less frequently applied technology that offers two advantages over GAC—near complete destruction of contaminants and, generally, lower costs. For the alternatives under evaluation at RMA, catalytic oxidation is also preferred over thermal oxidation because of lower required operating temperature of the reactor. Recent innovations in catalyst development have led to catalysts that can handle the decomposition of chlorinated compounds. Even tetrachloroethylene, a compound normally requiring very high oxidation temperatures, can be destroyed in the presence of a catalyst. Previous to these developments, the generation of monatomic chlorine during thermal decomposition created a masking effect over the catalyst. The new catalysts require a moist environment, which is provided by the emissions from the air stripper (as compared with GAC adsorption, where the emission stream would have to be dried first and the resulting condensate would need further treatment). Over the period of 3 to 5 years, the catalyst approaches deactivation and must be replaced. The vendor supplying the new catalyst often buys the old catalyst bed and recovers its platinum. Table 15.2-4 provides cost estimates for the use of catalytic oxidation.

Thermal oxidation and biofiltration are two other technologies that are applied to air streams. For the waste streams to be treated at RMA, however, they are not as effective as catalytic oxidation or GAC. Thermal oxidation tends to be most cost effective when used at sites where high hydrocarbon levels (greater than 50 percent lower explosive limit) can be sustained. At lower levels, fuel consumption becomes significant, and catalytic oxidation or GAC adsorption should be evaluated as control technologies. Although modern heat recovery equipment has significantly reduced the cost of fuel consumption, other factors such as public acceptance, byproduct formation, and treatment of criteria pollutants (i.e., carbon monoxide and nitrogen oxides) are distinct disadvantages of thermal oxidation units. As previously mentioned, the destruction of tetrachloroethylene found in the off gas requires a very high temperature; as a

result, additional treatment such as GAC may be required if levels surpass those mandated by the ARARs.

The use of biofiltration (a distribution system of perforated pipe buried in a soil bed) is precluded because of the difficulty in treating a variable loading of contaminants. The mass of organics in the air stream are expected to vary widely over time. There may potentially be periods where the mass of organics is insufficient to continually sustain the microorganisms. On other occasions, a spike of contaminants may be concentrated enough to pass through the bed and be released to the atmosphere. The primary maintenance problem with biofilters is controlling the moisture of the bed. The bed typically requires 99 percent relative humidity of the air in the soil pores; however, this percentage should not be difficult to obtain considering the air coming off the air stripper is saturated.

A comparison of the cost of using catalytic oxidation for 10 to 30 years versus using GAC without and with steam regeneration is presented in Table 15.2-5. In most cases, catalytic oxidation is the most cost-effective option. It is recommended that catalytic oxidation be given serious consideration as the primary treatment for off gas from groundwater treatment systems because more than 98 percent conversion may be achieved. For those scenarios where the quantity of contaminants still exceed air ARARs, a vapor-phase GAC unit could be used as a polishing unit.

Table 15.1-1 List of Technologies with Air Sidestreams

Technology	Anticipated Emissions	Air Treatment Technology	ARARs Considered (Y/N)	Part of Treatment Package (Y/N)	Costs
*Rotary Kiln Incineration	Particulates Acid Gas	Spray Tower Bag House Venturi Scrubber Caustic Quench	Y	Y	Included in Technology Package
In Situ/Microwave Heating	Volatile Organic Emissions	Emissions Captured in Hood	Y	Y	Included in Technology Package
*Thermal Desorption	Particulates Acid Gas	Spray Tower Bag House Venturi Scrubber Caustic Quench	Y	Y	Included in Technology Package
Vacuum Extraction	Vapor Emissions	Catalytic Oxidation GAC Adsorption	Y	N	Incorporated in Alternative Costing
Excavation	Particulates	Water Sprayer Surfactants	Y	Y	Included in Technology Package
In Situ Surface Soil Heating	Vapor Emission	Emissions Captured and Treated	Y	Y	Included in Technology Package
In Situ Vitrification	Vapor Emission	Emissions Captured and Treated	Y	Y	Included in Technology Package
In Situ Steam Cleaning	Vapor Emissions	Emissions Captured and Treated	Y	Y	Included in Technology Package
Vacuum Dusting	Particulates	–	–	–	–
Sand Blasting	Particulates/Dust Emissions	Building Containment	Y	Y	Included in Technology Package
Excavation/Odor Control Basin F	Ammonia	Acidified Scrubber	Y	N	Incorporated in Alternative Costing
Hot Gas Treatment	Vapor Emissions	After Burner or Activated Carbon	Y	Y	Included in Technology Package

* Reviewed to ensure that anticipated air emissions addressed by specified air treatment.
ARARS Applicable or Relevant and Appropriate Requirements
GAC Granular Activated Carbon

Technology	Anticipated Emissions	Air Treatment Technology	ARARs Considered (Y/N)	Part of Treatment Package (Y/N)	Costs
Transportation	Visible Dust Emissions-Particulates Organic Vapor Emissions	Lining, Covering, Packaging, Material, Dust Suppression (including water spraying)	Y	N	Incorporated in Alternative Costing
*Demolition	Dust Emission	Spray or Misting Water	Y	Y	Included in Technology Package
Air Stripping	Volatile Organic Emissions	Activated Carbon	Y	N	Incorporated in Alternative Costing

* Reviewed to ensure that anticipated air emissions addressed by specified air treatment.
ARARS Applicable or Relevant and Appropriate Requirements
GAC Granular Activated Carbon

Table 15.2-1 Concentrations and Flow Rates of Air Emissions from Air Stripping and Oxidation Units

Process Option	Contaminant of Concern	Water Concentration (µg/L)	Water Rate (gpm)	Treatment Unit	% Stripped*	Air Flow (scfm)	Mass in Emissions (g/hr)	Gaseous Effluent Concentration (µg/L)
1	1.2 DCA	7	10	Stripping	99.9%	70	0.02	0.13
	Chlorobenzene	130			99.9%		0.29	2.48
	Chloroform	3100			99.9%		7.03	59
	Methylene chloride	72			99.9%		0.16	1.37
	Tetrachloroethylene	98			99.9%		0.22	1.87
	TCE	20			99.9%		0.05	0.38
	Benzene	390			99.9%		0.88	7.44
2	Carbon tetrachloride	7	10	Stripping	99.9%	40	0.02	0.23
	Chlorobenzene	15			99.9%		0.03	0.50
	Chloroform	260			99.9%		0.59	8.66
	Methylene chloride	12			99.9%		0.03	0.40
	Tetrachloroethylene	6			99.9%		0.01	0.20
	TCE	4			99.9%		0.01	0.13
	Bicycloheptadiene	11			99.9%		0.02	0.37
	Benzene	9600			99.9%		22	320
	Toluene	10			99.9%		0.02	0.33
3	Carbon tetrachloride	7	10	Oxidation	70%	50	0.01	0.13
	Chlorobenzene	15			25%		0.01	0.10
	Chloroform	260			70%		0.41	4.87
	Methylene chloride	12			70%		0.02	0.22
	Tetrachloroethylene	6			70%		0.01	0.11
	TCE	4			70%		0.01	0.07
	Bicycloheptadiene	11			20%		0.00	0.06
	Benzene	9600			25%		5.5	64
	Toluene	10			25%		0.01	0.07
4	Carbon tetrachloride	6.9	30	Stripping	99.9%	200	0.05	0.14
	Chlorobenzene	110			99.9%		0.75	2.20
	Benzene	5000			99.9%		34	100
5	Carbon tetrachloride	6.9	30	Oxidation	70%	50	0.01	0.13
	Chlorobenzene	110			25%		0.06	0.74
	Benzene	5000			25%		2.8	33

mg/L Micrograms Per Liter
scfm Standard Cubic Feet Per Minute

gpm gallons per minute
g/hr gallons per hour
(µg/L) micrograms per liter

* Air stream was assumed to be nearly saturated and approximately 40 to 60°F. The percentage stripped was based on designed efficiencies and Henry's Law constant.

Table 15.2-2 Vapor-Phase Carbon Cost Summary

Process Option	Carbon Usage lbs/yr	Ventsorb 200 lbs $750 each Pac/yr	Ventsorb 200 lbs $750 each $/yr	Vapor Pac 1,800 lbs $4,500 each Pac/yr	Vapor Pac 1,800 lbs $4,500 each $/yr	Annual Power Costs*	Capital Costs	Present Worth Cost**
1	3,247	16	$12,176	2	$8,118	$399	$2,865	$61,000
2	3,890	19	14,588	2	9,725	329	2,865	71,000
3	1,345	7	5,044	1	3,363	352	2,865	39,000
4	5,555	28	20,831	3	13,888	700	2,865	106,000
5	594	3	2,228	–	–	352	2,865	21,000

* Includes heating costs and fan H.P.
** Options 1-3 based on 10-year present worth and options 4-5 based on 20-year present worth.

Table 15.2-3 Vapor-Phase GAC with Carbon Regeneration Unit

Process Option	Desorption Cycle Costs		Dehumidifier $/yr	Purge Cost $/yr	Cool Down Costs $/yr	Condenser Costs $/yr	Annual Power Costs*	Capital Costs	Present Worth Cost**
	Power $/yr	Water $/yr							
1	$139	$1,588	$3,106	4	1	$1,521	$370	$43,000	$89,000
2	243	2,778	3,106	7	1	1,521	370	43,000	98,000
3	194	2,223	3,106	6	1	1,521	370	43,000	93,000
4	776	2,223	3,106	12	2	6083	370	72,000	161,000
5	194	2,223	3,106	6	1	1,521	370	43,000	96,000

* Includes heating costs and fan H.P.

** Options 1-3 based on 10 year present worth and options 4-5 based on 20-year present worth.

Table 15.2-4 Catalytic Oxidation Cost Summary

Process Option	Water Flow (gpm)	Air Flow (scfm)	Catalytic Oxidizer Size (scfm)	Equipment Cost	Annual Power Costs	Amortized Catalyst Replacement Costs	Total Capital Costs	Total Annual O&M Costs	Present Worth Cost*
1	10	70	100	$46,900	$1,138	$777	$46,900	$1,276	$56,000
2	10	40	100	46,900	417	777	46,900	1,083	54,000
3	10	50	100	46,900	499	777	46,900	1,181	55,000
4	30	200	200	59,000	404	1,128	59,000	2,266	70,000
5	30	50	100	46,900	274	752	46,900	1,169	55,000

* Options 1-3 based on 10-year present worth and options 4-5 based on 20-year present worth.
gpm Gallons Per Minute
O&M Operations and Maintenance
scfm Standard Cubic Feet Per Minute

Table 15.2-5 Catalytic Oxidation Versus Vapor-Phase GAC–Total Cost Summary

Process Option	Catalytic Oxidation			Vapor-Phase GAC Adsorption Calgon Carbon			Vapor-Phase GAC Adsorption with Carbon Regeneration Unit Westvaco		
	Capital Costs	Annual O&M Costs	Present Worth Cost*	Capital Costs	Annual O&M Costs	Present Worth Cost*	Capital Costs	Annual O&M Costs	Present Worth Cost*
1	$46,900	$1,276	$56,000	$2,865	$8,517	$61,000	$43,200	$6,727	$89,000
2	46,900	1,914	54,000	2,865	10,054	71,000	43,200	8,026	98,000
3	46,900	1,181	55,000	2,865	5,400	39,000	43,200	7,420	93,000
4	59,000	2,266	70,000	2,865	14,588	106,000	72,000	15,571	161,000
5	46,900	1,169	55,000	2,865	2,580	21,000	43,200	7,420	96,000

* Options 1-3 based on 10-year present worth and options 4-5 based on 20-year present worth.
GAC Granular Activated Carbon
O&M Operation and Maintenance

APPENDIX A

POTENTIAL ACTION-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND INFORMATION TO-BE-CONSIDERED

INTRODUCTION

Appendix A is a compilation of potential action-specific applicable or relevant and appropriate requirements (ARARs) and information to-be-considered (TBC) for the technologies that are part of any of the alternatives considered in the Detailed Analysis of Alternatives (DAA). The potential ARARs and TBCs for each specific technology are listed in a separate table. There are a total of 37 Tables as detailed in the List of Tables. In general, each technology represents only one part of a complete alternative consisting of several technologies, therefore, several ARAR tables may have to be utilized for each alternative.

This document identifies action-specific ARARs, however, since some requirements do not fall neatly into the action-specific classification, there are some chemical- and location-specific requirements listed in the tables as well.

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LIST OF ACRONYMS AND ABBREVIATIONS

°F	Degrees Fahrenheit
ACGIH	American Conference of Governmental Industrial Hygienists
ACM	asbestos-containing material
ACOE	Army Corps of Engineers
AMC-R	
AIR	Automobile inspection and readjustment
AOC	Area of Contamination
AMC	Army Materiel Command
AR	Army Regulations
ARAR	Applicable or Relevant and Appropriate Requirement
Army	U.S. Army
BCY	Bank Cubic Yards
BDAT	Best Demonstrated Available Technology
CAMU	Corrective Action Management Units
CCR	Code of Colorado Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
CY	cubic yards
DA	Department of the Army
DA Pam	Department of the Army Pamphlet
DAA	Detailed Analysis of Alternatives
db(A)	decibels
DCPD	dicyclopentadiene
DOD	Department of Defense
DOT	Department of Transportation
DRMO	Defense Reutilization Management Office
DSA	Development and Screening of Alternatives
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FM	Field Manual
FS	feasibility study
ft	feet
FWQC	Federal Water Quality Criteria
GAA	granular activated alumina
GAC	granular activated carbon
GB	Isopropylmethyl Phosphonofluoridate
HE	high explosive
HEPA	High-efficiency Particulate
IRA	Interim Remedial Action
Kg/mo	Kilograms per month
L	Lewisite

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

LDR	land disposal restriction
LEL	lower exposure limit
$\mu g/m^3$	milligrams per cubic meter
mppcf	million particles per cubic foot
MTR	Minimum Technology Requirements
NCP	National Contingency Plan
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
OCP	organochlorine pesticides
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated Biphenyl
PEL	permissible exposure limit
PM_{10}	Particulate matter with diameter less than or equal to 10 micro meters
ppm	parts per million
RA	Regional Administrators (EPA)
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
REL	recommended exposure limit
RI	remedial investigation
RMA	Rocky Mountain Arsenal
ROD	Record of Decision
SF	square feet
STEL	Short-term exposure limit
TBC	to-be-considered guidance
TCLP	Toxicity Characteristic Leaching Procedure
TEGD	Technical Enforcement Guidance Document
TM	Technical Manual
TMV	Toxicity, Mobility, or Volume
TSCA	Toxic Substances Control Act
TU	temporary units
TWA	time weighted average
USC	United States Code
UV	ultraviolet
UXO	unexploded ordnance
VOC	Volatile organic compound
VX	Ethyl S-Dimethylaminoethyl Methylphosphonothiolate

STATUTORY CITATIONS

Citation	Citation Name
16 USC Section 661 et seq.	Fish and Wildlife Coordination Act
16 USC Section 668 et seq.	Bald Eagle Protection Act
16 USC Section 703-711	Migratory Bird Treaty Act
16 USC Section 1531 et seq.	Endangered Species Act
42 USCS Section 7412	Clean Air Act - National Emission Standards for Hazardous Air Pollutants (NESHAPS)
42 USCS Section 7502-7503	Clean Air Act - Nonattainment Plan Provisions/Permit Requirements
CRS Section 25-12-101 to 25-12-108	Colorado Revised Statutes - Noise Abatement
CRS Section 33-2-101 to 33-2-107	Colorado Nongame, Endangered, or Threatened Species Conservation Act
CRS Section 42-4-307(8)	Colorado Revised Statutes - Regulation of Vehicles and Traffic

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
	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.

Action	Citation	Requirements
Health and safety protection (continued)	AR-385-10 AR 385-64 AMC-R 395-100 DAA Pam 40-8 [TBC] FM 3-21 [TBC] TM 10-277 [TBC] ACOE Guidance on Safety Concepts for UXO [TBC]	If unexploded ordnance (UXO) is encountered during excavation, workers must comply with the substantive requirements of AMCR 385-100, AR 385-10, AR 385-64, as well as guidance provided in DA Pam 40-8, FM 3-21, TM 10-277 and ACOE guidance for UXO regarding health and safety of workers associated with ammunition, explosives, and chemical agents.
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. Since the DSA was completed, OSHA has lowered the PEL for all forms of cadmium, including dust and fumes. The current standard is: Cadmium (all forms) OSHA-PEL = 0.005 mg/m^3 (8 hr TWA) In addition to the chemicals listed in Table 1, excavation at Basin F is expected to encounter ammonia. The ammonia fumes will be neutralized using an acidified scrubber that utilizes hydrochloric acid. Worker exposure standards for these chemicals are as follows: Ammonia: ACGIH-TWA = 25 ppm, 17 mg/m^3 STEL = 35 ppm, 24 mg/m^3 NIOSH-REL = 25 ppm, 17 mg/m^3 STEL = 35 ppm, 27 mg/m^3 OSHA-PEL = 50 ppm, 35 mg/m^3 STEL = 35 ppm, 27 mg/m^3 Hydrogen Chloride: ACGIH-TWA = 5 ppm, 7.5 mg/m3 (ceiling) NIOSH-REL = 5 ppm, 7 mg/m3 (ceiling) OSHA-PEL = 5 ppm, 7 mg/m3 (ceiling)

Action	Citation	Requirements
Worker exposure (continued)		If chemical agent is encountered during excavation, workers must comply with the chemical-specific exposure guidelines for chemical agents and breakdown products outlined in Table A-17 of this document. (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Excavation and backfill of soils at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Excavation and backfill operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Noise Abatement		
Noise control during excavation and backfill	CRS Section 25–12–101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Soil excavation and backfill operations must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness.

Action	Citation	Requirements
Noise control during excavation and backfill (continued)		Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)
Air Emission Control		
Particulate emissions during excavation and backfill	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.
	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): Averaging Time — Primary Standard — Secondary Standard Annual (geometric mean) — 75 — 60 24–hour — 260 — 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$): Averaging Time — Primary Standard — Secondary Standard Annual (arithmetic mean) — 50 — 50 24–hour — 150 — 150
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Excavation and backfill of soils shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Excavation and backfill of soils could potentially cause emission of hazardous air pollutants.

Action	Citation	Requirements
Emission of hazardous air pollutants (continued)	42 USCS Section 7412	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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
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 as follows: 1) "No person shall emit or cause to be emitted into the atmosphere from any diesel-powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity."

Action	Citation	Requirements
Air emissions from diesel–powered vehicles associated with excavation and backfill operations (continued)		2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Excavation and backfilling of soils 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.
<u>Waste Characterization</u>		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 abandanced, recycled, and waste-like materials. These materials may have any of the following qualities: • Abandoned material may be - disposed of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike

Action	Citation	Requirements
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Wastes generated during soil excavation 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
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes.

Action	Citation	Requirements
Solid waste classification (continued)		5) "Inert material", which includes solids that are not soluble in water and therefore non-putrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, commercial, and special wastes are expected from soil excavation at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
Waste Management		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	If soil excavation at RMA generates hazardous wastes, the wastes must be treated, stored or disposed in accordance with RCRA regulations, including LDRs (if placement occurs).
Treatment and disposal of hazardous debris	57 FR 37194 et seq.	Hazardous debris generated during soil excavation activities must be treated using specific technologies to extract, destroy, or immobilize hazardous constituents on or in the debris. In certain cases, after treatment the debris may no longer be subject to RCRA Subtitle C regulation.
Solid waste disposal	6 CCR 1007-2, Part 1, Section 1 OSWER Directive 2345.3-03FS [TBC]	[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills]
Groundwater Injection		
Reinjection of treated groundwater	RCRA Section 3020 (b) 2 CCR 402-2, Rule 10 OSWER Directive 9234.1-06 [TBC]	Reinjection of treated groundwater must be managed in accordance with the guidelines in OSWER Directive 9234.1-06. Wells should be constructed and installed in compliance with the requirements of 2 CCR 402-2, Rule 10.

Action	Citation	Requirements
Waste Characterization		
Solid waste determination		Drums, debris, and equipment from structures that stockpiled must be evaluated to determine whether it may be recycled or reused or whether it is a solid waste.
	40 CFR 260 40 CFR 261.2 40 CFR 261.4 (a) 40 CFR 260.30-31	A solid waste is any discarded material that is not excluded by 40 CFR 261.4 (a) or 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Solid wastes including drums, debris, and equipment from structures that are temporarily stored in stockpiles must be 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 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

Action	Citation	Requirements
Solid waste classification	6 CCR 1007-2, Part 1, 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: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes are expected from sstockpiles at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.

Action	Citation	Requirements
<u>Waste Management</u>		
Treatment, storage, or disposal of hazardous wastes in waste piles	40 CFR Part 264 40 CFR 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 if placement occurs.
Design and operating requirements for waste piles that contain hazardous wastes	40 CFR 264.251	Waste piles that contain hazardous wastes must: • Have a liner that is designed, constructed, and installed to prevent migration of wastes out of the pile into adjacent soil, groundwater, or surface water. • Be constructed with materials to prevent failure, physical contact with the waste, and that will endure stress of installation and daily operation. • Be placed on a foundation that provides support to prevent failure of the liner. • Be installed to cover all surrounding earth likely to be in contact with the waste or leachate. • Have a leachate collection system. • Have a run-on control system capable of preventing flow onto the active portion of the pile during peak discharge from at least a 25-year storm. • Have a run-off management system to collect and control at least the water volume resulting from a 24-hour, 25-year storm. • Be covered or managed properly if the pile contains any particulate matter which may be subject to wind dispersal.
Ignitable and reactive wastes in waste piles	40 CFR 264.256 40 CFR 268 40 CFR 261.21 40 CFR 261.23	Ignitable or reactive wastes must not be placed in waste piles unless they meet all applicable requirements of 40 CFR 268 and (1) the waste is treated before placement so that it is no longer ignitable or reactive or (2) the waste is managed in such a manner that it is protected from any material or conditions which may cause it to react or ignite.

Action	Citation	Requirements
Incompatible wastes in waste piles	40 CFR 264.257 40 CFR 264.17 (b)	Incompatible wastes must not be placed in the same pile unless 40 CFR 264.17 (b) is complied with. Incompatible wastes must be separated from other materials.
Closure and post-closure care of waste piles	40 CFR 264.258	At closure, the owner or operator must remove or decontaminate all waste residues and manage them as hazardous wastes.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Stockpiling of drums, debris, and equipment from structures at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Stockpiling operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions of any natural stream or body of water.
	CRS 33-2-101 to 33-3-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
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.

Action	Citation	Requirements
	29 CFR 1910.120(b)	29 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 3A–1 in Appendix A1 of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
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.
	29 CFR 1910.120(b)	29 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under the RCRA and the CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, the ACGIH, and NIOSH are outlined in Table 3A–1 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR 10 50 CFR 20-21	Demolition of structures at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Demolition operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
Demolition		
Noise control	CRS Section 25–12–101 to 108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Demolition of structures must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)
Air emissions during demolition	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.

Action	Citation	Requirements
Air emissions during demolition (continued)	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (geometric mean)	75	60
24–hour	260	150

	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24–hour	150	150

Emission control for opacity	5 CCR 1001-3 Regulation 1, Section II 40 CFR 60 Appendix A	Demolition of structures shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Demolition of structures could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.
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 following limits:

Action	Citation	Requirements
Odor emissions (continued)		1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Air emissions from diesel–powered vehicles associated with demolition	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 as follows: 1) "No person shall emit or cause to be emitted into the atmosphere from any diesel–powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity." 2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Demolition of structures 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.

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
	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.

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are presented as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Trench construction and operation at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Trench construction shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
Noise Abatement		
Noise control	CRS Section 25–12–101 to 108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Installation of trenches must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness.

Action	Citation	Requirements
Noise control (continued)		Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)
Air Emissions		
Air emissions during trench construction	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.
	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): Averaging Time — Primary Standard — Secondary Standard Annual (geometric mean) — 75 — 60 24–hour — 260 — 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$): Averaging Time — Primary Standard — Secondary Standard Annual (arithmetic mean) — 50 — 50 24–hour — 150 — 150
Emission control for opacity	5 CCR 1001-3 Regulation 1, Section II 40 CFR 60 Appendix A	Trench construction shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.

Action	Citation	Requirements
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Trench construction could cause volatization of some contaminants.
	42 USCS Section 7412	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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use area—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air

Action	Citation	Requirements
Air emissions from diesel-powered vehicles associated with trench construction	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 as follows: 1) "No person shall emit or cause to be emitted into the atmosphere from any diesel-powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity." 2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Trench construction 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.

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	The following requirements must be considered for cap cover installation over unlined land disposal sites: 1. They must not be located within 200 ft of a Holocene-age fault. 2. They must be designed, constructed, and operated to prevent washout of hazardous waste by a 100-year flood (if the facility is located within the 100-year flood plain).
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Health and safety protection (continued)		Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are presented as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Cap/cover installation at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Cap/cover installation shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-1-7	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
Construction of Caps/Covers		
Design/installation of caps/covers	40 CFR 264.301 (i) 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 EPA/530/SW-89/047.
Air Emission Control		
Particulate emissions during cap/cover installation	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Action	Citation	Requirements
Particulate emissions during cap/cover installation (continued)		Averaging Time / Primary Standard / Secondary Standard Annual (geometric mean) 75 60 24–hour 260 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$): Averaging Time / Primary Standard / Secondary Standard Annual (arithmetic mean) 50 50 24–hour 150 150
	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5 (Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1)Section II 40 CFR 60 Appendix A	Installation of caps/covers shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Installation of caps/covers could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.
Air emissions from diesel–powered vehicles associated with installation of caps/covers	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 as follows:

Action	Citation	Requirements
Air emissions from diesel–powered vehicles associated with installation of caps/covers (continued)		1) "No person shall emit or cause to be emitted into the atmosphere from any diesel–powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity." 2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Installation of caps/covers 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.
<u>Noise Abatement</u>		
Noise control during cap/cover installation	CRS Section 25-12-101 to 108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Installation of caps/covers must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations land emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
	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] 20 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA.

Action	Citation	Requirements
Worker exposure (continued)		In addition to the chemicals listed in Table 1, workers installing the concrete liners will be exposed to Portland cement dust. Worker exposure standards for Portland cement are the following: Portland cement — ACGIH-TWA = 10 mg/m^3* NIOSH-REL = 10 mg/m^3 (total), 5 mg/m^3 (resp) OSHA-TWA = 10 mg/m^3 (total), 5 mg/m^3 (resp) PEL = 50 mppcf** * value is for total dust containing no asbestos land less than 1% crystalline silica ** mppcf = million particles per cubic foot (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are presented as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Installation and existence of concrete liners in ditches at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Liner installation shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]

Action	Citation	Requirements
Access controls for wildlife	40 CFR 264.14	Access controls shall be provided that minimize unauthorized entry of wildlife onto active portions of RMA. These may include 24-hour surveillance or a barrier (either natural or artificial) and a means of controlling access.
Noise Abatement		
Noise control during concrete liner installation	CRS Section 25-12-101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Concrete liner installation must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)
Air Emission Control		
Particulate emissions during installation of concrete liners	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): Averaging Time — Primary Standard — Secondary Standard Annual (geometric mean) — 75 — 60 24–hour — 260 — 150

Action	Citation	Requirements
Particulate emissions during installation of concrete liners (continued)	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$):
		Averaging Time / Primary Standard / Secondary Standard Annual (arithmetic mean) / 50 / 50 24–hour / 150 / 150
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Construction of concrete liners shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Concrete liner installation could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Concrete liner installation 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.

Action	Citation	Requirements
Noise Abatement		
Noise control during concrete liner installation	CRS Section 25-12-101 to 108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Installation of caps/covers must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
	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.

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Slurry wall construction at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Slurry walls shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
Noise Abatement		
Noise control during slurry wall construction	CRS Section 25–12–101 to 108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Installation of slurry walls must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness.

Action	Citation	Requirements
Noise control (continued)		Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)
Air Emissions		
Air emissions during slurry wall construction	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.
	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): Averaging Time — Primary Standard — Secondary Standard Annual (geometric mean) — 75 — 60 24–hour — 260 — 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$): Averaging Time — Primary Standard — Secondary Standard Annual (arithmetic mean) — 50 — 50 24–hour — 150 — 150
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Slurry walls shall not cause the emission into the atmosphere of any air pollutant which is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.

Action	Citation	Requirements
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Slurry wall construction could cause volatization of some contaminants.
	42 USCS Section 7412	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 of 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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Air emissions from diesel-powered vehicles associate with slurry wall construction	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 as follows:

Action	Citation	Requirements
Air emissions from diesel-powered vehicles associate with slurry wall construction (continued)		1) "No person shall emit or cause to be emitted into the atmosphere from any diesel-powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity." 2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Slurry wall construction 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.
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated

Action	Citation	Requirements
Solid waste determination (continued)		• Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
<u>Waste Characterization</u>		
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Wastes generated during slurry wall construction must be characterized. Solid wastes must be 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Determination of hazardous waste (continued)		
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys.

Action	Citation	Requirements
Solid waste classification (continued)		3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes are expected from slurry wall installation at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment, storage, or disposal of hazardous waste	40 CFR Part 264	If slurry wall construction at RMA generates hazardous wastes, the wastes must be treated and stored in accordance with RCRA regulations.
On-post land disposal of hazardous wastes	40 CFR Part 264 40 CFR Part 268 [TBC] EPA/540/G-89/006 [TBC]	Based upon a determination of whether the disposal technique constitutes placement, LDRs may be applicable. If placement occurs, the on-site disposal facility must comply with the substantive requirements of 40 CFR 264.

Action	Citation	Requirements
Treatment and disposal of hazardous debris	57 FR 37194 et seq.	Hazardous debris encountered during slurry wall installation must be treated using specific technologies to extract, destroy, or immobilize hazardous constituents on or in the debris. In certain cases after treatment, the debris may no longer be subject to RCRA Subtitle C regulation.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]

Action	Citation	Requirements
Siting		
Siting of on-post hazardous waste facilities	40 CFR 264.18	New facilities constructed on-post to treat, store, or dispose must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of hazardous waste by a 100-year flood (if the facility is located within the 100-year flood plain).
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910,1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Hazardous waste landfills at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Landfills shall not contribute to the harassment, harm, pursuit , hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33.2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
Landfill Design/Operation		
On-post hazardous waste landfill design/operation	40 CFR 264 Subpart N 40 CFR 268	On-post hazardous waste landfills shall be designed and operated in compliance with the substantive requirements of 40 CFR 264 Subpart N. If the landfill is located outside the AOC from which the hazardous waste was derived, placement has occurred and the landfill must comply with LDRs.
Off-post hazardous waste landfill operation	40 CFR 264 Subpart N OSWER Directive 9834.11	Off-post hazardous waste landfills shall be RCRA-permitted facilities and shall operate in compliance with all requirements of 40 CFR 264 Subpart N. The facilities shall also be in compliance with OSWER Directive 9834.11 regarding off-site disposal of hazardous waste from CERCLA sites.

Action	Citation	Requirements
Air Emission Control		
Emission of particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):
		Averaging Time — Primary Standard — Secondary Standard Annual (geometric mean) — 75 — 60 24–hour — 260 — 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$):
		Averaging Time — Primary Standard — Secondary Standard Annual (arithmetic mean) — 50 — 50 24–hour — 150 — 150
	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	On-post landfilling shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. On-post landfilling may cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.

Action	Citation	Requirements
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 of 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.
	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	On-post landfilling 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.
<u>Noise Abatement</u>		
Noise control	CRS Section 25-12-101 to 25-12-108	Colorado Noise Abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. On-post landfilling must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
Siting		
Siting of on-post solid waste facilities	40 CFR 257.3-1 40 CFR 258.11	New facilities constructed on-post for disposal of solid waste must adhere to the following requirements: 1) They must not restrict flow of a 100-year flood. 2) They must reduce temporary water storage capacity of the floodplain. 3) They must not result in washout of solid waste so as to pose a threat to human health or the environment.
	6 CCR 1007-2, Section 2.2.2	Surface waters shall be diverted from, or around, the disposal site and its working face.
	6 CCR 1007-2, Section 4.1	New on-post solid waste landfills shall be sited in compliance with the standards in 6 CCR 1007-2, Section 4.1.
	40 CFR 258.13-.15	New facilities shall not be located within 200 ft of a Holocene-age fault or within a seismic impact zone. Units located within unstable areas must be properly designed to ensure structural integrity of the unit.
	40 CFR 258.12	New solid waste disposal facilities shall not be located in wetlands, unless the following are demonstrated: • An alternative location (outside wetlands) is not available • The facility will not cause a significant degradation or net loss of wetlands • The construction and operation of the unit will not violate applicable state and federal water quality or effluent standards
	40 CFR 248.10	New solid waste disposal facilities must not pose a bird hazard to aircraft if located within 10,000 ft of a runway end used by turbojet aircraft or within 5,000 ft of a runway end used by only piston-type aircraft. If a new solid waste facility is located within a 5-mile radius of an airport, both the airport and the FAA must be notified.

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910,1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are presented as guidelines.)

Action	Citation	Requirements
Waste Characterization		
Solid waste determination	40 CFR 260 40 Cfr 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Solid waste classification	6 CCR 1007-2, Part 1, 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. 6CCR 1007-2, Part 1, Section 1. The Colorado solid waste rules contain the following five solid waste categories: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes.

Action	Citation	Requirements
Solid waste classification (continued)		4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes are expected to be placed in solid waste landfills at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703 50 CFR 424.02 (d) (2) 40 CFR 257.3-2 40 CFR 258.12 (a) (1) (iii) 50 CFR Part 10 50 CFR Parts 20-21 40 CFR 257.3-2 (a) and (b)	Solid waste landfills at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Landfills shall not contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g) 50 CFR Part 402 50 CFR Part 412.02 (d) (2)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers.

Action	Citation	Requirements
Protection of wildlife (continued)		[These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
Landfill Design/Operation		
On-post solid waste landfill design/operation	40 CFR 258 Subparts C & D	On-post solid waste landfills shall be designed and operated in compliance with the substantive requirements of 40 CFR 258 Subparts D and C, respectively.
	6 CCR 1007-2, Section 2.1.2	On-post solid waste landfills shall comply with the health laws, standards, rules, and regulations of the Colorado Department of Health, the Water Quality Control Commission, the Air Quality Control Commission, and all applicable zoning laws and ordinances.
	6 CCR 1007-2, Sections 2.1.4 to 2.1.6, and 2.2.8 to 2.2.12	On-post solid waste landfills shall comply with the substantive requirements of 6 CCR 1007-2, Sections 2.1.4 to 2.1.6 and 2.2.8 to 2.2.12
	6 CCR 1007-2, Section 2.2.6 (a)	The concentration of explosive gases generated by the landfill shall not exceed 1 percent of the total air volume (20 percent of the lower explosive limit, or LEL) within facility structures, with specified exceptions.
Off-post solid waste landfill design/operation	40 CFR 258 Subparts C & D CRS Sections 30-20-102 to 30-20-105	Off-post solid waste landfills must have a certificate of designation from the applicable governing body, be designed in accordance with all requirements of 40 CFR 258 Subpart D, and operate in compliance with all requirements of 40 CFR 258 Subpart C.
Groundwater Monitoring		
On-post and off-post solid waste landfill monitoring requirements	40 CFR 258 Subpart E 6 CCR 1007-2, Section 2.2.3 to 2.2.5 CRS 37-91-110 (1) (a) 2 CCR 402-2, Rule 10 RCRA Groundwater Monitoring Technical Enforcement Guidance Document (TEGD) [TBC]	On-post solid waste landfills must comply with substantive requirements of 40 CFR 258 Subpart E, and 6 CCR 1007-2, Section 2.2.3, while off-post landfills must comply with all requirements of 40 CFR 258 Subpart E and 6 CCR 1007-2, Section 2.2.3 to 2.2.5. Wells shall be located and installed in compliance with the general requirements of CRS 37-91-110 (1) (a) and the requirements of 2 CCR 402-2, Rule 10.
Air Emission Control		
Emission of particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Action	Citation	Requirements
Emission of particulates (continued)		Averaging Time / Primary Standard / Secondary Standard Annual (geometric mean) 75 60 24–hour 260 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$): Averaging Time / Primary Standard / Secondary Standard Annual (arithmetic mean) 50 50 24–hour 150 150
	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	On-post landfilling shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
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 of 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.
	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	On-post landfilling 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.

Action	Citation	Requirements
Visibility protection (continued)	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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.
Noise Abatement		
Noise control	CRS Sections 25-12-101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. On-post landfilling must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of hazardous waste by a 100-year flood (if the facility is located within the 100-year flood plain).
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. In addition to the compounds listed in Table 1, off gases from the rotary kiln incinerators may contain gaseous hydrogen chloride, hydrogen bromide, and hydrogen fluoride. These gases will be removed during further treatment of the off gases, including a caustic quench system using sodium hydroxide. The worker exposure standards for these compounds are as follows: Hydrogen bromide: ACGIH-TWA = 3 ppm, 9.9 mg/m^3 (ceiling); NIOSH-REL = 3 ppm, 10 mg/m^3 (ceiling); OSHA-PEL = 3 ppm, 10 mg/m^3 (ceiling) Hydrogen chloride: ACGIH-TWA = 5 ppm, 7.5 mg/m^3 (ceiling); NIOSH-REL = 5 ppm, 7 mg/m^3 (ceiling); OSHA-PEL = 5 ppm, 7 mg/m^3 (ceiling) Hydrogen fluoride: ACGIH-TWA = 13 ppm, 2.6 mg/m^3 (ceiling); NIOSH-REL = 3 ppm, 2.5 mg/m^3 15-min ceiling = 6 ppm, 5 mg/m^3; OSHA-PEL = 3 ppm; 5 ppm (ceiling); OSHA-STEL = 6 ppm 30-min max peak = 10 ppm Sodium hydroxide: ACGIH-TWA = 2 mg/m^3 (ceiling); NIOSH-REL = 2 mg/m^3 (ceiling); OSHA-PEL = 2 mg/m^3 (ceiling)

Action	Citation	Requirements
Worker exposure (continued)		(OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are presented as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Thermal desorption of soils at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Thermal desorption operations shall not use or contribute to the harassment, harm, pursuit , hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
Thermal Desorption Unit Operation		
Operation of thermal desorption unit	40 CFR 264 Subpart 0	The thermal desorption unit shall be operated to comply with substantive requirements of the incinerator regulations in 40 CFR 264 Subpart 0, including, but not limited to the following: • Stack emission • Monitoring • Inspections • Testing of the emergency waste feed cutoff system
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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:

Action	Citation	Requirements
Solid waste determination (continued)		• Abandoned mateiral may be - disposed of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Thermal desorption of soils will generate salt cake, metal fines, and other solids. These wastes and all others generated must be characterized and evaluated according to the following methods 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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 the following five solid waste categories: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys.

Action	Citation	Requirements
Solid waste classification (continued)		3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, commercial, and special wastes are expected from thermal desorption of soils at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment, storage, or disposal of hazardous wastes	40 CFR Part 264 40 CFR Part 268	Wastes that are determined to be RCRA hazardous wastes must be stored and treated, in compliance with RCRA regulations.
On-post land disposal of hazardous wastes	40 CFR Part 264 40 CFR Part 268 [TBC] EPA/540/G-89/005 [TBC]	Based upon a determination of whether the disposal technique constitutes placement, LDRs may be applicable. If placement does occur, the disposal facility must comply with the substantive requirements of 40 CFR Part 264.
Solid waste disposal	No citations	[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]

Action	Citation	Requirements
Air Emissions		
Emission of Particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): Annual (geometric mean) 75 60 24-hour 260 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$): Annual (arithmetic mean) 50 50 24-hour 150 150
	40 CFR 60 Subpart E	The thermal desorption unit shall operate in compliance with substantive requirements of 40 CFR 60 Subpart E.
	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Thermal desorption of soils shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Thermal desorption will cause volatization of some contaminants.
	42 USCS Section 7412	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.

Action	Citation	Requirements
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 of ozone. Storage and transfer of VOCs and petroleum liquids are controlled by these requirements.
	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. 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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Thermal desorption of soils 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.
<u>Noise Abatement</u>		
Noise control	CRS Section 25-12-101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Thermal desorption of soils must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of hazardous waste by a 100-year flood (if the facility is located within the 100-year flood plain).
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. In addition to the compounds listed in Table 1, off gases from the rotary kiln incinerators may contain gaseous hydrogen chloride, hydrogen bromide, and hydrogen fluoride. These gases will be removed during further treatment of the off gases, including a caustic quench system using sodium hydroxide. The worker exposure standards for these compounds are as follows: Hydrogen bromide ACGIH-TWA = 3 ppm, 9.9 mg/m^3(ceiling) NIOSH-REL = 3 ppm, 10 mg/m^3 (ceiling) OSHA-PEL = 3 ppm, 10 mg/m^3 (ceiling) Hydrogen chloride ACGIH-TWA = 5 ppm, 7.5 mg/m^3 (ceiling) NIOSH-REL = 5 ppm, 7 mg/m^3 (ceiling) OSHA-PEL = 5 ppm, 7 mg/m^3 (ceiling) Hydrogen fluoride ACGIH-TWA = 3 ppm, 2.6 mg/m^3 (ceiling) NIOSH-REL = 3 ppm, 2.5 mg/m^3 15-min ceiling = 6 ppm, 5 mg/m^3 OSHA-PEL = 3 ppm; 5 ppm (ceiling) OSHA-STEL = 6 ppm 30-min max peak = 10 ppm Sodium hydroxide ACGIH-TWA = 2 mg/m^3 (ceiling) NIOSH-REL = 2 mg/m^3 (ceiling) OSHA-PEL = 2 mg/m^3 (ceiling) If chemical agent is incinerated on post, the agent must be managed to comply with the exposure standards shown in Table A-17 of this document.

Action	Citation	Requirements
Worker exposure (continued)		(OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Incineration/pyrolysis of soils at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Incineration/pyrolysis operations shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. [These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.]
Operation of Incinerators		
Incinerator operations	40 CFR 264 Subpart O	On-post rotary-kiln incinerators must be operated in compliance with the substantive requirements of 40 CFR 264 Subpart O, including, but not limited to the following: • Waste-specific performance standards • Stack emission standards • Monitoring Off-post incinerators must be RCRA-permitted and comply with all requirements of 40 CFR 264 Subpart O.
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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:

Action	Citation	Requirements
Solid waste determination (continued)		• Abandoned mateiral may be - disposed of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Incineration/pyrolysis of soils will generate oversize soil, debris, metallic waste, ash, and salt cake. These wastes and all others generated 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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 the following five solid waste categories: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes means all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys.

Action	Citation	Requirements
Solid waste classification (continued)		3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes," which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, commercial, and special wastes are expected from incineration/pyrolysis of soils at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268 [TBC] EPA/540/G-89/006 [TBC]	Wastes that are determined to be RCRA hazardous wastes must be stored, treated, and disposed in compliance with RCRA regulations. If the soil is treated in a central incineration/pyrolysis facility at RMA that is outside the AOC from which the soil came, any waste returned to the AOC after treatment will be subject to LDRs since placement of the waste will have occurred.
Treatment of UXO containing chemical agent	AMC-R 385-131	UXO shall be incinerated as described in AMC-R 385-131 to a 5X level of docontamination so that it can be released from DOD control.

Action	Citation	Requirements
Treatment and disposal of hazardous debris	57 FR 37194 et seq.	Hazardous debris generated during incineration/pyrolysis activities must be treated using specific technologies to extract, destroy, or immobilize hazardous constituents on or in the debris. In certain cases, after treatment the debris may no longer be subject to RCRA Subtitle C regulation.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Air Emissions		
Emission of particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): Annual (geometric mean): Primary Standard 75, Secondary Standard 60 24-hour: Primary Standard 260, Secondary Standard 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$): Annual (arithmetic mean): Primary Standard 50, Secondary Standard 50 24-hour: Primary Standard 150, Secondary Standard 150
	40 CFR 60 Subpart E	Incineration/pyrolysis activities must operate in compliance with the particulate emission standards for incinerators in 40 CFR 60 Subpart E.
	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Incineration/pyrolysis operations shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.

Action	Citation	Requirements
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Incineration/pyrolysis will cause volatization of some contaminants.
	42 USCS Section 7412	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.
	CRS Section 25-7-101 et seq. 5 CCR 1001-5, Regulation 3	The Colorado Air Quality Control Commission requires that sources in the state that emit any of 67 listed pollutants in excess of 100 pounds per year submit an Air Pollution Emission Notice by December 31, 1992. The number of pollutants to report will increase to a potential 688 pollutants in future years.
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 of 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.
	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Incineration /pyrolysis operations 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.

Action	Citation	Requirements
Noise Abatement		
Noise control	CRS Section 25-12-101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Incineration/pyrolysis must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 3A-1 in Appendix A of the DSA.

Action	Citation	Requirements
Worker exposure (continued)		(OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
Off-Post Incinerator		
Incinerator facility operations	40 CFR 264 Subpart 0 OSWER Directive 9834.11	The off-post facility must have a RCRA permit to operate under the requirements of 40 CFR 264 Subpart 0. The facility should also be approved under the conditions of OSWER Directive 9834.11 for off-site disposal of hazardous wastes from a CERCLA site.

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA.

Action	Citation	Requirements
Worker exposure (continued)		In addition to the chemicals listed in Table 1, the Enhanced Surface Soil Vacuum Extraction Process (ESSVEP) generates hydrochloric acid vapors in the off gases. Worker exposure standards for hydrogen chloride are as follows: Hydrogen chloride ACGIH-TWA = 5 ppm, 7.5 mg/m^3 (ceiling) NIOSH-REL = 5 ppm, 7 mg/m^3 (ceiling) OSHA-PEL = 5 ppm, 7 mg/m^3 (ceiling) (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Soil heating at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Soil heating operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)

Action	Citation	Requirements
Waste Characterization		
Solid Waste Determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Soil heating will generate wastewater, off gases, and possibly spent carbon. These wastes and all others generated 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following:

Action	Citation	Requirements
Solid waste classification (continued)		1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes," which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes are expected from soil heating operations at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.

Action	Citation	Requirements
Waste Management		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Wastes that are determined to be RCRA hazardous wastes must be stored, treated, and disposed in compliance with RCRA regulations, including LDRs if placement has occurred.
Wastewater	40 CFR Part 122 40 CFR Part 125 40 CFR Part 129	Any wastewater generated during soil heating will be routed to the on-post RMA 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.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Air Emissions		
Emission of particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (geometric mean)	75	60
24–hour	260	150

	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24–hour	150	150

Action	Citation	Requirements
Emission of particulates (continued)	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Soil heating operations shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Soil heating will cause volatization of some contaminants.
	42 USCS Section 7412	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.
	CRS Section 25-7-101 et seq. 5 CCR 1001-5, Regulation 3	The Colorado Air Quality Control Commission requires that sources in the state that emit any of 67 listed pollutants in excess of 100 pounds per year to submit an Air Pollution Emission Notice by December 31, 1992. The number of pollutants to report will increase to a potential 688 pollutants in future years.
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 of 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.
	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.

Action	Citation	Requirements
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Soil heating 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.
Noise Abatement		
Noise control	CRS Section 25–12–101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Soil heating must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. In addition to the chemicals listed in Table 1, ethylene glycol will be used as a coolant in the vitrification process. Worker exposure standards for this chemical are as follows:

Action	Citation	Requirements
Worker exposure (continued)		Ethylene glycol ACGIH-TWA = 50 ppm, 127 mg/m^3 (ceiling) OSHA-ceiling = 50 ppm, 125 mg/m^3 (OSHA regulations and other safety and health requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	In situ vitrification at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. In situ vitrification operations shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers.
Air Emissions		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Emission of particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in µg/m^3):

Averaging Time	Primary Standard	Secondary Standard
Annual (geometric mean)	75	60
24–hour	260	150

Action	Citation	Requirements
Emission of particulates (continued)	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24–hour	150	150

	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	In situ vitrification of soils shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. In-situ vitrification of soils may cause volatilization of some contaminants.
	42 USCS Section 7412	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 of 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.

Action	Citation	Requirements
Volatile organic chemical emissions (continued)	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	In situ vitrification 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.
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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
	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 as follows:
Air emissions from diesel-powered vehicles associated with in-situ vitrification		1) "No person shall emit or cause to be emitted into the atmosphere from any diesel-powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity."

Action	Citation	Requirements
Air emissions from diesel–powered vehicles associated with in-situ vitrification		2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike.
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	In situ vitrification will generate grubbed vegetation and debris. These wastes and all others generated 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 and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used

Action	Citation	Requirements
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, commercial, and special wastes are expected from in situ vitrification at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.

Action	Citation	Requirements
Waste Management		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268 EPA/540/G-89/006 [TBC]	Wastes that are determined to be RCRA hazardous wastes must be stored, treated, and disposed in compliance with RCRA regulations, including LDRs if placement occurs.
Treatment and disposal of hazardous debris	57 FR 37194 et seq.	Hazardous debris generated during in situ vitrification activities must be treated using specific technologies to extract, destroy, or immobilize hazardous constituents on or in the debris. In certain cases after treatment, the debris may no longer be subject to RCRA Subtitle C regulation.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to on-post and off-post solid waste landfills.]

Action	Citation	Requirements
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.
	29 CFR 1910.120(b)	29 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 3A–1 in Appendix A1 of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR 10 50 CFR 20-21	Decontamination of structures at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Structure decontamination operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike.

Action	Citation	Requirements
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Wastes generated during structure decontamination activities must be characterized. Solid wastes must be 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 and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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 the following five solid waste categories: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes.

Action	Citation	Requirements
Solid waste classification (continued)		5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes are expected from hot gas decontamination at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Wastes that are determined to be RCRA hazardous wastes must be stored, treated, and disposed in compliance with RCRA regulations, including LDRs if placement occurs.
Wastewater	40 CFR Part 122 40 CFR Part 125 40 CFR part 129	Any wastewater generated during hot gas decontamination of structures will be routed to the on-post RMA 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.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
<u>Air Emission Control</u>		
Particulate emissions	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): <u>Averaging Time</u> — <u>Primary Standard</u> — <u>Secondary Standard</u> Annual (geometric mean) — 75 — 60 24-hour — 260 — 150

Action	Citation	Requirements
Particulate emissions (continued)	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24-hour	150	150

	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
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Hot gas decontamination operations shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Decontamination of structures could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.
	42 USC 7502-7503	New or modified major stationary sources in a nonattainment area are required to comply with the lowest achievable emission rate.

Action	Citation	Requirements
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Hot gas decontamination of structures 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.
Noise control	CRS Section 25–12–101 to 108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Decontamination of structures must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Table A-16 Potential Action-Specific ARARs and TBCs for UXO Demilitarization/Chemical Agent Decontamination

Action	Citation	Requirements
Detonation of UXO Containing High Explosives		
UXO detonation	AMC-R 755-B	High explosives will be detonated in compliance with the substantive requirements of AMC-R 755-B regarding demilitarization of class V materials.
On-post detonation of UXO	40 CFR 264.601 and .602	On-post detonation of UXO must comply with the substantive requirements of the environmental performance standards described in 40 CFR 264.601 and substantive portions of the monitoring, analysis, reporting, and corrective action requirements of 40 CFR 264.602.
Off-post detonation of UXO	40 CFR 264 Subpart X	Off-post facilities used for detonation of UXO must be RCRA-permitted units that have been permitted under 40 CFR 264 Subpart X.
Chemical Agent Decontamination		
Agent decontamination	AMC-R 385-131	Decontamination of chemical agent-contaminated material will comply with the requirements of AMC-R 385-131
Worker Protection		
Health and safety protection	AR-385-10 AR 385-64 AMC-R 385-100 DAA Pam 40-8 [TBC] FM3-21 [TBC] TM 10-277 [TBC] ACOE Guidance on Safety Concepts for UXO [TBC]	Workers shall comply with the substantive requirements of AMC-R 385-100, AR 385-10, AR 385-64, as well as guidance provided in DA Pam 40-8, FM 3-21, TM 10-277 and ACOE guidance for UXO regarding health and safety of workers associated with ammunition, explosives, and chemical agents.
	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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA.

Action	Citation	Requirements
Health and safety protection (continued)		Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. In addition to the chemicals listed in Table 1, workers involved in the demilitarization of HE- or agent-filled UXO will be exposed to several unique chemicals. Worker exposure standards for explosives are as follows: Aluminum (Pyro powder) ACGIH-TWA = 5 mg/m^3 OSHA-TWA = 5 mg/m^3 Lead Azide (Colloidal - as Pb)* TWA = 0.15 mg/m^3 (8 hr) STEL = 0.45 mg/m^3 (15 min) Nitroglycerin ACGIH-TWA = 0.05 ppm, 0.46 mg/m^3 (skin) NIOSH-REL = 0.1 ppm (skin) OSHA-PEL = 0.2 ppm, 2 mg/m^3 (15 min ceiling) STEL = 0.1 ppm * Source: Hazardous Component Safety Data Sheet (ARRADCOM Form 29)

Action	Citation	Requirements
Worker exposure (continued)		Picric Acid ACGIH-TWA = 0.1 mg/m^3 NIOSH-REL = 0.1 mg/m^3, STEL = 0.3 mg/m^3 (skin) OSHA-PEL = 0.1 mg/m^3 (8 hr TWA - skin) RDX (Cyclonite) ACGIH-TWA = 1.5 mg/m^3 (skin) Tetryl ACGIH-TWA = 1.5 mg/m^3 NIOSH-REL = 1.5 mg/m^3 (skin) OSHA - PEL = 1.5 mg/m^3 (8 hr TWA - skin) STEL = 3.0 mg/m^3 (15 min) 2,4,6-Trinitrotoluene (TNT) ACGIH-TWA = 0.5 mg/m^3 (skin) NIOSH-REL = 0.5 mg/m^3 (skin) OSHA-PEL = 1.5 mg/m^3 TWA = 0.5 mg/m^3 (skin) STEL* = 3 mg/m^3 (15 min - skin) * Source: Hazardous Component Safety Data Sheet (ARRAD COM Form 29) Worker exposure standards for chemical agents and their breakdown products are found in Table A-17 of this document. (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Demilitarization of UXO at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. UXO demilitarization shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
Emission of particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (geometric mean)	75	60
24-hour	260	150

	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24-hour	150	150

Action	Citation	Requirements
Emission of particulates (continued)	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Demilitarization of UXO shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. UXO demilitarization could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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 of 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.
	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Demilitarization of UXO 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.

Action	Citation	Requirements
Noise Abatement		
Noise control	CRS Section 25-12-101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. UXO demilitarization must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Acetic Acid	ACGIH-TWA = 10 ppm, 25 mg/m^3 STEL = 15 ppm, 37 mg/m^3 NIOSH-REL = 10 ppm, 25 mg/m^3 STEL = 15 ppm, 37 mg/m^3 OSHA-PEL = 10 ppm, 25 mg/m^3 (8 hr TWA)	SDP	GB
Acetylene	ACGIH -TWA = simple asphyxiant OSHA (ceiling)[3] = 2500 ppm	HP, ICP	L
Acetylene chloride [acetylene monochloride]	Animal toxicity data only[3]	ICP	L
Acetylene Dichloride** [1,2-dichloroethylene]	ACGIH-TWA = 200 ppm, 793 mg/m^3 NIOSH-REL = 200 ppm, 790 mg/m^3 (10 hr TWA) OSHA-PEL = 200 ppm, 790 mg/m^3 (8 hr TWA)	ICP	HL, L
Adamsite (DM) [10 chloro-5,10-dihydrophenarsazine]	LCt_{50}[1] = 11000-44000 mg-min/m^3 (inhal) ICt_{50}[1] = 370 mg-min/m^3 (inhal)	A	DM
Ammonia	ACGIH-TWA = 25 ppm, 17 mg/m^3 STEL = 35 ppm, 24 mg/m^3 NIOSH-REL = 25 ppm, 18 mg/m^3 STEL = 35 ppm, 27 mg/m^3 OSHA-PEL = 35 ppm, 27 mg/m^3 (STEL)	SDP	GB
Arsenic (Inorganic Compounds as As - including arsenous oxide, arsenic oxychloride, arsenic trichloride, arsenic trioxide, sodium arsenite)	ACGIH-TWA = 0.1 mg/m^3 (proposed) NIOSH-REL = 0.002 mg/m^3 (15 min ceiling) OSHA-PEL = 0.01 mg/m^3 (8 hr TWA)	HP, CP, ICP	HL, L
Bis(2-chlorovinyl)chloroarsine	Animal toxicity data only[3]	–	L
Calcium Chloride	Animal toxicity data only[3]	DP	HD

Calcium Sulfate	ACGIH-TWA	= 10 mg/m^3***	DP	HD
	OSHA-PEL	= 15 mg/m^3 (8 hr TWA - total dust)		
		= 5 mg/m^3 (8 hrs TWA - rf)		
Carbon Dioxide	ACGIH-TWA	= 5000 ppm, 9000 mg/m^3	CP, DP	CG, GB, HD, HL
	STEL	= 30000 ppm, 54000 mg/m^3		
	NIOSH-REL	= 5000 ppm, 9000 mg/m^3		
	STEL	= 30000 ppm, 54000 mg/m^3		
	OSHA-PEL	= 10000 ppm, 18000 mg/m^3 (8 hr TWA)		
	STEL	= 30000 ppm, 54000 mg/m^3		
Chlorine	ACGIH-TWA	= 0.5 ppm, 1.5 mg/m^3	CP	HL, L
	STEL	= 1 ppm, 2.9 mg/m^3		
	NIOSH-REL	= 0.5 ppm, 1.5 mg/m^3		
	STEL	= 1 ppm, 3 mg/m^3		
	OSHA-PEL	= 0.5 ppm, 1.5 mg/m^3 (8 hr TWA)		
	STEL	= 1 ppm, 3 mg/m^3		
Chloroacetic Acid	Animal toxicity data only[3]		–	HD
Chloroform**	ACGIH-TWA	= 10 ppm, 49 mg/m^3	DP, ICP, SDP	GB, HD
	NIOSH-STEL	= 2 ppm, 9.78 mg/m^3 (60 min)		
	OSHA-PEL	= 2 ppm, 9.78 mg/m^3 (8 hr TWA)		
1,2-Dichloroethane** [ethylene dichloride]	ACGIH-TWA	=10 ppm, 40 mg/m^3	ICP	HD
	OSHA-PEL	= 1 ppm, 4 mg/m^3 (8 hr TWA)		
	STEL	= 2 ppm, 8 mg/m^3		
	MPC	= 200 ppm		
Diethyldisulfide	Animal toxicity data only[3]		ICP	HD
Diisopropylcarbodiimide (DIPC)	Animal toxicity data only[3]		AS	GB

Distilled Mustard (HD) [2,2-dichloro-diethyl sulfide; bis(2-chloro-ethyl) sulfide]	LCt_{50}[1]	= 1500 mg-min/m^3 (inhal) = 10000 mg-min/m^3 (s/m-vapor) = 7.0 gm/70 kg man (s/m-liquid)	A	HD
	ICt_{50}[1]	= 200 mg-min/m^3 (eye injury) = 2000 mg-min/m^3 (s/m @ 70°-80°F)****		
Distilled Mustard (continued)	MPC	= 2 mg-min/m^3 (eye) = 5 mg min/m^3 (s/m)		
	PEL[2]	= 0.003 mg/m^3 uw (8 hr TWA)		
	Ceiling[2]	= 0.003 mg/m^3 (uw) = 0.003 mg/m^3 (naw/gp)		
	SEL[2]	= 0.003 mg/m^3 (1 hr TWA)		
Ethanethiol [ethyl mercaptan]	ACGIH-TWA	= 0.5 ppm, 1.3 mg/m^3	ICP	HD
	NIOSH-REL	= 0.5 ppm, 1.3 mg/m^3 (15 min ceiling)		
	OSHA-PEL	= 0.5 ppm, 1 mg/m^3 (8 hr TWA)		
	Ceiling	= 10 ppm, 25 mg/m^3		
Ethyl Chloride [chloroethane]	ACGIH-TWA	= 1000 ppm, 2640 mg/m^3	ICP	HD
	NIOSH-REL	= 1000 ppm, 2600 mg/m^3		
	OSHA-PEL	= 1400 ppm, 2600 mg/m^3 (8 hr TWA)		
Fluoride (Inorganic Compounds - including calcium fluoride and sodium fluoride)	ACGIH-TWA	= 2.5 mg/m^3	DP	GB
	NIOSH-REL	= 2.5 mg/m^3		
	OSHA-PEL	= 2.5 mg/m^3 (8 hr TWA)		
Hydrogen Chloride	ACGIH-TWA	= 5 ppm, 7.5 mg/m^3 (ceiling)	HP, CP	CG, HD, HL, L
	NIOSH-REL	= 5 ppm, 7 mg/m^3 (ceiling)		
	OSHA-PEL	= 5 ppm, 7 mg/m^3 (ceiling)		
Hydrogen Fluoride	ACGIH-TWA	= 3 ppm, 2.6 mg/m^3 (ceiling)	CP, HP	GB
	NIOSH-REL	= 3 ppm, 2.5 mg/m^3		
	Ceiling	= 6 ppm, 5 mg/m^3 (15 min)		
	OSHA-PEL	= 3 ppm, (8 hr TWA)		
	STEL	= 6 ppm		

Hydrogen Sulfide	ACGIH-TWA	= 10 ppm, 14 mg/m^3	ICP	HD
	STEL	= 15 ppm, 21 mg/m^3		
	NIOSH-REL	= 10 ppm, 15 mg/m^3 (10 min ceiling)		
	OSHA-PEL	= 10 ppm, 14 mg/m^3 (8 hr TWA)		
	STEL	= 15 ppm, 21 mg/m^3		
	MPC	= 50 ppm (10 min OT)		
Isopropyl Alcohol	ACGIH-TWA	= 400 ppm, 983 mg/m^3	HP	GB
	STEL	= 500 ppm, 1230 mg/m^3		
	NIOSH-REL	= 400 ppm, 980 mg/m^3		
	STEL	= 500 ppm, 1225 mg/m^3		
	OSHA-PEL	= 400 ppm, 980 mg/m^3 (8 hr TWA)		
	STEL	= 500 ppm, 1225 mg/m^3		
Lewisite (L) [dichloro(2-chlorovinyl)arsine]	LCt_{50}[1]	= 1200-1500 mg-min/m^3 (inhal)	A	HL, L
		= 100000 mg-min/m^3 (s/m)		
	ICt_{50}[1]	< 300 mg-min/m^3 (eye injury-vapor)		
		> 1500 mg-min/m^3 (s/m)		
	Ceiling[2]	= 0.0001 mg/m^3 (uw)		
		= 0.0001 mg/m^3 (naw/gp)		
	SEL[2]	= 0.0001 mg/m3 (1 hr TWA)		
Mercury Alkyl Compounds (including dimethyl mercury and methyl mercury salts)	ACGIH-TWA	= 0.01 mg/m^3	–	HL, L
	STEL	= 0.03 mg/m^3		
	NIOSH-REL	= 0.01 mg/m^3		
	STEL	= 0.03 mg/m^3 (skin)		
	OSHA-PEL	= 0.01 mg/m^3 (8 hr TWA)		
	STEL	= 0.03 mg/m^3		
	Ceiling	= 0.04 mg/m^3		

Methyl Chloride [chloromethane]	ACGIH-TWA STEL NIOSH-REL OSHA-PEL STEL Ceiling MPC	= 50 ppm, 103 mg/m^3 (skin) = 100 ppm, 207 mg/m^3 (skin) = reduce to lowest feasible concentration = 50 ppm, 105 mg/m^3 (8 hr TWA) = 100 ppm, 210 mg/m^3 = 200 ppm, 420 mg/m^3 = 300 ppm, 630 mg/m^3 (5 min/3 hr)	ICP	L
Methylene Chloride**	ACGIH-TWA NIOSH-REL OSHA-PEL Ceiling MPC	= 50 ppm, 174 mg/m^3 = reduce to lowest feasible concentration = 500 ppm, 1765 mg/m^3 (8 hr TWA) = 1000 ppm, 3530 mg/m^3 = 2000 ppm, 7060 mg/m^3 (5 min/2 hrs)	ICP	HD
Mustard-Lewisite Mixture	LCt_{50}[1] ICt_{50}[1]	= 1500 mg-min/m^3 (inhal) > 10000 mg-min/m^3 (s/m) = 200 mg-min/m^3 (eye injury) = 1500-2000 mg-min/m^3 (s/m)	A	HL
Phosphoric Acid [orthophosphoric acid]	ACGIH-TWA STEL NIOSH-REL STEL OSHA-PEL STEL	= 1 mg/m^3 = 3 mg/m^3 = 1 mg/m^3 = 3 mg/m^3 = 1 mg/m^3 (8 hr TWA) = 3 mg/m^3	ICP	GB
Phosphorus Pentoxide [POX, phosphoric anhydride]	Animal toxicity data only[3]		CP	GB

Sarin (GB) [isopropyl methylphosphono fluoridate; methyisopropo oxyfluoro-phosphine oxide]	LCt_{50}[1] (resp)	= 100 mg-min/m^3 (resting)	A	GB
		= 70 mg-min/m^3 (mild activity)		
	ICt_{50}[1] (resp)	= 75 mg-min/m^3 (resting)		
		= 35 mg-min/m^3 (mild activity)		
	TWA[2]	= 0.0001 mg/m^3 (uw - 8 hr TWA)		
		= 0.000003 mg/m^3 (naw/gw - 72 hr TWA)		
	Ceiling[2]	= 0.0001 mg/m^3 (naw/gw)		
	SEL[2]	= 0.0003 mg/m^3 (1 hr TWA)		
Sulfur	Eye irritation[3]	= 6 ppm	ICP	HD
Sulfur Dioxide	ACGIH-TWA	= 2 ppm, 5.2 mg/m^3	CP	HD
	STEL	= 5 ppm, 13 mg/m^3		
	NIOSH-REL	= 2 ppm, 5 mg/m^3		
	STEL	= 5 ppm, 10 mg/m^3		
	OSHA-PEL	= 2 ppm, 5 mg/m^3 (8 hr TWA)		
	STEL	= 5 ppm, 10 mg/m^3		
1,1,1,2-Tetrachloroethane	Animal toxicity data only[3]		ICP	HD
1,1,2,2-Tetrachloroethane** [acetylene tetrachloride]	ACGIH-TWA	= 1 ppm, 6.9 mg/m^3 (skin)	ICP	HD
	NIOSH-REL	= 1 ppm, 7 mg/m^3 (skin)		
	OSHA-PEL	= 1 ppm, 7 mg/m^3 (8 hr TWA - skin)		
beta-Thiodiglycol [thiodiethylene glycol]	Animal toxicity data only[3]		DP, HP	HD, HL
Tributylamine (TBA)	Animal toxicity data only[3]		AS	GB
1,1,1-Trichloroethane** [methyl chloroform]	ACGIH-TWA	= 350 ppm, 11910 mg/m^3	ICP	HD
	STEL	= 450 ppm, 2460 mg/m^3		
	OSHA-PEL	= 350 ppm, 1900 mg/m^3 (8 hr TWA)		
	STEL	= 450 ppm, 2450 mg/m^3		

1,1,2-Trichloroethane*	ACGIH-TWA	= 10 ppm, 55 mg/m^3 (skin)	ICP	HD
	NIOSH-REL	= 10 ppm, 45 mg/m^3 (skin)		
	OSHA-PEL	= 10 ppm, 45 mg/m^3 (8 hr TWA - skin)		
Vinyl Chloride* [chloroethylene; ethylene monochloride]	ACGIH-TWA	= 5 ppm, 13 mg/m^3	ACP	L
	NIOSH-REL	= Lowest reliably detectable concentration		
	OSHA-PEL	= 1 ppm, 2.6 mg/m^3 (8 hr TWA)		
	Ceiling	= 5 ppm, 13 mg/m^3 (15 min)		

* The values presented in this table are commonly considered chemical-specific ARARs or independently applicable requirements. They are provided for completeness and the convenience of the reader.

** Exposure information appears in DSA

*** Value is for total dust containing no asbestos and less than 1 percent silica

**** Skin absorption increases above 80°F (e.g., ICt_{50} = 1000 mg-min/m^3 at 90°F)

1 Reference: Chemical Agent Data Sheets, Volume 1, Edgewood Arsenal Special Report EO-SR-74001, December 1974 [TBC]

2 Reference: AR 385-64 [ARAR] and DA Pamphlet 40-8 [TBC]

3 Reference: N.I. Sax, Dangerous Properties of Industrial Materials, 6th Ed., 1984

A	Agent	mg-min/m^3	Milligrams per minute per cubic meter
AS	Agent stabilizer	mg/m^3	Milligrams per cubic meter
CG	Phosgene	MPC	Maximum peak concentration
CP	Combustion product	naw/gp	Non-agent worker/general population
DM	Adamsite	OT	One time exposure if no other measurable exposure occurs
DP	Decontamination product		
GB	Sarin	PEL	Permissible exposure limit
HD	Distilled mustard	ppm	Parts per million
HL	Mustard-Lewisite mixture	REL	Recommended exposure limit
HP	Hydrolysis product	rf	Respirable fraction
hr	Hour	s/m	Skin exposure/masked worker
ICP	Incomplete combustion product	SDP	Stabilizer decontamination product
ICt_{50}	Median incapacitating dose	SEL	Source emission limit
L	Lewisite	STEL	Short-term exposure limit
LCt_{50}	Median lethal dose	TWA	Time weighted average
		uw	Unmasked worker

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of hazardous waste by a 100-year flood (if the facility is located within the 100-year flood plain).
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 20 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. In addition to the chemicals listed in Table 1, soil solidification/stabilization will use Portland cement and possibly calcium silicate, calcium hydroxide, and calcium oxide. Worker exposure limits for these compounds are provided below: Calcium hydroxide: ACGIH-TWA = 5 mg/m^3; OSHA-TWA = 5 mg/m^3 Calcium oxide: ACGIH-TWA = 2 mg/m^3; NIOSH-REL = 2 mg/m^3; OSHA-PEL = 5 mg/m^3, TWA = 5 mg/m^3 Calcium silicate: ACGIH-TWA = 10 mg/m^3*; OSHA-PEL = 15 mg/m^3 (total dust), 5 mg/m^3 (resp) Portland cement: ACGIH-TWA = 10 mg/m^3*; NIOSH-REL = 10 mg/m^3 (total), 5 mg/m^3 (resp); OSHA-TWA = 10 mg/m^3 (total), 5 mg/m^3 (resp); PEL = 50 mppcf** * value is for total dust containing no asbestos and less than 1% crystalline silica ** mppcf = million particles per cubic foot (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Direct soil solidification/stabilization at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Solidification operations shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated

Action	Citation	Requirements
Solid waste determination (continued)		• Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Direct soil solidification/stabilization will generate oversize soil debris and metallic wastes. These wastes and all others generated must be characterized and evaluated according to the following method to determine whether the waste is hazardous: • Determine whether the waste is excluded form regulation under 40 CFR 261.4 • Determine whether the waste is listed under 40 CFR Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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, which include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes.

Action	Citation	Requirements
Solid waste classification (continued)		5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, commercial, and special wastes are expected from direct solidification/stabilization at RMA. No special testing requirements are specified for solid wastes. The management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment and storage of hazardous wastes	40 CFR Part 264	Wastes that are determined to be RCRA hazardous wastes must be stored and treated in compliance with RCRA regulations, including the tank requirements in 40 CFR 264 Subpart J.
On-post land disposal of hazardous wastes	40 CFR Part 264 EPA/540/G-89/006 [TBC] 40 CFR Part 268 [TBC]	Based upon a determination of whether the disposal technique constitutes placement, the LDRs may be applicable. If placement does occur, the disposal facility must comply with the substantive requirements of 40 CFR Part 264.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
<u>Air Emissions</u>		
Emission of Particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): <u>Averaging Time — Primary Standard — Secondary Standard</u> Annual (geometric mean) — 75 — 60 24–hour — 260 — 150

Action	Citation	Requirements
Emission of Particulates (continued)	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24–hour	150	150

	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Direct solidification/stabilization of soils shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Direct solidification/stabilization of soils could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Direct soil solidification/stabilization 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.

Action	Citation	Requirements
Noise Abatement		
Noise control	CRS Section 25-12-101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Soil stabilization/solidification must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	Due to the necessity to reduce exposure once contaminated soil has been solidified/stabilized, in situ solidification/stabilization of soil must not occur in the following situations: • Within 200 ft of a Holocene-age fault • Within a 100-year floodplain where washout of the soil may occur during a 100-year flood
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 20 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. In addition to the chemicals listed in Table 1, soil solidification/stabilization will use Portland cement and possibly calcium silicate, calcium hydroxide, and calcium oxide. Worker exposure limits for these compounds are provided below: Calcium hydroxide: ACGIH-TWA = 5 mg/m^3; OSHA-TWA = 5 mg/m^3 Calcium oxide: ACGIH-TWA = 2 mg/m^3; NIOSH-REL = 2 mg/m^3; OSHA-PEL = 5 mg/m^3, TWA = 5 mg/m^3 Calcium silicate: ACGIH-TWA = 10 mg/m^3*; OSHA-PEL = 15 mg/m^3 (total dust), 5 mg/m^3 (resp) Portland cement: ACGIH-TWA = 10 mg/m^3*; NIOSH-REL = 10 mg/m^3 (total), 5 mg/m^3 (resp); OSHA-TWA = 10 mg/m^3 (total), 5 mg/m^3 (resp); PEL = 50 mppcf** * value is for total dust containing no asbestos and less than 1% crystalline silica ** mppcf = million particles per cubic foot (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	In-situ soil solidification/stabilization at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Solidification operations shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers.
Air Emissions		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Emission of Particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$): Annual (geometric mean): Primary Standard 75, Secondary Standard 60 24-hour: Primary Standard 260, Secondary Standard 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$): Annual (arithmetic mean): Primary Standard 50, Secondary Standard 50 24-hour: Primary Standard 150, Secondary Standard 150
	5 CCR 1001-3, Regulation 1 Section III (D) 5 CCR 1001-5, Regulation 3	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.

Action	Citation	Requirements
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	In situ solidification/stabilization of soils shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Direct solidification/stabilization of soils could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	In situ soil solidification/stabilization 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.
<u>Noise Abatement</u>		
Noise control	CRS Section 25-12-101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Soil stabilization/solidification must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. (OSHA regulations and other safety and health requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Removal of sediments and in situ biotreatment of lake sediments at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Removal and treatment of sediments shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Removal of sediments from upstream and downstream traps could potentially cause volatilization of some contaminants.
	42 USCS Section 7412	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 of ozone. Storage and transfer of VOCs and petroleum liquids are controlled by these requirements.

Action	Citation	Requirements
Volatile organic chemical emissions (continued)		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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Air emissions from diesel–powered vehicles associated with removal of sediments from upstream and downstream traps	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 as follows: 1) "No person shall emit or cause to be emitted into the atmosphere from any diesel–powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity." 2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."
<u>Waste Characterization</u>		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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:

Action	Citation	Requirements
Solid waste determination (continued)		• Abandoned material may be - disposed of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	In situ biotreatment of lake sediments and removal of sediments from upstream and downstream traps may generate contaminated sediments. Sediments and all other wastes generated must be characterized. The wastes must be 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 and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes.

Action	Citation	Requirements
Solid waste classification (continued)		2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, commercial, and special wastes are expected from removal of sediments and in situ biotreatment at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268 EPA/540/G-89/006 [TBC]	If sediment removal or in situ biotreatment at RMA generates hazardous wastes, the wastes must be treated, stored, or disposed in accordance with RCRA regulations, including LDRs if placement occurs. [Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the folowing requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of any hazardous waste by a 100-year flood (if the facility is located within the 100-year floodplain).
Worker Protection		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
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.
	29 CFR 1910.120(b)	20 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 2 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife from hazardous source areas	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Biological reactor units shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Treatment units shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.302 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
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 requirments.

Action	Citation	Requirements
Volatile organic chemical emissions (continued)		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.
	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.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs.
	42 USCS Section 7412	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.
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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated

Action	Citation	Requirements
Solid waste determination (continued)		• Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Biological reactor treatment of groundwater at RMA will create wastes consisting of spent biomass, iron and manganese precipitates, suspended solids, and recovered DCPD. These and all other wastes generated in this process must be evaluated according to the following method to determine if 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys.

Action	Citation	Requirements
Solid waste classification (continued)		3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. Only small quantities of industrial, community, and commercial wastes, along with inert material, are expected to be generated during biological reactor treatment of groundwater at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Wastes from biological reactor treatment of groundwater that are determined to be RCRA hazardous wastes must be treated, stored, and disposed in compliance with RCRA regulations, including LDRs if placement occurs.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.)

Action	Citation	Requirements
Reinjection of treated groundwater	RCRA Section 3020 (b) 2 CCR 402-2, Rule 10 OSWER Directive 9234.1-06 [TBC]	Reinjection of treated groundwater must be managed in accordance with the guidelines in OSWER Directive 9234.1-06. Wells should be constructed and installed according to the requirements of 2 CCR 402-2, Rule 10.

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of any hazardous waste by a 100-year flood (if the facility is located within the 100-year floodplain).
Worker Protection		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Health and safety protection	29 CFR Part 1910	29 CFR Part 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.
	29 CFR 1910.120(b)	20 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 2 in Appendix A of the DSA. In addition to the chemicals in Table 2, the UV/ozone treatment will potentially utilize hydrogen peroxide and ozone. The worker exposure standards for these compounds are given below: Hydrogen peroxide ACGIH-TWA = 1 ppm, 1.4 mg/m^3 NIOSH-REL = 1 ppm, 1.4 mg/m^3 OSHA-PEL = 1 ppm, 1.4 mg/m^3 Ozone ACGIH-TWA = 0.1 ppm (ceiling), 0.20 mg/m^3 (ceiling) NIOSH-REL = 0.1 ppm (ceiling), 0.20 mg/m^3 (ceiling) OSHA-PEL = 0.1 ppm, 0.2 mg/m^3 STEL = 0.3 ppm, 0.6 mg/m^3 (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
<u>Protection of Wildlife</u>		
Protection of wildlife from hazardous source areas	Odor emissions (continued)	UV/ozone treatment units shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Treatment units shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 <u>et seq.</u> 40 CFR 6.302 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 3-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers.

Action	Citation	Requirements
Protection of wildlife from hazardous source areas (continued)		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
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 requirments. 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.
	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.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs.
	42 USCS Section 7412	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.
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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air

Action	Citation	Requirements
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	UV/ozone treatment of groundwater will create wastes consisting primarily of inorganic sludges. These and all other wastes generated in this process must be 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following:

Action	Citation	Requirements
Solid waste classification (continued)		1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes," which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. Only small quantities of industrial, community, and commercial wastes, along with inert material, are expected to be generated during UV/ozone treatment of groundwater. No special testing requirements are specified for solid wastes; the managment and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.

Action	Citation	Requirements
Waste Management		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Wastes from UV/ozone treatment that are determined to be RCRA hazardous wastes must be treated, stored, and disposed in compliance with RCRA regulations, including land disposal restrictions LDRs if placement occurs.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Reinjection of treated groundwater	RCRA Section 3020 (b) 2 CCR 402-2, Rule 10 OSWER Directive 9234.1-06 [TBC]	Reinjection of treated groundwater must be managed in accordance with the guidelines in OSWER Directive 9234.1-06. Wells should be constructed and installed according to the requirements of 2 CCR 402-2, Rule 10.

Action	Citation	Requirements
Siting of Soil Washing Facility		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of hazardous waste by a 100-year flood (if the facility is located within the 100-year flood plain). (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. In addition to the compounds listed in Table 1, workers involved in soil washing operations will be exposed to acids and bases, along with proprietary surfactants, chelating agents, and oxidizing agents. Exposure limits for commonly used acids and bases are as follows: Hydrochloric acid ACGIH-TWA = 5 ppm, 7.5 mg/m^3(ceiling) NIOSH-REL = 5 ppm, 7 mg/m^3 (ceiling) OSHA-PEL = 5 ppm, 7 mg/m^3 (ceiling) Sodium hydroxide ACGIH-TWA = 2 mg/m^3 (ceiling) NIOSH-REL = 2 mg/m^3 (15-min ceiling) OSHA-PEL = 2 mg/m^3, ceiling = 2 mg/m^3 Sulfuric acid ACGIH-TWA = 1 mg/m^3; STEL = 3 mg/m^3 NIOSH-REL = 1 mg/m^3 OSHA-PEL = 1 mg/m^3; TWA = 1 mg/m^3 If workers are involved with soil washing of agent-contaminated soils, they may be exposed to several unique chemicals. Worker exposure standards for these chemicals are listed in Table A-17 of this document. (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Soil washing at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Soil washing shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-1-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers.
Air Emissions		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Emission of particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (geometric mean)	75	60
24–hour	260	150

	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, PM_{10}, are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24–hour	150	150

	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.

Action	Citation	Requirements
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Soil washing shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Soil washing could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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 of 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.
	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.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Soil washing 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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.

Action	Citation	Requirements
Noise Abatement		
Noise control	CRS Section 25-12-101 to 25-12-108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Soil washing must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous wastes must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of hazardous waste by a 100-year flood (if the facility is located within the 100-year flood plain).
Worker Protection		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable requirements, not ARARs and TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Soil vacuum extraction operations at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Soil vacuum extraction installation shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers.
Air Injection/Vacuum Extraction Wells/Points		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Construction/installation of air injection/vacuum extraction wells	2 CCR 402-2, Rule 10 RCRA Groundwater Monitoring TEGD [TBC]	Wells/points used to inject air or extract vapors shall be of the same design as groundwater monitoring wells. The wells/points shall be constructed and installed to comply with the requirements of 2 CCR 402-2, Rule 10 and the guidance in the RCRA Groundwater Monitoring TEGD.

Action	Citation	Requirements
Air Emission Control		
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.
	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.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs.
	42 USCS Section 7412	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.
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 which are measured in excess of the following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Air emissions from diesel-powered vehicles associated with well construction	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 as follows:

Action	Citation	Requirements
Air emissions from diesel–powered vehicles associated with well construction (continued)		1) "No person shall emit or cause to be emitted into the atmosphere from any diesel–powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity." 2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."

Action	Citation	Requirements
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.
	29 CFR 1910.120(b)	29 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 3A–1 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Wastes generated during pipe plugging activities must be characterized. Solid wastes must be 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 and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following:

Action	Citation	Requirements
Solid waste classification (continued)		1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, special, and commercial wastes are expected from pipe plugging activities at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.

Action	Citation	Requirements
Waste Management		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	If pipe plugging in structures at RMA generates hazardous wastes, the wastes must be treated, stored or disposed in accordance with RCRA regulations, including LDRs if placement occurs.
Treatment and disposal of hazardous debris	57 FR 37194 et seq.	Hazardous debris generated during pipe plugging activities must be treated using specific technologies to extract, destroy, or immobilize hazardous constituents on or in the debris. In certain cases, after treatment the debris may no longer be subject to RCRA Subtitle C regulation.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Plugging of pipes at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Pipe plugging operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact remedial actions. They are included in this table for the convenience of the reader.)

Action	Citation	Requirements
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.
	29 CFR 1910.120(b)	29 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 3A–1 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Air Emissions		
Emission of Particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (geometric mean)	75	60
24–hour	260	150

	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24–hour	150	150

	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Vacuum dusting shall not cause the emission into the atmosphere of any air pollutant which is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Vacuum dusting 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.

Action	Citation	Requirements
Visibility protection (continued)	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 appropriate). The visibility standard applies only during hours when the hourly average humidity is less than 70 percent.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Vacuum dusting could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.
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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
<u>Waste Management</u>		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated

Action	Citation	Requirements
Solid waste determination (continued)		• Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Vacuum dusting of structures at RMA will create wastes consisting of filters with dust particles and debris. These wastes and all other solid wastes generated in this process must be 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys.

Action	Citation	Requirements
Solid waste classification (continued)		3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes are expected from vacuum dusting of structures at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Vacuum dusting wastes that are determined to be RCRA hazardous wastes must be stored, treated, and disposed in compliance with RCRA regulations, including land disposal restrictions LDRs if placement occurs.
Solid waste disposal		If solid waste must be disposed in a state-approved disposal site, that is, a site that has met minimum engineering requirements and obtained a "certificate of designation" from the state/local board of health. [Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]

Action	Citation	Requirements
Protection of wildlife		
Protection of Wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21 16 USC Section 661 et seq. 40 CFR 6.304 (g)	Vacuum dusting of structures at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Vacuum dusting operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife. Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions of any natural stream or body of water.
	CRS 33-2-101 to 33-3-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)

Action	Citation	Requirements
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.
	29 CFR 1910.120(b)	29 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 3A–1 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines)

Action	Citation	Requirements
Air Emissions		
Emission of Particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):
		Averaging Time — Primary Standard — Secondary Standard Annual (geometric mean) — 75 — 60 24–hour — 260 — 150
	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers, (PM_{10}), are as follows (in $\mu g/m^3$):
		Averaging Time — Primary Standard — Secondary Standard Annual (arithmetic mean) — 50 — 50 24–hour — 150 — 150
	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Steam cleaning of structures shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Steam cleaning may cause volatization of some contaminants.
	42 USCS Section 7412	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.

Action	Citation	Requirements
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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Air emissions from diesel–powered vehicles associated with construction or demolition	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 as follows: 1) "No person shall emit or cause to be emitted into the atmosphere from any diesel–powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity." 2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt for a period of 10 minutes, if the emissions are a direct result of a cold engine start–up and the vehicle is in a stationary position."
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Steam cleaning 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.

Action	Citation	Requirements
Visibility protection (continued)	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.
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.
	42 USC 7502-7503	New or modified major stationary sources in a nonattainment area are required to comply with the lowest achievable emission rate. Disposal of VOCs is regulated for all areas, including ozone nonattainment. The regulations control disposal of VOCs by evaporation or spilling unless reasonably available control technologies are utilized.
<u>Waste Management</u>		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - speculatively accumulated

Action	Citation	Requirements
Solid waste determination (continued)		• Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Steam cleaning will generate wastewater from condensate and potential spent filter media. These wastes and all others generated must be characterized. The wastes must be 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes.

Action	Citation	Requirements
Solid waste classification (continued)		4) "Special wastes",which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes, along with inert material are expected from steam cleaning of structures at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
Wastewater	40 CFR Part 122 40 CFR Part 125 40 CFR Part 129	Any wastewater generated during steam cleaning will be routed to the on-post RMA 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.
	40 CFR Part 262 40 CFR Part 264	Wastewater that is determined to be hazardous must be treated in accordance with provisions of the RCRA.
Treatment, storage or disposal of hazardous wastes	40 CFR Part 264 40 CFR Part 268	Wastes that are determined to be RCRA hazardous wastes, such as spent filter media from steam cleaning, must be stored, treated, and disposed in compliance with RCRA regulations, including LDRs if placement occurs.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]

Action	Citation	Requirements
On-post solid waste disposal	40 CFR 258 Subparts C and D 6 CCR 1007-2, Part 1, Section 1	If solid waste is disposed in an on-post landfill, the disposal site must comply with substantive requirements of CCR 1007-2, Part 1, Section 1, including minimum engineering requirements. In addition, the disposal facility must comply with substantive requirements of 440 CFR 258 Subparts C and D with respect to operation and design of the landfill.
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Steam cleaning of structures at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Steam cleaning operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions of any natural stream or body of water.
	CRS 33-2-101 to 33-3-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)

Action	Citation	Requirements
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.
	29 CFR 1910.120(b)	29 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 3A–1 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Air Emissions		
Emission of particulates	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (geometric mean)	75	60
24–hour	260	150

	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24–hour	150	150

	5 CCR 1001-3, Regulation 1, Section III (D) 5 CCR 1001-5, Regulation 3	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.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Sand blasting shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Sand blasting could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.

Action	Citation	Requirements
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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air.
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Sand blasting 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 Standards for the AIR Program area is a standard visual range of 32 miles. The averaging time is four 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.
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.
	42 USC 7502-7503	New or modified major stationary sources in a nonattainment area are required to comply with the lowest achievable emission rate.

Action	Citation	Requirements
Waste Management		
Solid waste determination citations	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which 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
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Sand blasting structures at RMA will create wastes that consist of dust, abrasives such as sand or pellets, debris, and possibly used filters. These wastes and all other solid wastes generated in this process must be evaluated according to the following process 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used

Action	Citation	Requirements
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes are expected from sand blasting of structures at RMA.

Action	Citation	Requirements
Solid waste classification (continued)		No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
Treatment, storage, or disposal of hazardous wastes	40 CFR Part 264 40 CFR Part 268	Wastes that are determined to be RCRA hazardous wastes, such as spent filter media, abrasives and debris, must be stored, treated, and disposed in compliance with RCRA regulations, including LDRs.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Sand blasting of structures at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Sand blasting operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions of any natural stream or body of water.
	CRS 33-2-101 to 33-3-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)

Action	Citation	Requirements
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.
	29 CFR 1910.120(b)	29 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 3A–1 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Salvage of structures at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Salvage operations shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers.
Salvage		(These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Noise control	CRS Section 25–12–101 to 108	Colorado noise abatement regulations control the maximum permissible noise levels for commercial, industrial, and residential zones. Demolition of structures must be conducted in such a manner that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Construction projects are subject to the maximum permissible noise levels for industrial zones as follows: 1) 7:00 a.m. to next 7:00 p.m. - 80 db(A) 2) 7:00 p.m. to next 7:00 a.m. - 75 db(A)
Air emissions during salvage	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

Action	Citation	Requirements
Air emissions during salvage (continued)	5 CCR 1001-14 40 CFR 81.306	Colorado Ambient Air Quality Standards for total suspended particulates are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (geometric mean)	75	60
24–hour	260	150

	40 CFR 50.6	National standards for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) are as follows (in $\mu g/m^3$):

Averaging Time	Primary Standard	Secondary Standard
Annual (arithmetic mean)	50	50
24–hour	150	150

Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Salvage of structures shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs. Salvage of structures could potentially cause emission of hazardous air pollutants.
	42 USCS Section 7412	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.
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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air

Action	Citation	Requirements
Air emissions from diesel–powered vehicles associated with salvage	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 as follows: 1) "No person shall emit or cause to be emitted into the atmosphere from any diesel–powered vehicle any air contaminant, for a period greater than 5 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40 percent opacity." 2) "Diesel-powered vehicles exceeding requirements listed above shall be exempt (for a period of 10 minutes) if the emissions are a direct result of a cold engine start-up and the vehicle is in a stationary position."
Visibility protection	40 CFR 51.300-307 40 CFR 52.26-29	Salvage of structures 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.
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.

Action	Citation	Requirements
	42 USC 7502-7503	New or modified major stationary sources in a nonattainment area are required to comply with the lowest achievable emission rate.
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of - burned or incinerated - accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled material which is - used in a manner constituting disposal - burned for energy recovery - reclaimed - speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Wastes generated during structure salvage activities must be characterized. Solid wastes must be 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 and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used

Action	Citation	Requirements
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes are expected from structure salvage activities at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.

Action	Citation	Requirements
Waste Management		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	If demolition of structures at RMA generates hazardous wastes, the wastes must be treated, stored, or disposed in accordance with RCRA regulations, including LDRs.
Treatment and disposal of hazardous debris	57 FR 37194 et seq.	Hazardous debris generated during structure salvage activities must be treated using specific technologies to extract, destroy, or immobilize hazardous constituents on or in the debris. In certain cases, after treatment the debris may no longer be subject to RCRA Subtitle C regulation.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Tanks and Containers		
Residues of hazardous waste in empty containers	40 CFR 261.7	A container or inner liner removed from a container that has held any hazardous waste is empty if: 1) All wastes have been removed that can be removed using the practices commonly employed to remove materials from that type of container (e.g., pouring, pumping, and aspirating), and 2) No more than one inch of residue remains on the bottom of the container or inner liner, or 3) a) No more than 3 percent by weight of the total capacity of the container remains in the container or inner liner if the container is less than or equal to 110 gallons in size, or b) No more than 0.3 percent by weight of the total capacity of the container remains in the container or inner liner if the container is greater than 110 gallons in size. A container that has held a hazardous waste that is a compressed gas is empty when the pressure in the container approaches atmospheric.

Action	Citation	Requirements
Residues of hazardous waste in empty containers (continued)		A container or an inner liner removed from a container that has held an acute hazardous waste listed in 40 CFR 261.31, 261.32, or 261.33(e) is empty if: 1) The container or inner liner has been triple rinsed using a solvent capable of removing the commercial chemical product or manufacturing chemical intermediate, or 2) The container or inner liner has been cleaned by another method that has been shown in the scientific literature, or by tests conducted by the generator, to achieve equivalent removal, or 3) In the case of a lined container, the inner liner that prevented contact of the commercial chemical product or manufacturing chemical intermediate with the container, has been removed. Any hazardous waste remaining in an empty container or an inner liner removed from an empty container is not considered a hazardous waste and is not subject to the RCRA regulations. Any hazardous waste in a container or inner liner removed from a container that is not empty is subject to RCRA hazardous waste regulations.
Closure of tanks and tank systems	40 CFR 264.197(a) 40 CFR 261.3(d) 40 CFR 264.310	At closure of a tank system, all waste residues, contaminated containment system components, contaminated soils, and structures and equipment contaminated with wastes must be removed, decontaminated, and managed as hazardous wastes unless 40 CFR 261.3(d) applies (i.e., unless residues and contaminated materials are not hazardous wastes). If the owner or operator demonstrates that not all soils can be practically removed or decontaminated as required, then the tank system must be closed in accordance with requirements that apply to landfills.

Action	Citation	Requirements
Closure of tanks and tank systems (continued)	40 CFR 264.198(a) 40 CFR 264.176	Ignitable or reactive waste should not be placed in tank systems unless the waste is treated, rendered, or mixed before or immediately after placement in the tank system, or unless the waste is stored or treated in such a way that it is protected from any material or condition that may cause the waste to ignite or react.
	40 CFR 264.198(b) NFPA Flammable and Combustible Liquids Code 1990 [TBC]	Facilities where ignitable or reactive waste is stored or treated in a tank should comply with requirements for the maintenance of protective distances between the waste management area and any public ways, streets, alleys, or an adjoining property line that can be built upon as provided in Tables 2–1 through 2–6 of the 1990 NFPA Flammable and Combustible Liquids Code.
	40 CFR 264.199 40 CFR 264.17	Incompatible wastes, or incompatible wastes and materials, must not be placed in the same tank system unless 40 CFR 264.17 is complied with. Hazardous waste must not be placed in a tank system that has not been decontaminated and that previously held an incompatible waste or material unless 40 CFR 264.17 is complied with.
	40 CFR 265.201(d)	Generators that accumulate between 100 and 1,000 kg/mo of hazardous waste in tanks must, upon closure, remove all hazardous wastes from tanks, control equipment, and discharge confinement structures.
	40 CFR 265.201(e) (1)	Generators of between 100 and 1,000 kg/mo of hazardous waste must not place ignitable or reactive waste in tanks unless the waste is treated before or immediately after placement in a tank or the waste is stored or treated in such a way that it is protected from any material or condition that may cause the waste to ignite or react. Ignitable or reactive waste must not be placed in the tank unless the tank is used solely for emergencies.
	40 CFR 265.201(e) (2) NFPA Flammable and Combustible Liquids Code 1990 [TBC]	Facilities where ignitable or reactive wastes are treated or stored in covered tanks are required to comply with the buffer zone requirements for tanks contained in Tables 2–1 through 2–6 of the 1990 NFPA Flammable and Combustible Liquids Code.

Action	Citation	Requirements
Closure of tanks and tank systems (continued)	40 CFR 264.111(a) and (b)	A facility must be closed in a manner that minimizes the need for further maintenance and controls, minimizes, or eliminates to the extent necessary to protect human health and the environment post closure escape of hazardous wastes, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the groundwater or surface waters or to the atmosphere.
	40 CFR 264.197 40 CFR 264 Subpart G	The closure plan and closure activities for tank systems must meet all of the substantive requirements provided in 40 CFR 264 Subpart G and 40 CFR 264.197.
Wastewater Treatment/Disposal		
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 40 CFR Part 264	Wastewater that is determined to be a hazardous waste must be treated in accordance with the provisions of RCRA.
Discharge of stormwater to on-post surface waters	40 CFR Parts 122-125 5 CCR 1002-8 Section 3.1.0	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 discharge to surface waters shall be conducted in compliance with the CWA technology-based standards, FWQC, Colorado surface water quality standards, monitoring requirements, and best management practices.
Decontamination and Disposal Standards for Chemical Agents	AMC-R 385-131 [TBC]	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. Items may not be released from government control until they have been decontaminated to the 5X level.

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of any hazardous waste by a 100-year flood (if the facility is located within the 100-year floodplain). (These regulations are commonly considered location-specific ARARS, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
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.
	29 CFR 1910.120 (b)	20 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 2 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Operation of air stripping units for groundwater treatment shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Air stripping units shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Air stripping units shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARS, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
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 requirments.

Action	Citation	Requirements
Volatile organic chemical emissions (continued)		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.
	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.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs.
	42 USCS Section 7412	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.
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 measured in excess of the following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR Part 60 Appendix A	Air stripping of VOCs from groundwater shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Visibility protection	40 CFR 51.300-307	Air stripping from groundwater 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.

Action	Citation	Requirements
Visibility protection (continued)	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.
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of – burned or incinerated – accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated • Recycled materials which is – used in a manner constituting disposal – burned for energy recovery – reclaimed – speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Air stripping of VOCs from groundwater will create wastes consisting of sludges and spent filters. These and all other wastes generated in this process must be 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 Part 261

Action	Citation	Requirements
Determination of hazardous waste (continued)		• Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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, which include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation.

Action	Citation	Requirements
Solid waste classification (continued)		If present, only small quantities of industrial, community, and commercial wastes, and inert material are expected from air stripping treatment of groundwater at RMA. No special testing requirements are specified for solid wastes. The management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
Waste Management		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Wastes from air stripping treatment of groundwater that are determined to be RCRA hazardous wastes must be treated, stored, and disposed in compliance with RCRA regulations, including LDRs if placement occurs.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Reinjection of treated groundwater	RCRA Section 3020 (b) 2 CCR 402-2. Rule 10 OSWER Directive 9234.1-06 [TBC]	Reinjection of treated groundwater must be managed in accordance with the guidelines in OSWER Directive 9234.1-06. Wells should be constructed and installed according to the requirements of 2 CCR 402-2, Rule 10.

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the following requirements: • They must not be located within 200 ft of a Holocene-age fault. • They must be designed, constructed, and operated to prevent washout of any hazardous waste by a 100-year flood if the facility is located within the 100-year floodplain. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
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.
	29 CFR 1910.120(b)	20 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and the NIOSH are outlined in Table 2 in Appendix A of the DSA. (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife from hazardous source areas	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21 16 USC Section 661 et seq. 40 CFR 6.302 (g)	Operation of a GAC adsorption unit shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. The GAC unit shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife. Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
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 requirments.

Action	Citation	Requirements
Volatile organic chemical emissions (continued)		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.
	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.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs.
	42 USCS Section 7412	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.
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 measured in excess of the following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of – burned or incinerated – accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated

Action	Citation	Requirements
Solid waste determination (continued)		• Recycled materials which is – used in a manner constituting disposal – burned for energy recovery – reclaimed – speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Groundwater treatment at RMA using GAC adsorption will create wastes consisting of spent carbon and carbon fines. These and all other wastes generated in this process must be 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes, resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys.

Action	Citation	Requirements
Solid waste classification (continued)		3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes and inert material are expected from GAC treatment of groundwater at RMA. No special testing requirements are specified for solid waste. The management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirmements.
<u>Waste Management</u>		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Wastes from GAC water treatment that are determined to be RCRA hazardous wastes must be treated, stored, and disposed in compliance with RCRA regulations, including LDRs if placement occurs.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]

Action	Citation	Requirements
Reinjection of treated groundwater	RCRA Section 3020 (b) 2 CCR 402-2, Rule 10 OSWER Directive 9234.1-06 [TBC]	Reinjection of treated groundwater must be managed in accordance with the guidelines in OSWER Directive 9234.1-06. Wells should be constructed and installed according to the requirements of 2 CCR 402, Rule 10.

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, and dispose of hazardous waste must adhere to the following requirements: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of any hazardous waste by a 100-year flood (if the facility is located within the 100-year floodplain). (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
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.
	29 CFR 1910.120 (b)	20 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and the NIOSH are outlined in Table 2 in Appendix A of the DSA. Chemical oxidation treatment of groundwater uses ozone and may use hydrogen peroxide to oxidize organic contaminants. The worker exposure standards for these compounds are given below. Hydrogen peroxide ACGIH-TWA = 1 ppm, 1.4 mg/m^3 NIOSH-REL = 1 ppm, 1.4 mg/m^3 OSHA-PEL = 1 ppm, 1.4 mg/m^3 Ozone ACGIH-TWA = 0.1 ppm (ceiling), 0.20 mg/m^3 (ceiling) NIOSH-REL = 0.1 ppm (ceiling), 0.20 mg/m^3 (ceiling) OSHA-PEL = 0.1 ppm, 0.2 mg/m^3 STEL = 0.3 ppm, 0.6 mg/m^3 (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Operation of chemical oxidation units for groundwater treatment shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Chemical oxidation units shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.

Action	Citation	Requirements
Protection of wildlife (continued)	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
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 requirments. 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.
	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.
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs.
	42 USCS Section 7412	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.
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 following limits:

Action	Citation	Requirements
Odor emissions (continued)		1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air.
Emission control for opacity	5 CCR 1001-3, Regulation 1, Section II 40 CFR 60 Appendix A	Chemical oxidation of organic compounds from groundwater shall not cause the emission into the atmosphere of any air pollutant that is in excess of 20 percent opacity. Visible emissions must be measured by EPA Method 9.
Visibility protection	40 CFR 51.300-307	Chemical oxidation of organic compounds from a groundwater 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.
<u>Waste Characterization</u>		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of – burned or incinerated – accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated

Action	Citation	Requirements
Solid waste determination (continued)		• Recycled materials which is – used in a manner constituting disposal – burned for energy recovery – reclaimed – speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Chemical oxidation of organic compounds will create wastes consisting primarily of sludges. This and all other wastes generated in this process must be 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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, which include the following: 1) "Industrial wastes," which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes.

Action	Citation	Requirements
Solid waste classification (continued)		4) "Special wastes," which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes. 5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes, and inert material are expected from chemical oxidation treatment of groundwater at RMA. No special testing requirements are specified for solid wastes. The management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Wastes from chemical oxidation of organic compounds in groundwater that are determined to be RCRA hazardous wastes must be treated, stored, and disposed in compliance with RCRA regulations, including LDRs if placement occurs.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]
Reinjection of treated groundwater	RCRA Section 3020 (b) 2 CCR 402-2, Rule 10 OSWER Directive 9234.1-06 [TBC]	Reinjection of treated groundwater must be managed in accordance with the guidelines in OSWER Directive 9234.1-06. Wells should be constructed and installed according to the requirements of 2 CCR 402-2, Rule 10.

Action	Citation	Requirements
Siting		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, and dispose of hazardous waste must adhere to the following: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of any hazardous waste by a 100-year flood (if the facility is located within the 100-year floodplain). (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
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. A key concern in GAA adsorption treatment of groundwater is the handling of corrosives (acids and caustics) used in GAA treatment and regeneration.
	29 CFR 1910.120 (b)	20 CFR 1910.120(b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on–site workers • Site characterization and analysis • Site control • On–site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling

Action	Citation	Requirements
Health and safety protection (continued)		• Sanitation • Air monitoring
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 29 CFR 1910.1000	Chemical–specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 2 in Appendix A of the DSA. A key concern in GAA treatment is the handling of corrosives used for pH adjustment in GAA treatment and regeneration. The principal corrosives used in GAA process are sulfuric acid and sodium hydroxide. In addition, calcium hydroxide may be used to precipitate iron and hardness prior to treatment. The worker exposure standards for these compounds are given below: Sodium hydroxide ACGIH-TWA = 2 mg/m^3 (ceiling) NIOSH-REL = 2 mg/m^3 (15-min ceiling) OSHA-PEL = 2 mg/m^3, ceiling = 2 mg/m^3 Sulfuric acid ACGIH-TWA = 1 mg/m^3; STEL = 3 mg/m^3 NIOSH-REL = 1 mg/m^3 OSHA-PEL = 1 mg/m^3; TWA = 1 mg/m^3 Calcium hydroxide ACGIH-TWA = 5 mg/m^3 OSHA-TWA = 5 mg/m^3 (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGIH and NIOSH values are provided as guidelines.)

Action	Citation	Requirements
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Groundwater remedial actions using GAA units shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. GAA units shall not cause or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.
	CRS 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
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 requirments. 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.
	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.

Action	Citation	Requirements
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of certain hazardous air pollutants is controlled by NESHAPs.
Emission of hazardous air pollutants (continued)	42 USCS Section 7412	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.
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 following limits: 1) For residential and commercial areas—odors detected after the odorous air has been diluted with seven more volumes of odor-free air 2) For all other land use areas—odors detected after the odorous air has been diluted with 15 more volumes of odor-free air
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of – burned or incinerated – accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned or incinerated • Recycled materials which is – used in a manner constituting disposal – burned for energy recovery – reclaimed – speculatively accumulated • Waste-like material is material that is considered inherently wastelike

Action	Citation	Requirements
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	GAA adsorption will create wastes consisting primarily of regeneration sludge. This and all other wastes generated in this process must be 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 Part 261 • Determine whether the waste is identified in 40 CFR Part 261 by testing the waste according to specified test methods and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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, which include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes.

Action	Citation	Requirements
Solid waste classification (continued)		5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, and commercial wastes, and inert material are expected from GAA treatment of groundwater at RMA. No special testing requirements are specified for solid wastes. The management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
<u>Waste Management</u>		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	Wastes from GAA adsorption that are determined to be RCRA hazardous wastes must be treated, stored, and disposed in compliance with RCRA regulations, including LDRs if placement occurs.
Solid waste disposal		[Refer to Table A-9 for citations and requirments relevant to both on-post and off-post solid waste landfills.]
Reinjection of treated groundwater	RCRA Section 3020 (b) 2 CCR 402-2, Rule 10 OSWER Directive 9234.1-06 [TBC]	Reinjection of treated groundwater must be managed in accordance with the guidelines in OSWER Directive 9234.1-06. Wells should be constructed and installed according to the requirements of 2 CCR 402-2, Rule 10.

Action	Citation	Requirements
Transportation of Hazardous Waste		
Off-post transportation		All shipments of hazardous waste from the site are required to meet the provision of 40 CFR Part 262 (Regulations for Hazardous Waste Generators) including, but not limited to, the following:
	40 CFR 262.20	1) This regulation requires a manifest that identifies the nature and volume of hazardous waste to be transported, the generator responsible, the transporter, and the designated disposal facility.
	40 CFR 262.23	2) This regulation describes the use of the manifest.
	40 CFR 262.30 to 262.33	3) These regulations address packaging, labeling, marking, and placarding requirements that are prerequisites to the transportation of hazardous waste.
	40 CFR 262.40	4) This regulation sets forth criteria that describe how long the generator should retain manifest records.
	40 CFR 262 Appendix	5) This regulation provides specific instructions for the completion of the hazardous waste manifest and the continuation sheet.
	40 CFR 268.7	6) This regulation requires that an LDR notification and certification document must accompany shipments.
	40 CFR 261.6	7) This regulation sets forth criteria for the transportation and storage of previously contaminated materials that are to be recycled.
	49 CFR Parts, 172, 173, 178, 179	Transporters of hazardous waste must also comply with DOT regulations for transportation of hazardous materials. These requirements include identifying the hazard class, along with proper packaging, labeling, marking, placarding of the trucks, and completing the shipping papers as detailed in the regulations. (These DOT requirements are technically not ARARs; rather they are independently applicable requirements that must be complied with as soon as the waste load leaves RMA. They are discussed here for convenience.)

Action	Citation	Requirements
Off-post transportation (continued)		The hazardous waste manifest requires the use of 49 CFR 172.102 to provide the proper shipping name for hazardous materials being shipped off site. Reportable quantities of hazardous substances provided in 49 CFR 172.101 may also be required prior to off-site shipment.
	40 CFR Parts 262 and 263	Transporters of hazardous waste requiring a manifest under 40 CFR Part 262 must also comply with the transporter requirements provided in 40 CFR Part 263, including obtaining an EPA identification number as a hazardous waste transporter.
		All transportation of hazardous wastes must meet requirements established to protect the air quality of the site and surrounding area as follows:
	5 CCR 1001-15 (Regulation 12)	1) Transportation of wastes in diesel-powered vehicles may be subject to state opacity and visibility standards.
	5 CCR 1001-4 (Regulation 2)	2) Loading, unloading, or transportation wastes may cause odors or emissions from contaminants which that state odor limitations.
	5 CCR 1001-3 (Regulation 1) Section III (D) (2) 5 CCR 1001-5, (Regulation 3) 40 CFR 50.6	3) Transportation on unpaved roadways may be subject to state requirements to reduce particulate emissions resulting from the use of the roadway.
	40 CFR 52.21 (f)(iii) 40 CFR 81.306	4) Federal regulations for the prevention of significant deterioration of air quality may be excluded upon written request of the governor if concentrations of particulate matter attributable to temporary actions causes compliance questions.
	AMC-R 385-131 [TBC]	Transporters of hazardous waste that is known to contain chemical agents may be covered by Army regulations including, but not limited to, AMC-R 385-131, which contains the following descriptions:
		1) Requirements for transportation and handling of agent-filled munitions and containers.

Action	Citation	Requirements
Off-post transportation (continued)		2) Minimum degree of treatment prior to off-post transport and disposal. Items may not be released from government control until they have been decontaminated to the 5X level.
On-post transportation		All on-post shipments of hazardous waste may be required to meet the provisions of 5 CCR 1001, 40 CFR Parts 52 and 81, and AR 50-6 including, but not limited to the following:
	5 CCR 1001-15 (Regulation 12)	1) Transportation of wastes in diesel-powered vehicles may be subject to state opacity and visibility standards.
	5 CCR 1001-4 (Regulation 2)	2) Loading, unloading, or transportation of wastes may cause odors or emissions from contaminants that exceed state odor limitations.
	5 CCR 1001-3 (Regulation 1) Section III (D) (2) 5 CCR 1001-5 (Regulation 3)	3) Transportation on unpaved roadways may be subject to state requirements to reduce particulate emissions resulting from the use of the roadway.
	40 CFR 52.21 (f) ((1) iii) 40 CFR 81.306	4) Federal regulations for the prevention of significant deterioration of air quality may be excluded upon written request of the governor if concentrations of particulate matter attributable to temporary actions cause compliance questions.
	AR 50-6 Chapter 4 [TBC]	5) This regulation describes procedures to be followed during the transportation of Chemical Surety Materials.

Action	Citation	Requirements
Access Restrictions		
Access controls	40 CFR 264.14	Access controls will be provided that will prevent unknowing entry and minimize unauthorized entry of persons or livestock onto active portions of RMA. These may include 24-hour surveillance or a barrier (either natural or artificial) and a means of controlling access.
Land Use/Deed Restrictions		
Land use and deed restrictions for former hazardous waste disposal units	40 CFR 264.119	If RMA ceases to be federal government property, a notation on the deed must indicate that ht eland was previously used to manage hazardous wastes and its use is restricted under 40 CFR 264 Subpart G regulations. A record of the type, location, and quantity of hazardous waste managed at each disposal unit must also be supplied to the local zoning authority or through authority over local land use.
Monitoring		
Groundwater monitoring	40 CFR 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 water management units. Monitoring wells should be constructed and installed according to the requirements of 2 CCR 402-2, Rule 10 and the guidance in t he RCRA Groundwater Monitoring TEGD.

Action	Citation	Requirements
Monitoring		
Groundwater monitoring	40 CFR 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.

Action	Citation	Requirements
Siting of Peroxide/Hypochlorite Treatment Facility		
Siting of hazardous waste facilities	40 CFR 264.18	New facilities constructed to treat, store, or dispose of hazardous waste must adhere to the following: 1) They must not be located within 200 ft of a Holocene-age fault. 2) They must be designed, constructed, and operated to prevent washout of hazardous waste by a 100-year flood, (if the facility is located within the 100-year flood plain). (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
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.
	29 CFR 1910.120 (b)	29 CFR 1910.120 (b) provides guidelines for workers involved in hazardous waste operations and emergency response actions on sites regulated under RCRA and CERCLA. Specific provisions include the following: • Health and safety program participation required by all on-site workers • Site characterization and analysis • Site control • On-site training • Medical surveillance • Engineering controls • Work practices • Personal protective equipment • Emergency response plan • Drum handling • Sanitation • Air monitoring

Action	Citation	Requirements
Worker exposure	ACGIH 1991-1992 [TBC] NIOSH 1990 [TBC] 29 CFR 1910.1000	Chemical-specific worker exposure guidelines established by OSHA, ACGIH, and NIOSH are outlined in Table 1 in Appendix A1 of the DSA. In addition to the chemicals listed in Table 1, peroxide/hypochlorite treatment involves the use of hydrogen peroxide and sodium hypochlorite. Hypochlorite the treatment is neutralized using hydrochloric acid. Worker exposure standards for these chemicals are: Hydrogen peroxide ACGIH-TWA = 1 ppm, 1.4 mg/m^3 NIOSH-REL = 1 ppm, 1.4 mg/m^3 OSHA-PEL = 1 ppm 1.4 mg/m^3 Sodium hypochlorite ACGIH-TWA = 0.1 ppm (ceiling), 0.20 mg/m^3 (ceiling) NIOSH-REL = 0.1 ppm (ceiling), 0.20 mg/m^3 (ceiling) OSHA-PEL = 0.1 ppm, 0.2 mg/m^3 STEL = 0.3 ppm, 0.6 mg/m^3 (OSHA regulations and other health and safety requirements are actually independently applicable regulatory requirements, not ARARs or TBCs. ACGHI and NIOSH values are provided as guidelines.)
Protection of Wildlife		
Protection of wildlife	16 USC Section 1531 et seq. 50 CFR Part 402 16 USC Section 668 et seq. 16 USC Section 703-711 50 CFR 424.02 (d) (2) 50 CFR Part 10 50 CFR Parts 20-21	Peroxide/hypochlorite treatment at RMA shall not jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of their habitat. Peroxide/hypochlorite treatment shall not use or contribute to the harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection of any endangered or threatened species of plants, fish, or wildlife.
	16 USC Section 661 et seq. 40 CFR 6.304 (g)	Actions shall be taken to protect the fish and wildlife resources that may be affected by remedial actions resulting in the control or structural modification of any natural stream or body of water.

Action	Citation	Requirements
Protection of Wildlife (continued)	CRS Section 33-2-101 to 33-2-107	Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. (These regulations are commonly considered location-specific ARARs, but may impact the remedial actions taken. They are included in this table for the convenience of the reader.)
Air Emissions		
Emission of hazardous air pollutants	5 CCR 1001-10, Regulation 8 40 CFR Part 61	Emission of listed hazardous air pollutants is controlled by NESHAPs. Soil flushing will cause volatization of some contaminants.
	42 USCS Section 7412	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 of 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.
	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.
Waste Characterization		
Solid waste determination	40 CFR 260 40 CFR 260.30-31 40 CFR 261.2 40 CFR 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 of – burned or incinerated – accumulated, stored, or treated before or in lieu of being abandoned by being disposed, burned, or incinerated

Action	Citation	Requirements
Solid waste determination (continued)		• Recycled materials which is – used in a manner constituting disposal – burned for energy recovery – reclaimed – speculatively accumulated • Waste-like material is material that is considered inherently wastelike
Determination of hazardous waste	40 CFR 262.11 40 CFR Part 261	Wastes generated during soil excavation activities must be characterized. Solid wastes must be 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 and by applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used
Solid waste classification	6 CCR 1007-2, Part 1, 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. The waste categories include the following: 1) "Industrial wastes", which includes all solid wastes resulting from the manufacture of products or goods by mechanical or chemical processes. 2) "Community wastes", which includes all solid wastes generated by the noncommercial and nonindustrial activities of private individuals of the community including solid wastes from streets, sidewalks, and alleys. 3) "Commercial wastes", which includes all solid wastes generated by stores, hotels, markets, offices, restaurants, and other nonmanufacturing activities, with the exclusion of community and industrial wastes. 4) "Special wastes", which includes any solid waste that requires special handling or disposal procedures. Special wastes may include, but are not limited to, asbestos, bulk tires, or other bulk materials, sludges, and biomedical wastes.

Action	Citation	Requirements
Solid waste classification (continued)		5) "Inert material", which includes solids that are not soluble in water and therefore nonputrescible, together with such minor amounts and types of other materials that do not significantly affect the inert nature of such solids. The term includes, but is not limited to, earth, sand, gravel, rock, concrete that has been in a hardened state for at least 60 days, masonry, asphalt-paving fragments, and other inert solids, including those that the Colorado Department of Health may identify by regulation. If present, only small quantities of industrial, community, commercial, and special wastes are expected from peroxide/hypochlorite treatment of debris at RMA. No special testing requirements are specified for solid wastes; the management and disposal rules are strictly oriented toward imposing minimum engineering and technology requirements.
Waste Management		
Treatment, storage, or disposal of RCRA hazardous waste	40 CFR Part 264 40 CFR Part 268	If peroxide/hypochlorite treatment at RMA generates hazardous wastes, the wastes must be treated, stored, or disposed in accordance with RCRA regulations, including LDRs.
Treatment and disposal of hazardous debris	57 FR 37194 et seq.	Hazardous debris treated with peroxide or hypochlorite must be treated to extract, destroy, or immobilize hazardous constituents on or in the debris. In certain cases after treatment, the debris may no longer be subject to RCRA Subtitle C regulation.
Solid waste disposal		[Refer to Table A-9 for citations and requirements relevant to both on-post and off-post solid waste landfills.]