NOTICE

All drawings located at the end of the document.

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Technology Literature Research

Operable Unit No 7 — Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203)

Final Report

April 15, 1994

EG&G ROCKY FLATS

Rocky Flats Site
Golden, Colorado

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LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
BOD	biochemical oxygen demand
C N P	carbon/nitrogen/phosphorous ratio
CAA	Clean Air Act
CAMU	corrective action management unit
CCR	Colorado Code of Regulations
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CHWA	Colorado Hazardous Waste Act
cm/sec	centimeters per second
COD	chemical oxygen demand
CPT	core penetration test
DC	direct current
DOE	U S Department of Energy
EPA	U S Environmental Protection Agency
FML	flexible membrane liner
GAC	granular activated carbon
HAP	hazardous air pollutant
HELP	Hydrological Evaluation of Landfill Performance
IAG	Interagency Agreement
IHSS	individual hazardous substance site
IM/IRA	interim measure/interim remedial action
LDR	land disposal restriction
LHSU	lower hydrostratigraphic unit
LTTD	low-temperature thermal desorption
MAC	maximum allowed concentration
MCL	maximum contaminant level
mg/L	milligrams per liter
MTR	minimum technology requirement
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NMOC	non-methane organic compound
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OH	hydroxyl
OU	operable unit
PCB	polychlorinated biphenyl
PCOC	potential chemicals of concern
PEG	polyethylene glycol
POTW	Publicly Owned Treatment Works
psi	pounds per square inch

PVC	polyvinyl chloride
RAO	remedial action objective
RBC	rotating biological contactor
RCRA	Resource Conservation Recovery Act
RF	radio frequency
RFI/RI	RCRA facility investigation/remedial investigation
SBR	sequencing batch reactor
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TBC	to-be-considered
TDS	total dissolved solid
TOC	total organic carbon
TSD	treatment, storage, and disposal
UHSU	upper hydrostratigraphic unit
UV	ultraviolet
VOC	volatile organic compound
WSIC	Waste Stream Identification and Characterization

EXECUTIVE SUMMARY

This Technology Literature Research report identifies technologies that may be used to address the contamination present at Operable Unit (OU) No 7 at the Rocky Flats site Results of this report will be used as the basis for an options analysis to develop an appropriate interim measure/interim remedial action (IM/IRA) for OU 7 This document was prepared in accordance with the Rocky Flats Interagency Agreement (IAG)

For purposes of this report, OU 7 is divided into four areas

- Present Landfill
- Inactive Hazardous Waste Storage Area (Individual Hazardous Substance Site [IHSS] 203)
- East Landfill Pond
- Spray evaporation areas adjacent to the East Landfill Pond (including IHSS 167 2 and 167 3)

The Present Landfill is an operating landfill that covers approximately 27 acres The landfill was originally intended for disposal of the site's nonradioactive waste However, in 1973, tritium was detected in the leachate Monitoring of waste was initiated to prevent further disposal of radioactive waste, and interim response measures were developed to control the generation and migration of the leachate

The Inactive Hazardous Waste Storage Area is located at the southwest corner of the landfill The area was used to store hazardous drummed liquids and solids In 1987, all cargo containers were removed and hazardous materials are no longer stored there

The East Landfill Pond was one of two detention ponds built as part of the interim measures discussed above The other pond was buried during expansion of the landfill Water was periodically sprayed on the ground adjacent to the ponds to prevent overflow These areas are now referred to as the spray evaporation areas

In addition to the above areas, OU 7 is also divided by media Technologies address contamination in landfill solids, landfill gas, groundwater, leachate, surface water, spray evaporation area soils, and East Landfill Pond sediments

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Source containment, the presumptive remedy for Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) municipal landfills, will be applied to the Present Landfill and Hazardous Waste Storage Area The presumptive remedy consists of the following elements institutional controls, a landfill cap, landfill gas collection (and treatment if necessary), source area groundwater control, and leachate collection (and treatment if necessary) Adoption of the presumptive remedy limits the number of technologies presented in this report

In order to develop technologies, the contamination was characterized for each media. Potential chemicals of concern (PCOCs) were developed for most media However, the presumptive remedy strategy eliminates the need for further characterization of the contamination in the landfill PCOCs or chemicals detected above background are presented in Section 2 PCOCs include volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), metals, and radionuclides

Technologies were identified to address the contamination in each media and are discussed in Section 4 and presented in Tables 4-1 through 4-6 Technologies associated with the presumptive remedy are presented first, followed by technologies for surface water and soils and sediments Where appropriate, the technologies were sorted into five categories institutional controls, containment, removal, treatment, and disposal

In the next task, Options Analysis, technologies will be assessed, grouped into alternatives, and evaluated in terms of remedial action objectives (RAOs), applicable or relevant and appropriate requirements (ARARs), and protection of human health and the environment Results will then be incorporated into the IM/IRA decision document

1. INTRODUCTION

1.1 Purpose of Report

This technology literature research document for Operable Unit (OU) No 7 at the Rocky Flats site presents the results of a comprehensive literature search performed to support the selection of an interim measure/interim remedial action (IM/IRA) for OU 7 Results of this report will be integrated into the IM/IRA decision document

This report is part of the Environmental Restoration program that addresses site characterization, remedial investigations, feasibility studies, and remedial/corrective actions currently in progress at the Rocky Flats site These activities are pursuant to an Interagency Agreement (IAG) among the U S Department of Energy (DOE), the U S Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH) dated January 22, 1991 (DOE 1991a) The IAG program developed by DOE, EPA, and CDH addresses the Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) issues CDH is the lead regulatory agency for OU 7

1.2 Organization of Report

The report addresses remedial technologies applicable to each of the media affected by contamination in OU 7 Later, as part of the options analysis, the technologies will be screened, evaluated in detail, and combined into alternatives that will address the operable unit as a whole Section 1 provides background information on Rocky Flats and OU 7 Section 2 summarizes the contamination in OU 7 by media Section 3 states the IM/IRA objectives Section 4 identifies potential technologies, provides a preliminary screening of technologies based on applicability to the site, and briefly discusses each of the remaining technologies

1.3 Rocky Flats Site Background

The Rocky Flats site is located at the foot of the Rocky Mountains in northern Jefferson County, Colorado The site is approximately 16 miles northwest of Denver in sections 1 through 4 and 9 through 15 of township 2 south, range 70 west It is near the suburban communities of Westminster, Broomfield, and Arvada The Rocky Flats site covers approximately 6,550 acres with approximately 400 acres used for industrial activities

The primary mission of Rocky Flats has been production of components for nuclear weapons The final products included component parts manufactured from uranium, plutonium, beryllium, stainless steel, and other metals Production activities included metalworking, fabrication and component assembly, plutonium recovery and purification, and associated quality control functions Research and development in the fields of chemistry, physics, materials technology, nuclear safety, and mechanical engineering were also conducted

Operations at the plant began in 1952 In 1989, many of the production functions at the plant were suspended In January 1992, the decision was made not to resume plutonium production The Rocky Flats site is currently in transition from a weapons production site to an environmental and waste management site Current waste handling practices involve onsite and offsite recycling and treatment of hazardous materials, onsite storage of radioactive mixed wastes, and offsite disposal of solid radioactive materials

1.4 OU 7 Background

OU 7 is located north of the plant complex at the western end of No Name Gulch For the purpose of selecting remedial actions, OU 7 is divided into the following four areas

- Present Landfill (Individual Hazardous Substance Site [IHSS] 114)
- Inactive Hazardous Waste Storage Area (IHSS 203)
- East Landfill Pond
- Spray evaporation areas adjacent to the East Landfill Pond (including IHSS 167 2 and 167 3)

Each of these areas is shown in Figure 1-1 and discussed in detail below

1 4 1 Present Landfill (IHSS 114)

The Present Landfill (IHSS 114) is an operating landfill that covers an area of approximately 27 acres Operation of the landfill was initiated in 1968 to provide for disposal of the site's nonradioactive solid wastes A portion of the natural drainage was filled with soils from an onsite borrow area to a thickness of up to 5 feet to construct a surface on which to start landfilling Waste was then delivered to the landfill and spread across the work area Wastes included paper, rags, floor sweepings, cartons, mixed garbage and rubbish, demolition material, and miscellaneous items

The waste disposal procedures currently used at the landfill have not significantly changed since the landfill went into operation in 1968 (DOE 1991b) Waste is delivered to the landfill three days a week throughout the morning and early afternoon In mid-afternoon, waste is spread across the work area After the waste has been dumped and radiation monitoring completed, the waste is compacted and buried with six inches of clean fill from onsite stockpiles A "lift" of waste is completed by the addition of a 3-foot-thick layer of compacted soil

Five gas vents are present within the operating landfill These vents are constructed of polyvinyl chloride (PVC) and extend above the ground surface approximately five feet Numerous monitoring wells are also present within the landfill

In 1973, tritium was detected in leachate draining from the landfill In response, a sampling program was undertaken to determine the location of the tritium source, monitoring of waste for radionuclides prior to burial was initiated to prevent further disposal of radioactive material, and the following interim response measures were developed to control the generation and migration of the landfill leachate

1 Construction of two detention ponds immediately east of the landfill,

2 A subsurface groundwater intercept system for diverting groundwater around the landfill,

3 A subsurface leachate collection system, and

4 A surface-water diversion system

Locations of the landfill structures constructed as interim response measures that still exist are shown in Figure 1-1

The surface-water diversion ditch was designed to divert surface water runoff around the landfill The West Landfill Pond was designed to impound leachate generated by the landfill The East Landfill Pond provided a backup system for any overflow from the West Landfill Pond and collected groundwater from the groundwater intercept system The leachate collection system drained only to the West Landfill Pond, however, intercepted groundwater could be directed to either pond or to the surface drainages downgradient of the East Landfill Pond by a series of valves

Between 1977 and 1981, portions of the leachate collection and groundwater intercept systems were buried during landfill expansion The eastward expansion covered the discharge points of the leachate collection system into the West Landfill Pond The West Landfill Pond was covered in May 1981 during further eastward expansion of the landfill In 1982, two slurry walls were constructed to prevent groundwater migration into the expanded landfill area These slurry walls were tied into the north and south arms of the groundwater intercept system

Although landfill wastes are buried in the leachate collection trench, there is no evidence of solid waste burial outside of the clay barrier or slurry walls Based on the Phase I RCRA facility investigation/remedial investigation (RFI/RI) field investigation at OU 7, there is evidence of groundwater flow beneath or through the northwestern section of the groundwater intercept system However, the quantity of groundwater flowing into the landfill and the length of the intercept system that is failing were estimated in the OU 7 Draft Revised Work Plan Technical Memorandum (DOE 1994)

The existing leachate collection system is only partially effective Although the gravel backfill portion of the diversion trench is effective in keeping leachate within the northern, southern, and western limits of the landfill, leachate seeps out along the eastern boundary just above the East Landfill Pond and may impact the groundwater around the pond Leachate is prevented from migrating downward beneath the landfill by the claystone bedrock

The existing surface-water diversion ditch appears to be effective in diverting offsite surface waters around the landfill and the East Landfill Pond It also serves to prevent surface water from flowing offsite

Because records indicate that some hazardous waste was disposed at the landfill, it was designated as an interim status RCRA-regulated unit and included in the Part B permit application for the Rocky Flats site The landfill currently accepts only nonhazardous solid waste and therefore will not be permitted as an operating RCRA unit In 1988, an alternate groundwater monitoring program was implemented at OU 7 in accordance with 6 Colorado Code of Regulations (CCR) 1007-3 and 40 Code of Federal Regulations (CFR) 265 90 (d) for interim status RCRA units OU 7 will remain under interim status until closure

1 4 2 Inactive Hazardous Waste Storage Area (IHSS 203)

The Inactive Hazardous Waste Storage Area (IHSS 203) is located at the southwest corner of the Present Landfill (Figure 1-1) This area was actively used between 1986 and 1987 as a hazardous waste storage area for both drummed liquids and solids Fifty-five-gallon containers with free liquids were stored in 14 cargo containers One additional container was used to store spill control items such as oil sorbent and sorbent pillows

In 1987, all cargo containers were removed from the storage area, and hazardous materials are no longer stored there

1 4 3 East Landfill Pond

As discussed above, the East Landfill Pond (Figure 1-1) was originally built as part of an interim response measure implemented in 1973 to control overflow from the West Landfill Pond and collect groundwater from the groundwater diversion system In 1974, an engineered pond embankment was constructed to replace the original temporary embankment The engineered embankment included a low-permeability clay core keyed into bedrock The area of the pond is approximately 2 7 acres

1 4 4 Spray Evaporation Areas

To prevent the two detention ponds from overfilling and discharging into the drainage, water was periodically sprayed on the ground surface adjacent to the landfill ponds to enhance evaporation Areas where spray evaporation operations historically occurred were designated as IHSS 167 1, 167 2, and 167 3 and incorporated into OU 6 Based on historical research, the locations of IHSSs 167 2 and 167 3 were changed to the areas adjacent to the East Landfill Pond These IHSSs now fall within the OU 7 boundary

1.5 Presumptive Remedies

Use of presumptive remedies is a method developed by EPA to streamline site investigation and selection of remedial actions based on historical data from successful remedial actions at similar sites Source containment is the designated presumptive

remedy for CERCLA municipal landfills (EPA 1993a) The containment presumptive remedy consists of the following elements

- Institutional controls
- Landfill cap
- Landfill gas collection (and treatment if necessary)
- Source area groundwater control to contain plume
- Leachate collection (and treatment if necessary)

The presumptive remedy as outlined above was adopted by DOE, CDH, and EPA and will be applied to the OU 7 landfill and the Inactive Hazardous Waste Storage Area This streamlined approach, which is consistent with Colorado Hazardous Waste Act (CHWA) closure requirements supported by guidance in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and recent EPA guidance for landfills (EPA 1991a, EPA 1993a, and EPA 1993b) eliminates the need for initial identification and screening of alternatives during the feasibility study and allows for acceleration of the schedule to implement remedial actions and achieve final closure As a result of the adoption of a presumptive-remedy strategy, the number of technologies evaluated in this report is limited

2. SUMMARY OF CONTAMINATION

Section 2 summarizes the contamination in each of the media A list of potential chemicals of concern (PCOCs) and the evaluation basis are included where appropriate

2.1 Present Landfill and IHSS 203

In 1992 and 1993, a Phase I RFI/RI was conducted at the Present Landfill and IHSS 203 to characterize the sources of contamination within OU 7 and to describe the nature and extent of contamination present at the source and in soils Prior to completion of the Phase I RFI/RI and initiation of Phase II, the focus of investigations at OU 7 shifted as a result of the adoption of the presumptive remedy strategy for streamlined site characterization and site remediation The presumptive remedy does not address exposure pathways outside the source area, nor does it include the long-term groundwater response action Because the presumptive remedy will be used, identification of PCOCs for the landfill and IHSS 203 is not necessary

2.2 Landfill Gas

PCOCs have not been identified for landfill gas to-date Modeling will be performed to assist in estimating risks associated with air emissions and assessing the need for landfill gas treatment The landfill gas is believed to contain primarily methane and carbon dioxide Chemicals detected in the landfill gas include 1,1,1-trichloroethane, 1,2-dichloroethene, 2-butanone, acetone, carbon dioxide, hydrogen sulfide, methane, methylene chloride, o-xylene, p,m-xylene, toluene, and trichloroethene

2.3 Groundwater

Existing data for OU 7 groundwater include the Phase I RFI/RI, background geochemical data, RCRA groundwater monitoring results for the Present Landfill, and data from sitewide groundwater, surface water, and geologic characterization programs Results of the Phase I RFI/RI and other investigations provide information on groundwater quality at the site, including dissolved and total analyte concentrations in groundwater from the upper hydrostratigraphic unit (UHSU) and lower hydrostratigraphic unit (LHSU)

As agreed by CDH, EPA, and DOE, data analysis activities have identified PCOCs for water through statistical comparisons of OU 7 contaminant concentrations versus background concentrations Preliminary PCOCs for groundwater are given in Tables 2-1 and 2-2 and include metals, radionuclides, volatile organic compounds (VOCs), and semivolatile organic compounds (SVOCs)

2.4 Leachate

Regulatory guidance indicates that containment/control of leachate is a component of the presumptive remedy, therefore, specification of PCOCs is not required However, to evaluate technologies, a list of chemicals that have concentrations above background was developed and is shown in Table 2-3 and include metals, radionuclides, VOCs, and SVOCs

2.5 Surface Water

Results of the Phase I RFI/RI and other investigations provide information on surface water quality at the site, including analyte concentrations in surface water from the pond and the two intercept system discharge points

Analysis of this data identified PCOCs for surface water through statistical comparisons of OU 7 contaminant concentrations versus background concentrations The preliminary list of PCOCs for surface water is given in Table 2-4 and include metals, radionuclides, VOCs, and SVOCs

2.6 East Landfill Pond Sediments and Spray Evaporation Area Soils

Results of the Phase I RFI/RI investigations conducted in 1992 and 1993 provide information that describes contamination in East Landfill Pond sediments and adjacent soils where spray evaporation of pond water occurred These data include analyte concentrations in soils collected from two depth intervals (0 to 2 inches and 0 to 10 inches) and analyte concentrations in pond sediments Other sources of data include background geochemical data describing soils and sediments and data from sitewide hydrologic and geologic characterization programs

Table 2-1
PCOCs* for All OU 7 UHSU Groundwater

Inorganics	
Total Metals	**Dissolved Metals**
Aluminum	Aluminum
Antimony	Antimony
Arsenic	Arsenic
Barium	Barium
Beryllium	Cadmium
Cadmium	Calcium
Calcium	Chromium
Chromium	Cobalt
Cobalt	Copper
Copper	Iron
Iron	Lithium
Lead	Magnesium
Lithium	Manganese
Magnesium	Molybdenum
Manganese	Nickel
Mercury	Potassium
Molybdenum	Selenium
Nickel	Sodium
Potassium	Strontium
Selenium	Zinc
Silicon	
Silver	**Dissolved Radionuclides**
Sodium	Gross Beta
Strontium	Radium-226
Tin	Strontium-89,90
Vanadium	
Zinc	
Total Radionuclides	
Americium-241	
Cesium-137	
Radium-226	
Strontium-89,90	
Water-Quality Parameters	
Chloride	
Cyanide	
Fluoride	
Nitrate/Nitrite	
Sulfate	
Total Dissolved Solids	

Organics	
SVOCs	**VOCs**
1,4-Dichlorobenzene	1,1,1-Trichloroethane
2,4,5-Trichlorophenol	1,1,2-Trichloroethane
2,4-Dimethylphenol	1,1-Dichloroethane
2-Chloronaphthalene	1,1-Dichloroethene
2-Methylphenol	1,2-Dichloroethane
4-Nitrophenol	1,2-Dichloropropane
4 Methylphenol	1,2-Dichloroethene-04
Acenaphthene	1,4-Dichlorobenzene
Benzoic acid	2-Butanone
Bis (2-ethylhexyl) phthalate	2-Hexanone
Di-n-butyl phthalate	4-Methyl - 2-pentanone
Diethylphthalate	Acetone
Fluorene	Benzene
Naphthalene	Bromodichloromethane
Pentachlorophenol	Bromofluorobenzene
Phenanthrene	Bromoform
Phenol	Carbon disulfide
	Carbon tetrachloride
	Chlorobenzene
	Chloroethane
	Chloroform
	Ethylbenzene
	Methylene Chloride
	Tetrachloroethene
	Toluene
	Toluene-D8
	Total Xylenes
	Trichloroethene
	Vinyl chloride

*PCOCs are subject to state approval

Note Concentration ranges for PCOCs and background concentrations are given in the revised work plan for OU 7 (DOE 1994)

Table 2-2
PCOCs* for Downgradient OU 7 LHSU Groundwater

Inorganics	
Total Metals	**Dissolved Metals**
Aluminum	Aluminum
Arsenic	Antimony
Barium	Arsenic
Calcium	Barium
Chromium	Beryllium
Copper	Cadmium
Iron	Calcium
Lead	Chromium
Lithium	Cobalt
Magnesium	Copper
Manganese	Iron
Nickel	Lead
Potassium	Lithium
Selenium	Magnesium
Silicon	Manganese
Silver	Mercury
Sodium	Molybdenum
Strontium	Nickel
Tin	Potassium
Zinc	Selenium
	Silver
Total Radionuclides	Sodium
Americium-241	Strontium
Cesium-137	Thallium
Tritium	Tin
Uranium-235	Zinc
Water-Quality Parameters	**Radionuclides**
Nitrate/Nitrite	Gross Alpha
	Gross Beta
	Uranium-238
	Uranium-235
	Strontium-89,90

Organics
VOCs
1,1,1-Trichloroethane
1,1-Dichloroethene
Acetone
Chlorobenzene
Methylene chloride
Toluene
Total xylenes
SVOCs
Bis (2-ethylhexyl) phthalate
Di-n-butyl phthalate
Naphthalene

Note Concentration ranges for PCOCs and background concentrations are given in the revised work plan for OU 7 (DOE 1994)

Table 2-3
Chemicals Detected in Leachate Above Background

Inorganics	
Total Metals	**Dissolved Metals**
Antimony	Barium
Barium	Calcium
Calcium	Iron
Iron	Lithium
Lithium	Magnesium
Magnesium	Manganese
Manganese	Potassium
Potassium	Sodium
Silicon	Strontium
Sodium	Tin
Strontium	Zinc
Zinc	
	Dissolved Radionuclides
Total Radionuclides	Gross Beta
Gross Beta	Strontium-89,90
Strontium-89,90	Uranium-235
Tritium	
Water-Quality Parameters	
Nitrite	

Organics	
VOCs	**SVOCs**
1,1-Dichloroethane	2,4-Dimethylphenol
1,2-Dichloroethane	4-Methylnaphthalene
2-Butanone	4-Methylphenol
2-Hexanone	Acenaphthene
4-Methyl-2-pentanone	Bis (2-ethylhexyl) phthalate
Acetone	Fluorene
Benzene	Naphthalene
Carbon disulfide	Phenanthrene
Chloroethane	Dibenzofuran
Chloromethane	Diethyl Phthalate
Ethylbenzene	
Methylene chloride	
o-xylene	
Tetrachloroethene	
Total xylenes	
Trichloroethene	
Vinyl acetate	
Vinyl chloride	
Toluene	

Note Concentration ranges for chemicals detected in leachate and the associated background concentrations are given in the revised work plan for OU 7 (DOE 1994)

Table 2-4
PCOCs* for Surface Water

Inorganics	
Total Metals	**Dissolved Metals**
Arsenic	Antimony
Barium	Arsenic
Calcium	Barium
Lithium	Calcium
Magnesium	Lithium
Manganese	Magnesium
Molybdenum	Manganese
Nickel	Nickel
Potassium	Potassium
Selenium	Sodium
Sodium	Strontium
Strontium	Tin
Thallium	Vanadium
Tin	Selenium
Zinc	Cadmium
	Lead
Total Radionuclides	
Americium-241	**Dissolved Radionuclides**
Gross Alpha	Americium-241
Gross Beta	Gross Alpha
Strontium-89,90	Gross Beta
Tritium	Strontium-89,90
Uranium-235	Uranium-238
Uranium-238	
Water-Quality Parameters	
Nitrate	

Organics	
Total VOCs	**Total SVOCs**
1,1-Dichloroethane	Bis (2-ethylhexyl) phthalate
Acetone	Di-n-butyl phthalate
Benzene	
Carbon disulfide	
Chloroethane	
Ethylbenzene	
Methylene chloride	
Toluene	
Total xylenes	
Vinyl acetate	

*PCOCs are subject to state approval

Note Concentration ranges for PCOCs and background concentrations are given in the revised work plan for OU 7 (DOE 1994)

Data analysis identified PCOCs for East Landfill Pond sediments and adjacent soils through statistical comparisons of onsite contaminant concentration versus background concentrations The PCOCs for evaporation spray area soils are given in Table 2-5 and include metals and radionuclides PCOCs for East Landfill Pond sediments are given in Table 2-6 and include metals, radionuclides, VOCs, and SVOCs

Table 2-5
PCOCs in Spray Evaporation Area

Analyte		Metals
Metals		Arsenic
Arsenic		Barium
Barium		Calcium
Calcium		Selenium
Lead		
Magnesium		**Radionuclides**
Sodium		Americium-241
Strontium		
Vanadium		
Zinc		
Radionuclides		
Americium-241		
Radium-226		
Water-Quality Parameters		
Nitrate/Nitrite		

* PCOCs are subject to state approval

Note Concentration ranges for PCOCs and background concentrations are given in the revised work plan for OU 7 (DOE 1994)

Table 2-6
PCOCs* for East Landfill Pond Sediments

Inorganics	Organics
Total Metals	**VOCs**
Aluminum	2-Butanone
Arsenic	Toluene
Barium	
Beryllium	**SVOCs**
Calcium	Acenaphthene
Chromium	Acenaphthylene
Copper	Anthracene
Iron	Benzo (a) anthracene
Lead	Benzo (a) pyrene
Magnesium	Benzo (b) fluoranthene
Potassium	Benzo (ghi) perylene
Selenium	Benzo (k) fluoranthene
Sodium	Benzoic Acid
Strontium	Bis (2-chloroisopropyl) ether
Vanadium	Bis (2-ethylhexyl) phthalate
Zinc	Chrysene
	Fluoranthene
Radionuclides	Fluorene
Cesium-137	Indeno (1,2,3-cd) pyrene
	Phenanthrene
	Pyrene

*PCOCs are subject to state approval

Note Concentration ranges for PCOCs and background concentrations are given in the revised work plan for OU 7 (DOE 1994)

3. IDENTIFICATION OF IM/IRA OBJECTIVES

3.1 IM/IRA Objectives

The primary objective of the IM/IRA is to remediate the source, soils, sediments, surface water, and groundwater in a manner that facilitates final closure of the landfill in July 1997

Remedial action objectives are outlined below As discussed in Section 1 4, source containment will be applied as a presumptive remedy to the landfill

3 1 1 Remedial Action Objectives for Presumptive Remedy

Remedial action objectives (RAOs) for the presumptive remedy include the following (EPA 1993a)

- To prevent direct contact with landfill contents,
- To minimize infiltration and resulting contaminant leaching to groundwater,
- To control surface water runoff and erosion,
- To collect (and treat if necessary) contaminated groundwater and leachate near the source area, to contain the contaminant plume, and to prevent further migration from source area, and
- To control (and treat if necessary) landfill gas

3 1 2 Additional RAOs

Additional RAOs identified for OU 7 include the following

- To remediate contaminated surface water and sediments in the East Landfill Pond,
- To remediate evaporation spray area soils if necessary, and
- To remediate groundwater

3.2 IM/IRA Scope and Schedule

An IM/IRA decision document will be prepared in accordance with the terms and conditions of the Rocky Flats IAG signed by DOE, EPA, and CDH on January 22, 1991 The draft proposed Phase I IM/IRA decision document will be prepared in accordance with paragraphs 15 and 150 of the Rocky Flats IAG, will be consistent with guidance for implementing interim actions under remedial authority provided in the preamble to the NCP 55 FR 8704, March 8, 1990, and will comply with the CHWA closure requirements The draft proposed Phase I IM/IRA decision document will include the Phase II RFI/RI scope and provide the information required to recommend an alternative consistent with the CDH closure regulations The accelerated schedule eliminates the Table 6 milestones in the IAG The proposed milestone schedule is provided in Table 3-1

Table 3-1
OU 7 IM/IRA Proposed Milestone Schedule

Milestone	Date
Submit Draft IM/IRA decision document to CDH/EPA	05/03/95
Submit Final IM/IRA decision document to CDH/EPA	07/03/95
Submit IM Design Work Plan to CDH/EPA	08/08/95
IM Design Work Plan Complete	09/06/95
Submit IM/IRA Responsiveness Summary	10/04/95
Submit Final IM/IRA decision document and Responsiveness Summary	02/09/96
Begin IM/IRA Construction Process	03/05/96
Submit Draft Phase I IM/IRA Implementation Document to CDH/EPA	04/04/96
Submit Title II Design to CDH/EPA	09/03/96

3.3 Compliance with ARARs

There are three types of applicable or relevant and appropriate requirements (ARARs) for OU 7 chemical specific, action specific, and location specific Chemical-specific ARARs identify acceptable limits for defining an amount or concentration of a chemical that may be safely discharged into the environment These standards usually take the form of health-based or risk-based numerical limitations that restrict ambient concentrations of various chemical substances above a threshold level Chemical-specific ARARs are used to determine action levels and remediation goals Location-specific ARARs identify requirements that apply because the site has some special quality related to geography or the presence of a protected resource These requirements may limit the remedial action that may be implemented or create the need for more stringent remedial efforts Action-specific ARARs are requirements (usually treatment or monitoring standards) that influence remedial actions

In addition to ARARs, other guidance to-be-considered (TBC) is identified in this chapter where appropriate TBCs are advisories, criteria, or guidance that that may be useful in developing CERCLA remedies TBCs may be used to supplement promulgated standards when the meaning of those standards is ambiguous or when they do not address a particular situation

ARARs for OU 7 are discussed in detail in a separate report (EG&G 1994)

3 3 1 Chemical-Specific ARARs

3 3 1 1 Groundwater and Surface Water

One major area of concern for OU 7 is the potential for landfill leachate to migrate into groundwater supplies EPA guidance directs that cleanup actions presume that groundwater be considered a potential source of drinking water unless site-specific factors indicate otherwise Because site-specific factors rendering drinking water standards inappropriate have not been identified, all federal and state chemical-specific water standards have been listed as ARARs for OU 7 They include the following

- Safe Drinking Water Act maximum contaminant levels (MCLs)
- RCRA groundwater protection standards
- Colorado Water Quality Control Act surface-water standards (general and site-specific)
- Colorado Water Quality Control Act groundwater standards (general and site-specific)
- Colorado primary drinking water regulations

Safe Drinking Water Act MCLs are generally relevant and appropriate for CERCLA response actions Where contaminated groundwater is an issue and is considered a potential source of drinking water, MCLs are likely to become action levels (i e, cleanup standards) MCLs set safe levels for human consumption of certain chemicals in drinking water In addition to federal Safe Drinking Water Act MCLs, Colorado has also promulgated MCLs for drinking water, as well as general and stream-segment-specific standards for Colorado waters Colorado expands the list of chemical-specific standards to include some metals and agricultural chemicals not covered in the federal acts Collectively, these standards address metals, radionuclides, and inorganic and organic chemicals

3 3 1 2 Air

OU 7 is a potential source of airborne substances that are regulated under National Ambient Air Quality Standards (NAAQS) and National Emission Standards for Hazardous Air Pollutants (NESHAPs) They include particulate matter, lead, VOCs, and radionuclides Modeling of landfill generated gases based on the core samples will be performed to estimate air emissions and make a preliminary assessment of the need to treat landfill gas Until a preliminary assessment determines that air emissions will not trigger any ARARs associated with air quality, they will be included

Hazardous air pollutant (HAP) emission standards are being released for the new HAPs identified in the 1990 Clean Air Act (CAA) Amendments These standards have not yet been promulgated for any appropriate source categories However, proposed air emission regulations for non-methane organic compound (NMOC) releases in municipal solid waste landfills have been issued (56 Fed Reg 24468 1991) It sets a threshold limit of 150 mg/yr for NMOCs by weight before treatment standards are triggered Because these limits are health based and the source category is appropriate, its use is relevant and appropriate for determining acceptable NMOC limits This proposed standard has therefore been listed as TBC

3 3 1 3 Soil

Chemical-specific requirements for soil contamination are scarce To-date, neither federal nor Colorado law contains comprehensive numerical standards for hazardous constituents Although there are no identified chemical-specific ARARs for soils, there are TBCs that may assist in determining the level of soil contamination around the landfill and the need for remedial action EPA has proposed numerical treatment standards for organic and metal constituents in soil (58 Fed Reg 48092 1993)

RCRA delisting guidance may also be useful in determining unacceptable levels of hazardous constituents in soils (EPA 1990a) This guidance document lists maximum allowed concentrations (MACs) for various hazardous constituents, above which solids containing those wastes are not eligible for delisting Although the guidance states that these levels are not to be used for setting cleanup levels, MACs may be relevant and appropriate for defining a boundary beyond which soils are clearly contaminated. This document is listed as an appropriate TBC in the absence of an ARAR

3 3 2 *Location-Specific ARARs*

3 3 2 1 Historic, Archaeological, and Cultural Resources

To comply with federal and Colorado laws designed to preserve areas with historical, natural, cultural, or archaeological value, the identification of cultural resources and prehistoric or historic artifacts located at OU 7 is required The presence of an abandoned stagecoach line creates the need for an assessment of its cultural or historic value A cultural resources survey revealed that OU 7 lacks sufficient cultural or historical value for inclusion in the national or state register of historic places There are, therefore, no ARARs related to cultural or historical values at OU 7

3 3 2 2 Artificial Wetlands

The OU 7 East Landfill Pond may be considered a suspected wetland because it is an area "inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 CFR 328 3[b]) At OU 7, tall marsh occurs on the edge of the East Landfill Pond, short marsh occurs north and south of the pond throughout the spray evaporation areas The size of the wetland, the nature of the planned activities, and the amount of disruption to aquatic life all determine the potential need to limit activities, make offsets, or mitigate the threat in other ways While the East Landfill Pond has not yet been identified as a wetland, it exhibits enough wetland characteristics that it would be premature to exclude laws and regulations pertaining to wetlands from the list of potential ARARs Consequently, the Clean Water Act Section 404 permitting requirements and Executive Order 11990, Wetland Assessment, have been identified as ARARs

3 3 2 3 Ecological Protection

The Endangered Species Act, Bald and Golden Eagle Protection Act, and the Colorado Nongame Endangered, or Threatened Species Conservation Act have all been identified as ARARs because of the existence of regulated species under those acts in and around Rocky Flats No studies address the presence of wildlife at OU 7, however, other studies measuring the presence of plant and animal life at Rocky Flats indicate that several regulated species are located at the site Bald eagles occur occasionally in the area during winter months, but no roost areas or nest sites exist at the site for this species A pair of peregrine falcons nested approximately 10 kilometers northwest of the site in 1991, and this species may occur as a migrant periodically The ferruginous hawk and Preble's meadow jumping mouse, both candidates for listing as a threatened or endangered species, are present at Rocky Flats The site is also potential habitat for many other protected plant animal species, including the Ute lady's tresses, Colorado butterfly plant, black-footed ferret, white-faced ibis, mountain plover, long-tailed curlew, and swift fox Neither Rocky Flats nor OU 7 has been identified as critical habitat for any regulated species (DOE 1994)

3 3 3 Action-Specific ARARs

Since the Present Landfill opened in 1968, its operations policies for waste disposal at the landfill have conformed to applicable state and federal regulations (Rockwell International 1988) Regular radiation monitoring began in 1973, and groundwater monitoring began in 1977 Although the landfill accepted some hazardous waste in years past (that practice ended in 1986), none of the hazardous waste stream categories differ from those found at an ordinary municipal landfill In 1986 and 1987, the Waste Stream Identification and Characterization (WSIC) program, identified the following hazardous waste stream categories

- Containers filled with paint, solvent, degreasers, and foam polymers
- Rags contaminated with solvents, paint, etc
- Oil and paint filters
- Metal and asbestos shavings

Like a municipal landfill, the Present Landfill poses little long-term threat to the environment and because of the size of the landfill and heterogeneity of the waste, treatment is impractical The Present Landfill is sufficiently similar to a municipal landfill site so that guidance applicable to municipal landfills regarding remediation methods is appropriate In accordance with *Presumptive Remedy for CERCLA Municipal Landfill Sites*, containment is identified as the appropriate strategy for remedial action (EPA 1993a, 1993b) This presumption, consistent with the Superfund Accelerated Cleanup Model, relates to containment of the landfill mass and collection and/or treatment of landfill gas Rocky Flats intends to implement this presumptive remedy for the landfill mass

Action-specific ARARs for sediments underlying the East Landfill Pond, spray evaporation areas near the pond, and the pond water itself depend upon how serious the contaminants are If the waste can be best characterized as hazardous leachate, typical for a municipal landfill, then municipal solid waste disposal requirements (40 CFR Parts 257 and 258) may be appropriate Areas exhibiting sufficient hazardous waste characteristics are regulated under more stringent land disposal restrictions (40 CFR Part 268) Even if the wastes are subject to hazardous waste land disposal restrictions, site circumstances may permit an alternative option Instead of sending the waste to a permitted treatment, storage, and disposal (TSD) facility or incinerating, it may be returned to the landfill mass and covered This third option is an example of the corrective action management unit (CAMU) concept Regulations outlining these disposal options have been identified as action-specific ARARs

CAA air monitoring requirements are included because of their importance in monitoring regulated air pollutants under state and federal law Although emission limitations and control technology guidance for hazardous air pollutants (40 CFR Part 63) have not yet been issued, it is important to monitor the presence of these substances should standards be promulgated and to ensure that the remedial action chosen is generally protective of human health and the environment General monitoring requirements under the old NESHAPs program (40 CFR Part 61) have been identified as potential ARARs Should an assessment of landfill gases reveal the OU 7 air emissions pose no threat to the environment, then these requirements may become unnecessary

Radiation protection standards are applicable or relevant and appropriate because the Present Landfill contains radionuclides Identified ARARs offer performance objectives for closure, environmental monitoring requirements, and criteria for waste characteristics that would safely permit near-surface disposal of radioactive wastes The specific requirements may be found under the following DOE orders and federal regulations

- Licensing Requirements for Land Disposal of Radioactive Waste, 10 CFR Part 61 (1993)
- Radiation Protection of the Public and the Environment, DOE Order 5400 5, Change 2 (January 7, 1993)
- Radioactive Waste Management, DOE Order 5480.2A (September 26, 1988)

These standards are useful because they frequently contain more detailed guidance on methods for handling radioactive substances than more generic guidance for solid waste

4. IDENTIFICATION AND INITIAL SCREENING OF POTENTIAL IM/IRA TECHNOLOGIES

For each medium described in Section 2, a number of remedial technologies are potentially applicable for control of contamination at the site An initial screening of remedial technologies was based on the following questions

- Is the technology feasible for the given media?
- Is the technology applicable to the contamination and OU 7 site conditions?
- Will the technology work within the constraints of the interim action?

Technologies that pass this initial screening are then discussed in further detail It should be noted that many of the technologies are not "stand alone," but must be part of a treatment train or combination of technologies to be fully effective for the site For example, if treatment of VOCs and metals is required, a treatment that addresses VOCs but not metals should not be eliminated if it can be combined with a technology that would remove metals Development of treatment trains for each technology is part of the options analysis and beyond the scope of this literature review However, pre- and post-treatment requirements may be discussed here as appropriate

As discussed in Section 1 5, the presumptive remedy for the landfill consists of the following elements

- Institutional controls
- Landfill cap
- Landfill gas collection (and treatment if necessary)
- Source area groundwater control to contain plume
- Leachate collection (and treatment if necessary)

Technology options for the presumptive remedy are discussed in Sections 4 1 through 4 5

4.1 Institutional Controls - Presumptive Remedy

Institutional controls are nonengineering methods by which federal, state, and local governments or private parties can restrict access to contaminated or affected environmental media Most institutional controls take the form of use or access restrictions These may include simple physical actions such as fencing and warning signs, or more complex regulatory actions such as implementing zoning controls, water use and well restrictions, or proprietary restrictions such as covenants, restrictive easements, or deed restrictions

Many institutional controls are already in place at the site, including a three-strand barbed-wire cattle fence surrounding the facility, which is posted to identify the land as a government reservation/restricted area At the landfill, there is a 4-foot-high fence around the perimeter of the landfill with an access gate and posted warning signs Fencing and gates are operated and maintained by DOE

Institutional controls for groundwater and leachate include restrictions on the drilling of new water wells and the abandonment of existing wells There are no existing water supply wells on the Rocky Flats site The nearest supply wells downgradient from OU 7 are at least two miles from the source of contamination EG&G is developing a procedure to screen and review any plans for constructing new wells on site

All technologies listed in Table 4-1 are technically feasible and may be applicable to OU 7 depending on the final remedy Higher fencing may be required around the landfill and may need to extend around the spray evaporation areas and the East Landfill Pond

4.2 Landfill Cap - Presumptive Remedy

Placement of a constructed cap over the surface of the landfill to minimize exposure and reduce infiltration is part of the presumptive remedy Three types of caps are presented in Table 4-2 Each of the caps is technically feasible, however, only the composite barrier cap will meet RCRA and CHWA capping criteria Therefore, the native soil cap and single barrier cap will be eliminated from further evaluation

Table 4-1
OU 7 Technology Literature Research
Identification and Initial Screening of Remedial Technologies
Institutional Controls - Presumptive Remedy

Response Action • Remedial Technology - Process Option	Description	Comments
Institutional Controls		
• **Land Use Restrictions**	Legal restrictions on future use of the site	Some restrictions already in place
- Deed Restrictions	Restrictive covenants on deed to the landfill property Includes limitations on excavation and basements in contaminated areas	
- Zoning Change	Zoning change, administrative consent order, or judicial order prohibiting certain land uses	
• **Access Restrictions**	Physical restrictions to limit access to site	Some restrictions already in place, including a barbed-wire fence around the site and a 4-ft -high fence around the landfill
- Fencing	Restrict general public and large wildlife from onsite hazards	
- Written Warnings	Place warning signs in area to warn public of hazards	
• **Water Use Controls**	Restrictions on use of water associated with site	
- Well Permit Regulation	Regulate drilling of new wells in potentially contaminated shallow aquifer	Alternate water sources exist
- Inspect and Seal Existing Wells	Voluntary abandonment of existing shallow wells in contaminated areas Properly seal bedrock wells to prevent downward contaminant migration	Ineffective monitoring wells can be plugged and abandoned
- Point-of-Use Treatment	Provide individual water treatment systems to all potentially affected well water systems	There are no affected water supply systems at this time
• **Public Education**	Increase public awareness of site conditions and remedies through written notices, meetings, and news releases	The draft IM/IRA decision document will be available for public review and comment

Table 4-2
OU 7 Technology Literature Research
Identification and Initial Screening of Remedial Technologies
Landfill Solids - Presumptive Remedy

Response Action • Remedial Technology - Process Option	Description	Comments
Containment Actions		
• **Capping**	Provides physical barrier between contaminants and the environment May include surface regrading and revegetation	
- Native Soil Cover	Reduces exposure to and migration of, contaminated materials through use of a native soil cover	Allows significant amount of precipitation to infiltrate to the landfill Does not meet RCRA capping criteria
- Single Barrier Cap	Uses a cap constructed of a single layer of various media, such as clay, flexible membrane liner, asphalt, or concrete-based material	Allows for some infiltration Does not meet RCRA capping criteria
- Composite Barrier Cap	Uses multiple layer design Media include soil and synthetics	Minimizes infiltration of precipitation Creates relatively high volume of clean runoff Meets RCRA capping criteria

The composite barrier cap will be designed to meet the closure requirements of 40 CFR Part 265 and 6 CCR 1007-3, Section 265 The regulation states that at final closure of the landfill the owner or operator must cover the landfill or cell with a final cover designed and constructed to

- Provide long-term minimization of migration of liquids through the closed landfill,
- Function with minimum maintenance,
- Promote drainage and minimize erosion or abrasion of the cover,
- Accommodate settling and subsidence so that the cover's integrity is maintained, and
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present

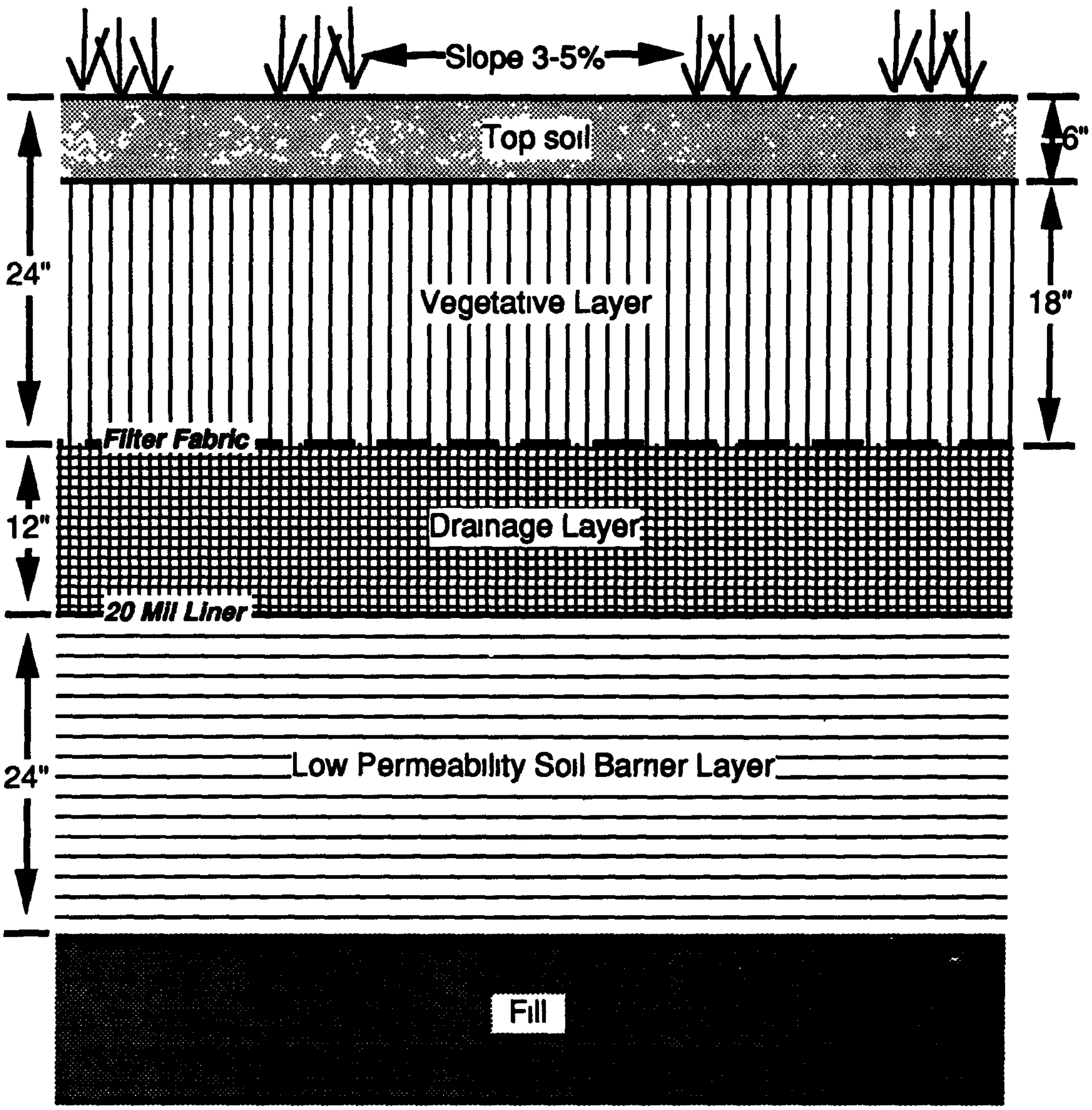
The recommended design (EPA 1989a) to meet these performance specifications consists of three layers as shown in Figure 4-1

- Vegetative/topsoil layer designed to promote plant growth and thus ensure stability and minimize erosion
- Drainage layer or geo-net to promote lateral flow of water and thus minimize infiltration to the low permeability soil
- Low permeability soil barrier layer to provide maximum protection from infiltration into the landfill and thus minimize leachate production and contamination of groundwater

The vegetative/topsoil layer is designed to minimize erosion without causing ponding The layer consists of 24 inches of soil, including 6 inches of topsoil Medium textured soils with minimum compaction are used for growth of locally adapted perennial plants requiring little or no maintenance Once developed, vegetation must limit erosion to 2 tons per acre per year The final slope, taking into account settling and subsidence, should be 3 to 5 percent

The drainage layer is designed to remove any water that has infiltrated through the vegetative/topsoil layer Water is transported off the cap to the drainage system. The standard design consists of drainage material with a hydraulic conductivity of $1x10^{-2}$ centimeters per second (cm/sec) and a minimum slope of 3 percent The drainage layer is composed of 12 inches of granular material or a geosynthetic A filter layer should be included over the drainage layer to prevent migration of fines from the top layer In addition, if a geosynthetic is used for the drainage layer, a geosynthetic bedding may be required to minimize slippage between the drainage layer and the underlying liner and to prevent the liner from deforming into the net of the drainage layer

The low permeability soil barrier layer is designed to provide long-term minimization of infiltration into the landfill The layer is made up of a flexible membrane liner (FML) underlain by compacted soil The minimum thickness for the FML is 20 mil, although thicknesses of 40 to 60 mil are recommended A minimum 3 percent slope is required after allowance for settlement



NOTE:
Thickness of layers shown reflects the minimum thickness allowed.

Not To Scale

U S DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

Typical Composite Barrier Cap

Technology Literature Research	Operable Unit No 7
Date April 1994	Figure 4-1

M\EEC\COMPOSITE BARRIER.3 MDW\3-24\94

The integrity of the liner is highly dependent on proper installation Subgrade compaction, field seaming, and possible wrinkles and folds should be carefully monitored during construction

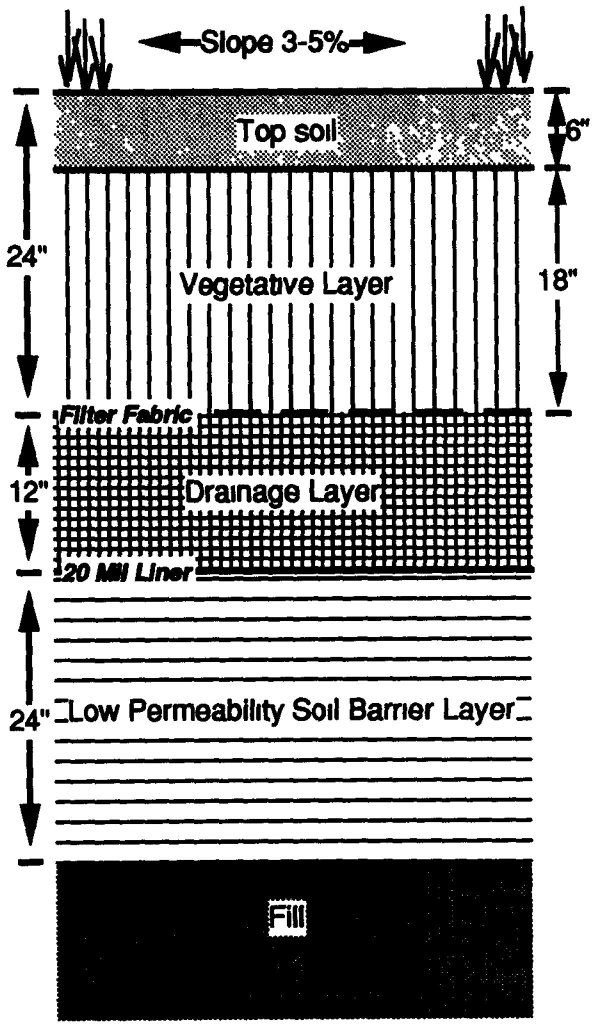
Underneath the FML is a 24-inch-thick layer of compacted soil, constructed in 6 inch lifts The hydraulic conductivity must be 1×10^{-7} cm/sec or less The layer must be below the maximum depth of frost penetration to prevent damage due to freeze and thaw conditions During design, consideration should be given to the potential for desiccation in a semi-arid region An FML or bentonite mat are possible options

Compaction of the landfill solids may be necessary prior to cap placement based on the potential for differential settlement Estimations of the number and size of voids within the landfill may be based on visual observations, daily operational procedures, analysis of cone penetration tests (CPT), and results of additional fieldwork

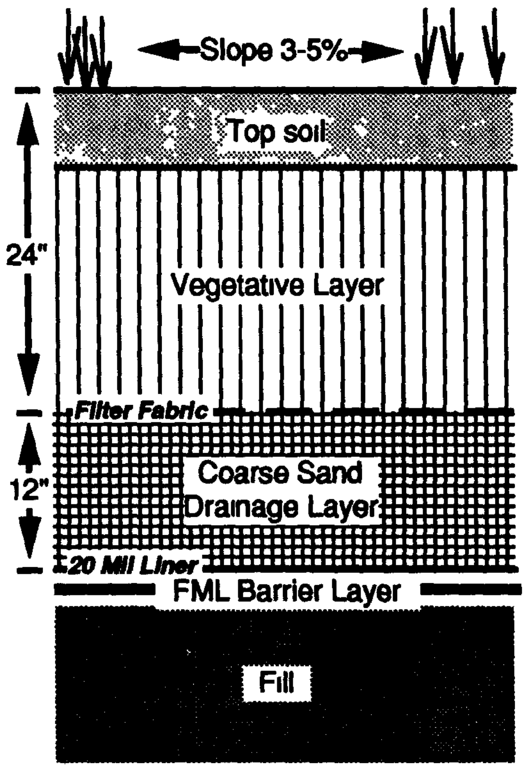
Potential borrow sources will be evaluated during alternative development and preliminary design The Hydrological Evaluation of Landfill Performance (HELP) model will be used verify effectiveness of materials and layer thickness Alternative capping options are shown in Figure 4-2

Landfill precompaction can be accomplished using dynamic compaction or grout injection Dynamic compaction consists of dropping heavy weights from heights thereby compacting the soil in place This involves accurate prediction of energy and impact spacing requirements and careful control of site operations Grout injection involves injection of a low-viscosity grout slurry, which saturates and solidifies a layer within the vadose zone This technique is limited by geologic soil type and water level and is difficult to perform at shallow depths Addition of a geosynthetic layer, as discussed below, is another option

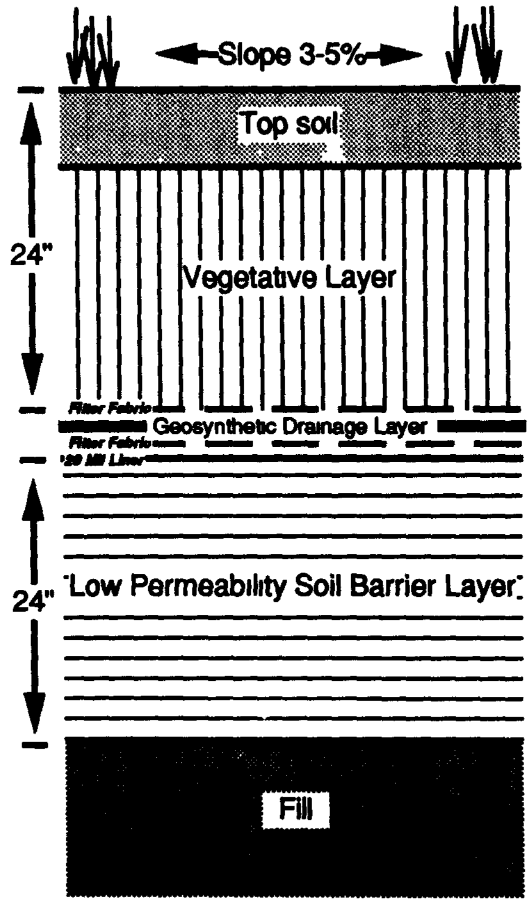
Additional layers may be added during alternative development and design to address issues such as gas venting, burrowing animals, and differential subsidence Typical cap designs with optional layers are shown in Figure 4-3 The gas venting layer is discussed under gas technologies in Section 4 3 1 A biotic barrier layer would prevent burrowing animals such as prairie dogs from damaging the cap Another optional layer



Composite Barrier



Composite Barrier with FML Barrier Layer



Composite Barrier with Geonet Drainage Layer

NOTE:
Thickness of layers shown reflects the minimum thickness allowed

Not To Scale

U S DEPARTMENT OF ENERGY Rocky Flats Plant, Golden, Colorado	
Optional Materials for Composite Barrier	
Technology Literature Research	Operable Unit No 7
Date April 1994	Figure 4-2

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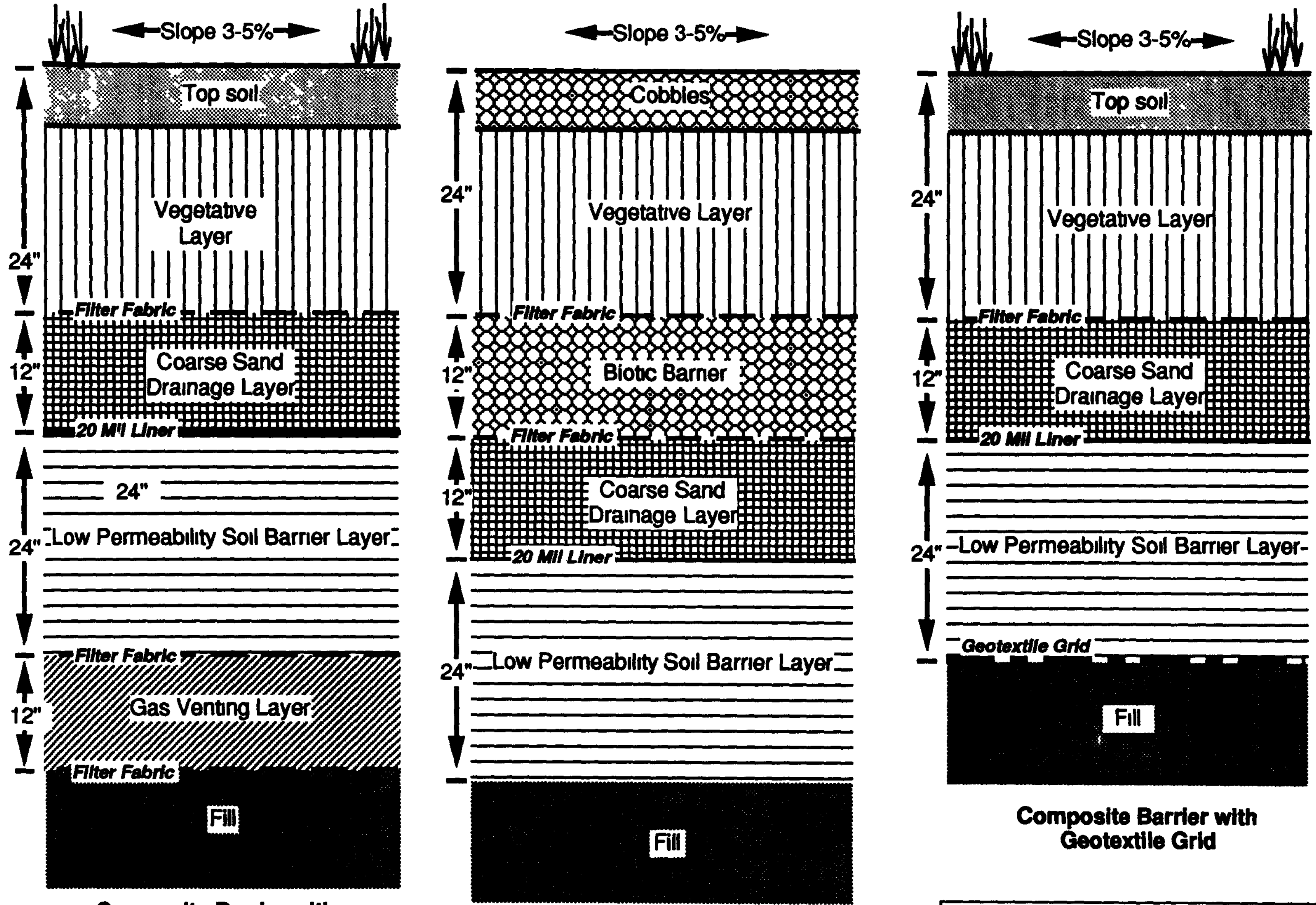

Composite Barrier with Gas Venting Layer

Composite Barrier with Biotic Barrier Layer

Composite Barrier with Geotextile Grid

NOTE:
Thickness of layers shown reflects the minimum thickness allowed

Not To Scale

M\EEC\COMPOSITE BARRIER 7 MDW\3 24\94

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U S DEPARTMENT OF ENERGY Rocky Flats Plant, Golden, Colorado	
Optional Layers for Composite Barrier Caps	
Technology Literature Research	Operable Unit No 7
Date April 1994	Figure 4 3

that should be consıdered durıng desıgn ıs a geotextıle grıd to provıde structural support Thıs layer would address problems due to dıfferentıal settlıng because of the nonhomogeneous nature of the fill CPT scans taken at OU 7 durıng the Phase I RFI/RI field ınvestıgatıon ındıcate the presence of voıds and uncompacted materıals ın the landfill

4.3 Landfill Gas Control - Presumptive Remedy

Collectıon and treatment (ıf requıred) are the presumptıve remedıes for landfill gas Landfill gas ıs generated by decomposıtıon of organıc materıals, chemıcal reactıons, and vaporızatıon of lıquıds ın the landfill As dıscussed ın Sectıon 2 2, the OU 7 landfill gas contaıns prımarıly methane, whıch ıs not regulated Technology optıons for gas collectıon and treatment are presented ın Table 4-3

4 3 1 Collectıon

The landfill cap (dıscussed ın Sectıon 4 2 as part of the presumptıve remedy) wıll prevent uncontrolled releases of landfill gas to the atmosphere However, gas may buıld up under the cap and potentıally cause damage to the cap, hınder growth of vegetatıon, and ıncrease lateral mıgratıon Gas collectıon systems are desıgned to control mıgratıon of gases to prevent these problems There are two maın types of landfill gas collectıon systems passıve and actıve

A passıve collectıon system controls gas mıgratıon by provıdıng a preferentıal pathway for gas flow wıthout use of mechanıcal equıpment Gas ıs vented to the atmosphere ın a controlled manner Because no mechanıcal equıpment ıs used, capıtal and operatıon and maıntenance (O&M) costs are low However, the potentıal exısts for odor problems due to release of gas to the atmosphere There are three types of passıve systems pıpe vents, ventıng trenches, and permeable layers

Pıpe vents are vertıcal or lateral perforated pıpes surrounded by a layer of coarse gravel They are strategıcally placed to release pressures ın areas where gas ıs collectıng Pıpe vents are consıdered effectıve at reducıng pressures, although they have a small zone of ınfluence

Ventıng trenches are backfilled wıth gravel to provıde a pathway for gases Typıcal trenches are 4 feet wıde, up to 20 feet deep, and surround the waste sıte A barrıer system may be added to the outsıde wall of trenches to control lateral flow Ventıng

Table 4-3
OU 7 Technology Literature Research
Identification and Initial Screening of Remedial Technologies
Landfill Gas - Presumptive Remedy

Response Action • Remedial Technology - Process Option	Description	Comments
Collection/Removal Actions		
• **Passive**	Control migration of gases by altering the path of flow using high permeability, preferential pathway Flow offsite may be limited by low permeability barriers	Gas recovery for treatment not possible with passive systems May be limited by impermeable layers Potential odor problems Low energy Low maintenance
- Vent Pipes	Pipe vents are used for venting gas at points where it is collecting and building up pressure	Small zone of influence
- Venting Trench	Gravel trenches form a path of least resistance for gases	Depth limited to 20 ft Gases may migrate underneath
- Permeable Layer	High permeability layer provides preferential pathway for gases	Less effective in areas of high rainfall or prolonged freezing temperatures Most applicable near sources of gases
• **Active**	Control gas migration by extraction/collection via vacuum blowers or compressors	More efficient than passive May be limited by impermeable layers Not sensitive to freezing or saturation of surface or cover soils Gas recovery for treatment possible
- Extraction Wells	Gases drawn into a perforated pipe surrounded by permeable material by blower or compressor system	Good for deep landfills
- Extraction Trench	Gases drawn into perforated pipe in gravel-filled trench by blower or compressor system	Depth limited to 20 ft
- Permeable Layer	Gases drawn into permeable layer by blower or compressor system	Perched water table or impermeable geological layer limits technology Less effective in areas of high rainfall or prolonged freezing temperatures Most applicable near sources
Treatment Actions		
• **Thermal**	Use of heat to destroy contaminants	
- Open flare	Gases combusted by exposure to open flame	Lower combustion efficiency than enclosed flame Open flame may cause public concern
- Enclosed Flare	Gases combusted by exposure to flame within a flame enclosure or stack	For destruction of vapors that are easily burned and have no harmful products of combustion May require supplementary fuels for a continuous burn

trenches are generally considered more effective than pipe vents, however, the depth is limited to 20 feet, and gases may migrate underneath the trench

A highly permeable layer may also be used to provide a preferential pathway for gas migration This layer is often incorporated into cap design The gas venting layer underlies the low permeability layer (Section 4 2) A typical design consists of 12 inches of sand or geosynthetic with a minimum hydraulic conductivity of $1x10^{-3}$ cm/sec This layer is sandwiched by geotextile filter fabric, which allows gas to migrate into the venting layer while preventing fines that may block flow A typical cap configuration with the gas venting layer is shown in Figure 4-2 High permeability layers are generally used in conjunction with some sort of venting system Venting systems must be carefully designed to minimize the number of penetrations into the cap and prevent infiltration along the vents

In active gas collection systems, blowers or compressors are used to establish a pressure gradient to draw gas into the system The gas is collected, which then allows for subsequent odor control, treatment, and recovery Active gas removal options include extraction wells, extraction trenches, and permeable layers Each is similar to its passive counterpart except that a vacuum actively pulls the gas into the system, providing a wider zone of influence Extraction wells are the most common method and are able to draw gases from 100 to 300 feet

4 3 2 Treatment

The landfill gas contains primarily methane and carbon dioxide Modeling will be performed to estimate air emissions If data show that treatment of the landfill gas is necessary for OU 7, the main technology is flaring This technology treats gases by combustion in an open or enclosed flame Open flares are common at municipal landfills Enclosed flares address the potential for public concern over a visible flame and provide increased efficiency Enclosed flares are the most common method of gas treatment at CERCLA sites For gas treatment by enclosed flare, an active gas collection system (Section 4 3 1) is connected to a main header, which conveys the gas to the enclosed flare system The system consists of a stack with a burner assembly at the base Landfill gas is fed into the stack and ignites A supplemental fuel is required to maintain combustion if methane content is below 20 percent or if higher temperatures are required for contaminant destruction

The design of an enclosed flare system is based on the methane content, other contaminants present, gas production rates, and gas collection rates Adjustments to flow rates, residence time, and operating temperature are used to maintain maximum efficiency The system should be designed with maximum flexibility because operating parameters will change over time

4.4 Source Area Groundwater Control - Presumptive Remedy

One component of the presumptive remedy is source area groundwater control If appropriate, this component may be accomplished in a number of ways, including pump and treat, slurry walls, etc These potential technologies may then be combined with other components of the presumptive remedy to develop a range of containment alternatives suitable for site-specific conditions

4 4 1 Containment and Collection

Containment of groundwater is a common component of the overall remediation of sanitary landfill sites Typically, groundwater is diverted at the perimeter to prevent clean water from entering the landfill and manage the migration of leachate and is extracted downgradient to capture the contaminated groundwater plume Containment and collection actions for groundwater and leachate are presented in Table 4-4

Contaminated groundwater that has been extracted may have to be temporarily stored before treatment This can be accomplished by installing onsite storage tanks or lagoons Existing storage tanks north of OU 4 could be utilized if sufficient capacity is available and mixing of incompatible wastes is avoided

Vertical barriers, such as slurry walls, are viable technologies for groundwater containment The most common vertical barrier used at landfill sites is a soil-bentonite slurry wall, which reduces the horizontal permeability of soil Slurry walls can be excavated a limited distance into rock material (i e , keyed into bedrock) but are not generally installed in rock Vertical barriers could be improved at OU 7 to prevent clean groundwater from entering the landfill and becoming contaminated by leachate

Table 4-4
OU 7 Technology Literature Research
Identification and Initial Screening of Remedial Technologies
Groundwater and Leachate - Presumptive Remedy

Response Action • **Remedial Technology** - Process Option	**Description**	**Comments**
Containment Actions		
• **Hydraulic Controls**		
- Subsurface Drains	Underground, gravel-filled trenches used to intercept and channel groundwater or leachate to a sump, wet well, or surface discharge	A groundwater intercept and leachate collection trench exists at OU 7 but is only partially effective
- Injection Wells	Facilitate groundwater movement by injecting clean water into uppermost aquifer	Potential for increasing the volume of contaminated groundwater
- Extraction Wells	Wells installed to capture leachate or groundwater Pump rate must be high enough to ensure flow toward wells	Wells could be installed within the landfill but not into bedrock
• **Physical Controls**		
- Slurry Walls	Low permeability, fixed walls installed in a trench to contain or divert flow of groundwater and/or leachate	Provides consistent barrier to lateral flow Existing slurry walls divert groundwater east of existing collection trench
- Grout Curtains	Fixed, impermeable barriers formed by injecting grout into the ground through well points	Difficult to completely seal a large area
- Sheet Piling	Thin, impermeable barrier to groundwater/leachate flow constructed by driving lengths of interlocking steel into the ground	Difficult to install in rocky soils or at depths greater than 30 feet
- Bottom Sealing	Inject grout to form a horizontal barrier beneath the site to prevent downward migration of contaminants	Not feasible due to natural clay underlying the landfill Does not prevent horizontal movement
Collection Actions		
• **Hydraulic Collection**		
- Subsurface Drains	Groundwater or leachate is collected in a trench containing gravel and perforated pipe, then transferred by pumping or gravity flow	Existing subsurface drain collects leachate but is in need of improvement
- Extraction Wells	Contaminated groundwater or leachate is pumped to the surface using a series of wells drilled through the uppermost aquifer	Extraction wells could be installed for leachate and groundwater collection However, leachate generation in the landfill is minimal such that wells may not be needed

Response Action • Remedial Technology - Process Option	Description	Comments
Treatment Actions		
• **Physical Treatment**		
- Solvent Extraction	Separate components of a solution by mixing with a solvent that has an affinity for the preferred contaminant	Solvent must be recovered from treated effluent, used for recovery of valuable products No further research recommended
- Flocculation	Agglomerate small, unsettleable particles into larger, more settleable particles by mixing with polymers	Use for removal of suspended solids, removes heavy metals when used in conjunction with precipitation and sedimentation
- Sedimentation	Uses gravity to allow suspended solids in an aqueous solution to settle	Removes settleable material, high potential for leachate treatment, use in conjunction with precipitation
- Centrifugation	Solids in a fluid are separated by rapidly rotating the fluid in a vessel	Accelerated sedimentation used in conjunction with flocculation
- Carbon Adsorption	Dissolved organics are adsorbed onto carbon as contaminated water is passed through column	Applicable to a variety of organics, well-developed, spent carbon must be disposed or regenerated, currently in use at OU 2
- Ion Exchange	Remove heavy metals by using synthetic resins that exchange a less harmful ion for a heavy metal ion in solution	Removes dissolved inorganics, including radionuclides, low energy, less efficient for high concentrations of inorganics, best as a polishing stage currently in use at OU 1
- Reverse Osmosis	Separate dissolved materials by high-pressure filtration through a semi-permeable membrane	Best as polishing stage for dissolved heavy metals, requires pretreatment for solids removal, requires extensive bench/pilot tests
- Air/Steam Stripping	Air or steam is used to strip volatile organics from liquid, concentrating them in the condensate	Air stripping is a possible pretreatment for adsorption, possible air emissions problems, steam stripping applicable to high concentrations of volatile compounds
- Filtration	Precipitated solids containing metals are filtered out	Pretreatment or polishing technique for suspended solids removal
- Ultrafiltration	Separate high molecular weight dissolved materials using low pressure over a semi-permeable membrane	Applicable for high molecular weight dissolved materials, possible polishing step, used for product recovery
• **Chemical Treatment**		
- Dechlorination	Chlorinated compounds are broken apart by the addition of chemical reagents	Developed primarily for PCB-contaminated wastes, applicability to other chlorinated compounds still in developmental stage, no further research recommended
- Neutralization	Use pH adjustment to render an acid or caustic waste non-corrosive	Can be used in conjunction with other treatment processes
- Precipitation	Remove dissolved heavy metals by altering the ionic equilibrium to produce insoluble precipitates	Use in combination with coagulation, flocculation, sedimentation and/or filtration, currently in use at OU 2

Response Action • Remedial Technology - Process Option	Description	Comments
Treatment Actions (continued)		
- Oxidation	Destroy organics by adding an oxidant for oxidation of the compounds to less toxic compounds	May also reduce toxicity of some inorganics, oxidants include ozone and hydrogen peroxide
- Electrolytic Process	Cathodes and anodes are immersed in water using a DC current to plate out dissolved metals	Applicable for heavy metals, not organics, can operate at neutral pH
- Reduction	Reduce toxicity or enhance precipitation of metals by transferring electrons from a reducing agent to the contaminant	Potential for introducing hazardous ions into solution Best for reduction of hexavalent chromium
- Hydrolysis	Displacement of a functional group on an organic molecule with a hydroxyl group from water	Requires pH, temperature adjustment, potential formation of toxic by-products
- Ultraviolet (UV) Oxidation	Contaminants are oxidized and dechlorinated using oxidizers such as hydrogen peroxide or ozone in the presence of ultraviolet light	Use for low-concentration organics, especially chlorinated hydrocarbons, dissolved minerals in water reduce effectiveness of UV light, currently in use at OU 1
• **Biological Treatment**		
- Anaerobic Reactors	Microbes break down organics under anaerobic conditions	Suitable for high-concentration wastewaters only No further research recommended
- Contact Stabilization	Biomass assimilates organics in one tank, digests in second tank, then is recycled	Suitable for high-concentration wastewaters only No further research recommended
- Waste Stabilization Ponds	Break down organics by aerobic oxidation and hydrolysis in a lagoon Mixing and aeration provided by wind and algal action	Not suitable for cold climates No further research recommended
- Land Application	Direct, controlled application of biodegradable wastewater onto land for microbial decomposition	Potential for soil contamination due to buildup of radionuclides and metals No further research recommended
- Permeable Treatment Beds	Trenches placed perpendicular to groundwater flow are filled with a reactive, permeable medium to behave as an underground reactor	Short life, too many potential problems No further research recommended
- Activated Sludge	Break down organics by aerobic oxidation and hydrolysis in an aboveground aerated tank, recirculate biomass	Not suited for low organic concentrations, some metals and organics may be toxic to organisms, possible air emissions problems
- Extended Aeration	Similar to activated sludge but with a larger aeration basin for greater aeration of biomass	Not suitable for groundwater with low organic concentrations, possible air emissions problems
- Engineered Wetlands	Contaminants are absorbed in a monitored wetlands environment	Potentially applicable as a polishing stage for treated groundwater/leachate

Response Action • **Remedial Technology** - **Process Option**	**Description**	**Comments**
Treatment Actions (continued)		
- Trickling Filter	Break down organics aerobically by spraying liquid over bed of rock in which microorganisms are grown	Requires uniform flow rate, temperature, and waste composition, possible air emissions problems
- Aerated Lagoon	Break down organics by aerobic oxidation and hydrolysis in a lagoon with mechanical aerators	Use in conjunction with a clarifer, some metals and organics may be toxic to organisms, possible air emissions problems
- Rotating Biological Contactor	Break down organics by passing water through a series of rotating discs coated with biomass and partially exposed to atmosphere	Pretreatment may be required Some metals and organics may be toxic to organisms
- *In situ* Bioremediation	Extract groundwater, add nutrients and oxygen, and reinject upgradient Provide *in situ* aeration	Aquifer hydraulic conductivity may be low, problems if fractured bedrock exists Requires adequate hydraulic control
- Submerged Fixed Film Reactor	Break down organics with biomass on a submerged medium with forced aeration from below	Not suitable for metals or radionuclides
- Powdered Activated Carbon	Activated sludge system combined with powdered activated carbon maintained in the reactor	Treats wider range of organics than typical activated sludge
- Sequencing Batch Reactor	Aeration digestion and settling take place in two parallel reactors	Not suitable for low concentrations of organics
- Fluidized Bed Reactor	Contaminated water and air flow in an up-flow pattern through a medium consisting of loose particles that become fluidized	Not suitable for low concentrations of organics
Disposal Actions		
• **Onsite**		
- Groundwater Reinjection	Inject treated groundwater or leachate back into aquifer using injection wells, infiltration galleries, etc	Potential for dilution or flushing out additional contamination Avoids NPDES permit restrictions
- Discharge to Surface Waters	Discharge to No Name tributary to Walnut Creek after treatment	Requires discharge below Safe Drinking Water Act MCLs Possible NPDES permit restrictions
• **Offsite**		
- TSD Facility	Transport to an offsite treatment, storage, and disposal facility	Not feasible due to possible presence of radionuclides in water
- Discharge to Publicly Owned Treatment Works (POTW)	Discharge to Rocky Flats wastewater treatment plant for polishing	May cost less than operation of an onsite polishing system influent must be free of hazardous constituants

A groundwater collection system may be needed to extract contaminated groundwater downgradient from the landfill The two types of groundwater collection systems used most often are extraction wells and subsurface drains Subsurface drains consist of underground, gravel-filled trenches generally equipped with tile or perforated pipe for greater hydraulic efficiency The drains can be used to collect contaminated groundwater and transport it to a central treatment area Drains are typically used in geological units of low permeability Extraction wells are used more frequently than subsurface drains Well diameter, flow rate, and spacing are determined based on the desired groundwater capture zone and the hydrogeologic characteristics of the aquifer Groundwater collection systems can be used for both contaminated groundwater and to create a hydraulic barrier to prevent movement

4 4 2 Treatment

Treatment actions for contaminated groundwater are also presented in Table 4-4 Treatment of contaminated groundwater can be accomplished using physical, chemical, or biological technologies Typically, a combination of several technologies is employed They may be used for pretreatment, for the removal of a particular class of contaminants, or as a final polishing stage before discharge There are two existing onsite treatment facilities The OU 1 facility utilizes ultraviolet (UV) oxidation and ion exchange to treat collected groundwater and the OU 2 facility utilizes precipitation, filtration, and carbon adsorption to treat groundwater seeps and surface water

4 4 2 1 Physical Treatment

Physical treatment processes alter the physical structure of a contaminant to reduce the constituent's toxicity, mobility, or volume Physical processes such as gravitational settling, filtration, and adsorption are used to separate hazardous compounds from the contaminated media

The solvent extraction process is used to separate components of a solution and recover valuable products, and no further research is recommended on this process (Table 4-4)

Flocculation

The processes of coagulation and flocculation are employed to separate suspended solids from water whenever their natural subsidence rates are too slow to provide effective clarification Particles in suspension are stabilized by negative surface charges, causing them to repel each other Because this prevents these charged particles from colliding to form larger "flocs," they do not settle very rapidly Coagulation is the destabilization of these colloids by neutralizing the forces that keep them apart This is accomplished by adding chemical coagulants such as aluminum salts, iron salts, or polyelectrolytes and applying mixing energy Precipitation, clarification, sludge thickening, and dewatering depend on coagulation and flocculation for their success

Sedimentation

Sedimentation is the process where particles suspended in a liquid are made to settle by means of gravitational and inertial forces acting on the suspended particles and on the liquid itself Sedimentation using gravitational forces is accomplished in a clarifier, producing an effluent with lower suspended solids content

Centrifugation

Sedimentation using inertial force is accomplished in a centrifuge, which is commonly used to thicken and dewater sludges Centrifugal forces cause solids to move to the outside of the centrifuge, while the water remaining on the inside is drawn off

Carbon Adsorption

Adsorption using granular activated carbon (GAC) is highly applicable to most high-molecular-weight organics It is an effective and reliable means of removing low-solubility organics over a broad concentration range Contaminated water is passed through a column of GAC, which selectively adsorbs the hazardous constituent. When the activated carbon has been used to its maximum adsorptive capacity, it is then removed for disposal or regeneration Carbon adsorption is being utilized at the OU 2 groundwater treatment facility

The first step in evaluating activated carbon adsorption for a specific application is to assess its feasibility utilizing a liquid phase adsorption isotherm test An adsorption isotherm test is a batch test designed to demonstrate the degree to which a particular dissolved organic compound (adsorbate) is adsorbed on activated carbon (adsorbent) The data generated show the distribution of adsorbate between the adsorbent and solution phases at various adsorbate concentrations From the data, a plot of the amount of impurity remaining in solution at constant temperature can be generated

The adsorption isotherm test should provide an estimate of how often testing should be performed The amount of the contaminant in the column effluent is plotted against the volume throughput of each column The result is a series of curves, each curve representing a column The curves obtained are termed breakthrough curves, as they represent the concentration or amount of contaminants present in the effluent (which have passed through the column unabsorbed)

After a contact time has been established, and the evaluation of the breakthrough curves has indicated whether a single bed or a staged system is preferred, the designer can select the adsorber configuration If the breakthrough curve is steep, usually in the case of single or similar contaminants, the single fixed bed downflow adsorber is the most economical choice The contact time will establish the total carbon volume as noted above By weighing considerations such as flow and carbon volume, the designer will select the vessel size and whether multiple units (operated in parallel) may be required The fixed bed downflow system has the added advantage of operating as a media filter with elimination of suspended solids in the effluent

Another form of the staged bed system is the upflow moving bed design This system may be of use when long contact times are required and the breakthrough curve indicates that even a two-stage system is insufficient to provide economical use of the carbon

Ion Exchange

Ion exchange is a reversible process in which the interchange of ions occurs between a solution and an essentially insoluble solid in contact with the solution Toxic ions are removed from the aqueous phase by being exchanged with the relatively non-toxic ions held by the ion exchange material Synthetic resins or zeolite are commonly used as exchange material The ion exchange process may be operated using a batch or continuous technique and is effective in removing dissolved metal and radionuclide ions. Ion exchange is being utilized at the OU 1 groundwater treatment facility

Reverse Osmosis

Reverse osmosis involves filtering contaminated water through a semi-permeable membrane at a pressure greater than the osmotic pressure caused by the dissolved materials in the water The membrane is typically fabricated in the form of a plane or cylinder Operating pressures range from atmospheric to 1,500 pounds per square inch (psi) This technology is used to remove dissolved organic and inorganic materials and to reduce the concentration of soluble metals, total dissolved solids (TDS), and total organic carbon (TOC)

Air/Steam Stripping

Air stripping and steam stripping are mass transfer processes In a packed tower aeration system, air and water are run counter-current through a random or structured media The media enhances air/liquid contact by breaking the water into thin films and exposing a large amount of liquid surface area to air The more surface area exposed, the greater the opportunity for transfer of volatile organics out of the water and into the passing air

In steam stripping, steam is admitted through a perforated pipe in the bottom of a packed column as contaminated water flows downward through the column The steam provides the heat of vaporization to the waste All vapor blown through the liquid is then passed out of the unit with the VOCs, and the nonvolatile impurities remain in the column The vapor is passed through a condenser to return it to the liquid state, and the stripped product is collected in a condensate receiver

Filtration

Filtration can be used to remove suspended solids that are not typically removed by settling It can also be used as pretreatment for carbon adsorption, reverse osmosis, and other technologies requiring influent water with minimal amounts of suspended solids Filtration is commonly performed with a sand filter, which removes suspended solids by several mechanisms, including straining, adsorption, flocculation, and sedimentation Filtration is being utilized at the OU 2 groundwater treatment facility

Ultrafiltration

Ultrafiltration is a low-pressure membrane filtration process used to separate high molecular weight dissolved materials and colloidal materials A semi-permeable membrane (0 1 to 1 0 microns thick) is used to remove emulsified oils, metals, radionuclides, and proteins Pretreatment is required to remove suspended solids and free oil

4 4 2 2 Chemical Treatment

Chemical treatment methods include technologies that alter the chemical structure of a contaminant to reduce its toxicity, mobility, or volume Chemical and physical treatment technologies are frequently used in combination to produce the desired treatment results

The dechlorination process (Table 4-4) is limited primarily to polychlorinated biphenyl (PCB)-contaminated wastes, and no further research is recommended on this process

Neutralization

Neutralization involves combining either an acid or a base with a hazardous waste stream to adjust the liquid pH to acceptable levels Neutralization may be required as a pretreatment or post-treatment process Lime, calcium hydroxide, caustic, soda ash, and ammonium hydroxide are commonly used bases, sulfuric acid, hydrochloric acid, and nitric acid are commonly used acids Commercially available acids and bases are relatively low in cost

Precipitation

Chemical precipitation is a physical-chemical process in which a dissolved contaminant is transformed into an insoluble solid, facilitating its subsequent removal from the liquid phase by sedimentation or filtration The process usually involves adjustment of pH to shift the chemical equilibrium to a point that no longer favors solubility, addition of the chemical precipitant, and flocculation in which the precipitated particles agglomerate into larger particles Usually, metals are precipitated from solution as hydroxides, sulfides, or carbonates Precipitation is also used for the removal of radionuclides and is currently utilized at the OU 2 groundwater treatment facility

Oxidation

Oxidation processes involve the exchange of electrons between chemical species and produce a change in the oxidation (valence) state of the species involved Specifically, oxidation processes are referred to as oxidation-reduction (redox) reactions because one of the species involved gains electrons (reduction) and the other loses electrons (oxidation) This exchange of electrons will destroy organic compounds by breaking carbon bonds and creating new, smaller compounds Three chemical oxidants that are widely used in water treatment processes are chlorine, ozone, and hydrogen peroxide

Electrolytic Process

An electrolytic process uses cathodes and anodes that are immersed in a tank containing the contaminated water, while a direct current (DC) is imposed on the system The system is used to plate out dissolved metals, oxidize cyanide, or reduce chromium in wastewaters It is particularly applicable for high cyanide-bearing wastes Limitations are the form of the waste, the nonselective nature of the process, and the long process time.

Reduction

Chemical reduction involves the transfer of electrons from a reducing agent to the contaminant ITs major function is to reduce the oxidation state of a metal, thus render it non-toxic, and facilitate its precipitation Reduction is an effective treatment for hexavalent chromium, mercury, organic lead compounds, and chelated metals Reducing agents include sulfur dioxide, sulfite salts, or ferrous sulfate Introduction of foreign ions into the waste is a potential disadvantage with many of the reducing agents This process has little potential for organic waste streams

Hydrolysis

Hydrolysis is a chemical reaction of water with a contaminant in which hydrogen and hydroxyl (OH) are mixed with the contaminant, usually forming two or more new compounds Hydrolysis of organic compounds can result from a neutral reaction with water, or it can be catalyzed in the presence of an acid or a base A major limitation with hydrolysis is the possible formation of toxic byproducts

UV Oxidation

UV oxidation is the simultaneous oxidation of organic compounds (using ozone or hydrogen peroxide as oxidants) and exposure of those compounds to UV light It is effective in treating low concentrations of organics (especially chlorinated hydrocarbons) to below detection limits Effectiveness of this technology is limited by the presence of dissolved minerals or suspended solids, which impede UV light radiation UV oxidation using hydrogen peroxide (UV/peroxide) is being utilized at the OU 1 groundwater treatment facility

4 4 2 3 Biological Treatment

Biological treatment is the enhancement of natural processes of living organisms to bring about the decomposition of toxic and hazardous compounds Microorganisms (bacteria and fungi) can break down compounds into simpler substances by aerobic or anaerobic respiration, fermentation, and photosynthesis Native microorganisms may be used or special microorganisms may be introduced to address a particular contaminant or site condition Stable operating conditions are necessary, including pH, temperature, dissolved oxygen content, nutrients, microbial mix, and contaminants Changes in these conditions could upset the balance of the system or even be toxic to the microorganisms

In general, biological processes are the most cost-effective techniques for treating aqueous waste streams containing organic constituents They have been applied successfully at full scale to a variety of industrial and sanitary wastewaters Environmental impacts associated with biological processes are limited The greatest concern is the potential release of VOCs to the atmosphere as a result of aeration

Contaminated water may contain organic compounds that are not readily biodegradable Therefore, it is usually necessary to acclimate a biological system to the waste prior to routine operation of the process Moreover, contaminated water may contain compounds that are refractory and/or toxic to biological systems The presence of such compounds at high concentrations may preclude use of biological treatment or necessitate use of another treatment process in conjunction with biological treatment

For biological processes to function, several operational requirements must be satisfied Most notable, near neutral pH must be maintained and nutrient requirements (carbon, nitrogen, phosphorous, and trace elements) must be satisfied Sudden changes in loading (both concentration and flow) must also be avoided

Several biological treatment processes such as anaerobic reactors, contact stabilization, waste stabilization ponds, land application, and permeable treatment beds are not suitable for the OU 7 site and are not recommended for further research (Table 4-4)

Activated Sludge

Activated sludge processes break down organic wastes in aqueous streams by aerobic oxidation and hydrolysis, producing a liquid effluent and a concentrated biomass sludge First, aqueous wastes are pumped into a tank equipped with an aeration device A biomass sludge mixed with air or pure oxygen is then mixed into the tank The aerated sludge/waste mixture is then transferred to a clarifier, where the biomass sludge and treated aqueous waste are separated by sedimentation Treated effluent is discharged and a portion of the sludge is returned to the aeration unit to provide a continuous source of microorganisms Excess sludge must be treated and/or disposed

Extended Aeration

Extended aeration is similar to activated sludge, but the aeration basin is larger, thus extending the aeration of the bacteria Extended aeration is more stable, the larger tanks serve as internal equalization, and it produces less waste sludge Most "packaged plants" that can be purchased from vendors are extended aeration designs

Engineered Wetlands

Wetlands, under favorable conditions, have been shown to remove organic and inorganic nutrients and toxic materials from water that flows through them Treatment in wetlands may include settling out of sediments and chemicals sorbed onto sediments, denitrification and chemical precipitation, and mineral uptake by vegetation with subsequent burial in sediments when the plants die

Trickling Filter

A trickling filter is a fixed-film reactor in which contaminated water is pumped to the top of the reactor and distributed over the medium The water is broken up into thin films and trickles down through the medium Organic contaminants transfer into the bacterial film and degrade, while oxygen transfers through the thin film of water to the bacteria Waste byproducts (i e , carbon dioxide) transfer through the thin film of water into the atmosphere Trickling filters require very uniform waste composition, flow rate, and temperatures above freezing

Aerated Lagoon

A lagoon is equipped with an aeration device that provides movement of the aqueous waste to cause mixing with air The oxygen supplied by aeration is used by microorganisms to oxidize organic waste, producing carbon dioxide Algae use carbon dioxide for photosynthesis, which in turn provides more oxygen Lagoons can be used to polish biochemical oxygen demand (BOD) in effluent from activated sludge systems or trickling filters

Rotating Biological Contactor

A rotating biological contactor is a fixed-film reactor in which water enters in a plug-flow fashion The medium first rotates down into the water, where organic contaminants transfer to the bacteria The medium then rotates up into the atmosphere, a thin film of water forms on the medium, and oxygen transfers through the film of water to the bacteria Rotating biological contactor is considered the most energy-efficient oxygen transfer method for a biological treatment system

***In Situ* Bioremediation**

In situ biological treatment of groundwater involves the stimulation of biological growth in the contaminated zone to reduce semivolatile organic concentrations Microorganisms that can use some or all of the contaminants as substrates will normally exist in a contaminated environment The microorganisms are stimulated to increase their biological growth and consumption of contaminants through addition of essential nutrients Aerobic systems also require an oxygen source *In situ* treatment is highly dependent on geological and hydrological conditions The process is relatively inexpensive, but the design of the system requires site-specific engineering *In situ* bioremediation is generally not effective for inorganics

Submerged Fixed-Film Reactor

In a submerged fixed-film reactor, a plastic medium is placed in a reactor tank, and the water level is maintained above the height of the medium The bacteria grow on the plastic medium as in a fixed-film system, however, the water is in intimate contact with the film as opposed to passing through in thin films One submerged fixed-film system design can treat influent organic compounds at concentrations as low as 1 to 20 milligrams per liter (mg/l) Water enters the top of the tank and flows down through the medium in a plug flow pattern Small amounts of air are released below the medium · This reactor operates in a decay mode, where the bacteria are grown using a synthetic feed source The decay period during which groundwater is treated can last between six months to one year

Powdered Activated Carbon

In an activated sludge system, powdered activated carbon is maintained in the reactor to facilitate the removal of a wider range of organic contaminants

Sequencing Batch Reactor

The sequencing batch reactor design basically uses two tanks in parallel One tank is filled with contaminated water, then aerated until digestion of the organics by the bacteria is complete Aeration is then stopped, the bacteria is allowed to settle, and the treated water is decanted The two reactors switch back and forth to maintain a constant influent flow The advantages of a sequencing batch reactor are simplicity of operation and the variety of influent conditions that can be accommodated The main disadvantage for groundwater would be operation with low concentrations of influent organics

Fluidized Bed Reactor

A fluidized bed reactor is basically a submerged fixed-film type of design in which the medium is very small and loosely packed Water and air flow in an upflow pattern through the medium, fluidizing the bed Small packing allows for very high concentrations of bacteria that can be maintained within the reactor This design has advantages for high concentrations of organic compounds but has not widely been applied to full-scale installations

4 4 3 Disposal Actions

Onsite disposal of treated groundwater may be accomplished either by reinjecting it into the aquifer or by discharging to onsite surface waters Groundwater recharge is one of the most common methods for combining water reuse and effluent disposal Recharge using injection wells has been used to replenish groundwater supplies in many areas It also presents the advantage of avoiding National Pollutant Discharge Elimination System (NPDES) permit restrictions for discharge to surface waters

Depending on the location of the water treatment facility, the treated effluent may be discharged to No Name Gulch (East Landfill Pond outlet) or to the C2 pond, if the OU 1 treatment facility is used Treated groundwater from CERCLA remedial actions that is discharged to surface water must meet the substantive requirements of a NPDES permit, but would not have to meet the RCRA land disposal restriction levels because discharges to surface waters that meet the requirements of an NPDES permit are exempt from the RCRA land disposal restrictions (EPA 1988a)

Offsite disposal includes transporting contaminated groundwater to an offsite TSD facility or to a Publicly Owned Treatment Works (POTW) Either case is not feasible if radionuclides are present in the water Direct discharge to a POTW may be appropriate for waste streams that are amenable to treatment provided by the POTW More often, pretreatment will be required before discharge to the POTW

4.5 Leachate Control - Presumptive Remedy

Collection and treatment of leachate to prevent exposure to contaminated leachate seeps and leaching to groundwater or surface water is part of the presumptive remedy Leachate from landfills is a product of natural biodegradation, infiltration of precipitation, and migration of groundwater through the waste Landfill leachate is typically high in BOD, chemical oxygen demand (COD), and heavy metals

4 5 1 Containment and Collection

The function of a leachate collection system is to minimize or eliminate the migration of leachate away from the solid waste unit Most containment and collection technologies for leachate are similar to those for groundwater discussed in Section 4 4 1 If leachate is to be controlled at a seep, other technologies are potentially applicable These generally include surface containment and collection systems such as small collection ponds, dikes, berms, and pumping to storage and/or treatment

4 5 2 Treatment

Leachate from sanitary landfill sites may have high BOD, COD, and inorganics concentrations that may vary over time In addition, the leachate at OU 7 has concentrations of metals, radionuclides, VOCs, and SVOCs that are above background Leachate chemical composition is similar to that of groundwater because they are hydraulically connected Treatment technologies to be considered for landfill leachate, therefore, are similar to those for groundwater treatment, as discussed in Section 4 4 2

4 5 3 Disposal

Disposal actions for leachate are similar to those described in Section 4 4 3 for groundwater

4.6 Surface Water

Generally, surface waters such as large ponds, rivers, or streams are not treated at sanitary landfill sites However, in situations where small onsite ponds exist, it may be viable to collect and treat contaminated surface water Management of surface waters in these instances will likely be accomplished in conjunction with contaminated groundwater and leachate because they exhibit similar characteristics and are hydraulically connected Institutional controls, containment and collection, and treatment actions for surface water are presented in Table 4-5

4 6 1 Institutional Controls

The primary institutional control for surface waters at OU 7 is the restriction of access to the East Landfill Pond Existing access restrictions include the perimeter fence around the Rocky Flats site and fencing around the landfill itself (Section 4 2) The existing landfill fence, however, does not completely surround the East Landfill Pond Additional fencing may be required to restrict access by humans and wildlife to any part of the pond

4 6 2 Containment and Collection

Containment of surface waters at the site is being accomplished in two ways Surface water diversion ditches redirect offsite surface waters around the landfill, collect runoff from the landfill, and return them to the natural drainage downstream from the East Landfill Pond The pond itself does not discharge, instead, evaporation of pond water is enhanced by periodically spraying the water onto the embankments above the pond

If the pond water is required to be collected for treatment, the most likely collection action will be pumping directly to existing holding tanks approximately one-quarter mile to the south

Table 4-5
OU 7 Technology Literature Research
Identification and Initial Screening of Remedial Technologies
Surface Water

Response Action • Remedial Technology - Process Option	Description	Comments
Institutional Controls		
• **Access Restrictions** - Fencing	Provide sufficient fencing around the landfill pond to prevent access by humans and wildlife	Existing chain-link fence only restricts access to western half of pond, does not extend to edge of water
• **Public Education**	Increase public awareness of site conditions and remedies through written notices, meetings, and news releases	The draft IM/IRA decision document will be available for public review and comment
Containment Actions		
• **Hydraulic Controls** - Enhanced Evaporation	Surface water is pumped and sprayed into the atmosphere to increase the amount of water exposed to evaporative forces	Existing spray evaporation system sprays water over land around pond, possible contamination of soils may result
• **Physical Controls** - Diversion Ditches	Construct ditches that divert surface water runoff around contaminated area	Existing ditches divert surface water around landfill and pond, runoff from landfill cap may tie in with existing ditches
- Dams	Earth or concrete structures contain surface water, allowing controlled releases and facilitating settlement	Existing earth dam prevents surface water generated onsite from flowing offsite
Collection Actions		
• **Hydraulic Collection** - Direct Pumping	Pump water through temporary pipeline directly to treatment facility	May be impractical if existing OU 1 and OU 2 treatment facilities are to be utilized
- Holding Tanks	Pump water to holding tanks north of OU 4 or to newly constructed tanks or lagoons and store for eventual treatment or discharge	Possibly the quickest way to remove pond water to facilitate remediation of pond sediments
Treatment Actions		
• Refer to Table 4-4 Treatment Actions		

4 6 3 Treatment

The concentratıons of contamınants wıll lıkely be more dılute than leachate or groundwater and may requıre only mınor polıshıng Treatment actıons for surface water are ıncluded ın the lıst of treatment actıons for groundwater and leachate presented ın Table 4-4

4 6 4 Dısposal

Dısposal technologıes for surface water are sımılar to those for groundwater and are descrıbed ın Sectıon 4 4 3

4.7 Spray Area Soils/Pond Sediments

4 7 1 Instıtutıonal Controls

Instıtutıonal controls are nonengıneerıng methods of lımıtıng the use of or access to a desıgnated area Exıstıng ınstıtutıonal controls for OU 7 are dıscussed ın Sectıon 4 2 Technology optıons are presented ın Table 4-6 All of the technologıes are consıdered technıcally feasıble Future use restrıctıons wıll be addressed on a sıtewıde basıs The approprıateness of addıtıonal access restrıctıons ıs dependent on other remedıal actıons taken and wıll be addressed further durıng alternatıve evaluatıon

4 7 2 Contaınment Actıons

Contaınment actıons provıde a means by whıch contamınant mıgratıon ıs mınımızed or elımınated Contaınment actıons for soıls and sedıments are outlıned ın Table 4-6 and ınclude placement of a constructed cap over the contamınated areas and surface controls

4 7 2 1 Cap

A cap wıll mınımıze exposure and reduce ınfıltratıon, and surface controls wıll control runoff and erosıon. The type of contamınatıon and subsequent treatment (ıf necessary) wıll determıne whıch cappıng method wıll be most approprıate for the soıls and sedıments If the soıls and sedıments are not contamınated, rendered non-characterıstıc, or can be delısted after treatment, a natıve soıl cover or sıngle barrıer cap would be suffıcıent However, ıf the soıls/sedıments are not delısted, a full RCRA cap as descrıbed ın Sectıon 4 2 would be requıred In addıtıon, the total thıckness of the

Table 4-6
OU 7 Technology Literature Research
Identification and Initial Screening of Remedial Technologies
Spray Evaporation Area Soils and Pond Sediments

Response Action • Remedial Technology - Process Option	**Description**	**Comments**
Institutional Controls		
• **Use Restrictions**	Legal restrictions on use of site	Some restrictions already in place
- Deed Restrictions	Restrictive covenants on deeds to the site or restrictive easements may include limitations on excavation and basements in contaminated areas	
- Zoning Ordinances	Zoning ordinances, administrative consent orders, or judicial orders prohibiting certain land uses	
• **Access Restrictions**	Physical restrictions to limit access to site	Some restrictions already in place
- Fencing	Restrict general public and large wildlife from onsite hazards	
- Written Warnings	Place warning signs at site to warn public of hazards	
Containment Actions		
• **Cap**	Provides physical barrier between contaminants and the environment May include surface controls	
- Native Soil Cover	Reduce exposure to, and migration of, contaminated materials through use of a native soil cover	Allows much of the existing infiltration to reach the soils/sediments Does not meet RCRA capping criteria
- Single Barrier Cap	Utilizes a cap constructed of a single layer of media, such as clay, flexible membrane liner, asphalt or concrete-based material	Allows for some infiltration Does not meet RCRA capping criteria
- Composite Barrier Cap	Uses multiple layer design Media include soil and synthetics Includes RCRA cap or modified RCRA cap	Minimizes infiltration of precipitation and generation of leachate Meets RCRA capping criteria
• **Surface Controls**	Address surface soils and surface water	
- Grading	Modifies topography to manage surface water infiltration, runon and runoff, and erosion	
- Revegetation	Stabilizes soil surface, promotes evapotranspiration, and minimizes erosion	
Collection/Removal Actions		
• **Excavation**	Removal of media by hand, backhoe, or other suitable equipment	Appropriate for isolated areas and volumes less than 100,000 cy
• **Dredging**	Removal of media underwater using commercially available dredging equipment	May harm plant and animal life May cause secondary migration to surface water
• **Consolidation**	Consolidation of media for the purpose of limiting area prior to implementing containment actions	Appropriate for small areas with minimum depth of contamination

Response Action • Remedial Technology - Process Option	Description	Comments
Treatment Actions		
• **Physical**	Uses physical properties of materials to separate constituents of waste stream	
- Gravity Separation	Physical separation of components of a fluid mixture Includes evaporation sedimentation, centrifugation, flocculation, and filtration	Conventional technology May be applicable for dewatering sediments Typically serves as pretreatment step
- Soil Washing	Organic solvents, surfactants, or chelating agent solutions are mixed with excavated soils to extract organics, inorganics, and/or radionuclides	Can remove some organics, metals, and radionuclides Liquid residual requires further treatment
- Soil Flushing	Surfactant solution is percolated through *in situ* contaminated solids to groundwater and is brought to the surface for removal, recirculation or onsite treatment and reinjection	Can remove some organics, metals, and radionuclides Lack of hydraulic control may create problems Possible contamination due to surfactants used
- Soil Vapor Extraction (SVE)	Vertical or horizontal vents used to volatize contaminant residuals Steam/hot gas can be used to enhance volatilization Vapors are collected and treated at surface	Applicable for SVOCs and VOCs
- Air Stripping	Mechanical aeration of soils to remove volatile organics	Applicable for VOCs Highly temperature dependent
• **Chemical**	Uses chemical reaction to decrease toxicity of contaminants	
- Precipitation	Alteration of equilibrium to bring a substance in solution into its solid phase	Conventional technology Often used for metals Solids must be in solution
- Oxidation/Reduction	Reactions alter state of a compound through loss of an electron to detoxify, decompose, precipitate, or stabilize contaminants	Applicable to organics and metals Solids must be in solution Reactions can be explosive
- Dechlorination	Use of reagent to dechlorinate halogenated organic compounds, creating large numbers of non-toxic products	Applicable only for halogenated organics (PCBs, dioxins) Ineffective for metals Dewatering may be required
• **Biological**	Degradation of contaminants using microorganisms	
- Biological Reactors	Degradation of organic compounds in an aboveground system using acclimated microorganisms in an aerobic or anaerobic environment	Demonstrated effectiveness for organics Inorganics would be unaffected by the process and may be toxic to bacteria
- Enzymatic Biodegradation	Addition of enzymes to enhance the biological degradation of organic contamination in a controlled reactor	Applicable to organics Inorganics would be unaffected by the process and may be toxic to bacteria
- Composting	Soils mixed with bulking agent and formed into windrows to promote biological degradation of organics	Applicable to organics Inorganics would be unaffected by the process and may be toxic to bacteria
- *In Situ* Bioremediation	In-place degradation of organic contaminants using acclimated microorganisms	Applicable to organics Inorganics would be unaffected by the process and may be toxic to bacteria

Response Action • Remedial Technology - Process Option	**Description**	**Comments**
Treatment Actions (continued)		
• **Thermal**	Use of heat to decontaminate soils	
- Rotary Kiln	Thermal treatment of contaminated soils by combustion of horizontally rotating cylinder designed for uniform heat transfer	Applicable for organics
- Fluidized Bed Incineration	Waste injected into stationary or circulating hot bed of sand where combustion occurs	Applicable for organics and some inorganics
- Infrared Thermal	Uses silicon carbine elements to generate thermal radiation beyond the end of the visible spectrum for thermal destruction	Applicable for organics
- Low Temperature Thermal Desorption	Involves the volatilization of organics from soil without achieving combustion temperatures Volatiles can be destroyed in an afterburner	Applicable for VOCs and SVOCs Non-volatile compounds are not removed
- Pyrolysis	Thermal conversion of organic material into solid, liquid, and gaseous components in an oxygen deficient environment	Requires auxiliary fuel, small capacity
- Radio Frequency (RF)/ Microwave Heating	Electrodes are placed in contaminated soils RF energy field heats soils and volatilizes contaminants that are collected in vents or at the surface	Vaporizes VOC and SVOCs, which volatilize below 500°F
- Vitrification	Electrodes are placed in soil and current is passed through soil to create resistive heating Soil eventually melts, organics are volatilized or destroyed, and inorganics are dissolved within vitrified mass	Applicable to organics, inorganics, and low-level radioactive wastes Requires uniform composition of soil and high silica content May require off gas treatment
• **Stabilization/Solidification**	Chemical addition to solids to form a solidified mass with reduced mobility of contaminants	Bench scale testing would be required for all stabilizing agents to develop the effective stabilizing mixture May require secondary containment May be subject to leaching Will increase waste volume May require off gas treatment Organics may interfere with process
- Proprietary Agents	Waste reacts with proprietary additives	Provides for chemical and physical bonding
- Cement Based	Slurry of wastes and water is mixed with cement to form a solid	Solids are suspended, not chemically bound, may be incompatible with some wastes
- Lime-Based Pozzolanic	Waste is reacted with lime and a fine-grained material (fly ash, ground blast furnace slag, cement kiln dust) to form a solid	Provides chemical and physical bonding May reduce toxicity through neutralization
- Thermoplastic	Waste is dried and dispensed through a heated plastic matrix of asphalt bitumen, paraffin, or polyethylene	Wastes must be dried before use, requires trained operators, may be incompatible with some wastes
- Polymerization	Waste is mixed with a prepolymer and a catalyst that causes solidification through formation of a sponge-like polymer matrix	Pollutants are not chemically bound, strongly acidic leachate may be produced
- *In Situ* Stabilization	Contaminated soil mixed with a variety of stabilizing agents to reduce mobility of contaminants	Non-uniform composition of solids often makes process difficult to implement

Response Action • Remedial Technology - Process Option	Description	Comments
Disposal Actions		
• **RCRA Subtitle C Disposal**	Disposal of contaminated solids at RCRA Subtitle C landfill	Solids may require treatment due to land disposal restrictions Radioactive contaminated solids may require separate handling and disposal
- Offsite	Requires excavation, transportation, and disposal	Few facilities accept radioactive or mixed waste Appropriate waste characterization must be performed
- Onsite	Requires construction of a RCRA cell, excavation, transportation, disposal, and monitoring	CAMU designation would allow disposal onsite at existing landfill instead of new cell
• **RCRA Subtitle D Disposal**	Disposal of uncontaminated or treated and delisted waste at municipal landfill	Solids may require treatment and delisting of treated waste
- Offsite	Involves excavation, transportation, and disposal	
- Onsite	Requires excavation and consolidation	CAMU designation would allow onsite disposal of contaminated wastes

cap would have to be sufficient to confine radiation until it has decayed During design, consideration may be given to extending the landfill cap over the soils and sediments or only capping hot spots

4 7 2 2 Surface Controls

The primary surface controls are regrading and revegetation Grading is used to reshape the surface to manage surface water infiltration and runoff while controlling erosion The spreading and compaction steps used in grading are standard construction techniques utilizing standard construction equipment Grading is often performed in conjunction with capping and revegetation

Regrading may include creating a diversion/collection system of ditches, berms, and ponds Ditches and berms are used to divert runon away from the site and intercept runoff Ponds control suspended solids concentrations in the surface flows by providing sufficient time for particulates to settle The existing surface water diversion system is discussed in Section 1 4 1

Revegetation establishes a vegetative cover to decrease generation of dust and erosion by wind and water and to develop a naturally stable surface environment Revegetation is a cost-effective method to stabilize the surface of hazardous waste disposal sites, especially when preceded by capping and grading Grasses and legumes with a shallower root structure are preferable to woody plants for the vegetative cover

4 7 3 *Removal Actions*

The removal response actions consist of operations that partially or completely remove contaminants from their original location Removal actions for spray evaporation area soils and pond sediments are given in Table 4-6 Removal technologies generally cause land disposal restrictions (LDRs) 40 CFR Part 268 to become effective LDRs require that a generator of a hazardous and/or mixed waste treat the waste to meet specific concentration-based treatment standards or use specific treatment technologies prior to waste disposal The LDRs also prohibit long-term storage of hazardous or mixed waste that does not meet the treatment standards except for accumulation of quantities required to facilitate proper recovery, treatment, or disposal Three technologies are considered technically implementable for the solids/sediment media excavation, dredging, and consolidation

4 7 3 1 Excavation

Excavation is the direct removal of the media by hand or using mechanical equipment Excavation is generally limited to identified hot spots, areas with volumes of less than 100,000 cubic yards (EPA 1991a), or a minimum depth of contamination Conventional excavation equipment consists of bulldozers, front-end loaders, and backhoes During excavation, consideration must be given to maintaining sidewall stability and surface runoff control All excavated areas would be backfilled with clean fill as necessary, regraded for proper drainage, and revegetated Excavation is technically implementable for the spray area soils and/or the pond sediments if water in the pond is removed first

4 7 3 2 Dredging

Dredging is the process of removing bottom sediments from a body of water without dewatering, thus limiting fugitive dust emissions Dredging may be accomplished using mechanical, hydraulic, or pneumatic equipment Considerations include potential difficulty in controlling area and depth of dredging under water and potential for contaminating the surface water

4 7 3 3 Consolidation

Consolidation relocates contaminated material from outlying areas to one or more contaminated areas to minimize the area of contamination Consolidation is usually implemented in conjunction with containment measures, particularly capping Because consolidation generally involves handling, stockpiling, and hauling of contaminated material, potential increased exposure and fugitive transport during implementation must be addressed

Designation of the site (or part of the site) as a CAMU would simplify the cleanup process A CAMU is defined as an area (not necessarily contiguous) designated by the EPA regional administrator for the purpose of implementing corrective action requirements under RCRA Consolidating or placing remediation wastes in a CAMU does not trigger LDRs and minimum technology regulations (MTRs)

The State of Colorado's proposed CAMU regulations define remediation waste as

> "all solid and hazardous wastes, and all media (including groundwater, surface water, soils, and sediments) and debris, which contain listed hazardous wastes or which themselves exhibit a hazardous waste characteristic, that are managed for the purpose of implementing corrective action requirements under §§ 264 101, 265 5, Section 25-15-308, C R S , and RCRA section 3008(h) [42 U.S C § 6928(h)] For a given facility, remediation wastes may originate only from within the facility boundary, but may include waste managed in implementing RCRA sections 3004(v) [42 U S C § 6924(v)], 3008(h) [42 U S C § 6928(h)], § 264 101, § 265 5, OR Section 25-15-308, C R S for releases beyond the facility boundary "

EPA added the CAMU designation to the Subtitle C regulations to allow more flexibility during RCRA cleanup EPA recognized that remediation wastes often pose a lower risk than as-generated wastes because of a high level of EPA oversight and large volumes of media with low levels of contamination

Although final federal CAMU regulations have been published, EPA has determined that the ruling is less stringent than the existing requirements, therefore, states are not required to adopt the law However, regulators in the State of Colorado have indicated that the law will likely be adopted and have encouraged its use to facilitate cleanup at

OU 7 The State of Colorado ιs proposιng changes to the rulιng to clarιfy the language and requιre protectιon of the groundwater and deed restrιctιons

A CAMU desιgnatιon would allow spray evaporatιon area soιls and sedιments from the East Landfill Pond to be consolιdated ιnto the landfill wιthout trιggerιng LDRs or MTRs The soιls and sedιments could then be capped wιth the landfill solιds as part of the presumptιve remedy

4 7 4 *Treatment Actιons*

Treatment actιons serve to reduce the toxιcιty, mobιlιty, and/or volume of contamιnants through physιcal or chemιcal alteratιon of the contamιnants Treatment processes generally wιll produce secondary resιdues as a byproduct Requιrements for handlιng the resιduals and wastes wιll vary wιth regard to the contamιnants ιnvolved and the treatment methods employed Therefore, the resιdues produced by each treatment must be consιdered separately There are five types of treatment technologιes for soιls and sedιments physιcal treatment, chemιcal treatment, bιologιcal treatment, thermal treatment, and stabιlιzatιon/solιdιficatιon These technologιes are presented ιn Table 4-6 and dιscussed below.

4 7 4 1 Physιcal Treatment

Physιcal treatment processes take advantage of the physιcal propertιes of materιals to separate the constιtuents of the waste stream Fιve types of physιcal treatment are dιscussed below gravιty separatιon, soιl washιng, soil flushιng, soιl vapor extractιon, and aιr strιppιng

Gravity Separation

Gravιty separatιon concentrates contamιnants wιth sιmιlar densιtιes Thιs technology ιs often used as a pretreatment step to separate solιds from solutιon or from a mιxture of solιds Gravιty separatιon ιncludes such conventιonal technologιes as shakιng tables sedιmentatιon, centrιfugatιon, flocculatιon, and oιl/water separatιon Each of these technologιes keeps the partιcles slιghtly apart so they can move relatιve to each other and separate ιnto lιght and heavy densιtιes

Gravity separation is a proven technology, but it has two disadvantages some of the processes have a low capacity and in some, contaminants must be in aqueous solution, which may require further treatment

Soil Washing

Soil washing is a process that mixes excavated soils with a washing fluid to remove contaminants The process is based on the principle that contaminants are concentrated in the fine soil fraction (15 to 100 millimeters) (The Hazardous Waste Consultant 1989) Soil washing essentially provides volume reduction by segregating the highly contaminated fine particles The reduced volume is then treated further by some other method such as stabilization/solidification Volume reduction may result in significant savings in treatment and disposal costs

The washing fluid is determined by the contaminant(s) to be removed and may consist of water, solvents, surfactants (for organics), and chelating agents (for metals) Complex mixtures or variations in wastes make formulation of a surface-washing fluid difficult and a series of different washing fluids may be required Bench treatability testing is required to determine the best washing fluid and any pretreatment requirements

Soil washing is effective for organics, metals, and radionuclides The process is flexible and can be tailored to specific mixtures or contaminants

The method is not effective for soils with a high percentage of fines, because the volume reduction would be minimal A high humic content may also inhibit the process Soil washing has two disadvantages the process may require the addition of potentially hazardous washing agents and contaminants are not destroyed but transferred into solution

Soil Flushing

Soil flushing is the *in situ* version of soil washing Solvents are passed through the soils using an injection/recirculation process Hydraulic control of the solution is extremely important

Soil Vapor Extraction

Soil vapor extraction (SVE) is an *in situ* process that removes VOCs and SVOCs by applying a vacuum to introduce air flow through unsaturated soils As it moves through the void spaces between soil particles, the air flow causes the release of additional volatiles from the soils

A high-vacuum pump is connected by a pipe manifold to a series of strategically placed extraction wells and horizontal pipes Well location is based on modeling or pilot testing The wells are drilled into the contaminated soil zone to a depth just above the water table The air is collected at the surface and treated as necessary

SVE is effective for VOC and SVOC removal The process requires high permeability and homogeneous soils with low humic and moisture contents Excessive debris may cause short-circuiting of the air flow thus limiting the area receiving treatment

Air Stripping

Air stripping is a commercially available process in which volatile contaminants in the soil are transferred to the air Correct temperature, pressure, air-to-water ratios, and surface area must be maintained for effective treatment The process is most applicable to soils with low concentrations (less than 100 parts per million) of contaminants

4 7 4 2 Chemical Treatment

Chemical treatment processes use chemical reactions to transform waste stream contaminants into less toxic, neutral substances Chemical treatment processes that passed the preliminary screening in Table 4-6 include precipitation, oxidation, and dechlorination

Precipitation

Chemical precipitation is a process by which the pH is adjusted to the lower solubility limit for a contaminant so that it comes out of solution Acids or bases—typically hydroxides, sulfides, and carbonates—are added to an aqueous solution to bring about the required change in pH An aqueous slurry has to be created using the soils or sediments The process is commonly used for metals removal However, a high-pH effluent and a potentially hazardous metal sludge are often generated by the process

Oxidation/Reduction

Oxidation/reduction reactions alter the oxidation state of a compound in aqueous solution through addition or loss of an electron Oxidation/reduction reactions can reduce toxicity, change solubility, and increase the stability of the end products However, the reactions are nonspecific so the waste must be carefully characterized to prevent undesirable reactions that may be explosive or increase toxicity Typical oxidizing agents are hydrogen peroxide, ozone, and hypochlorites Typical reducing agents are iron, aluminum, zinc, and sodium compounds

Dechlorination

Dechlorination is a process in which chlorine or other halogens are chemically removed from organic compounds The high affinity of alkali metals for chlorine and other halogens is the basis for the process A sodium or potassium based reagent of an alkali metal and polyethylene glycol (PEG) is commonly used Effectiveness of the process is adversely affected when the moisture content of the soil is greater than 7 percent Therefore, dewatering should be considered as a pretreatment step Byproducts of dechlorination may include chloride salts, polymers, and heavy metals *In situ* dechlorination can be used in areas with uniform, shallow (less than 2 feet) contamination

Dechlorination is applicable to treatment of chlorinated organic compounds, including PCBs, dioxins, chlorinated hydrocarbons, and acids Wastes with chlorinated organic concentrations greater than 5 percent or moisture content greater than 20 percent may require excessive reagent

4 7 4 3 Biological Treatment

As discussed in Section 4 4 2 3, biological treatment is the enhancement of natural processes of living organisms to bring about the decomposition of toxic and hazardous organic compounds Stable operating conditions are necessary and changes in these conditions could upset the balance of the system or even be toxic to the microorganisms Heavy metals, radionuclides, and cyanides in particular are often toxic, although special bacteria are being developed that can remove heavy metals (Environmental Remediation Technology 1994) General technologies for soil treatment include biological reactors, enzymatic biodegradation, composting, and *in situ* bioremediation and are presented in Table 4-6

Biological Reactors

Biological reactors provide an environment for microorganisms that is conducive to biodegradation of the required organic contaminants These systems require an aqueous slurry, which could be made using surface water from the East Landfill Pond There are two types of reactors suspended and fixed film In the first, microorganisms are suspended in the aqueous solution generally in an aerated basin In the second, microorganisms form a film over a fixed media and are brought into contact with the contaminated solution by various means

Biological reactors are widely used for wastewater applications and include such processes as activated sludge, sequencing batch reactors (SBRs), rotating biological contactors (RBCs), and trickling filters Types of biological reactors are discussed in more detail in Section 4 4 2 3

Biological reactors are effective for a broad range of organics and are particularly effective for low contaminant concentrations Post-treatment includes dewatering and drying with possible treatment of the remaining water

Enzymatic Biodegradation

Enzymatic biodegradation uses enzymes to break down organics Enzymes are highly specific proteins capable of catalyzing only one type of reaction or operating on one type of chemical Enzymes can be natural to a cell or can be produced by injecting foreign genes into the microorganism Commercial enzymes could be applied directly to contaminated soils The technology is currently being developed and may be applicable to many contaminants, although each enzyme is highly specific

Composting

Composting is a method of *ex situ* biological treatment based on decomposition of organic compounds A number of different methods for composting exist, however, the basic processes are similar Soils are mixed with compost or other bulking agents (sawdust, wood chips) and amendments (if necessary) and formed into windrows or long piles Moisture content between 45 and 65 percent is generally desired The windrows are periodically aerated by turning the piles or through a forced air system The microorganisms digestive reactions are exothermic and temperatures on the interior of the windrow may reach 140 to 160°F Leachate collection and odor control may be necessary Following treatment, the compost is screened to remove bulking agents and dried Composting has been used extensively for municipal sludge treatment, and the dried product is typically used as mulch

Composting is effective for organic contaminants Metals, radionuclides, and cyanides may be toxic to bacteria Other disadvantages to composting include large space requirements and possible odors

***In Situ* Bioremediation**

The goal of *in situ* bioremediation is the same as other methods of bioremediation—to enhance development of native microorganisms in the soil that will treat the given contaminants and increase contact with those contaminants Soils are left in place and tilled to increase mixing and aeration resulting in treatment to maximum depth of 2 feet Contamination at greater soil depths may be treated using other methods of *in situ* bioremediation but are not required for the shallow contamination at OU 7 Nutrients may be added to the water or applied as fertilizer For *in situ* systems, carbon/nitrogen/phosphorus ratios should be 120 10 1 (C N P) An irrigation system may be required to provide optimum moisture content in the range of 60 to 80 percent If irrigation is used, control of surface runoff and infiltration must be considered Soil pH of 5 5 to 8 5 promotes the highest microbial activity, although soil pH greater than 6 is best for immobilization of metals The pH can be adjusted using conventional agricultural techniques such as lime addition

The main advantage of *in situ* bioremediation is that it is an onsite, natural process that does not require excavation and generally produces non-toxic residues It is an effective biological treatment method for areas with widespread, low levels of shallow contamination

4 7 4 4 Thermal Treatment

Thermal treatment processes use thermodynamic principles to bring about the destruction of contaminants Thermal treatment processes include rotary kiln incineration, fluidized bed incineration, infrared treatment, low-temperature thermal desorption, and pyrolysis Each process is discussed below and presented in Table 4-6

Generally, air emissions must be addressed as part of the treatment train Metals that volatilize may vaporize during incineration and are difficult to remove using conventional air-pollution control devices In addition, elemental metals cannot be broken down further Therefore, thermal treatment is not useful where heavy metals are the primary contaminant Thermal treatment technologies may be used as part of a treatment train after metals have been removed

Rotary Kiln

A rotary kiln is essentially a long, inclined rotating tube Waste is added at the high end and passes through the combustion zone, which is rotating to promote mixing The wastes are oxidized to gases Auxiliary fuel and an enriched oxygen supply may be required to maintain combustion temperatures (1,500 to 3,000°F) Gases pass through a second combustion chamber and air scrubber system to treat acid gas and high-particulate content The ash may also require additional treatment (generally solidification) prior to disposal Pretreatment may include size reduction

Rotary kiln treats a variety of organic contaminants It has a neutral effect on most metals and radionuclides but is not applicable to wastes with volatile or semivolatile metals Regulatory and community acceptance of incineration has historically been difficult to obtain in Colorado Wastes with heavy metals, inorganic salts ($NaSO_4$, KSO_4), explosive materials, and high fine content may be detrimental to this system

Fluidized Bed Incineration

Fluidized bed incineration makes use of a bed of inert granular material (generally sand) to improve heat transfer Air is blown through the sand bed and wastes until the particles are suspended and flow like a fluid—thus the term "fluidized " High turbulence allows operation at low temperatures (750 to 1,000°C) The process produces little ash and has low particulate emissions Offgas treatment is often required, although limestone may be added directly to the bed to capture acidic gases and thus eliminate the need for a wet scrubber and the associated water residual (EPA 1988a) A homogeneous feed is required so solids reduction may be part of the pretreatment

Fluidized bed incineration applies to a variety of organic contaminants and some inorganics It has no effect on metals and radionuclides As with the rotary kiln, alkali salts and heavy metals can be detrimental to the process Pilot testing is required The main disadvantage is that incineration has been difficult to implement in Colorado because of a lack of regulatory and community acceptance

A circulating fluidized bed is a variation that is commonly used in hazardous waste treatment Higher air velocities, rotation of solids, and finer sorbents allow the unit to be more efficient, compact, and easier to feed

Infrared Thermal

In infrared thermal treatment, a variety of wastes are exposed to thermal radiation beyond the visible range This is generally provided by silicon carbide resistive heating elements A thickness of about 1 to 2 inches of waste is conveyed through the furnace on a wire mesh belt Treatment temperatures range from 800 to 1,600°F Wastes should be homogeneous and contain at least 22 percent solids to facilitate handling Therefore, some pretreatment may be required Residuals include ash, off gases, and scrubber water

Infrared thermal treatment is applicable to a variety of organic contaminants, has a neutral effect on most metals and radionuclides, and is not applicable to wastes with volatile metals One advantage of this method is that particulates in the emissions are low compared with thermal treatments that rely on heavy mixing and turbulence

Low-Temperature Thermal Desorption

The low-temperature thermal desorption (LTTD) process removes VOCs and SVOCs from soil by volatilization at relatively low temperatures (in the range of 500 to 1,100°F) Using air, heat, and/or mechanical agitation, the contaminants are physically transferred from the soil into a gas stream that can be released to the atmosphere or treated Residuals include ash, off gases, and scrubber water

The system consists of two main elements—an indirectly fired rotary dryer and a gas treatment system Contaminated soils are fed into the rotary dryer, which vaporizes the VOCs and SVOCs in the soil Temperature inside the dryer can be controlled by adjusting the firing rate of the burners, the soil feed rate to the dryer, and the residence time of the soil within the dryer Typical residence times range from 1 to 5 hours Offgas treatment varies but often involves an inert gas (nitrogen) carrier to transport vaporized organics to the treatment system where they are condensed and collected

Pyrolysis

Pyrolysis involves heating of waste in the absence of oxygen to thermally degrade waste to gas and inorganic ash residual There are two chambers The first separates the volatiles from nonvolatiles at temperatures ranging from 1,000 to 1,400°F The second burns the gas at higher temperatures (2,200°F) to destroy the remaining contamination Heating may be direct or indirect but requires auxiliary fuel Ash residual may be hazardous as a result of leachability

Pyrolysis is effective for a variety of contaminants Unlike conventional incineration process, salts, metals, and volatile metals are not detrimental to the process Disadvantages include a low capacity and a need for auxiliary fuel

Radio Frequency Heating

Radio frequency (RF) heating is an innovative, *in situ* treatment that volatilizes organics using radiation of energy through the soils Antennae are placed in 3- to 6-inch diameter boreholes in the contaminated area The resistance of the media to the electromagnetic energy raises the temperature of the soil to about 500°F volatilizing the VOCs and SVOCs The volatilized organic compounds can be allowed to migrate to the surface to be collected, or vapor extraction can be used for subsurface collection Off gases can then be treated to remove organics

The RF treatment is limited to organics that volatilize below 500°F, mostly halogenated solvents and petroleum products

The advantages of this system include the following

- It is conducted *in situ* with a minimum amount of disturbance to contaminated soils
- No water, chemicals, solvents, or other materials are added to the soils
- The process is not affected by large voids, debris, rocks, or tightly packed soils

RF is presently considered an innovative technology It is included in the treatability studies program at the Rocky Flats site and is under consideration for VOCs removal from media at OU 1 RF may be applicable for separating organic compounds from radionuclides, particularly prior to stabilization/solidification where organics may interfere with the process

Vitrification

The vitrification process decomposes organic compounds and melts wastes into a glass-like solid matrix The resulting vitrified mass has excellent structural integrity, resists weathering and leaching, and its durability is comparable to marble The process can be performed *in situ* or *ex situ* There are a variety of *ex situ* processes available *In situ* vitrification is discussed below

Generally, four electrodes are placed into the soil and a high-voltage (12,500 to 14,000 v) current is passed between them, heating the soil to temperatures of 1,600 to 3,600°F A conductive mix of materials is often spread over the soil surface and used as a starter path for the electric circuit The heat gradually works its way downward through the soils at a rate of 1 to 2 inches per hour to depths up to 30 feet Organic compounds may be volatilized and migrate to the surface where they must be contained by a hood and treated if necessary The remaining inorganics are dissolved and encapsulated as the soils cool into a vitrified mass

Vitrification is applicable to a variety of organic and inorganic contamination Vitrification is often used for soils with a high concentration of contaminants or radionuclides that must be immobilized In addition to providing a highly stable noncrystaline solid, vitrification results in a volume reduction of 20 to 40 percent depending on the void volume

For optimal operation, vitrification requires a homogeneous soil free of debris with a high silica content and low moisture content (less than 25 percent) Saturated soils can be vitrified, however, the cost is greatly increased because the heat must first evaporate the water The presence of volatile metals may also complicate the process

4 7 4 5 Stabilization/Solidification

The purpose of stabilization/solidification is to limit the solubility or mobility of contaminants This may consist of adding materials that maintain contaminants in their least mobile or toxic form, binding them into an immobile/insoluble matrix, and/or decreasing the surface area exposed to potential solvents Stabilization/solidification is used primarily for inorganics Although treatment of organic contaminants has been demonstrated (Environmental Remediation Technology 1994), organic compounds generally interfere with the stabilization/solidification process

Pretreatment often includes organic removal, pH adjustment, and precipitation of heavy metals to reduce their mobility Reagents may be added to enhance cure time and compressive strength Stabilization/solidification methods generally require bench scale testing to determine the proper additives and the best mix ratio

Solidification/stabilization is a well-established technology It is particularly suited for wastes with radioactive contamination and residuals from treatment processes prior to final disposal

The main disadvantages are that organic compounds may interfere with the process, and the process results in a larger volume of waste Brief descriptions of six common types of stabilization/solidification are given below and in Table 4-6

Proprietary Agents

Proprietary stabilization/solidification uses a number of proprietary binding agents to increase structural strength and improve resistance to leaching Contaminants may be physically surrounded or chemically fixed by reactions with the solidifying agent

Cement Based

The cement-based stabilization/solidification process mixes wastes with cement The type of cement is selected to emphasize a particular cementing reaction Water is added as necessary for proper hydration The equipment used is similar to that used for cement mixing and handling The final product varies from a granular material to a cohesive solid

Lime-Based Pozzolanic

In lime-based pozzolanic stabilization/solidification, waste is entrapped by siliceous and aluminosilicate materials that form a cement-like substance when mixed with lime and water Pozzolanic materials include blast-furnace slag, ground brick, and fly ash Reactions are generally slower than in cement-based stabilization/solidification The final product can vary from fine-grained materials to a cement-like solid

Thermoplastic

In thermoplastic stabilization/solidification, the waste is microencapsulated in a thermoplastic material such as asphalt bitumen, paraffin, or polyethylene The waste material must be dried before stabilization/solidification

Polymerization

Polymerization uses the formation of a larger polymer of a particular compound to promote greater physical, chemical, and biological stability A catalyst is used to initiate the reaction

***In Situ* Stabilization**

In *in situ* stabilization, stabilizing agents are applied directly to the soil using conventional drilling equipment If the contamination is less than 2 feet deep, earth moving or farming equipment can be used for mixing Each of the stabilization agents described above may be used *in situ*

4 7 5 *Disposal Actions*

Representative disposal options for soils and sediments include onsite and offsite land disposal In addition to direct disposal, treatment process residuals or end-products may also require disposal The type of landfill required for final disposal of soils and sediments will depend on the contamination present

4 7 5 1 Subtitle D

If soils and sediments are not hazardous, they could also be disposed of at the existing OU 7 landfill under Subtitle D Subtitle D regulations (40 CFR 257, 258) cover monitoring, closure, and post-closure requirements for existing solid waste landfills

4 7 5 2 Subtitle C

RCRA Subtitle C requirements apply to hazardous waste treatment, storage, and disposal and are generally more stringent than Subtitle D requirements LDRs (40 CFR 268), which are part of Subtitle C, establish prohibitions, treatment standards, and storage limitations Wastes must be treated according to these standards before the wastes or their treatment residuals can be land disposed Offsite Subtitle C disposal would probably be at the Hιghway 36 Landfill near Last Chance, Colorado Soιls and sedιments would be transported ιn accordance wιth federal and State of Colorado transportatιon regulatιons Dιsposal by thιs method would be contιngent upon Hιghway 36 acceptιng the waste

Onsιte Subtιtle C dιsposal would requιre the constructιon of a Subtιtle C cell onsιte Because of the extensιve regulatιons and the small quantιty of waste involved, thιs optιon ιs not consιdered vιable and ιs elιmιnated from further consιderatιon

4 7 5 3 CAMU

If a CAMU ιs establιshed, as dιscussed ιn Sectιon 4 7 3 3, hazardous wastes could be dιsposed of at the exιstιng landfill and LDRs would not apply Because the landfill ιs the source of contamιnatιon of soιls and sedιments ιn the area of the East Landfill Pond, ιt may be appropriate to apply the CAMU concept and return the contamιnated soιls and sedιments to the landfill for dιsposal

4 7 5 4 Radιoactιve

Unlιke other hazardous wastes, radιonuclιdes cannot be destroyed, they can only decay through theιr natural process Therefore, low-level radιoactιve wastes may have to be dιsposed of at a facιlιty specιfically permιtted to accept thιs type of waste such as Envιrocare ιn Utah Specιfic types of characterιzatιon would be requιred for acceptance at these facιlιtιes Dιsposal at lιcensed radιoactιve waste sιtes ιs expensιve, although pretreatment for volume reductιon may provιde sιgnιficant cost savιngs

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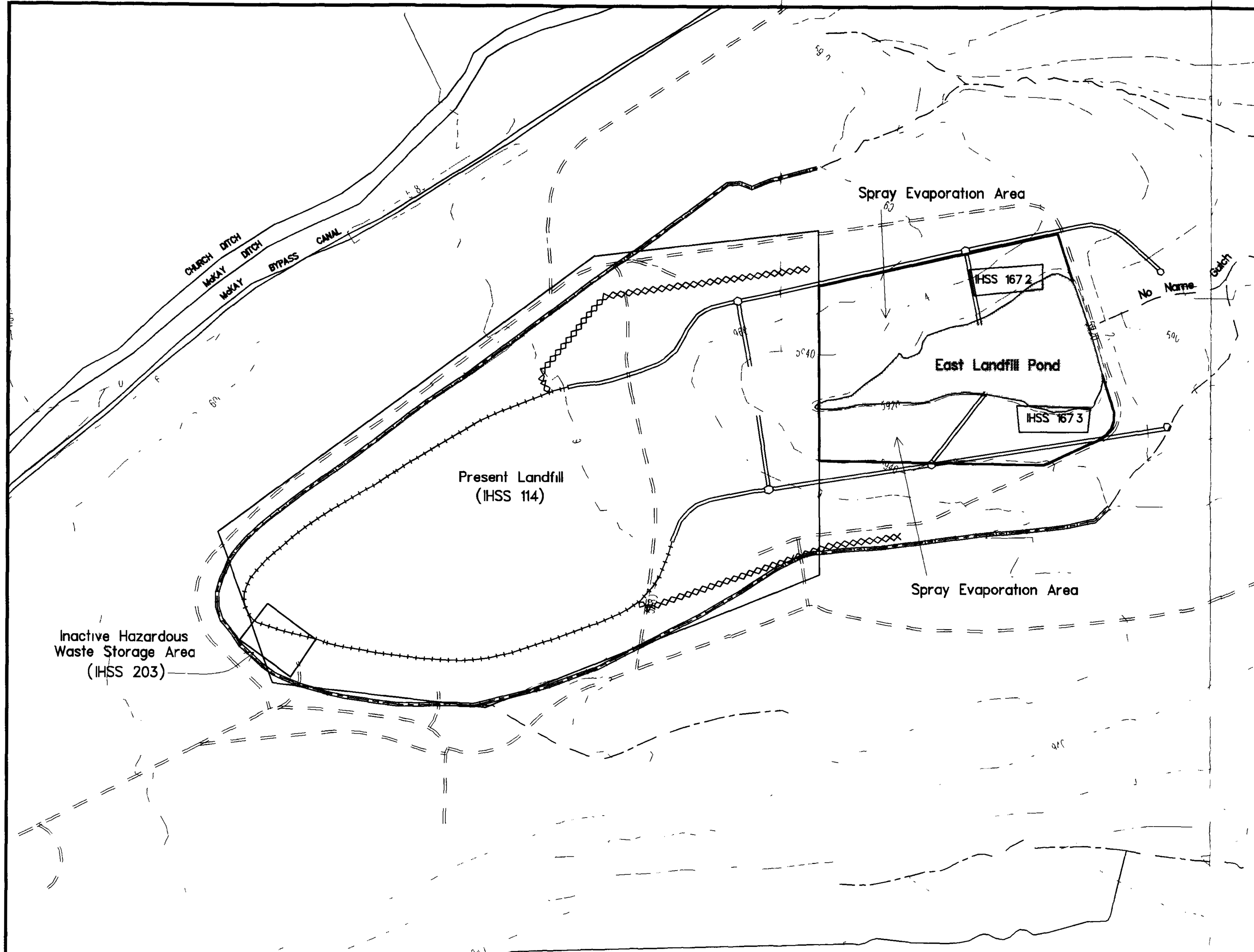

US DEPARTMENT OF ENERGY
Rocky Flats Site Golden Colorado

Potential Remedial Action Areas at OU 7

Technology Literature Research

Operable Unit No 7

Date April 1994

Figure 1-1

04/12/94 SITEPLAN.MAP

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