U.S. Department of Energy

Office of Legacy Management, Washington, DC

FINAL DOE AREAS FEASIBILITY STUDY

for the:

LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH
UNIVERSITY OF CALIFORNIA, DAVIS

Prepared for:

SM Stoller Corporation
2597 B ¾ Road
Grand Junction, Colorado 81503

Prepared by:

Weiss Associates
5801 Christie Avenue, Suite 600
Emeryville, California 94608-1827

March 07, 2008
Rev. 0

Weiss Associates
Environmental Science, Engineering and Management

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ACRONYMS AND ABBREVIATIONS

AH	animal hospital
ALARA	as-low-as-reasonably-achievable
Am-241	americium-241
ARAR(s)	Applicable or Relevant and Appropriate Requirement(s)
bgs	below ground surface
C-14	carbon-14
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CHE	Center for Health and the Environment
cm/sec	centimeters per second
Co-60	cobalt-60
COC(s)	constituent(s) of concern
COPC(s)	constituent(s) of potential concern
Cr-VI	hexavalent chromium
CRWQCB	California Regional Water Quality Control Board
Cs-137	cesium-137
CSU	California State University
D&D	decontamination and decommissioning
D&M	Dames and Moore
dB	decibels
DOE	United States Department of Energy
DOG	Division of Oil and Gas
DOT	Department of Transportation

DSCSOC	Davis South Campus Superfund Oversight Committee
DSS	Domestic Septic System
DST	domestic septic tank
DTSC	Department of Toxic Substances Control
DWQ	drinking water quality
DWR	Department of Water Resources
EDPs	Eastern Dog Pens
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPC	exposure point concentration
FEMA	Federal Emergency Management Administration
FFA	Federal Facility Agreement
FONSI	Finding of No Significant Impact
FRTR	Federal Remediation Technologies Roundtable
FS	Feasibility Study
ft	feet
GW	ground water
HAP	hazardous air pollutants
HDPE	high-density polyethylene
HH	human health
HHRA	Human Health Risk Assessment
HI	hazard index
hp	horsepower
HSU	hydrostratigraphic unit
LEHR	Laboratory for Energy-Related Health Research
LRDP	Long-Range Development Plan
MCLs	maximum contaminant levels
MCLG	maximum contaminant level goal
MEDE	maximum effective dose equivalent
mg/kg	milligrams per kilogram
mil	millimeter

ml/g	milliliters per gram
MOA	Memorandum of Agreement
mrem	millirem
mrem/year	millirem per year
N/A	not applicable
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
No.	number
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NUFT	Non-Isothermal Unsaturated Flow and Transport
O&M	operations and maintenance
OERR	Office of Emergency and Remedial Response
ORIA	Office of Radiation and Indoor Air
ORMP	Office of Resource Management and Planning
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PAHs	polycyclic aromatic hydrocarbons
pCi/g	picoCuries per gram
PL	Public Law
PM_{10}	10 microns aerodynamic diameter
PNNL	Pacific Northwest National Laboratory
POTW	publicly-owned treatment works
PRG	Preliminary Remediation Goal
Pu-241	plutonium-241
Ra/Sr	Radium/Strontium
Ra-226	radium-226
RAOs	Remedial Action Objectives
RAs	removal actions
RCRA	Resource Conservation and Recovery Act

rem	Roentgen-equivalent man
RPM	remedial project manager
RWQCB	Regional Water Quality Control Board
Sr-90	strontium-90
SVOC(s)	semi-volatile organic compound(s)
SWERA	Site-Wide Ecological Risk Assessment
SWRA	Site-Wide Risk Assessment
SWRCB	State Water Resources Control Board
SWT	Southwest Trenches
TBCs	to-be-considered guidelines
TBD	to be determined
TCLP	toxic characteristic leaching procedure
TMV	toxicity, mobility, or volume
TPHRL	Toxic Pollutant Health Research Laboratory
UC	University of California
UC Davis	University of California, Davis
UCOP	University of California Office of the President
US ACE	United States Army Corps of Engineers
US EPA	United States Environmental Protection Agency
US FWS	United States Fish and Wildlife Service
USC	United States Code
USCA	United States Code Annotated
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VELB	Valley Elderberry Longhorn Beetle
VOC(s)	volatile organic compound(s)
WA	Weiss Associates
WDPs	Western Dog Pens
µg/kg	micrograms per kilogram

EXECUTIVE SUMMARY

The United States Department of Energy (DOE) has prepared this Feasibility Study (FS) to identify remedial alternatives for DOE areas at the Laboratory for Energy-Related Health Research (LEHR or the Site) at the University of California, Davis (UC Davis). DOE is responsible for remediation of the environmental impacts associated with past activities at the LEHR Federal Facility, which is located within the United States Environmental Protection Agency (US EPA) National Priorities List (NPL) site known as the LEHR/Old Campus Landfill. This FS will lead to a Proposed Plan and Record of Decision, which will document proposed and final remedies, respectively, for the DOE portions of the Site.

DOE has accelerated site cleanup by completing several removal actions that successfully addressed principal environmental threats at the Site. As a result, the mass of residual contamination is very low and site risks are either at or below State and federal human health risk thresholds for current and projected site use as a research facility. Additionally, Site risks are below the level of concern for all ecological receptors (UC Davis, 2006b). However, risk estimates suggest that residual soil contamination in some areas could pose a risk to a hypothetical on site resident and/or possibly impact ground water. These are very conservative estimates since the long-range plan for the site does not include residential use and, based on available data, the mass of residual contamination in soil is too low to significantly impact ground water quality.

In accordance with the Superfund process and applicable State laws and policies, this FS develops a range of remedial alternatives for areas where residual contaminants in soil potentially result in an excess cumulative human cancer risk greater than 10^{-6}, an excess human hazard index (HI) of greater than one or may impact ground water above background levels within the next 500 years. Ground water contamination for all areas at the Site will be addressed in the UC Davis FS based on a Memorandum of Agreement (MOA) between DOE and UC Davis.

This FS uses information presented in the DOE Areas Remedial Investigation (WA, 2003) and *Site-Wide Risk Assessment, Volume I: Human Health Risk Assessment (Part B-Risk Characterization for DOE Areas)* (WA, 2005) to identify potential human health risks and potential impacts to ground water posed by residual contamination at the LEHR Federal Facility. Specifically, these reports identify the Southwest Trenches (SWT), the Radium/Strontium (Ra/Sr) Treatment Systems, Eastern Dog Pens (EDPs), Domestic Septic System (DSS) Numbers (Nos.)3 and 4, and Dry Wells A-E as potential areas of environmental impacts. The site-wide risk assessment identified no significant current or future human health or ecological risks or ground water impacts associated with the DOE Disposal Box, DSS No. 1, DSS No. 5, DSS No. 6, DSS No. 7 and Western Dog Pens (WDPs). A Federal Facility Agreement (FFA) was negotiated among DOE, the US EPA, California Department of Toxic Substances Control, California Regional Water Quality Control Board and the California Department of Health Services—Radiation Health Branch. The FFA provides the framework for conducting and documenting site cleanup. As an NPL site, environmental restoration must be conducted according to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and Superfund guidance and policy. Therefore, this FS was prepared to fulfill the requirements of Section 300.430(e) of the NCP.

The Remedial Investigation and Risk Assessment indicate that human health risks at the Site are limited.

The CERCLA FS process includes the following steps:

1. Identifying remedial action objectives (RAOs) specifying contaminants and media of concern, potential exposure pathways and remediation goals based on applicable or relevant and appropriate requirements (ARARs).

2. Identifying applicable technologies based on applicability, effectiveness and cost.

3. Assembling suitable technologies into alternative remedial actions (alternatives) and analyzing the alternatives based on overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; cost; and state and community acceptance.

Additionally, this FS evaluates the environmental impacts of the alternatives in accordance with the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) requirements. Evaluating environmental considerations of the alternatives concurrently with the FS allows these considerations to be integrated with the CERCLA process, thereby eliminating the need for a separate NEPA/CEQA analysis, and is consistent with DOE policy and guidance.

Remedial Action Objectives

The risk management process indicates that current site risks are limited, and soil is the only contaminated media to be addressed in this FS. Human health risks exceeding the CERCLA point of departure of 10^{-6} are present in the DSS No. 4 (DSS 4), the Eastern Dog Pens (EDPs) and Southwest Trenches (SWT) areas. In the DSS 4 area, excess cancer risk is present for a hypothetical resident through exposure to the polycyclic aromatic hydrocarbons (PAHs) benzo(a)anthrecene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene. The majority of this risk is driven by plant ingestion (i.e., homegrown produce). The summed cancer risk (i.e., summed total risk for all COCs) for the hypothetical resident is 5.0×10^{-4}, which falls within the CERCLA risk range, but exceeds the 10^{-6} point of departure. Benzo(a)pyrene contained in soil at DSS 4 presents elevated risk to a hypothetical construction worker doing subsurface work in the DSS 4 area. The total risk for this worker is at the CERCLA point of departure risk of 1×10^{-6}. In the EDPs, dieldrin contained in soil and strontium-90 (Sr-90) contained mainly in concrete curbing present a cumulative risk of about 5×10^{-6} for a hypothetical resident. In the SWT area, elevated cancer risk is present for a hypothetical resident through exposure to Sr-90 and its daughter product, yttrium-90. The majority of this risk is driven by plant ingestion. The total cancer risk of 3 x 10^{-6} for the hypothetical resident slightly exceeds the CERCLA point of departure risk of 10^{-6}.

Residual contamination in soil in the DSS 3, DSS 4, Dry Wells A-E, Radium/Strontium (Ra/Sr) Treatment Systems and SWT areas have potential to impact the beneficial use of ground water in limited areas and within the Site boundaries. These predictions are based on conservative transport model predictions of soil contaminant concentrations that could impact ground water within the next 500 years. With high mobility compounds, such as nitrate or carbon-14 (C-14), these impacts may have already occurred or could occur in much shorter time frames. At DSS 3, elevated nitrate concentrations may impact a limited area of ground water above the California maximum contaminant level (MCL), formaldehyde may impact a limited area of ground water above the California Department of Health Services action level and molybdenum may impact ground water above background. At DSS 4, transport modeling suggests that selenium will not impact ground water above California MCLs or background, but it was retained in the risk management process due to the historical detection of selenium in downgradient ground water monitoring well UCD1-024 and the lack of nearby ground water monitoring wells. At Dry Wells A-E, chromium, hexavalent chromium (Cr-VI), mercury and silver are predicted to impact a limited area of ground water above California MCLs, while molybdenum, cesium-137 (Cs-137) and Sr-90 are predicted to impact a limited area of ground water at concentrations above background. At the Ra/Sr Treatment Systems area, nitrate is predicted to impact a limited area of ground water above the California MCL, C-14 is predicted to impact a limited area of ground water above the derived limit based on the federal MCL for beta particles and photon emitters of four milliroentgen equivalent man per year (mrem/year) (US EPA, 2000b) while radium-226 (Ra-226) may result in limited impacts above background. At the SWT area, limited impacts above the California MCL are anticipated for nitrate and impacts above the federal MCL are anticipated for C-14.

The FS establishes human health-based remediation goals as the higher of background or a remediation goal that achieves a risk of 10^{-6}, and ground water impact goals as soil concentrations that produce significant impacts above site ground water background. No constituents exceeded a hazard quotient of 1.0. The resulting RAOs are:

- Prevent human incidental ingestion of surface and subsurface soil that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Prevent direct dermal contact with surface and subsurface soil that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Prevent external radiation from surface and subsurface soil that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Prevent human inhalation of contaminants bound to resuspended surface soil particles that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.

- Prevent human ingestion of plants grown in site surface and subsurface soil that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Mitigate potential future impact to ground water.
- Minimize threats to the environment including, but not limited to, sensitive habitats and critical habitats of species protected under the state and federal Endangered Species Act.
- Comply with all ARARs.
- Minimize impact to UC Davis research at the Site.

Technology Identification

DOE evaluated a full range of technologies and process options. Thirteen options were identified that could potentially achieve the RAOs:

1. No action;
2. Land-use restrictions;
3. Subsurface hazard notification (a specific land-use restriction);
4. Ground water monitoring;
5. Nutrient injection;
6. Excavation using conventional heavy equipment;
7. Excavation using oversized augers;
8. *Ex situ* shallow-rooted phytoremediation;
9. Thermal desorption
10. On-site reuse;
11. Off-site reuse;
12. Off-site disposal; and
13. Single-layer asphalt cap with plastic liner.

Description and Evaluation of Remedial Alternatives

The Risk Assessment identified COCs that require FS remedial alternatives in the following DOE areas:

- Ra/Sr Treatment Systems;
- DSS 3;
- DSS 4;
- Dry Wells A-E;
- SWT; and
- EDPs.

Remedial alternatives were developed for each of these areas by assembling retained process options in a manner that addresses specific ARARs, NCP requirements and FS area conditions.

Ground water-impacting COCs are present in all of these areas, and human health COCs are present in the DSS 4 and SWT areas. All of the areas contain at least one low-mobility constituent (e.g., Ra-226, Sr-90, PAHs or metals), and some of the areas contain localized areas of more mobile constituents (e.g., nitrate and formaldehyde). The former have no practical treatment options, while the latter are potentially treatable, both *in* and *ex situ.*

Application of this ARAR, the NCP requirements and information on site conditions resulted in a consistent set of alternatives that applied to all areas. These alternatives are:

- No action;
- Long-term ground water monitoring and contingent remedial action;
- Capping, long-term ground water monitoring and land-use restrictions; and
- Removal and off-site disposal.

In areas where nitrate and/or formaldehyde were present, additional *in* and *ex situ* treatment alternatives were developed:

- Removal and on-site treatment; and
- *In situ* bioremediation.

The Risk Assessment identified that no COCs were present in the following DOE areas:

- DOE Disposal Box;
- DSS 1;
- DSS 5;
- DSS 6;
- DSS 7; and
- Western Dog Pens (WDP).

Table ES-1 presents the remedial drivers and the alternatives for each of the DOE areas.

Chapter 4 presents a detailed analysis of the remedial alternatives. As discussed above, the NCP identifies nine criteria to be used in the detailed analysis of alternatives. These are categorized into three groups:

The Threshold Criteria:

- Overall protection of human health and the environment; and
- Compliance with ARARs.

These criteria must be met in order for an alternative to be selected.

The Primary Balancing Criteria:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume;
- Short-term effectiveness;
- Implementabilty; and
- Cost.

These criteria are the primary considerations in selecting an alternative.

And the Modifying Criteria:

- State acceptance; and
- Community acceptance.

These criteria must be considered in the remedy selection.

For each alternative, an evaluation was conducted of how the alternative addresses the first seven NCP criteria. In addition, a comparative evaluation of the characteristics of each alternative against the other alternatives with respect to the first seven criteria is presented for each area.

The California Department of Toxic Substances Control (DTSC), the Regional Water Quality Control Board—Central Valley Region and the Department of Health Services—Radiation Health Branch reviewed and determined that the remedial alternatives, as presented in this FS, are viable.

Public acceptance of the alternatives will be established as part of the CERCLA public participation process. A summary of the remedial alternatives and the preferred remedy will be presented in the Proposed Plan. A public meeting will be held during the 30-day comment period for the Proposed Plan to receive comments from the public. Per the CERCLA process, all public comments will be considered in the selection of the final remedy, and responses to the public comments will be presented in the Record of Decision.

Evaluation of the likely environmental impacts associated with all of the alternatives discussed in this FS, except the no action alternatives, indicates that there would be either no impact or minimal impact to the environment should any of the proposed alternatives be selected. The following values should not be impacted:

- Aesthetics and scenic values;
- Agricultural resources;
- Flood plains;
- Historical and cultural resources;
- Mineral resources;
- Public services;
- Socioeconomic conditions (including population and housing);
- Surface recreational water;
- Utilities and service systems; and
- Wetlands.

Short-term, minimal impacts would occur in the following areas:

- Air quality;
- Biological resources;
- Noise (occupational and public health considerations);
- Transportation of low-level radioactive waste;
- Traffic; and
- Water resources.

These impacts are expected to be fully mitigated by compliance with existing regulations. Most impacts (i.e., dust and noise) would be limited to the Site and immediate surroundings, and are expected to have no long-lasting consequences.

Significant long-term impacts to public health and water quality may occur under the no action alternative in areas where remaining contamination presents a threat to public health or ground water values.

Table ES-1. Summary of Remedial Drivers and Alternatives for the DOE Feasibility Study Areas

	← Remedial Drivers →			← Remedial Alternatives →							
Area	Human Health Risk	Ecological Risk	Ground Water Impact[1]	No Further Action	Long-Term Ground Water Monitoring/ Contingency Remediation	Long-Term Ground Water Monitoring/ Contingency Remediation /Land-Use Restrictions	Capping and Long-Term Ground Water Monitoring and Land-Use Restrictions	Removal and Off-Site Disposal	Removal and On-Site Treatment	Limited Removal and Off-Site Disposal	*In Situ* Bioremediation
Ra/Sr Treatment Systems Area			●	●	●		●	●	●	●	●
DSS 1				●							
DSS 3			●	●	●		●	●	●	●	●
DSS 4	●[2]		●	●		●	●	●[3]			
DSS 5				●							
DSS 6				●							
DSS 7				●							
Dry Wells A-E			●	●	●		●	●		●	
Southwest Trenches	●[4]		●	●	●	●	●	●	●	●	●[3]
Western Dog Pens				●							
Eastern Dog Pens	●[4]			●		●[5]		●			

Notes
● = Applicable remedial driver/alternative
[1] Contaminant(s) in vadose zone soil may result in future ground water impacts.
[2] Risk exceeds 10^{-6} for hypothetical resident and construction worker
[3] Includes land-use restrictions
[4] Risk exceeds 10^{-6} for hypothetical resident
[5] Land-use restrictions only - no ground water monitoring

Abbreviations
DSS Domestic Septic System
Ra/Sr Radium/Strontium

1. INTRODUCTION

The U.S. Department of Energy (DOE) has prepared this Feasibility Study (FS) to identify remedial alternatives for DOE areas at the Laboratory for Energy-Related Health Research (LEHR or the Site) at the University of California, Davis (UC Davis) (Figures 1-1 and 1-2). DOE is responsible for remediation of the environmental impacts associated with past activities at the LEHR Federal Facility, which is located within the United States Environmental Protection Agency (US EPA) National Priorities List (NPL) site known as the LEHR/Old Campus Landfill. This FS will lead to a Proposed Plan and Record of Decision, which will document proposed and final remedies, respectively, for the DOE portions of the Site.

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Services—Radiation Health Branch. The FFA provides the framework for conducting and documenting site cleanup. As an NPL site, environmental restoration must be conducted according to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and Superfund guidance and policy. Therefore, this FS was prepared to fulfill the requirements of Section 300.430(e) of the NCP.

Based on historical use, DOE and UC Davis have developed an MOA to allocate responsibility for environmental restoration of the LEHR/Old Campus Landfill Superfund Site (DOE, 1997). Under this agreement, DOE is responsible for environmental restoration of environmental impacts associated with the LEHR Federal Facility, as defined above. UC Davis is responsible for environmental restoration of Old Campus Landfill areas including, but not limited to, Landfill Disposal Units 1, 2 and 3; the 49 waste burial holes; the UC Davis disposal trenches; and site ground water (Figure 1-2).

For consistency with the FFA (US EPA, 1999) and internally within this FS report, the following terms and definitions are used in this document:

- COCs—Chemical or radiological constituents released at the Site that may result in adverse health or environmental impacts. COCs for each of the DOE areas were identified based on the area's excess cumulative human cancer risk, excess human non-cancer HI, and potential impacts to ground water (See Tables 2-1 and 2-2). No ecological COCs were identified in the Final Site-Wide Ecological Risk Assessment (SWERA) (UC Davis, 2006b).
- LEHR—As defined in the FFA, the land and improvements located within the historic boundary line on Figure 1-2.
- LEHR Site—As defined in the FFA, the area referred to in the NPL known as LEHR/Old Campus Landfill Superfund Site.
- LEHR Federal Facility—As specified in the FFA, the following areas at LEHR:
  - all buildings;
  - Cobalt-60 (Co-60) irradiation field;
  - SWT area;
  - Ra/Sr Treatment Systems area;
  - WDPs area;
  - EDPs area;
  - DSSs areas;
  - DOE Disposal Box; and

  - areas where contamination originating from the areas listed above have come to be located, excluding areas assigned to the UC Davis by the MOA.

- DOE-funded research activities—All DOE-funded research activities at LEHR between 1958 and 1988.
- DOE FS areas—Areas where CERCLA and/or California ground water protection standards are exceeded; i.e., the SWT area; Ra/Sr Treatment Systems area; WDPs area; DSS No. 3 (DSS 3); DSS 4, Dry Wells A-E and EDPs (Figure 1-2).
- UC Davis FS areas—Landfill Disposal Units 1, 2 and 3; the 49 waste burial holes; ground water; and the eastern and southern disposal trenches (Figure 1-2).

1.1 Report Organization

In addition to this introduction, this report includes:

- Section 2—Applicable or Relevant and Appropriate Requirements (ARARs) and Remedial Action Objectives (RAOs). This section identifies the federal standards, requirements, criteria, limitations or more stringent state standards determined to be legally applicable, or relevant and appropriate to the proposed remedial action alternatives. The RAOs presented in this section were developed to address contaminants and media of concern, potential exposure pathways and remediation goals.
- Section 3—Identification and Evaluation of General Response Actions and Remedial Technologies. This section identifies five general response actions: no action; institutional action; treatment; removal and disposal; and containment. Remedial technologies for each general response action are identified and evaluated. The retained technologies or "process options" are used to develop the remedial alternatives presented in Section 4.
- Section 4—Description and Evaluation of Remedial Alternatives. This section identifies the COCs, environmental impacts and principal threats for the DOE FS areas. This section also discusses the nature and extent of contamination at the DOE FS areas. The remedial alternatives for each DOE FS area are described, compared and evaluated based on nine criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction in toxicity, mobility or volume through treatment; short-term effectiveness; implementability; cost; state acceptance and community acceptance.
- Section 5—Assessment of Environmental Impacts. This section integrates the National Environmental Policy Act (NEPA) and California Environmental

Quality Act (CEQA) process with the FS to eliminate the need for separate NEPA and CEQA analyses.

- Section 6—References.
- Appendix A—Remedial Alternative Cost Estimates. This appendix provides cost estimates and assumptions for all of the remedial alternatives excluding no action.
- Appendix B—Excavation Volume Determinations. This appendix provides excavation volumes based on the spatial distribution of contaminants in soil.
- Appendix C—Dry Wells A-E Area Ground Water Investigation. This appendix documents the ground water investigation conducted by DOE in 2004 and 2005.
- Appendix D—Formaldehyde Vapor Risk Estimate. This appendix provides the calculations of vapor emissions associated with soil off-haul for DSS 3.
- Appendix E—Contaminant Loading Estimate for Soil to Ground Water Contaminant Migration. This appendix provides the methodology and calculations used to estimate the maximum areas of ground water impacts from residual contaminants in the DOE areas.
- Appendix F—Time-Series Trend Analysis of Ground Water Constituents of Concern. This appendix provides a summary of the spring 2006 DOE sampling event and provides time-series plots of ground water concentrations for wells downgradient of the DOE FS Areas.

1.2 Site Background

1.2.1 Site Description

The LEHR site is located in Solano County, California, in the southeast quarter of Section 21, Township 8 North, Range 2 East, Mount Diablo Base and Meridian (Figure 1-1). It is approximately 1.5 miles south of the town of Davis and is bounded by UC Davis research facilities, farmland and the South Fork of Putah Creek. The southern boundary of the Site is the northern levee of the South Fork of Putah Creek.

LEHR covers approximately 15 acres and contains laboratory buildings and undeveloped land. Figure 1-2 shows the spatial distribution of buildings at LEHR. Of the 15 acres, approximately 40 percent is paved or covered by structures, approximately 55 percent is unpaved and relatively free of vegetation, and 5 percent is covered by large, deep-rooted vegetation. The land and buildings are owned and maintained by the Regents of the University of California.

1.2.2 Site Historical Operations

For the period prior to DOE's use of LEHR, aerial photographs from 1937, 1952 and 1957 provide evidence of former site conditions and usage. In 1937, the LEHR site location was primarily open grassland with scattered brush and trees, and was similar to the agricultural land in the surrounding area. Remnants of an apparent golf course were visible mainly on the eastern half of the LEHR location. Additionally, a small structure was present within a group of trees along the southern boundary adjacent to the South Fork of Putah Creek. By 1952, the former golf course and structure were absent and much of the vegetation at the LEHR location appeared to have been cleared or used for cattle grazing. By 1957, new roads had been established in the southern portion of the LEHR location and there was evidence of grading or excavation activities in the EDPs area. UC Davis operated two landfills within the boundaries of LEHR: Landfill Disposal Unit 1 from the early 1940s through mid-1950s, and Landfill Disposal Unit 2 from 1956 through 1967 (Figure 1-2).

The Atomic Energy Commission (now DOE) began conducting radiological studies on laboratory animals, particularly beagles, in the early 1950s. Initial studies were carried out on the main UC Davis campus and involved the irradiation of beagles. DOE-funded research activities began at LEHR in 1958. DOE-funded research at LEHR through the mid-1980s focused on the health effects from chronic exposure to radionuclides, primarily strontium-90 (Sr-90) and radium-226 (Ra-226). In the early 1970s, a Co-60 irradiator facility was constructed by DOE at LEHR to study the effects of chronic exposure to gamma rays on bone marrow cells of beagles. In 1975, DOE initiated a program at LEHR to study the potential health effects of combustion products from fossil fuel power plants. In 1983, the Toxic Pollutant Health Research Laboratory (TPHRL) began operating at LEHR. Studies at TPHRL included the use of americium-241 (Am-241) and plutonium-241 (Pu-241).

All DOE-funded research activities at LEHR had ceased by 1988. Environmental investigations began in 1984, building decontamination and decommissioning (D&D) was completed in 1997, and CERCLA RAs were completed in 2002.

1.2.3 Current and Future Land Use

UC Davis currently operates the Center for Health and the Environment (CHE) at the former LEHR facility. Research activities at CHE include the study of toxic and carcinogenic agents and occupational health (UC Davis, 2003). These activities are likely to continue in the foreseeable future.

The Site is designated as "Urban and Built-up Land" by the State of California Department of Conservation for Yolo and Solano Counties Important Farmlands Maps (UC Davis, 2002). Specific land uses on the Site and the immediate adjacent areas are under the control of UC Davis and are consistent with the UC Davis Long-Range Development Plan (LRDP) (UC Davis, 2003). The LRDP designations for the LEHR site are "Academic/Administrative Low Density" and "Support Services" (UC Davis, 2003).

1.2.4 LEHR Federal Facility Non-Building Areas and Removal Actions

The following non-building areas are identified as the LEHR Federal Facility: Ra/Sr Treatment Systems, DSS 1-7, WDPs, Co-60 irradiation field, EDPs, DOE Disposal Box and the SWT disposal area (Figure 1-2).

To date, DOE has conducted one time-critical and four non-time-critical RAs. A time-critical RA was conducted in the DOE Disposal Box area in 1996. The four non-time critical RAs were for the SWT area in 1998, the Ra/Sr Treatment Systems area I and II in 1999 and 2000, the WDPs area in 2001, and the DSS 3 and 6 area in 2002. DSS 2, parts of the DSS 1, and parts of the DSS 5 leach field were removed during the Ra/Sr Treatment Systems area RA.

1.2.5 LEHR Federal Facility Buildings

1.2.5.1 Buildings Description

The 18 buildings used for DOE-funded research are shown on Figure 1-2. The buildings, where the majority of the research was conducted, are discussed briefly below.

From 1961 through 1969, beagles were fed with food containing limited quantities of Sr-90. The majority of this research was conducted in Animal Hospital (AH)-1 (Building H-219) (Bechtel, 1993). Other experiments involving small amounts of Pu-241 were also conducted in AH-1. In 1963, Ra-226 injection experiments were conducted on beagles, primarily using the facilities in AH-2 (Building H-218) (Bechtel, 1993).

The Specimen Storage and Feed Mixing Building (Building H-216) was used to mix and store non-radioactive dog food and store samples from the dog experiments (Bechtel, 1993). The Specimen Storage Room (Room 425) housed the historical library of tissue, organ and bone samples from the dog experiments. Many of these samples were known to be radioactive and were contained in plastic bags, which were hung from open racks.

In the early 1970s, a Co-60 irradiator facility was constructed at the LEHR site to study the effects of chronic exposure to gamma rays on bone marrow cells of beagles. The Co-60 Building (Building H-229) was originally built to house and use a Co-60 irradiation source. Following removal of the Co-60 source in 1993, the Co-60 Building was used to store lead bricks, an Am-241/Pu-241 glove box, bagged electrical motors, miscellaneous radioactive sources and vials contained in a safe, and other miscellaneous DOE items (IT Corp., 1997).

In 1975, construction began on the Cellular Biology Laboratory. This laboratory was established for conducting research in cellular biology focusing on the blood-forming and immunological functions of bone marrow cells and their alterations by ionizing radiation (DOE, 1988). In 1983, DOE began using the TPHRL to conduct exposure studies of laboratory animals to toxic materials. Studies at the TPHRL included: studies of the effects of Pu-241 and Am-241 on behavior in beagles and monkeys, radioactive and toxic gas-particle mechanistic aerosol studies, aerosol inhalation deposition studies, intratracheal applications of carcinogen-coated particles and an organic vapor uptake study in beagles (LEHR, 1987).

The MOA between DOE and UC Davis signed in 1988 allowed UC Davis to use some of the building for non-DOE research. This agreement assigned UC Davis with responsibility for any contamination caused by their use. On September 8, 1988, UC Davis corresponded with the California Department of Health Services to amend their Broadscope Radioactive Materials license #1334-57 to include the following buildings: Maintenance Shop (H-212), Main Building (H-213), Reproductive Biology Laboratory (H-215), Inter-Regional Project No. 4 (H-217), Occupational and Environmental Medicine Building (H-289), Co-60 Annex (H-290), Geriatrics Building Number 1 (H-292), Geriatrics Building Number 2 (H-293), Cellular Biology Laboratory (H-294), Small Animal Housing (H-296), TPHRL (H-299) and Storage Space (H-300). With the amendment of their State of California Broadscope Radioactive Materials License, UC Davis has accepted responsibility for any future release of these buildings.

On July 12, 2005, a quit claim was recorded with Solano County, which transferred ownership of all Site buildings to the Regents of the University of California.

1.2.5.2 Building Decontamination and Decommissioning

Portions of the AH-2 and Specimen Storage and Feed Mixing buildings were released by DOE to UC Davis following final surveys conducted in 1984 and 1989 (Vitkus and Payne, 1995). The remainder of these buildings as well as AH-1 (H-219) and the Co-60 Building (H-239) were D&D between 1992 and 1995. In 1995, the Imhoff waste water treatment facility (Figure 1-2) was demolished. Waste generated from this activity was volume-reduced, packaged and shipped to the DOE Hanford site for disposal as low-level radioactive waste.

To allow the release of AH-1, AH-2, the Specimen Storage Building and the Co-60 Building for use without radiological restrictions, all radioactive material and contamination was removed from the buildings. In general, passive decontamination techniques, such as high-efficiency particulate air vacuuming, damp cloth wiping, and hand washing/scrubbing, were applied first (*Federal Register, 1997*). To remove more tightly bound contaminants from surface material such as fiberglass and epoxy-coated cages, chipping and grinding were employed as the decontamination methods. When decontamination of cages was no longer cost-effective, the remaining contaminated material was removed, volume-reduced, and shipped off-site for disposal as low-level radiological waste (*Federal Register, 1997*).

During the D&D process, sub-floor and construction material were analyzed for radioactive contamination. The sampling targeted material below slab cracks and expansion joints, and adjacent to penetrations, such as floor drains and clean-out ports. Neither on-site soil screening nor off-site laboratory analyses revealed any contamination above natural background concentrations (IT Corp., 1997). Post-decontamination final status surveys, as verified by the California Department of Health Services and the DOE Independent Verification Contractor, confirmed that the residual radioactive contamination in AH-1 and AH-2, the Specimen Storage Building, and the Co-60 Building met the requirements for unrestricted use (DHS, 1995; DHS, 1997).

A certification docket was compiled in 1997 to document the successful D&D of AH-1, AH-2, the Specimen Storage Building, and the Co-60 Building at LEHR for unrestricted use. A notice of certification of the radiological condition of the property was published in the Federal Register on October 3, 1997.

After RAs were completed, DOE surveyed and decommissioned a portion of AH-1, the southern half of Building H-292 and the Co-60 irradiation field. These areas had been used as field laboratory or waste storage activities during CERCLA RAs. These areas met the requirements for unrestricted use (DHS, 2004a,; DHS, 2004b; and DHS, 2004c).

1.2.6 Other Areas

In 2002, UC Davis collected 10 surface soil samples (0 to 0.5 feet [ft] below ground surface [bgs]) from non-operable unit areas on the LEHR Site. Non-operable unit areas refers to areas of the LEHR Site that are not covered by buildings, parking lots or other structures, and are not under investigation (MWH, 2004). Since the non-operable unit areas are outside of the potential areas for environmental releases and no significant contamination was identified in the samples, they are not addressed in this FS.

1.3 Contaminant Fate and Transport

In general, the results of DOE areas investigations and RA confirmation studies have shown that contaminants have not migrated significant distances from their original release areas. The DOE release areas consisted primarily of contaminated surface materials (soil, concrete and gravel) and subsurface buried waste, structures, soil and leach fields. The source contamination consisted of radionuclides, metals, organic chemicals and nitrate. No significant sources of volatile organic chemicals existed in the DOE areas, except formaldehyde at DSS 3. Four mechanisms could have transported contamination from the release areas:

1. Contaminants could have migrated through the vadose zone to ground water from the surface and subsurface source areas predominantly due to rain water infiltration/leaching and downward movement. Ground water could then transport contaminants downgradient.

2. Rain water could have leached contaminants from soil, or mobilized contamination from surface soil and structures, and carried contaminants in storm water runoff to Putah Creek.

3. Wind may have entrained contaminated dust from surface soil and structures, and carried the contamination to downwind locations.

4. Radon gas could have diffused from subsurface sources and entered indoor and/or outdoor air. Radon gas could have dispersed from subsurface sources along pressure gradients and permeable sediments or conduits.

1.3.1 Vadose Zone Modeling

A one-dimensional numerical modeling code was used to simulate contaminant transport from surface and shallow subsurface DOE areas sources through the vadose zone. Vadose zone modeling calculations were performed using the Non-Isothermal Unsaturated Flow and Transport (NUFT) (Nitao, 1998) numerical code developed and validated by Lawrence Livermore National Laboratory. The results of vadose zone modeling were used to estimate the time required for DOE area source material to migrate through the vadose zone and to determine soil cleanup levels protective of ground water quality (designated levels). Peak concentrations in ground water were modeled for time periods exceeding 10,000 years. If the NUFT model results indicated that a particular constituent in a DOE area soil would potentially impact ground water above background levels within the next 500 years, then the soil contamination at the DOE area is addressed in the area's remedial alternatives. The 500-year threshold was selected because chemical degradation, radiological decay and/or technological advances will likely mitigate potential impacts beyond this threshold. Because of the one-dimensional nature of the NUFT model, mass of contamination and the volume of contaminated ground water that might be produced from residual vadose zone contamination was not modeled. Estimates of these impacts are discussed below in Section 1.3.3.

Initial vadose zone model development and parameter selection/justification was presented in the *Draft Final One Dimensional Vadose Zone Modeling for the US Department of Energy Areas at the Laboratory for Energy-Related Health Research* (WA, 1997a) report. This report documented the basic modeling approach and parameter selection process that was used in subsequent simulations.

Modeling refinements that increased site-specific versatility and simulation efficiency were documented in the *Work Plan for Removal Actions in the Southwest Trenches, Ra/Sr Treatment Systems, and Domestic Septic System Areas* (WA, 2000).

The modeled designated levels were determined according to *The Designated Level Methodology for Waste Classification and Cleanup Level Determination* (CRWQCB, 1989). The modeling details specific to each DOE area were presented in the following documents:

- EDPs and WDPs—*Final Engineering Evaluation/Cost Analysis for the Western and Eastern Dog Pens* (WA, 2001a);
- DSS 1, 4, 5, and the Dry Wells area—*DOE Areas Remedial Investigation Report* (WA, 2003);
- SWT area—the *Final Southwest Trenches Area 1998 Removal Action Confirmation Report* (WA, 2001b);

- Ra/Sr Treatment Systems area—*Final Radium/Strontium Treatment Systems Area Removal Action Confirmation Report* (WA, 2001c); and

DSS 3 and 6—*Domestic Septic System 3 and 6 Confirmation Report* (WA, 2001d, *Sampling and Analysis Plan for the DOE Disposal Box Area Confirmation Data Gaps at the Laboratory for Energy-Related Health Research,* University of California, Davis, December.

WA, 2002a, *Domestic Septic Systems 3 and 6 Removal Actions Work Plan for the Laboratory for Energy-Related Health Research,* University of California, Davis, Rev. 0, May.

- WA, 2002b).

1.3.2 Dust Emissions and Radon Gas Emanation Modeling

Fugitive dust and radon gas modeling was conducted for LEHR DOE areas. The fugitive dust model simulated windborne emissions of contaminated dust. The emissions estimates were used to quantify human health risk from inhalation of contaminated dust. The radon gas model simulated radon emissions from contaminated soil to indoor and outdoor air. The radon emission estimates were used to determine human health risk from radon exposure. The details of fugitive dust and radon gas modeling were presented in the *Site-Wide Risk Assessment*, *Volume I: Human Health Risk Assessment (Part A-Risk Estimate)* (UC Davis, 2005).

1.3.3 Contaminant Loading Estimates for Soil to Ground Water Contaminant Migration

As part of this FS, calculations were performed to estimate the area and diameter of ground water contamination that would result if the entire mass of a COC in soil is immediately transferred into the shallowest water-bearing unit. These calculations do not predict maximum concentrations. The resulting plume was assumed evenly distributed over an area in hydrostratigraphic unit 1 (HSU-1) at concentrations equal to the ground water goals (i.e., the California Maximum Contaminant Level [MCL] for drinking water or the Site background concentration). No degradation was assumed. The procedures involved in this calculation included estimating the mass of contamination in the vadose zone, and the resulting ground water plume area and diameter for each ground water impact COC in the DOE Areas (Table 1-1). The procedures, results and uncertainties of these calculations are presented in Appendix E.

The estimated masses of ground water COCs in the vadose zone, estimated ground water plume areas and plume diameters are shown in Table 1-1. Nitrate was the only ground water COC with estimated DOE Areas vadose zone masses greater than 6 kilograms. Estimated radionuclide COC masses were approximately 1 milligram or less. Most of the estimated plume areas are much less than one acre in area. Contaminated areas that exceeded one acre (based on the MCL thresholds) were formaldehyde at DSS 3, nitrate at the Radium/Strontium Treatment Systems (Ra/Sr) area and nitrate at the Southwest Trenches (SWT) area. Areas larger than one acre (based on background thresholds) were formaldehyde at DSS 3, silver in the Dry Wells A-E (Dry Wells) area, nitrate at the Ra/Sr area and carbon-14 at the Ra/Sr and SWT areas. The actual areas of ground water impacts are expected to be markedly less due to dilution and dispersion of all constituents, and biodegradation of formaldehyde and denitrification of nitrate (See Section 4.6.2.7).

1.4 Baseline Risk Assessment Summary

The human health baseline risk assessment is a three-step process consisting of a risk estimate, risk characterization and risk management decisions (Figure 1-3). As previously discussed, the SWERA did not identify any ecological COCs at the Site. The risk estimate began with a broad Tier 1 quantitative analysis of sample data from each area. The sample data were screened against conservative screening values and if an analyte exceeded the screening value, it was carried into the human health or ecological risk calculations, or ground water impact simulations as a constituent of potential concern (COPC). Carcinogenic and non-cancer risks were estimated for a variety of human receptors using site-specific physical parameters, standard exposure assumptions, and widely published and accepted toxicity factors. Potential ground water impacts were estimated using chemical- and site-specific parameters in a model to simulate contaminant migration through vadose zone soil to the underlying ground water.

After the human health risks and ground water impacts were estimated, the risk estimate included further refinement of the COPCs. Human health COPCs were eliminated if statistical testing showed the concentration data did not exceed background. Human carcinogen COPCs that exceeded background were carried forward if their risk was greater than 10^{-6} or if they contributed more than 10 percent to the cumulative cancer risk. None of the carcinogen COPCs in a DOE area were carried forward if the cumulative cancer risk for that area was below 10^{-6}. Human non-cancer COPCs were carried forward if their hazard quotient exceeded 1.0. Ground water COPCs were carried forward if the concentration in ground water was above site background. If a COPC was below ground water background, its concentration in soil was still compared to soil background and the modeling results. If the COPC exceeded soil background and the model indicated ground water impact within 500 years, it was carried forward as a ground water COPC. The human health risk estimate was documented in the *Site-Wide Risk Assessment*, *Volume I: Human Health Risk Assessment (Part A-Risk Estimate)* (UC Davis, 2005) and the ground water risk estimate for DOE areas was documented in the DOE areas Remedial Investigation (WA, 2003).

All of the COPCs that were carried forward from the risk estimate were evaluated in the risk characterization. A weight-of-evidence approach for risk factors and sources of uncertainty was used to characterize the COPC risks. Human health COPCs and ground water COPCs were characterized relative to their spatial distribution, percentage of samples that exceeded background, analytical bias/uncertainty, degradation/decay rates, data representativeness and relation to site operations. The characterizations were evaluated and reduced to summaries of their significant points and COPCs were recommended as COCs for the FS based on their characterized risk. The risk characterization for human health and ground water COPCs was documented in the *Site-Wide Risk Assessment*, *Volume I: Human Health Risk Assessment (Part B-Risk Characterization for DOE Areas)* (WA, 2005).

The risk management step was carried out through Remedial Project Manager (RPM) feedback on the risk characterization document. Risk management activities involved:

- RPM evaluations of the risk factors and sources of uncertainty presented in the risk characterization document;
- RPM comments on the COC recommendations; and
- RPM agreement with the responses to comments and the final edits to the risk characterization document.

The risk management decisions are documented in the RPM approval documents, which agree with the COCs selected in the final risk characterization (WA, 2005).

As shown in Figure 1-3, the risk management decisions result in a list of COCs to be addressed in the FS remedial alternatives and a list of ground water COPCs to be added to the existing field sampling plan. The latter is intended to add assurances that the risk management decisions to not address the COPCs in the FS alternatives are protective. The ground water COPCs are shown in Table 1-2. The FS COCs are identified in Section 2

As previously discussed, the mass of residual contamination in the DOE areas is very low and site risks are either at or below State and federal human health risk thresholds for current and projected site use as a research facility. Additionally, Site risks are below the level of concern for all ecological receptors (UC Davis, 2006b). However, risk estimates suggest that residual soil contamination in some areas could pose a risk to a hypothetical on-site resident and/or possibly impact ground water. These are very conservative estimates since the long-range plan for the site does not include residential use and, based on available data, the mass of residual contamination in soil is too low to significantly impact ground water quality.

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Table 1-1. Summary of Contaminant Loading Estimates for Soil to Ground Water Contaminant Migration

Area	COC	Estimated Mass (kilograms)	Ground Water Goal[1]		Ground Water Background[2]	
			Affected Area[3] (acres)	Diameter (feet)	Affected Area[3] (acres)	Diameter (feet)
Ra/Sr TS	Nitrate	400	3.6	446	1.3	269
	Carbon-14	1.9E-7	0.038 [4]	46	1.5	290
	Radium-226	1.2E-6	0.010	23	0.042	48
DSS 3	Formaldehyde	5.7	5.1 [5]	531	20	1,061
	Molybdenum	4.9	0.026 [6]	38	0.31	131
	Nitrate	92	0.83	214	0.30	129
DSS 4	Selenium	0.027	0.0020[4]	10	0.018	31
Dry Wells A-E	Chromium	6.0	0.12	81	0.24	114
	Hexavalent Chromium	0.025	5.0E-04	5.3	6.3E-04	5.9
	Mercury	0.18	0.032	42	0.63	187
	Molybdenum	0.092	4.8E-04 [6]	5.2	5.8E-03	18
	Silver	2.7	0.060 [7]	58	1.2	257
	Cesium-137	1.4E-10	1.2E-06 4	0.26	2.4E-04	3.6
	Strontium-90	1.1E-10	9.8E-04	7.4	0.0046	16
SWT	Nitrate	270	2.4	365	0.88	220
	Carbon-14	5.6E-7	0.11 [4]	79	4.5	498

Note
These calculations do not predict maximum concentrations.
[1] Ground water concentration does not exceed ground water goal (California MCL unless otherwise noted).
[2] Ground water concentration does not exceed site background.
[3] Goal is based on the California primary maximum contaminant level for drinking water.
[4] Goal is based on the derived limit for drinking water from the 4 roentgen equivalent man per year Federal MCL for beta particles and photon emitters (US EPA, 2000a).
[5] Formaldehyde goal is based on the California Department of Health Services State Action Level of 100 µg/L.
[6] Goal is based on the United States Environmental Protection Agency, Region 9 preliminary remediation goal for tap water.
[7] Goal is based on the California secondary maximum contaminant level for drinking water.

Abbreviations

COC	constituent of concern
DSS 3	Domestic Septic System Number 3
DSS 4	Domestic Septic System Number 4
MCL	maximum contaminant level
Ra/Sr TS	Radium/Strontium Treatment Systems area
SWT	Southwest Trenches area
TS	Treatment System

Table 1-2. Ground Water Constituents of Potential Concern to be Monitored in the DOE Areas

Area	Constituents of Potential Concern to be Monitored[1]
Domestic Septic System No. 1	Aluminum
Domestic Septic System No. 3	Aluminum, Silver
Domestic Septic System No. 4	Aluminum, Chromium, Nickel
Domestic Septic System No. 5	Aluminum
Domestic Septic System No. 6	Aluminum
Domestic Septic System No. 7	None
Dry Wells A-E Area	None
Radium/Strontium Treatment Systems	Americium-241
Southwest Trenches	Mercury, Zinc
Western Dog Pens	None
Eastern Dog Pens	alpha-Chlordane, gamma-Chlordane, Dieldrin
DOE Disposal Box	None

Notes
[1]Through amendment to the Site field sampling plan.

Abbreviations
DOE United States Department of Energy
No. number

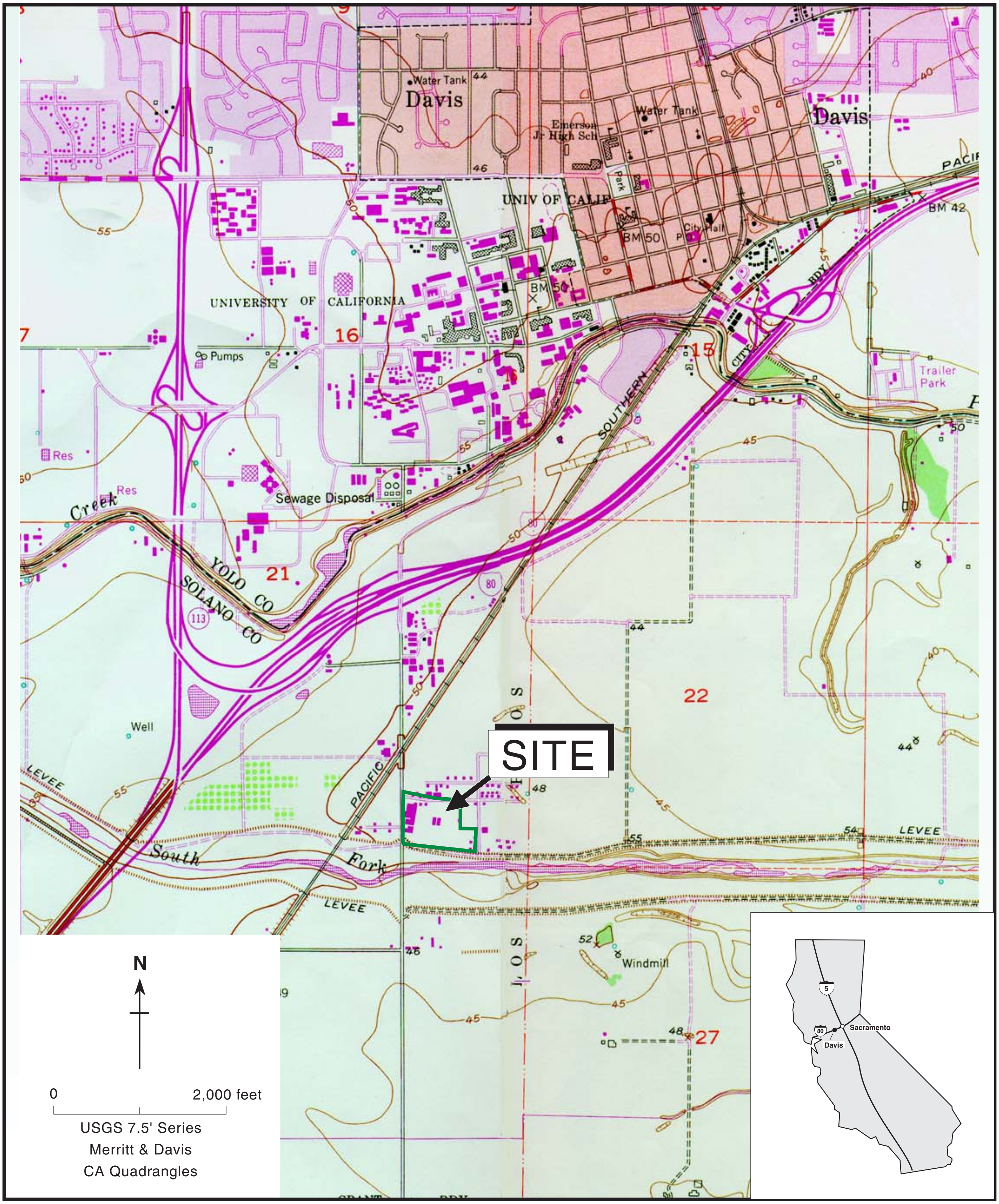

Figure 1-1. Location of the LEHR Site, UC Davis, California

Weiss Associates

Figure 1-2. LEHR Site Features and FS Areas

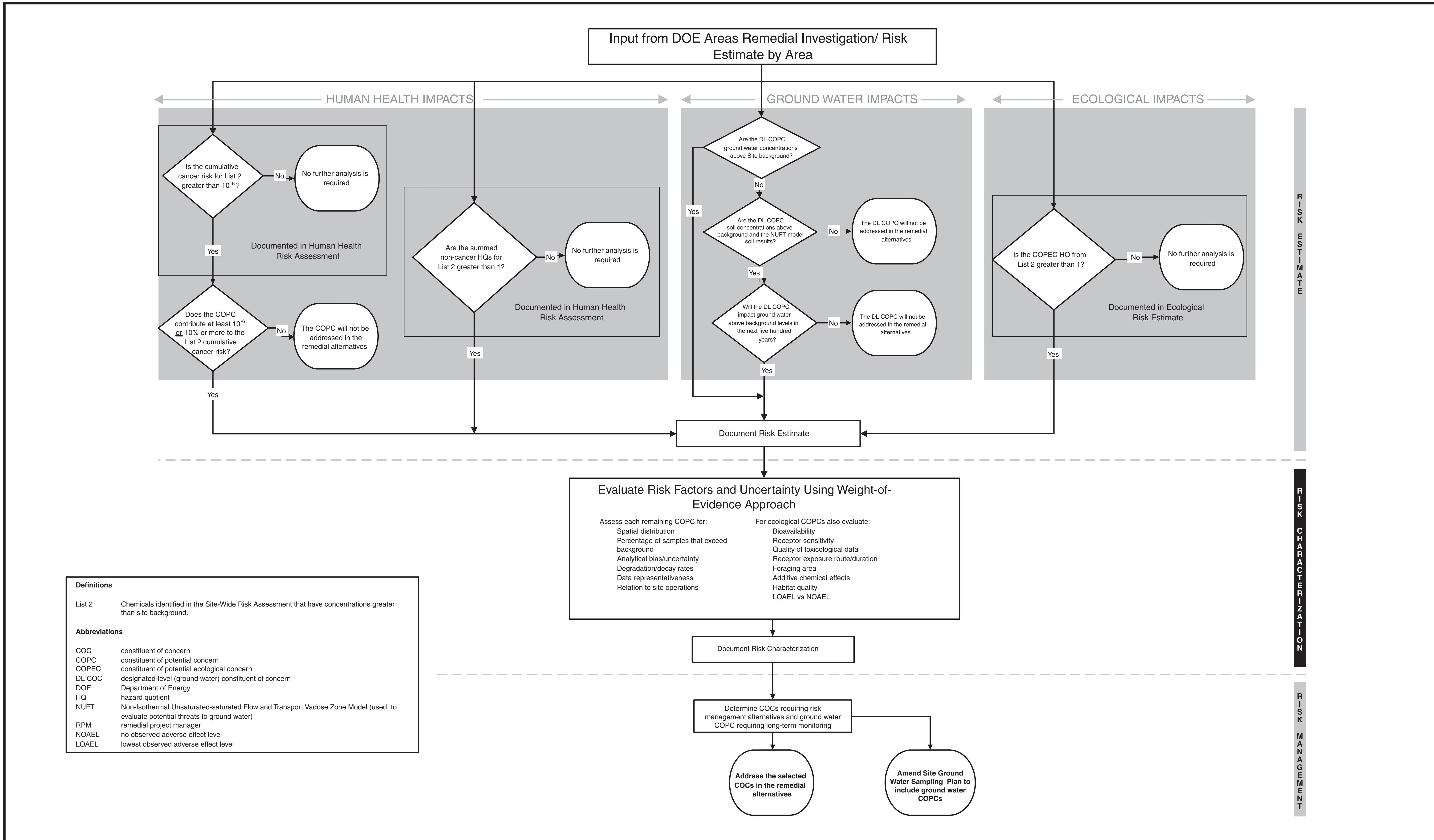

Figure 1-3. Risk Assessment Process

2. REMEDIAL ACTION OBJECTIVES

RAOs establish the contaminants and media of concern, the potential exposure pathways, and remediation goals for protecting human health and the environment. The contaminants and media of concern for human health established in the risk management process are discussed below, followed by a discussion of ARARs and remedial action objectives.

2.1 Contaminants and Media of Concern

The risk management process indicates that current site risks are limited and soil is the only contaminated medium to be addressed in this FS. Table 2-1 identifies COCs contained in soil that could result in risk to hypothetical residents and construction workers at the Site In the DSS 4 area, excess cancer risk to a hypothetical resident is present for exposure to polycyclic aromatic hydrocarbons (PAHs), benzo(a)anthrecene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene (Table 2-1). The majority of this risk is driven by plant ingestion (i.e., homegrown produce). The summed cancer risk (i.e., summed total risk for all COCs) for the hypothetical resident is 5.0×10^{-4} (Table 2-1), which slightly exceeds the upper-bound of the CERCLA risk range.

Benzo(a)pyrene contained in soil at DSS 4 presents a 1.0×10^{-6} risk to a hypothetical construction worker doing subsurface work in the DSS 4 area, which is an acceptable risk under CERCLA. In the EDPs, dieldrin contained in soil and Sr-90 contained mainly in concrete curbing present a cumulative risk of about 5×10^{-6} for a hypothetical resident. In the SWT area, elevated cancer risk is present for a hypothetical resident through exposure to Sr-90 and its daughter product yttrium-90. The majority of this risk is driven by plant ingestion (Table 2-1). The total cancer risk of 3×10^{-6} for the hypothetical resident slightly exceeds the CERCLA point of departure of 1×10^{-6}.

Table 2-2 identifies COCs contained in soil which have potential to impact ground water in limited areas (Table 1-1) and within Site boundaries, based on conservative transport model predictions of soil contaminant concentrations that could impact ground water within the next 500 years. With high mobility compounds, such as nitrate or carbon-14 (C-14), impacts may have already occurred or could occur in much shorter time frames. At DSS 3, elevated nitrate concentrations may impact a limited area of ground water above the California maximum contaminant level (MCL), formaldehyde may impact a limited area of ground water above the California Department of Health Services action level and molybdenum may impact a limited area of ground water above background. At DSS 4, transport modeling suggests that selenium will not impact ground water above California MCLs or background (Table 2-2), but selenium was retained in the risk management process due to the historical detection of selenium in downgradient ground water monitoring well UCD1-024 and the lack of nearby ground water monitoring wells. At Dry

Wells A-E, chromium, hexavalent chromium (Cr-VI), mercury and silver are predicted to impact a limited area of ground water above California MCLs, while molybdenum, cesium-137 (Cs-137) and Sr-90 are predicted to impact a limited area of ground water at concentrations above background. At the Ra/Sr Treatment Systems area, nitrate is predicted to impact a limited area of ground water above the California MCL, C-14 is predicted to impact ground water above the federal MCL while Ra-226 may result in limited impacts above background. At the SWT area, impacts above the California MCL are anticipated for nitrate and limited impacts above the federal MCL are anticipated for C-14.

All DOE areas contain or potentially contain chemicals and radionuclides in soil above site background. These constituents result in risks that are below the CERCLA risk point of departure for residential land use, except for Sr-90 in the SWT area, Sr-90 and dieldrin in the EDPs and PAHs in the DSS 4 area. This FS does not evaluate the future management of soil disposed or reused off-site after remediation is complete. It is assumed that existing and future UC Davis procedures for land development and waste management will comply with all applicable disposal and reuse requirements for soil potentially containing residual chemicals and radionuclides.

2.2 Applicable or Relevant and Appropriate Requirements

RAOs are established after consideration of all ARARs. Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986, requires attainment of ARARs, (30 Code of Federal Regulations [CFR] Section 300.400(g)) in the remediation process. The NCP describes the process for attaining ARAR requirements. This section describes ARARs for the Site and for potential remedial alternatives evaluated in this FS.

2.2.1 Definitions

ARARs are federal standards, requirements, criteria, limitations or more stringent state standards determined to be legally applicable or relevant and appropriate to the circumstances at a given CERCLA site. Under Section 121 of CERCLA and Section 300.400(g) of the NCP, actions undertaken under CERCLA Section 120 must attain ARARs.

Applicable requirements are requirements promulgated under federal or state law that would be legally applicable to the site activities if the actions were not taken pursuant to Sections 104, 106, 120, 121 and 122 of CERCLA. These requirements directly and fully address on-site activities.

Relevant and appropriate requirements are federal or state requirements that, while not legally applicable to the Site, apply to sites or circumstances sufficiently similar to the subject site that their application is appropriate because they serve to further reduce the risk posed by the CERCLA site. In some cases, only a portion of the requirement may be relevant and appropriate. Only those requirements that are both relevant and appropriate must be addressed at CERCLA sites. The lead and support agencies have the discretion to determine which requirements are relevant and appropriate to the project.

Only substantive requirements are considered when determining ARARs for on-site activities. Substantive requirements are requirements that pertain directly to actions or conditions in the environment. Substantive requirements apply to on-site actions. “On-site” includes not only the aerial extent of contamination subject to CERCLA action, but also all areas in very close proximity to the contamination necessary for implementation of the response action.

Compliance with administrative requirements or requirement permits from federal, state or local administrative bodies is not required for activities undertaken under CERCLA Sections 104, 106, 120, 121 or 122 (40 CFR Section 300.400(e), 42 United States Code Annotated [USCA] Section 9621). Administrative requirements are mechanisms that facilitate the implementation of the substantive requirement of a statute or regulation. These are interpreted broadly by the US EPA to include all administrative provisions from other laws, such as recordkeeping, consultation and reporting requirements.

Activities conducted off-site must meet both the substantive and administrative requirements that are determined to be applicable.

ARAR evaluations should recognize that current conditions may be compliant, but that future conditions may not be compliant due to the migration of contaminants from the vadose zone to ground water.

2.2.2 Types of Applicable or Relevant and Appropriate Requirements

ARARs to be reviewed for CERCLA sites fall into three broad categories, based on the COPCs, site location, site conditions and the actions being considered. The three categories are:

- Chemical-specific ARARs—Usually health- or risk-based requirements that define acceptable concentrations of a chemical in the environment. An example of a chemical-specific ARAR is an ambient air quality standard or a MCL defined by section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act (Pub. L. 93–523).
- Location-specific ARARs—Requirements that restrict activities in certain environmentally sensitive areas such as flood plains, wetlands, endangered species habitat or historically significant areas.
- Action-specific ARARs—Requirements that are technology or activity based. These ARARs regulate discrete actions or the design and use of certain equipment. An example of an action-specific ARAR is Clean Water Act requirement to control the discharge of sediment into tributaries of navigable water ways.

2.2.3 State and Local Applicable or Relevant and Appropriate Requirements

Remedial actions must comply with ARARs, which include state-promulgated environmental regulations that are more stringent than federal environmental requirements. To be considered "promulgated", a requirement must be legally enforceable, based on specific enforcement provisions or the state's legal authority, and must be generally applicable. State rules must also be identified in a timely manner in order to be considered as ARARs. Local or regional requirements that are promulgated and legally enforceable by the state may also serve as ARARs.

2.2.4 To-Be-Considered Guidelines

When ARARs are not fully protective of human health and the environment, the NCP allows for other local ordinances, unpromulgated criteria, advisories or guidance documents to be identified to supplement the ARARs if they are helpful in achieving an acceptable level of risk (40 CFR §300). The identification of to-be-considered guidelines (TBCs) is not mandatory; however, it is recommended if it will assist in determining a level of cleanup that protects human health and the environment.

2.2.5 Chemical-Specific Requirements

The following are chemical-specific ARARs and TBCs for the LEHR DOE areas. These requirements are summarized in Table 2-3.

Federal Requirements

- Solid Waste Disposal Act, RCRA, Identification and Listing of Hazardous Waste (42 United States Code [USC] §6921, 40 CFR Part 261) implemented by the State of California in the Health and Safety Code and Title 22 of the California Code of Regulations discussed below;
- Radiological Criteria for License Termination (10 CFR Part 20, Subpart E, US NRC, 1997);
- Clean Water Act (33 USCA 1251-1376; 40 CFR 122, 125 and 136);
- Pre-treatment standards under the Clean Water Act;
- Safe Drinking Water Act (42 USCA 300; 40 CFR 141.11-16, 141.23-24, 141.50-51, 141.61-62,);
- National Emissions Standards for Hazardous Air Pollutants; Section 112 of the Clean Air Act (40 CFR Part 61, 10 CFR 20.101-20.108);
- Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination (US NRC, 1999); and

- Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination (US EPA, 1997).

State Requirements

- California Health and Safety Code, Division 20, Chapter 6.5, Section 25100 *et seq.;*
- Criteria for Identifying Hazardous Wastes (California Code of Regulations [CCR], Title 22, 66261.21-33);
- Drinking Water Standards for Public Water Systems, (CCR, Title 22, 64431-64445);
- Porter-Cologne Water Quality Control Act (Generally, California Water Code, Div. 7, § 13000, *et seq.* and 23 CCR Chap. 15, 2510-2559, 2580-2601);
- The Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65), Division 20 of the California Health and Safety Code;
- State Water Board's regulations governing discharges of waste (Title 23 CCR, Division 3, Chapter 15, Section 2510 *et seq.*);
- Consolidated Regulations for Treatment, Storage, Processing or Disposal of Solid Waste, (Title 27 CCR);
- General Requirements (Section 20080 *et seq.*);
  - Applicability and Classification Criteria (Section 20200 [c]);
  - Designated Waste (Section 20210);
  - Water Quality Monitoring and Response Programs for Solid Waste Management Units (Section 20385);
  - Waste Classification and Management (Sections 20220, 20230);
  - Water Quality Protection Standard, Water Quality Monitoring and Response Programs for Solid Waste Management Units (Water Standard Sections 20390, 20395, 20400, 20405, 20410, 20420, 20415, 20430); and
  - Closure and Post-Closure Maintenance Requirements for Solid Waste Landfills (Section 21090).
- Executive Order D-62-02 by the Governor of the State of California, requiring that the State and Regional Water Boards impose a moratorium on the disposal of "decommissioned materials" at active Class III landfills and unclassified waste management units throughout the state;
- Central Valley Regional Water Quality Control Board Basin Plan, "Policy for Investigation and Cleanup of Contaminated Sites" and "Policy for Application of Water Quality Objectives";

- State Water Resources Control Board Resolution 68-16, "Anti-Degradation Policy";
- State Water Resources Control Board Resolution 92-49, "Policies and Procedures for Investigation and Cleanup and Abatement of Discharges under Water Code Section 13304" (as amended April 21, 1994); and
- State Water Resources Control Board Resolution 88-63, "Sources of Drinking Water Policy."

Guidance

- Staff Report of the RWQCB Central Valley Region, "The Designated Level Methodology for Waste Cleanup Level Determination"; and
- Staff Report of the RWQCB Central Valley Region, "A Compilation of Water Quality Goals," August 2003.

2.2.6 Location-Specific Requirements

The following are location-specific ARARs and TBCs for the LEHR DOE areas. These requirements are summarized in Table 2-4.

Federal Requirements

- Endangered Species Act of 1973 (16 USC Section 1531 *et seq.*; 50 CFR Parts 10, 11, 17, 200, 402, and 424 and 40 CFR 257.3);
- National Historic Preservation Act of 1966 (16 USC 470 *et seq.*; Public Law 89-665 and amendments of 1980; Public Law 96-515, 36 CFR 800);
- Fish and Wildlife Coordination Act (16 USC 661-666);
- Floodplain Management (Executive Order 11988, 40 CFR 6); and
- Protection of Wetlands (Executive Order 11990, 10 CFR 1022).

State Requirements

- California Endangered Species Act (California Fish and Game Code §2050-2068).

2.2.7 Action-Specific Requirements

The following are action-specific ARARs and TBCs for the LEHR DOE areas. These requirements are summarized in Table 2-5.

Federal Requirements

- Clean Water Act Section 404 (33 USC 1344, 33 CFR 328 and 40 CFR 230);
- Underground Injection Control Program, 40 CFR Parts 144-147
- National Pollution Discharge Elimination System Requirements for Storm Water Discharges Associated with Construction Activity (40 CFR Parts 122, 123, 124, implemented by State Water Resources Control Board Order No. 92-08 DWQ);
- National Emissions Standards for Hazardous Air Pollutants (42 USC 7401-7671; 40 CFR 61, Subpart H);
- Federal Facilities Compliance Act of 1992 (PL 102-386);
- Transportation of Hazardous Material ..49 USC 5101-5127; and 49 CFR 172.3 and 172.200-700 et seq;
- Noise Control Act of 1972, as amended by the Quiet Communities Act of 1978 (40 CFR 204, 205, 211);
- Occupational Radiation Protection (10 CFR 835);
- Standards for Protection Against Radiation (10 CFR 20);
- Licensing Requirements for Land Disposal of Radioactive Waste (10 CFR 61);
- Radiation Protection of the Public and the Environment (DOE Order 5400.5); and
- Radioactive Waste Management (DOE Order 435.1).

State and Local Requirements

- 22 CCR 66262 et seq; Standards Applicable to Generators of Hazardous Waste
- Radiation Control Law[1] (California Health and Safety Code §114960 *et seq.*);
- State Department of Health Service Radiation Regulations (17 CCR, Chapter 5, Subchapter 4 § 30100 *et seq.*);
- CEQA, California Public Resources Code § 21000 *et seq.;*

[1] Under section 114985 of the California Health and Safety Code, the Radiation Control Law applies to persons, defined to exclude the United States Department of Energy, or any successor thereto, and federal government agencies licensed by the United States Nuclear Regulatory Commission, under prime contract to the United States Department of Energy, or any successor thereto. Hence, the portions of the Radiation Control Law (California Health and Safety Code, § 114960, et seq,) addressing the management of low level radioactive waste within California would be considered as relevant and appropriate for alternatives that include off-site disposal of low-level radioactive
waste.

- Non-Vehicular Air Pollution Control, Health and Safety Code, Chapter 3, Emissions Limitations (California Health and Safety Code §41700);
- Control of Radioactive Contamination in the Environment (California Health and Safety Code §114705 *et seq.*);
- Yolo-Solano Air Quality Management District Rules and Regulations, Rule 2.3, Ringlemann Chart; and
- Requirements for Land Use Covenants, Title 22 CCR, Division 4.5, Chapter 39, Section 67391.1.

2.2.8 Risk-Based Requirements

In addition to meeting ARARs, RAOs must reduce risk from the Site to levels acceptable under CERCLA. As specified in 40 CFR Section 300.430 (e)(2)(i)(A)(2), the acceptable human exposure to carcinogens at CERCLA sites is an excess upper-bound lifetime cancer risk between 1 in 10,000 (10^{-4}) to 1 in 1,000,000 (10^{-6}). Furthermore, in situations involving radionuclides, the US EPA states that a specific risk estimate of 10^{-4} may be considered acceptable if justified based on site-specific conditions (US EPA, 1997). For systemic toxicants, acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety (40 CFR § 300.430 (e)(2)(i)(A)(1)). This exposure is measured using an HI. An HI of less than 1.0 represents an acceptable exposure.

2.3 Other Pertinent Factors

In addition to CERCLA clean-up standards and ARARs applicable to potential human and ecological risk and ground water impacts, an MOA between UC Davis and DOE was considered in the development of RAOs. The MOA requires that DOE dispose all wastes generated by DOE's activities to the satisfaction of the regulatory agencies. The MOA also requires that the remedial actions be implemented in a manner that minimizes impact to UC Davis research at LEHR.

2.4 Determination of Remedial Action Objectives

After consideration of CERCLA risk standards, ARARs and the division of responsibilities between UCD and DOE per the MOA, RAOs are developed. Table 2-1 was developed from the Site-Wide Risk Assessment (SWRA) to address the NCP requirement that RAOs address human health-based COCs, potential exposure routes, human health cancer risks, human health hazards and remediation goals. The human health-based remediation goals are the higher of background or a remediation goal that achieves a risk of 10^{-6}. Table 2-2 contains the ground water goals, which are designated levels that will be protective of ground water within the next 500 years (see Sections 1.3.1

and 1.3.3). No constituents exceeded a hazard quotient of 1.0. The COC selection process is described in detail in Section 2.1. The DOE areas RAOs are:

- Prevent human incidental ingestion of surface and subsurface soil that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Prevent direct dermal contact with surface and subsurface soil that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Prevent external radiation from surface and subsurface soil that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Prevent human inhalation of contaminants bound to resuspended surface soil particles that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Prevent human ingestion of plants grown in site surface and subsurface soil that pose an excess cumulative cancer risk between 10^{-4} to 10^{-6}, using 10^{-6} as the point of departure.
- Mitigate potential future impact to ground water.
- Minimize threats to the environment including, but not limited to, sensitive habitats and critical habitats of species protected under the state and federal Endangered Species Act.
- Comply with all ARARs.
- Minimize impact to UC Davis research at the LEHR Site.

Table 2-1. Human Health Constituents of Concern and Remediation Goals for Soil

			CANCER RISK BY EXPOSURE ROUTE							
DOE Area	Receptor / COC	EPC[1] (0-10 ft) (mg/kg or pCi/g)	Soil Ingestion	Soil Dermal Exposure	Above-Ground Plant Ingestion[2]	Below-Ground Plant Ingestion[2]	External Radiation	Dust Inhalation	Total Cancer Risk	Remediation Goal[3] (mg/kg or pCi/g)
Domestic Septic System No. 4										
	On-Site Resident									
	Benzo(a)anthracene	3.8	4.E-06	1.E-06	9.E-06	1.E-06	-	3.E-10	2.E-05	0.2
	Benzo(a)pyrene	2.4	3.E-05	7.E-06	3.E-05	5.E-06	-	2.E-09	7.E-05	0.03
	Benzo(b)fluoranthene	2.7	3.E-06	8.E-07	3.E-06	5.E-07	-	2.E-10	7.E-06	0.4
	Benzo(k)fluoranthene	1.5	3.E-06	7.E-07	3.E-04	5.E-05	-	7.E-11	4.E-04	0.004
	Dibenzo(a,h)anthracene	1.1	7.E-06	2.E-06	4.E-06	6.E-07	-	5.E-10	1.E-05	0.1
	Indeno(1,2,3-cd)pyrene	0.86	2.E-06	4.E-07	1.E-06	1.E-07	-	4.E-11	4.E-06	0.2
								Total Risk	**5.E-04**	
	On-Site Construction Worker									
	Benzo(a)pyrene	2.4	8.E-07	3.E-07	-	-	-	7.E-10	1.E-06	2
								Total Risk	**1.E-06**	
Southwest Trenches										
	On-Site Resident									
	Strontium-90+Daughter	0.94	1.E-07	-	3.E-06	-	2.E-07	2.E-12	3.E-06	0.3
								Total Risk	**3.E-06**	
Eastern Dog Pens										
	On-Site Resident									
	Dieldrin	0.019	5.E-07	9.E-08	2.E-06	2.E-07	-	4.E-11	3.E-06	0.006
	Strontium-90+Daughter [4]	0.33	4.E-08	-	1.E-06	-	5.E-08	5E-13	1.E-06	0.3
								Total Risk	**4.E-06**	

Table 2-1. Human Health Constituents of Concern and Remediation Goals for Soil (continued)

Notes

Source data from HHRA, Tables 7 and 8.

[1]The 95% upper confidence limit on the mean of the exposure point concentration; chemical concentrations are in milligrams per kilogram and radionuclide concentrations are in picoCuries per gram.

[2]Homegrown produce. For radionuclides, plant ingestion is not subdivided into above-ground and below-ground plants.

[3]10^{-6} risk-based concentrations determined using one significant figure total cancer risk; chemical concentrations are in milligrams per kilogram and radionuclide concentration is in picoCuries per gram.

[4] Eastern Dog Pens concrete was disposed offsite in 2007 after the EPCs and risks were estimated in the HHRA. Without concrete, and accounting for radioactive decay since the Eastern Dog Pens was last sampled in March of 1999, the strontium-90 EPC and risk were re-determined. The updated strontium-90 EPC and risk are shown above. Dieldrin EPCs and risk were assumed unchanged by the concrete disposal.

Abbreviations

-	not calculated
COC	constituent of concern
DOE	Department of Energy
EPC	exposure point concentration
ft	feet
HHRA	Human Health Risk Assessment
pCi/g	picoCuries per gram
mg/kg	milligrams per kilogram
No.	number

Table 2-2. Ground Water Impact Constituents of Concern and Remediation Goals

DOE Area	Ground Water Impact[1] COC	Maximum Soil Concentration (mg/kg or pCi/g)	Number of Detections Above Background / Total Samples	Soil Background (mg/kg or pCi/g)	Background Remediation Goal[2] (mg/kg or pCi/g)	MCL Remediation Goal[3] (mg/kg or pCi/g)
Domestic Septic System No. 3	Formaldehyde	2.2	32/35	0	0.00378	0.0151 [6]
	Molybdenum	2.5	7/14	<0.26	<0.26 [5]	3.11 [7]
	Nitrate	106	7/41	36	36 [5]	36 [5]
Domestic Septic System No. 4	Selenium	2.0	3/13	1.2	4.0	35
Dry Wells A-E Area	Chromium	245	1/41	181	181 [5]	181 [5]
	Hexavalent Chromium	1.62	2/32	1.3	1.3 [5]	1.3 [5]
	Mercury	5.3	9/41	0.63	0.63 [5]	0.63 [5]
	Molybdenum	1.3	29/37	<0.26	0.30	3.6 [7]
	Silver	53.8	28/41	0.55	0.55 [5]	0.83
	Cesium-137	0.191	16/32	0.012	0.1	20 [8]
	Strontium-90	0.176	13/28	0.056	0.0595	0.28
Radium/Strontium Treatment Systems	Nitrate	304	29/126	36	36 [5]	36 [5]
	Carbon-14	2.41	6/103	0.13	0.13 [5]	2.34 [8]
	Radium-226	1.72[4]	5/106	0.752	0.752 [5]	1.9
Southwest Trenches	Nitrate	909	114/456	36	36 [5]	36 [5]
	Carbon-14	5.84	37/105	0.13	0.13 [5]	0.292 [8]

Notes
[1]Vadose zone soil contaminant with potential to impact ground water.
[2]Concentration predicted by transport modeling at which ground water impacts above site background are possible.
[3]Concentration predicted by transport modeling at which ground water impacts above California drinking water MCL, unless noted.
[4]The sample containing the maximum radium-226 result in the Radium/Strontium Treatment Systems area was recollected and reanalyzed. The reported maximum value is the average of the initial result (1.81 pCi/g) and recollected sample result (1.63 pCi/g).
[5]The calculated remediation goal is below soil background. Soil background was selected as the remediation goal. Calculated remediation goals are presented in the Risk Characterization for DOE Areas (Weiss, 2005b).
[6]Based on the California Department of Health Services State Action Level of 100 µg/L.
[7]Based on the United States Environmental Protection Agency, Region 9 preliminary remediation goal for tap water.
[8]Based on the derived limit for drinking water from the 4 roentgen equivalent man per year Federal MCL for beta particles and photon emitters (US EPA, 2000a).

Table 2-2. Ground Water Impact Constituents of Concern and Remediation Goals (continued)

Abbreviations

COC	constituent of concern
DOE	Department of Energy
MCL	California Maximum Contaminant Level
mg/kg	milligrams per kilogram
No.	number
pCi/g	picoCuries per gram
PRG	Preliminary Remediation Goal
µg/L	micrograms per liter

Table 2-3. Chemical-Specific Requirements for the LEHR Facility

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
Federal				
Solid Waste Disposal Act, Resource Conservation and Recovery Act, (42 USC §6921, 40 CFR Part 261, 262,)	Requires identification and listing of hazardous waste. If waste is listed in 40 CFR 261 or tested according to specified test methods or by applying knowledge of the hazardous characteristics of the waste, and the waste is determined to be hazardous, compliance with 40 CFR 262, Standards Applicable to Generators of Hazardous Waste, is required. These requirements are adopted by the State of California in Chapter 6.5 of the Health and Safety Code and are discussed in detail herein.	Applies to all alternatives that require removal of contaminated soil or other material containing constituents that may render the soil or material a hazardous waste based on the characteristics of the materials. Constituents include those listed in Tables 2-1 and 2-2.	Monitoring Capping Removal Bioremediation	Applicable
Clean Water Act (33 USCA 1251-1376, 40 CFR 122, 125, 136)	Both on-site and off-site discharges from CERCLA sites to surface waters are required to meet substantive Clean Water Act limitations, monitoring requirements and best management practices.	Applies to all alternatives that have the potential to add pollutants to water discharges at or from the Site, such as earthmoving, on-site treatment, and irrigation. Pollutants include constituents listed in Tables 2-1 and 2-2.	No Action Monitoring Capping Removal Bioremediation	Applicable
Safe Drinking Water Act (42 USCA 300 and 40 CFR 141.11-16, 141.23-24, 141.50-51, and 141.61-62)	Establishes MCLs as health-based standards and MCLGs as health goals for public water supply systems. The LEHR site is not a public water supply system. However, this requirement is relevant and appropriate.	MCLs are used as a reference for defining acceptable residual levels of site contaminants with potential to impact ground water in areas of the site where migration of contaminants from soil to ground water has occurred or may occur. See Table 2-2 for MCL Remediation Goals for each DOE area.	No Action Monitoring Capping Removal Bioremediation	Relevant and Appropriate

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
Establishment of Cleanup Levels at CERCLA Sites with Radioactive Contamination (US EPA, 1997, OSWER Directive No. 9200.4-18) and US EPA 1999, OERR and ORIA Joint Directive 9200.4-31P	OSWER Directive No. 9200.4-18 provides guidance for establishing protective cleanup levels for radioactive contamination at CERCLA sites. The guidance provides that cleanup should generally achieve a carcinogenic risk within the $1x10^{-4}$ to $1x10^{-6}$ range based on the reasonable maximum exposure for an individual. A specific risk estimate near $1x10^{-4}$ may be considered acceptable if justified based on site-specific conditions. The Joint Directive 9200.4-31P provides further clarification that cleanup levels should generally not be based on dose-based guidance and that reference to 15 mrem per year in the OSWER Guidance Directive No. 9200.4-18 should not be used as a "to be considered" for establishing a 15 millirem per year cleanup level at CERCLA sites.	Applies to Southwest Trenches and Eastern Dog Pens where residual Strontium-90+Daughter products may remain.	Alternative 1 (SWT, EDPs) Alternative 2 (SWT, EDPs) Alternative 3 (EDPs, SWT) Alternative 4c (SWT) Alternative 4 (EDPs)	To Be Considered
NESHAPS Section 112 of the Clean Air Act (40 CFR Part 61, 10 CFR 20.101-20.108, NESHAPS for Radionuclides).	The 1990 amendments replaced the US EPA's eight designated HAPs and 25 preliminarily assessed HAPs with a list of 189 HAPs, including radionuclides. The amendments mandate that US EPA regulate all new and existing major sources and certain area sources which emit or may emit any of the 189 HAPs.	Applicable to any action, such as those that include earthmoving, where airborne contaminants may be generated.	Alternative 3 Alternative 4	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
State and Local				
Criteria for Identifying Hazardous Wastes (CCR, Title 22, 66261. 21–33)	Tests for identifying hazardous characteristics are set forth in these regulations. If a chemical is either listed or tested and found hazardous, then remedial actions must comply with the applicable CCR Title 22 requirements.	Applies to removal of contaminated soil or other material containing constituents that may render the soil or material a hazardous waste based on the characteristics of the materials will occur. Constituents include those listed Table 2-1 and Table 2-2.	All alternatives, except Alternative 1	Applicable
Porter-Cologne Water Quality Control Act (California Water Code, Div. 7 13000, *et seq* and 23 CCR Chap. 15, 2510-2559, 2580-2601)	Establishes authority for state and regional water boards to determine site-specific waste discharge requirements and to regulate disposal of waste to land. Contains corrective action requirements stating that a COC not exceed background values unless it is technically or economically infeasible, in which case the default cleanup values would be the Basin Plan Water Quality Objectives.	Applies where residual soil contamination above background will remain. Not applicable in EDPs, WDPs, DSSs 1, 5, 6, and 7.	Alternative 1 Alternative 2 Alternative 3 Alternative 4c	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
Central Valley Regional Water Quality Control Board Basin Plan, "Policy for Investigation and Cleanup of Contaminated Sites" and "Policy for Application of Water Quality Objectives"	Describes water basins in the Central Valley Region, establishes beneficial uses of ground and surface waters, establishes water quality objectives and numerical standards, establishes implementation plans to meet water quality objectives and protect beneficial uses, and incorporates statewide water quality control plans and policies. Any activity, including, but not limited to, the discharge of contaminated soils or waters, or *in situ* treatment or containment of contaminated soils or waters, must not result in actual water quality exceeding water quality objectives. The "Policy for Investigation and Cleanup of Contaminated Sites" establishes and describes policy for investigation and remediation of contaminated sites. Also includes implementation actions for setting ground water and soil cleanup levels. Cleanup levels for soils should be equal to levels that would achieve background concentrations in ground water unless such levels are technically and economically infeasible to achieve. In such cases, soil cleanup levels are such that ground water will not exceed applicable ground water quality objectives. "Policy for Application of Water Quality Objectives" defines water quality objectives and explains how the RWQCB applies numerical and narrative water quality objectives to ensure the reasonable protection of beneficial uses of water, and how the RWQCB applies Resolution No. 68-16 to promote the maintenance of existing high quality waters. Applies to all cleanups of discharges that may affect water quality.	Applies to alternatives that allow for residual soil contamination above background to remain. (All areas, except for DSS 7, EDPs and WDPs)	Alternative 1 Alternative 2 Alternative 3 Alternative 4c (4b for Dry Wells A-E)	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
State Water Resources Control Board Resolution No. 68-16, "Anti-Degradation Policy"	Requires that high-quality surface and ground waters be maintained to the maximum extent possible. Degradation of waters will be allowed (or allowed to remain) only if it is consistent with the maximum benefit to the people of the state, does not unreasonably affect present and anticipated beneficial uses, and does not result in water quality less than that prescribed in RWQCB and SWRCB policies, as defined by the substantive requirements. If degradation is allowed, the discharge must meet best practicable treatment or control, which must prevent pollution or nuisance and result in the highest water quality consistent with maximum benefit to the people of the state.	Applies to alternatives that allow for residual soil contamination above background to remain. All areas, except DSS 7 and WDPs.	Alternative 1 Alternative 2 Alternative 3 Alternative 4c (4 for EDPs)	Applicable
State Water Resources Control Board Resolution No. 88-63, "Sources of Drinking Water Policy"	Specifies that, with certain exceptions, all ground and surface water have the beneficial use of municipal or domestic water supply. Applies in determining beneficial uses for water that may be affected by discharges of waste. SWRCB Resolution 88-63 applies to all sites that may be affected by discharges of waste to ground water or surface water. The resolution specifies that, with certain exceptions, all ground water and surface water have the beneficial use of municipal use or domestic supply. Consequently, California State primary MCLs are relevant and appropriate; however, the most stringent federal or state standard will be the ARAR.	Applies to alternatives that allow for residual soil contamination above background to remain. All areas, except for DSS 7 and WDPs.	Alternative 1 Alternative 2 Alternative 3 Alternative 4c (4 for EDPs)	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
The Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) Division 20 of the California Health and Safety Code	Proposition 65 prohibits the discharge of a significant amount of a known human carcinogen or reproductive toxin into any source of drinking water. Title 22 CCR Section 12000 *et seq* lists chemicals subject to the discharge prohibition and regulatory levels defining a significant amount for many of these chemicals.	Applies to alternatives for DSS3 and Dry Wells A-E where residual formaldehyde and mercury, respectively, will remain in the soil and have potential to impact ground water. Also applies to all areas where radionuclides remain in the soil.	All Alternatives	Applicable
Title 22 CCR, Sections 64431-64445	Title 22 CCR Sections 64431-64445 provides primary MCLs that must be met by all public drinking water systems to which they apply. The LEHR site is not a public water supply system. However, this requirement is relevant and appropriate.	MCLs are used as a reference for defining acceptable residual levels of site contaminants with potential to impact ground water in areas of the site where migration of contaminants from soil to ground water has occurred or may occur. See Table 2-2 for MCL Remediation Goals for each DOE area.	No Action Monitoring Capping Removal Bioremediation	Relevant and Appropriate
Title 27 CCR, Division 2, Subdivision 1, Section 20080 *et seq* and Title 23 CCR, Division 3, Chapter 15, Section 2510 *et seq*	Establishes waste and siting classification systems and minimum waste management standards for discharges of waste to land for treatment, storage or disposal. Engineered alternatives that are consistent with Title 27 and Title 23 CCR performance goals may be considered. Establishes corrective action requirements for responding to leaks and other unauthorized discharges. Applies to all discharges of waste to land for treatment, storage or disposal that may affect water quality.	Applies to waste generated (all areas except DSS 1, 5, 6, and 7, and the WDPs). Specific requirements are discussed below.	All Alternatives except Alternative 1	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
Title 23 CCR, Sections 2520 and 2521	Requires that hazardous waste be discharged to Class 1 waste management units that meet certain design and monitoring standards. Applies to discharges of hazardous waste to land for treatment, storage and disposal.	Applies to alternatives with actions that will generate potentially hazardous waste that would require off-site disposal. Applies to all areas except DSS 1, 5, 6, and 7, and the WDPs.	Alternatives 4a, 4b and 4c for Ra/SR Treatment Systems, DSS3, and SWT Alternatives 4a and 4b for Dry Wells A-E Alternative 4 for DSS4 Alternatives 3 and 4 for EDPs	Applicable
Title 27 CCR, Sections 20200 (c) and 20210	Requires that designated waste be discharged to Class I or Class II waste management units. Applies to discharges of designated waste (non-hazardous waste that could cause degradation of surface or ground water) to land for treatment, storage, or disposal.	Applies to all remediation activities that may generate waste that can cause ground or surface water degradation. Applies to waste generated for off-site disposal from all areas except DSS 1, 5, 6, and 7, and the WDPs.	Alternatives 4a, 4b and 4c for Ra/SR Treatment Systems, DSS3, and SWT Alternatives 4a and 4b for Dry Wells A-E Alternative 4 for DSS4 Alternatives 3 and 4 for EDPs	Applicable
Title 27 CCR, Section 20230	Requires that inert waste does not need to be discharged at classified units. Applies to discharges of inert waste to land for treatment, storage, or disposal.	Applies to all inert waste generated at the site and shipped off-site for disposal.	All Alternatives except Alternative 1	Applicable
Title 27 CCR, Sections 20200 (c) and 20220	Requires that non-hazardous solid waste be discharged to a classified waste management unit. Applies to discharges of non-hazardous solid waste to land for treatment, storage or disposal.	Applies to all non-hazardous wastes generated at the site and shipped off-site for disposal.	All Alternatives except Alternative 1	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
Title 27 CCR, Section 20080 (g) and Title 23 CCR, Section 2510 (g)	Requires monitoring of land where discharges had ceased as of November 27, 1984. If water quality is threatened, corrective action consistent with Title 27 and Title 23 is required.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable
Title 27 CCR, Section 20385 and Title 23 CCR, Section 2550.1	Requires detection monitoring for all areas where waste has been discharged to land to determine the threat to water quality. Once a significant release has occurred, evaluation or corrective action monitoring is required.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable
Title 27 CCR, Section 20390 and Title 23 CCR Section 2550.2	Requires establishment of a water quality protection standard consisting of a list of constituents of concern, concentration limits, compliance monitoring, and all monitoring points. Applies to all areas where waste has been discharged to land where ground water in threatened.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable
Title 27 CCR, Section 20395 and Title 23 CCR, Section 2550.3	Requires development of a list of constituents of concern which include all waste constituents that are reasonably expected to be present in the soil from discharges to land, and could adversely affect water quality. Applies to all areas where waste has been discharged to land where ground water is threatened.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
Title 27 CCR, Section 20400 and Title 23 CCR, Section 2550.4	Concentration limits must be established for ground water, surface water and the unsaturated zone and must be based on background, equal to background, or for corrective actions, may be greater than background, not to exceed the lower of the applicable water quality objective or the concentration technologically or economically achievable. Specific factors must be considered in setting cleanup standards above background levels. If water quality is threatened, this section applies to setting soil cleanup levels for all cleanup of discharges of waste to land.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Relevant and Appropriate
Title 27 CCR, Section 20405 and Title 23 CCR, Section 2550.5	Requires identification of the point of compliance, hydraulically downgradient from the area where waste was discharged to land. Applies to all areas where waste has been discharges to land where ground water is threatened.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable
Title 27 CCR, Section 20410 and Title 23 CCR, Section 2550.6	Requires monitoring of all soil cleaning activities for compliance with remedial action objectives for three years for the date of achieving cleanup levels.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable
Title 27 CCR, Section 20415 and Title 23 CCR, Section 2550.7	Requires general soil, surface water and ground water monitoring for all areas where waste has been discharged to land.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable
Title 27 CCR, Section 20420 and Title 23 CCR, Section 2550.8	Requires detection monitoring to determine if a release has occurred in all areas where waste has been discharged to land where ground water is threatened.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
Title 27 CCR, Section 20425 and Title 23 CCR, Section 2550.9	Requires an assessment of the nature and extent of the release, including a determination of the spatial distribution and concentration of each constituent. Applies to sites at which monitoring results show statistically significant evidence of a release.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Applicable
Title 27 CCR, Section 20430 and Title 23 CCR, Section 2550.10	Requires implementation of corrective action measures that ensure that cleanup levels are achieved throughout the zone affected by the release by removing the waste constituent or treating it in place. Source control may be required. Also requires monitoring to determine the effectiveness of the corrective actions. This section applies to all soil cleanup activities if water quality is threatened.	Applies to all prior discharges to land that may threaten water quality.	All Alternatives	Relevant and Appropriate
Title 27 CCR, Section 21090	Requires a final cover for landfills constructed in accordance with specific prescriptive standards, to be maintained as long as wastes pose a threat to water quality. This section is relevant and appropriate for waste contained or left in place at the end for remedial actions that could affect water quality.	Applies to all alternatives where waste is left in place.	All Alternatives	Relevant and Appropriate
Title 22 CCR Division 4.5, Section 66261.21-33	Provides criteria for identifying and handling hazardous waste. Regulations include soluble threshold limit concentration and total threshold limit concentration analytical procedures (CCR, Title 22, Division 4.5, Section 66261.21-33).	Applies to all hazardous waste generated during removal actions	All Alternatives except Alternative 1	Applicable
California Health and Safety Code, Division 20, Chapter 6.5, Section 25100 *et seq*	Governs hazardous waste control.	Applies to all hazardous waste generated during removal actions	All Alternatives except Alternative 1	Applicable

Table 2-3. Chemical-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Description	Applicability	Alternative(s)	ARAR Category
Title 22 CCR, Section 66268 *et seq*	Defines land disposal restrictions (LDRs) establishing specific treatment standards of hazardous wastes prior to disposal to land.	Applies to soil excavated that potentially contains hazardous constituents. Also applies to waste with hazardous constituents treated on site.	All Alternatives except Alternative 1	Applicable

Abbreviations

ARAR	applicable or relevant and appropriate requirement
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CFR	Code of Federal Regulations
COC	constituent of concern
HAP	hazardous air pollutants
LEHR	Laboratory for Energy-Related Health Research
MCLG	maximum contaminant level goal
MCL	maximum contaminant level
NESHAPS	National Emission Standards for Hazardous Air Pollutants
No.	number
OERR	Office of Emergency and Remedial Response
ORIA	Office of Radiation and Indoor Air
OSWER	Office of Solid Waste and Emergency Response
RWQCB	Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
USC	United States Code
USCA	United States Code Annotated
US EPA	U.S. Environmental Protection Agency

Table 2-4. Location-Specific Requirements for the LEHR Facility

Requirement/Authority	Comments	Applicability	Alternative(s)	ARAR Category
Federal				
Endangered Species Act of 1973 (16 USC § 1531 *et seq*, 50 CFR Parts 10, 11, 17, 200, 402, & 424, and 40 CFR 257.3)	Facilities or practices shall not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife. Activities will be evaluated to determine their impact on listed species and species proposed for listing and their habitat. If jeopardy or adverse modification will result from any site activities, a determination will be made based on a consultation with the US FWS regarding the need for mitigation measures and/or an incidental take statement. Specific mitigation measures will be identified and implemented per US FWS guidelines.	Applies to any activities that may impact listed species. Applies to EDPs where proposed activities may potentially impact the VELB habitat. No impacts are associated with residual contamination (University of California at Davis, 2006)	All Alternatives except Alternative 1	Applicable
Executive Order 11988 (Floodplain Management) and 11990 (Protection of Wetlands) (40 CFR 6, 10 CFR 1022)	Directs all federal agencies to avoid, if possible, development and other activities in the 100-year base floodplain. Where the base floodplain cannot be avoided, special considerations and studies for new facilities and structures are needed. Design and siting are to be based on scientific, engineering, and architectural studies; consideration of human life, natural processes and cultural resources; and the planned lifespan of the project. Federal agencies are required to: 1) reduce the risk of flood loss; 2) minimize the impact of floods on human safety, health, and welfare, and 3) restore and preserve the natural and beneficial values served by floodplains in carrying out agency responsibility. DOE can meet requirements of these Executive Orders through applicable DOE and NEPA procedures, as stated in 44 Federal Register 12594.	The Site is not currently identified as being located within the 100-year base floodplain. However, floodplain status needs to be confirmed prior to initiating development. Applies to all areas of the site where monitoring and capping systems may be constructed. These area exclude DSSs 1, 5, 6, and 7 and the WDPs.	Alternative 2 Alternative 3 Alternative 4c (4 for EDPs)	Applicable

Table 2-4. Location-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternative(s)	ARAR Category
National Historic Preservation Act of 1966 (16 USC 470 *et seq*, Public Law 89-665 and amendments of 1980, Public Law 96-515, 36 CFR 800)	Requires federal agencies to take into account the effects of their projects on historic properties listed, or eligible for listing, on the National Register of Historic Properties and to afford the Advisory Council a reasonable opportunity to comment on them.	Applies to all areas of the site except DSS 1, 5, 6 and 7, and the WDPs, where excavation or other activities may disturb historic (including architectural, curatorial, and archaeological) resources with demonstrated or likely research significance or native American cultural items.	All Alternatives except Alternative 1	Applicable
Fish and Wildlife Coordination Act (16 USC 661-666)	Requires action to preserve endangered species or threatened species. Prior to conducting any ground-disturbing activities in areas with potential for presence of such species, surveys will be conducted for species of concern.	Applies to all areas, except DSS 1, 5, 6 and 7, and the WDPs, where excavation and monitoring activities may disturb listed species.	All Alternatives except Alternative 1	Applicable
State And Local				
California Endangered Species Act (California Fish and Game Code § 2050–2068)	Requires action to preserve endangered species or threatened species. Prior to conducting any ground-disturbing activities in areas with potential for presence of such species, surveys will be conducted for species of concern.	Applies to all areas, except DSS 1, 5, 6 and 7, and the WDPs, where excavation and monitoring activities may disturb listed species.	All Alternatives except Alternative 1	Applicable

Abbreviations

ARAR	Applicable or Relevant and Appropriate Requirements
CFR	Code of Federal Regulations
DOE	Department of Energy
DSS	Domestic Septic System
EDPs	Eastern Dog Pens
NEPA	National Environmental Policy Act
USC	United States Code
US FWS	U.S. Fish and Wildlife Service
VELB	Valley Elderberry Longhorn Beetle
WDP	Western Dog Pens

Table 2-5. Action-Specific Requirements for the LEHR Facility

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
Federal				
Clean Water Act § 404 (33 USC 1344, 33 CFR 328 and 40 CFR 230)	Establishes a national program to control the discharge of dredged or fill materials into "waters of the United States". "Waters of the United States" is defined to include all tributaries of navigable waters and nearly all wetlands. Although no permit would be required for actions affecting a wetland, the substantive provisions of Section 404, including agency coordination prior to construction, state water quality certification, and possibly even mitigation for loss, may be applicable. These requirements may apply if site activities cause turbid water to enter drainages or if site activities impact wetlands adjacent to Putah Creek.	Applies to all areas, except DSS 1, 5, 6 and 7, and the WDPs, where excavation or soil disturbing activities would occur that could potentially impact Putah Creek and adjacent wetlands.	All Alternatives except Alternative 1	Applicable
National Pollution Discharge Elimination System (40 CFR Parts 122, 123, 124, implemented by State Water Resources Control Board Order No. 99-08 DWQ)	Regulates pollutants in discharge to storm water associated with construction activities (clearing, grubbing or excavation) involving the disturbance of one acre or more. Ensures storm water discharges do not contribute to a violation of surface water quality standards. Includes measures to minimize and/or eliminate pollutants in storm water discharges and monitoring to demonstrate compliance. This requirement is applicable to activities that will disturb one or more acres of the site.	Applies to EDPs and Ra/Sr Treatment Systems, where excavation or activities would disturb one or more acres.	Alternative 3 (Ra/Sr) Alternative 4	Applicable
Pretreatment Standards under the Clean Water Act	Discharges of treated waste to sanitary sewers may be proposed and would be regulated under the pretreatment program of the UC Davis POTW. The Regional Water Quality Control Board is involved in oversight of the pretreatment program.	Applies to all areas, except DSS1, 5, 6 and 7, and the WDPs, where discharges to sanitary sewer may occur as part of the monitoring activities.	Alternative 2 Alternative 3 Alternative 4c	Applicable

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
40 CFR Parts 122, 123, and 124, National Pollution Discharge Elimination System, implemented by California Storm Water Permit for Industrial Activities, State Water Resources Control Board, Order No. 97-03-DWQ	Regulates pollutants in storm water discharge associated with hazardous waste treatment, storage, and disposal facilities, wastewater treatment plants, landfills, land application sites and open dumps. The requirements are to ensure that storm water discharges do not contribute to a violation of surface water quality standards. Applies to storm water discharges from industrial areas. Includes measures to minimize and/or eliminate pollutants in storm water discharges and monitoring to demonstrate compliance.	May apply to in-situ remediation system in the Ra/Sr Treatment System Area, DSS3 and SWT.	Alternative 5	Applicable
Underground Injection Control Program, 40 CFR Parts 144-147	40 CFR Parts 144-147 set forth requirements for the Underground Injection Control (UIC) program promulgated under Part C of the SDWA and, to the extent that they deal with hazardous waste, RCRA States must meet these requirements in order to obtain primary enforcement authority for the UIC program in that State.	Applies to alternatives utilizing underground injection.	Alternative 5 (Ra/Sr, DSS3, SWT)	Relevant and Appropriate
National Emissions Standards for Hazardous Air Pollutants (42 USC 7401-7671, 40 CFR 61, Subpart H)	Emissions of radionuclides from any DOE facility to the ambient air shall not exceed levels that would result in an effective dose equivalent of 10 mrem/yr.	Applies to all areas, except DSS 1, 5, 6, 7 and the WDPs where excavation or soil disturbing activities would occur.	All Alternatives except Alternative 1	Applicable
Transportation of Hazardous Material ..49 USC 5101-5127; and 49 CFR 172.3 and 172.200-700 et seq	49 USC 5101-5127; and 49 CFR 172.3 and 172.200-700 et seq. regulate transportation, including security, of hazardous material in intrastate, interstate, and foreign commerce to ensure the safe transportation of such material.	Applies to all alternatives where hazardous materials and wastes would be transported off site.		Applicable

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
Federal Facilities Compliance Act of 1992, (PL 102-386)	This act amends the Solid Waste Disposal Act and states that all federal agencies are subject to all substantive and procedural requirements of federal, state, and local solid and hazardous waste laws in the same manner as any private party.	Applies to all areas, except DSS 1, 5, 6, 7 and the WDPs where excavation of soil with hazardous waste constituents would potentially occur.	All Alternatives except Alternative 1	Applicable
10 CFR 835 Occupational Radiation Protection	Provides for the protection of radiation workers at DOE facilities. Includes dose limits and requirements to reduce the dose to levels that are ALARA.	Applies to SWT and EDPs where residual radioactive contamination will be excavated.	All Alternatives except Alternative 1	Applicable
Radioactive Waste Management (DOE Order 435.1)	Specifies requirements for managing DOE radioactive waste, including off-site disposal requirements for radioactive waste shipped to commercial facilities.	Applies to all areas, except DSS 1, 5, 6, 7 and the WDPs where excavation of soil with radioactive constituents would potentially occur.	All Alternatives except Alternative 1	Applicable

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
Radiation Protection of the Public and the Environment (DOE Order 5400.5) and Environment, Safety, and Health Reporting (and DOE Order 231.1) which replaced Paragraph 1a(3)(a) of Chapter II of DOE Order 5400.5	This order establishes requirements for DOE facilities and operations for control of radiation exposure to the public. Although not promulgated standards, the DOE Order requirements were developed for protection of the public and the environment and are mandatory requirements for DOE activities. Chapter I adopts the International Commission on Radiological Protection recommendation that radiation dose to individuals be based on consideration of levels that are ALARA. Chapter II establishes a DOE public dose limit for all exposure modes and DOE sources of radiation of 100 mrem/yr effective dose equivalent. The public dose limit specifically applies to remedial actions. This radiation dose limit also forms the basis for the release of radionuclides to the environment and the release of properties for unrestricted use discussed in Chapter IV. Dose-based limits recommended by this order should only be used to demonstrate order compliance and should not be used in lieu of CERCLA risk-based requirements.	Applies to all areas where radionuclides may remain at levels above natural background.	Alternative 1 Alternative 2 Alternative 3 Alternative 4c (4 for EDPs)	Applicable
Noise Control Act of 1972, as amended by the Quiet Communities Act of 1978 (40 CFR 204, 205, 211)	Construction and transportation equipment noise levels (e.g., portable air compressors, and medium and heavy trucks), process equipment noise levels and noise levels at the property boundaries of the project are regulated under this act. State or local agencies typically enforce these levels.	Applies to all areas where excavation or ground water monitoring may occur.	All Alternatives except Alternative 1	Applicable

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
Standards for Protection Against Radiation (10 CFR 20, Subpart E)	DOE activities conducted at the LEHR are not subject to the NRC's licensing requirements. However, DOE policy articulated in DOE Order 5400.5 is to adopt and implement standards generally consistent with those of the NRC for DOE facilities and activities not subject to licensing authority. Subpart E defines radiological criteria for unrestricted use of sites with residual radioactivity. This criterion is relevant and appropriate only if it is more protective than the CERCLA risk-based requirements. In some cases the as low as reasonably achievable (ALARA) requirements in 10 CFR 20 Subpart E could result in cleanup below the CERCLA 10^{-6} point of departure. For example, an ALARA evaluation might indicate that a small area of residual contamination below the CERCLA point of departure be remediated to reduce activities to background levels. Additionally, the 10 CFR 20 Subpart E ALARA requirement addresses factors such as potential deaths from transportation accidents and other factors relating to the decommissioning process (Subpart E 20.1402).	Applies to all areas where radionuclides may remain at levels above natural background.	All Alternatives	Relevant and Appropriate
Licensing Requirements for Land Disposal of Radioactive Waste (10 CFR 61)	Establishes requirements for radiation protection, access restrictions, future impacts, siting, drainage, final cover, buffer zones, ground water monitoring and waste disposal requirements.	Applies to all areas where radionuclides may remain at levels above natural background.	All Alternatives except Alternative 1	Relevant and Appropriate

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
State and Local				
State Water Resources Control Board Resolution No. 92-49 (as amended April 21, 1994)	Establishes requirements for investigation, and cleanup and abatement of discharges. Among other requirements, dischargers must clean up and abate the effects of discharges in a manner that promotes the attainment of either background water quality, or the best water quality that is reasonable if background water quality cannot be restored. Requires the application of Title 23, CCR, Section 2550.4 requirements to cleanups.	Applies to all areas.	All Alternatives except Alternative 1	Applicable
Yolo-Solano Air Quality Management District Rules and Regulations, Rule 2.3, Ringlemann Chart	Establishes a permissible limit on visible emissions (Ringlemann Chart) resulting from construction activities, such as soil disturbance during site remediation activities.	Applies to all areas, except DSS1, 5, 6, 7 and the WDPs where excavation of soil with radioactive constituents would potentially occur.	All Alternatives except Alternative 1	Applicable
Prohibited Acts (Health and Safety Code § 41700)	Prevents discharge of pollutants into the air that will cause injury, detriment, nuisance, or annoyance to any considerable number of persons or the public. Regulation is applicable to construction activities site remediation activities.	Applies to all areas, except DSS1, 5, 6, 7 and the WDPs where excavation of soil with radioactive constituents would potentially occur.	Alternative 3 Alternative 4a Alternative 4b	Applicable
Control of Radioactive Contamination in the Environment (California Health and Safety Code, § 114705, *et seq*)	Establishes state surveillance and control programs for activities that could lead to the introduction of radioactive materials into the environment. This statute specifically exempts DOE from state surveillance of storage, packaging, transportation and loading of radioactive materials.	Applies to the excavation, treatment, storage and transportation of buried waste or soil at LEHR containing radioactive materials at levels that could result in a significant release to the environment. If these conditions are encountered, state surveillance, monitoring or other controls may be required to ensure that there are no significant releases of radioactive materials to the environment.	Alternative 3 Alternative 4a Alternative 4b	Applicable

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
Radiation Control Law (California Health and Safety Code, § 114960, *et seq*)	Institutes and maintains a regulatory program for sources of ionizing radiation to provide for compatibility with standards and regulatory programs of the federal government and an integrated system within the state. Applicable unless activity is governed by DOE statutory authority.	Applies to all actions that would leave radionuclides in place at levels above natural background and to actions where low-level radioactive waste would be removed and disposed offsite. Under Section 114985 of the California Health and Safety Code, the Radiation Control Law applies to persons, defined to exclude the United States Department of Energy, or any successor thereto, and federal government agencies licensed by the United States Nuclear Regulatory Commission, under prime contract to the United States Department of Energy, or any successor thereto. Hence, the portions of the Radiation Control Law (California Health and Safety Code, § 114960, et seq,) addressing the management of low level radioactive waste within California would be considered as relevant and appropriate for alternatives that include off-site disposal of low-level radioactive waste.	All Alternatives	Relevant and Appropriate

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
State Department of Health Service Radiation Regulations (17 CCR, Chapter 5, Subchapter 4 § 30100, *et seq*)	Presents regulations of the Department of Health Services pertaining to radiation, such as standards for protection against radiation, low-level radioactive waste disposal and transportation regulations. Applicable unless activity is governed by DOE statutory authority or regulation.	Applies to all areas where radionuclides may remain at levels above natural background. Also applies to all areas where waste containing radionuclides above natural background is excavated.	All Alternatives	Applicable
Executive Order D-62-02 by the Governor of the State of California	Restricts the disposal of decommissioned waste in Class III landfills and unclassified waste management units, as described in 27 CCR, Sections 20260 and 20230.	Applies to all areas where waste containing radionuclides above natural background is excavated.	All Alternatives except Alternative 1	Relevant and Appropriate
Title 22 CCR, 66262 et seq.	Presents standards applicable to generators of hazardous waste, including waste characterization, manifest, and transportation requirements	Applies to all alternatives where hazardous waste will be generated	All Alternatives except Alternative 1 and Alternative 2 for EDP	Applicable
Title 22 CCR, Division 4.5, Chapter 39, Section 67391.1	Provides requirements for land-use covenants.	Applies to all areas that where residual contamination requires additional controls based on land use.	Alternative 2 (DSS 4, EDPs) Alternative 2b (SWT) Alternative 3	Applicable
Title 27, CCR, Section 20090(d) and Title 23 CCR, Section 2511(d)	Requires that remedial actions intended to contain wastes at the place of release shall implement applicable provisions of Title 27 Division 2 and Title 23 Chapter 15 to the extent feasible.	Applies to all areas where residual contamination requires remediation or monitoring.	All Alternatives except Alternative 1	Applicable

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

Requirement/Authority	Comments	Applicability	Alternatives	ARAR Category
California Environmental Quality Act, California Public Resources Code § 21000 *et seq*	CEQA is a statute that requires state and local agencies to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible. A public agency must comply with CEQA when it undertakes an activity defined by CEQA as a "project." A project is an activity undertaken by a public agency or a private activity, which must receive some discretionary approval from a government agency, which may cause either a direct physical change in the environment or a reasonably foreseeable indirect change in the environment. The environmental review required imposes, at a minimum, an initial review of the project and its environmental effects. Depending on the potential effects, a further and more substantial review may be conducted in the form of an environmental impact report. A project may not be approved as submitted if feasible alternatives or mitigation measures are able to substantially lessen the significant environmental effects of the project.	Applies to all areas where a state agency will take a discretionary action.	All Alternatives	Relevant

Abbreviations

ALARA	as-low-as-reasonably-achievable
ARAR	Applicable or Relevant and Appropriate Requirement
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CEQA	California Environmental Quality Act
DOE	U.S. Department of Energy
DSS	Domestic Septic System
DWQ	drinking water quality

Table 2-5. Action-Specific Requirements for the LEHR Facility (continued)

EDPs	Eastern Dog Pens
LEHR	Laboratory for Energy-Related Health Research
mrem/yr	millirem per year
No.	number
NRC	Nuclear Regulatory Commission
PL	Public Law
POTW	publicly-owned treatment works
Ra/Sr	Radium/Strontium
SWT	Southwest Trenches
USC	United States Code
WDP	Western Dog Pens

3. IDENTIFICATION AND EVALUATION OF GENERAL RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

3.1 Overview of Remedial Technology and Process Option Screening Process

This section identifies response actions that are capable of meeting the RAOs identified in Section 2. A full array of potentially applicable remedial technologies and process options was developed for each of the response actions. In accordance with US EPA guidance (US EPA, 1988), this initial list was reduced by evaluating the options with respect to technical implementability. The retained technologies and process options were then screened by evaluating their implementability, effectiveness and cost. Retained technologies and process options were used to develop the remedial alternatives discussed in Section 4. The screening process is described in Section 3.4.

3.2 Identification of Response Actions

Response actions are actions that either partially or wholly satisfy the RAOs. Resources available through the US EPA, DOE, academic institutions, private organizations, public organizations, and remedial action technology vendors were used to identify potential response actions and their remedial technologies and process options (Figure 3-1). In particular, the Hazardous Waste Cleanup Information Internet site (US EPA, 2005), available through the US EPA Technology Innovation Program, and the US EPA treatment technologies Internet site (US EPA, 2003a) were the primary sources for identifying potential remedial action technologies.

In general, all response actions potentially applicable to treating, containing, removing, and disposing contaminated soil in the DOE areas were considered. Potential response actions were limited to soil cleanup technologies because the DOE areas consist of ground surface and the vadose zone, while ground water contamination will be addressed in the UC Davis FS per the FFA and MOA. The potential response actions are discussed in the following section.

3.3 General Response Actions

Six general response actions were identified as potential options for the DOE areas at LEHR (Figure 3-1). Detailed descriptions of potential remedial technologies and process options are presented below for each general response. Primary advantages and limitations were identified for each option and technology to aid in the screening and evaluation process.

3.3.1 No Action

A no-action alternative will be evaluated for each of the DOE areas, as required by the NCP. For many of the DOE areas, removal actions have been conducted, and in these cases "no-action" may be referred to as "no further action." No action (or no further action) is an acceptable response action when all local, state, and federal agency requirements have been satisfied; the site no longer requires active remediation, monitoring or land-use restrictions; and the site is acceptable for unrestricted use by the public.

No action means that the party held responsible for contamination at a site is released from that responsibility. A site with no-further-action status can be used and/or sold as though no release of contamination had occurred. However, a site can lose no-further-action status if previously undiscovered contamination is found or if the site does not satisfy a newly implemented regulatory agency requirement. If a site loses no-further-action status, the parties that were previously released from responsibility may be responsible again and required to take action.

No action advantages:

- Status allows the site to be used and/or sold as though no release of contamination occurred.
- The site is acceptable for residential use.
- No tangible cost.

No action limitations:

- Status is not permanent. Future mitigation response may occur after institutional knowledge has dwindled.
- Unanticipated risk may persist due to flaws in site characterization and risk assessment.

3.3.2 Institutional Controls

Institutional control is any response that mitigates human health and ecological risk without removing, treating or preventing migration of contamination. The remedial technologies identified under institutional controls are land-use restrictions and ground water monitoring.

3.3.2.1 Land-Use Restrictions

Land-use restrictions are physical, administrative and legal mechanisms used to protect public health and the environment from residual contamination. CERCLA permits land-use restrictions, along with other response actions, as part of an overall site remedy. Both public and private land-use restrictions may be considered. Private (or proprietary) land-use restrictions include deed restrictions, covenants and easements. Public (or governmental) land-use restrictions include zoning ordinances and ground water use permitting programs.

California Administrative Code Title 22 contains regulation regarding requirements for land-use covenants in Section 67391. Environmental restrictions are identified in a written instrument, which is drafted by DTSC, jointly signed by the landowner/DTSC, and subsequently recorded with the County. Typically, these covenants may restrict residential development and the use of contaminated ground water. A covenant may also establish controls on excavation and removal of contaminated soil from the site. Surveys would be required to define the restricted area(s). DTSC is responsible for the oversight component of ensuring the landowner meets its land-use covenant obligations.

Land-use restrictions advantages:

- Prevent human and ecological exposure to contamination and the operation of remedial treatment technologies.
- Can be implemented quickly with low effort and cost.

Land-use restrictions limitations:

- Difficult to maintain over long periods of time due to loss of institutional and administrative knowledge.
- Existing or planned site operations and development may conflict with land-use restrictions.
- May affect aesthetics and property value.

3.3.2.2 Ground Water Monitoring

Ground water monitoring may be selected if there is moderate certainty that active soil remediation is not necessary to achieve remedial action goals. Monitoring can be implemented in conjunction with land-use restrictions to manage risk. Groundwater monitoring as a general response action includes the evaluation of groundwater remedial alternatives if groundwater monitoring shows that groundwater has been impacted for any of the COCs.

A monitoring program typically consists of collecting samples at specific locations and regular intervals until data show that remedial action goals have been achieved. The number of sample locations, the sample collection frequency, number and type of analytes, and reporting requirements drive monitoring program costs.

In general, monitoring programs are designed to collect sufficient data to determine if contaminants are migrating from unsaturated soil to ground water, and if a plume concentration and/or size is decreasing or expanding either laterally or vertically. Downgradient monitoring points are installed at positions that will detect migrating contamination in time to protect downgradient receptors. Sample frequency and density should be sufficient to detect changes that could alter the necessary course of remedial action. The results of monitoring could show that remedial action will need to continue longer than anticipated from treatment technology performance predictions. Monitoring may also trigger DOE's evaluation of additional ground water remedial alternatives.

When cleanup objectives are attained, the monitoring program should have generated sufficient data to justify no further action.

Monitoring advantages:

- Ensures regional ground water protection.
- Activities rarely conflict with existing or planned site use.
- Relatively low short-term cost.

Monitoring limitations:

- Does not treat or contain contamination.
- Unidentified subsurface heterogeneities may lessen the effectiveness of the monitoring system.

3.3.3 In Situ *Treatment*

Any remedial technology that treats subsurface contamination without removal falls under the category of *in situ* treatment. Proven *in situ* remedial technologies considered for the LEHR site include soil vapor extraction, bioremediation, *in situ* flushing and stabilization remedial technologies. Innovative *in situ* remedial technologies considered for the Site include thermal desorption/soil vapor extraction, vadose zone bioremediation and phytoremediation.

3.3.3.1 Soil Vapor Extraction

Soil vapor extraction is an *in situ* remedial technology that removes volatile organic compounds (VOCs) adsorbed to soil in the vadose zone. This technology involves applying a vacuum to contaminated soil through extraction wells. The vacuum causes a negative pressure gradient, which drives vapor movement toward the wells. Vapor phase volatile constituents are readily removed from the subsurface through the extraction wells. If necessary, extracted vapor is then treated before release to the atmosphere.

Soil vapor extraction is generally more successful when applied to more volatile VOCs. The increased subsurface airflow associated with soil vapor extraction can also stimulate biodegradation of less volatile organics. Extraction wells may be either vertical or horizontal. In areas with high ground water levels, water table depression pumps may be required to offset the effect of upwelling induced by the vacuum, or to dewater a portion of the saturated zone to apply soil vapor extraction.

Soil vapor extraction advantages:

- Proven effective in removing VOCs and certain semi-volatile organic compounds (SVOCs) under high-permeability soil conditions.
- Equipment is usually reliable, readily available through various vendors, and relatively easy to install.

- System operation usually does not conflict with normal site operations.
- Treatment times are relatively short, ranging from six months to two years under optimal conditions (US EPA, 2003b).
- Can be combined with other technologies to improve contaminant mass removal rates and efficiency.

Soil vapor extraction limitations:

- Ineffective at treating non-volatile inorganic constituents or organic compounds, and most SVOCs.
- Generally not effective at treating contamination in low-permeability sediments or contamination located in the capillary fringe or below the water table (without dewatering).
- Extracted vapors may require costly treatment prior to atmospheric discharge.
- Air emissions source permits are required.
- Usually cost-prohibitive after approximately 90 percent of the contamination is removed.

3.3.3.2 Phytoremediation

Soil phytoremediation involves the use of plants to remove or mineralize contamination within the root zone. Plant-based remedial mechanisms involve complex interactions between soil chemistry, plant biology and other organisms present in contaminated soil. In general, phytoremediation applications involve extraction of contamination from soil. Contaminants are extracted from the subsurface when roots take up soil moisture containing dissolved contamination. Extracted contaminants may be broken down to basic minerals in the plant, transported to the leaves and evaporated, or remain fixed in the plant cellular structure. Contaminated plants are harvested and disposed or treated.

Typical phytoremediation applications include the use of trees for hydraulic control in shallow aquifers (< 10 ft deep), and a deep planting technique for contaminant extraction and hydraulic control at greater depths. Tree uptake applications typically involve rows of poplar or willow trees, which have high water uptake rates. Various tree row configurations have been used to remediate shallow nitrate and other forms of contamination at several sites (Gatliff, 2000).

Deep planting is a patented technology that consists of drilling a large diameter borehole to a desired depth and installing a casing within the borehole. A young tree is planted at the borehole base and cultivated to encourage root growth into the surrounding and underlying soil. This technique has been used to extract nitrate contamination and reduce ground water plume size at three sites. It was demonstrated to reach 35-ft contaminated depth and remediating depths in excess of 50 ft are considered possible by the vendor. Other deep-planting applications include trichloroethylene and petroleum hydrocarbon remediation (Gatliff, 2000).

Small plants identified as “metal hyperaccumulators” have shown the ability to extract high concentrations of metals from shallow soil without exhibiting toxic response (Lasat, 2002). Hyperaccumulator applications are still in the research stage. No vendors offering metal hyperaccumulator remediation were identified for this FS.

Phytoremediation advantages:

- Costs are low relative to other forms of active remediation (Gatliff, 2000; FRTR, 2005a).
- Trees extract contaminated water without discharge permitting or compliance requirements.
- Deep tree planting is effective at capturing dissolved contaminants in saturated zone sediments.
- Phytoremediation is aesthetically desirable because trees and plants can improve the appearance of a site.
- Phytoremediation is generally desirable to the public due to the ease of understanding and a desire to see living things transform a contaminated site.

Phytoremediation limitations:

- Phytoremediation effectiveness is limited by the time required for plants or trees to mature and meet treatment design specifications.
- Phytoremediation is not always applicable to high levels of contamination due to toxic effects on the plants that are used.
- Deep contamination is inaccessible to roots unless the deep planting technique can be applied.
- Deep tree planting is unproven in vadose zone applications. No vadose zone case study data are available. A vendor of the technology predicted low mass removal and low radius of influence in the vadose zone.
- Deep tree contaminant capture relies in part on depressing the water table in the vicinity of the tree and inducing ground water flow towards the tree. This capture mechanism is not available in the vadose zone.
- Restricts land use.
- Heavy, tight soil (deep soil) will limit root growth.
- Root uptake is typically limited to contamination that is readily dissolved in soil moisture.
- Irrigation may mobilize vadose zone contaminants to ground water.
- Contamination that is tightly sorbed to clay and silt is usually unavailable to plant roots.

- Metal hyperaccumulator plants are typically small and slow growing.
- Detritus from plants (e.g., leaves, branches, seeds) may require low-level and/or hazardous waste disposal.

3.3.3.3 Bioremediation

Bioremediation is the engineered improvement of existing biological conditions to enhance removal, degradation/mineralization or stabilization of contamination. Soil bioremediation techniques generally involve the use of microorganisms or plants. Remediation using plants (i.e., phytoremediation) was covered in the previous section. Remediation using microorganisms is covered here.

The most common form of enhanced soil bioremediation is bioventing, which uses aerobic microorganisms to degrade/mineralize organic chemicals under unsaturated conditions. Bioventing is effective for organic chemical remediation, because soil usually contains large numbers of microorganisms that routinely decompose organic matter. Of these organisms, bacteria are the most numerous and biochemically active group, particularly at low oxygen levels. Bacteria require a carbon source for cell growth and an energy source to sustain metabolic functions. Nutrients, including nitrogen and phosphorus, are also required for cell growth. Aerobic bacteria metabolize organic material to yield carbon dioxide and water, a process commonly referred to as aerobic respiration. To degrade large amounts of organic chemicals, a substantial bacterial population is required, which, in turn, requires oxygen for both the metabolic process and the growth of the bacterial mass.

In situ bioventing systems typically use vertical or horizontal wells in the vadose zone to supply air or oxygen gas under low pressure. Alternatively, vacuum can be applied to vadose zone wells to increase air circulation. Nutrient addition and pH adjustments may be applied to the contaminated soil to improve conditions for microbial growth.

Several technologies have been developed to enhance aerobic soil bioremediation within the saturated zone. These technologies include oxygen and air bubbling systems, hydrogen peroxide injection and the injection of proprietary oxygen release compounds. In general, these technologies have a limited ability to deliver significant oxygen mass throughout the subsurface. Numerous injection points and/or wells are required unless the saturated soil is highly permeable.

Enhanced anaerobic bioremediation has been applied to chlorinated organic compounds in the saturated zone. This technology uses proprietary hydrogen-releasing compounds to stimulate the anaerobic biodegradation process. The hydrogen-releasing compound is injected into areas of contamination located at or below the water table.

Enhanced anaerobic bioremediation has been applied to nitrate contamination using hydrogen gas or hydrogen-releasing compounds. Anaerobic bacteria use hydrogen to reduce nitrate to nitrogen gas and water.

Treatment systems that inject a carbon source (e.g., ethanol, glucose, lactate or sucrose) into nitrate-contaminated ground water have proven effective for denitrification. Anaerobic denitrification occurs during microbial respiration in the absence of oxygen and presence of a carbon source. Indigenous aerobic bacteria use the carbon source as an electron donor and existing oxygen as the electron acceptor. Denitrification begins when the existing oxygen is depleted. When the carbon source remains in excess, indigenous denitrifying bacteria proliferate and reduce the nitrate contamination to nitrogen gas. This technique could be used in the vadose zone by saturating the soil with a carbon-source solution.

Enhanced bioremediation can also stabilize contaminants. Microorganisms can cause stabilization of radionuclides, metals, and other inorganic compounds through reactive processes that bind the contaminants to soil. These processes are complex and are currently in the research stage.

Bioremediation advantages:

- Usually causes minimal disturbance to site activities after equipment is installed.
- Oxygen and hydrogen delivery equipment is readily available and relatively easy to install.
- Treatment times can be relatively short (six months under optimal conditions).
- Bioremediation techniques can be combined with other technologies to optimize remedial activities.

Bioremediation limitations:

- Bioventing only treats organic chemicals in vadose zone soil.
- Enhanced anaerobic bioremediation is usually limited to treating only chlorinated compounds in saturated zone soil.
- Low-permeability sediments can greatly limit oxygen or hydrogen and nutrient delivery.
- Low cleanup standards are not always achievable within a cost-effective time frame.
- High constituent concentrations may be toxic to microorganisms.
- Permits are generally required for ground water nutrient injection.
- Nutrient injection saturates the vadose zone and stimulates contaminant mobilization.

3.3.3.4 *In situ* Flushing

In situ soil flushing is the extraction of contaminants from vadose zone soil using water or surfactant-enhanced aqueous solutions. Soil flushing is accomplished by passing the water or aqueous solution through sediments using an injection or infiltration process. Solutions must be recovered from the underlying aquifer and are recycled if possible. The cost of surfactant-enhanced soil flushing can vary significantly depending on the type and concentration of surfactants used (FRTR, 2005b).

Contaminated ground water and flushing fluids recovered from *in situ* flushing operations may require treatment prior to discharge. If practical, recovered fluids can be reused in the flushing process rather than discharging. A major cost factor for surfactant-enhanced flushing is surfactant separation for reuse. Recovered treatment fluid results in process sludges and residual solids, such as spent carbon and spent ion exchange resin, which must be treated before disposal. Recovered flushing fluids may have volatile contaminant air emissions that should be collected and treated to meet regulatory standards. Flushing additives may remain in soil and become a contaminant transport concern.

In situ flushing advantages:

- Soil flushing is generally a short- to medium-term process.
- The process is applicable to many contaminants, including radioactive contaminants.

In situ flushing limitations:

- The technology should be used only where flushed contaminants and soil flushing fluid can be contained and recaptured. Otherwise, contaminants can be washed beyond the capture zone, increasing the extent of contamination.
- Regulatory agencies may not approve the introduction of surfactants into the subsurface.
- Low-permeability or heterogeneous soils are difficult to treat with soil flushing.
- Surfactants can adhere to soil and reduce effective soil porosity and permeability.
- Flushing fluids can react with soil and lose their effectiveness.
- Above ground separation and treatment of recovered fluids can drive the economics of the process.
- This technology has shown little commercial success.

3.3.3.5 *In situ* Stabilization

Contaminant stabilization typically involves mixing additives into contaminated soil, fixing contamination in a solid matrix, and/or diverting ground water or infiltration water around contaminated source areas to prevent contaminant migration. Common stabilization agents include cement, lime, fly ash, soluble silicates, sulfur, thermoplastic polymers (e.g., asphalt bitumen, paraffin, polyethylene), thermosetting polymers (e.g., vinyl ester monomers, urea formaldehyde, epoxy polymers) and other proprietary additives.

Additive mixing is usually intended to sorb contaminants onto soil minerals or induce reactions with contaminants to produce lower toxicity reaction products. Sorbing additives are typically used on heavy metals and pesticide contamination and are useful at reducing the toxic characteristic leaching procedure (TCLP) concentration of contaminated soil. Sorbing additives are applicable when ground water protection is the primary remedial action objective.

Additives can be applied *in situ* by spraying a stabilizing agent on the surface of shallow contamination or injecting it into subsurface source areas. Spray-on applications can be mixed using commonly available agricultural machinery, while deeper mixing is accomplished using various auger assemblies driven by heavy drilling equipment.

Reactive additives are applicable to source contamination that can migrate to multiple exposure media. Reactive sulfur-based chemicals are in common use for reducing Cr-VI to trivalent chromium. Zero-valent iron will react with nitrate to form less toxic nitrogen compounds. Nitrate stabilization in ground water has been demonstrated using permeable reactive barriers containing zero-valent iron.

Stabilization advantages:

- Containment and ground water protection issues associated with technologies that mobilize contaminants are avoided.
- Stabilization is generally applicable to non-volatile organics, radionuclides, metals and some inorganics.
- Stabilization materials are widely available.
- Auger/caisson and reagent/injector head systems for adding/mixing stabilizers in soil are well demonstrated.

Stabilization limitations:

- Stabilization does not remove chemical contamination unless the contaminant undergoes a change in chemical composition. Radionuclides and metals may become part of a more stable complex, but they remain present in the soil.
- Infiltration control or capping may be necessary to control/protect stabilization reactions.
- In general, applications below or near the seasonal high water table are not permanent due to dissolution of the stabilization agent.
- A soil cover sufficiently thick to absorb gamma radiation is required if stabilization is used to contain gamma emitters.
- Transportation costs may be high if large volumes of stabilizer are needed.
- Soil volumes can increase due to addition of stabilizing additives.
- Well-distributed delivery can be difficult to attain for *in situ* applications.

3.3.3.6 *In situ* Thermal Desorption with Soil Vapor Extraction

Thermal desorption is the application of heat to physically separate organic chemicals from soil. Thermal wells can be installed at subsurface locations to heat soil and volatilize organic contaminants. The vaporized organic chemicals are then removed from the subsurface using a soil vapor extraction system and treated prior to discharge to the atmosphere. VOC thermal desorption can be effective without desiccating all of the moisture from vadose zone soil. However, desiccation is necessary to desorb SVOCs, pesticides and PCBs. If desiccation is necessary to remove the chemicals of concern, ground water and surface water recharge must be controlled. Water recharge can significantly increase thermal desorption energy costs.

In situ thermal desorption advantages:

- The excavation costs, site disruptions and work area requirements associated with traditional *ex situ* thermal desorption are avoided.
- Thermal desorption costs are competitive.
- Thermal desorption can consistently reduce volatile organic chemical concentrations in soil.

Thermal desorption limitations:

- One vendor holds several patents on *in situ* thermal desorption processes and associated technologies. Equipment availability and implementation are essentially limited to one vendor.
- State and local regulations may require pilot testing before thermal desorption can be implemented.
- Air quality permits are required and source monitoring must be implemented to discharge treated vapors.

3.3.4 Removal with Ex Situ *Treatment*

All of the remedial technologies involving *ex situ* treatment would be implemented on excavated soil. The *ex situ* remedial technologies that were considered were soil washing, stabilization and thermal desorption. *Ex situ* treatment can occasionally reduce concentrations or stabilize contaminants to make the soil acceptable for on-site or off-site reuse. *Ex situ* treatment may also reduce contamination in soil or separate less contaminated fractions of soil to make it acceptable for less expensive disposal options.

3.3.4.1 Excavation

Excavation is traditionally performed using heavy earth moving and/or digging equipment, such as dozer/scrapers, backhoe excavators, or hand-held shovels. Oversized augers were identified as a non-traditional process option to excavate small volumes of deep soil or locations that are difficult to access.

Excavation planning should be based on data that accurately characterize the location and extent of contamination. A data collection strategy is typically developed to guide excavation decisions during a RA. Field screening samples are analyzed using rapid techniques that provide results within a few minutes to hours. Excavation is halted when the field screening samples indicate achievement of remedial action goals. Confirmation samples are collected from the excavation floor and sidewalls and sent to an off-site laboratory for formal analysis, validation, and comparison to remedial action goals. Depending on the confirmation results, additional contaminated soil may be excavated or the excavation may be backfilled.

Excavation advantages:

- Contamination removal is in the short term.
- Cost-effective when the volume of contaminated material is relatively small and easily characterized.
- Will remove all classes of contamination.
- A proven method of removing contamination sorbed to clay and fine soil.

Excavation limitations:

- Excavation costs may be prohibitive for large contaminated areas or large volumes of deep contamination.
- Overlapping auger excavation may not recover 100 percent of the contaminated soil.
- *In situ* technologies are usually more cost-effective than excavation when the contaminated material is sand or gravel that is free of fine particles (e.g., clay and silt).
- Multiple contaminants can greatly complicate excavation field decisions. Excavations usually don't meet all remedial objectives for multiple COCs. Compromise decisions may be necessary.
- Excavation operations usually require significant land area and may disrupt existing site operations.
- Subsurface objects/structures or above-ground structures may limit the practical extent of excavation due to safety and/or cost considerations.
- Time constraints may require backfilling an excavation before confirmation sample results are available from the laboratory. Further excavation is then considerably more expensive and complicated.

3.3.4.2 Soil Washing

Soil washing is a water-based media transfer technology for scrubbing soils *ex situ* to remove contaminants. The target contaminant groups for soil washing are SVOCs, fuels, and heavy metals, but it can be used on certain VOCs and pesticides. The technology is applicable to soil consisting primarily of coarse-grained particles (0.24 to 2 millimeter [mil] optimum range), but having most of the contaminant mass sorbed onto fine-grained particles or organic matter (FRTR, 2005c).

The soil washing process separates contaminants sorbed onto fine soil particles from bulk soil on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals. The process removes contaminants from soil by:

- Dissolving or suspending them in the wash solution (which can be sustained by chemical manipulation of pH for a period of time); or
- Concentrating them into a smaller volume of soil through particle size separation, gravity separation and attrition scrubbing (similar to techniques used in sand and gravel operations).

Particle size separation can be a useful technique to reduce soil contamination, because most organic and inorganic contaminants tend to sorb onto clay, silt and organic soil particles. Washing processes break the weak adhesion of fine (i.e., small) clay and silt particles from the coarser sand and gravel soil particles. The contaminated fine particles are then separated from the cleaner coarse particles. The reduced volume of contaminated material can then be further treated or disposed. Attrition scrubbing (agitating coarse particles until surface wears off) can be used to further remove adherent contaminant films from the remaining volume of coarser particles.

Sequential washing using different wash formulations and/or different soil-to-wash-fluid ratios may be required for complex mixtures of contaminants in the soil. The residual contaminated water generated from soil washing is treated with aqueous treatment technologies before discharge or reuse. A bench-scale treatability study is recommended before applying this technology.

Soil washing advantages:

- Soil washing can reduce the total volume of contaminated waste and leave a large clean fraction of soil for on-site reuse.
- Soil washing works well on high levels of contamination.
- Soil washing systems can incorporate multiple techniques to remove a wide variety of contaminants with different physical and chemical properties.
- The duration of soil washing is typically short- or medium-term (i.e., days to a few months).

Soil washing limitations:

- Wash fluid formulation may be difficult for complex waste mixtures (e.g., metals with organics).
- High humic content in soil may require pretreatment.
- The aqueous waste stream will require treatment.
- Additional treatment steps may be required to address wash solvent remaining in the treated residuals.
- Soil washing equipment is not widely available.

- Attrition washing (e.g., coarse particle agitation) can increase the volume of waste fines.

3.3.4.3 *Ex situ* Stabilization

The basic concepts of soil stabilization were presented in Section 3.3.3.5. *Ex situ* applications include machine-mixing operations that apply stabilizers into contaminated soil for off-site disposal or occasional on-site reuse. *Ex situ* applications more commonly involve additives that fix the contamination in a solid matrix. Solidification is less common for *in situ* applications.

Ex situ stabilization advantages:

- Containment and ground water protection issues associated with *in situ* technologies are avoided unless the soil is reused on site.
- Stabilization is applicable to a wide variety of contaminants.
- *Ex situ* stabilization materials and handling equipment are widely available.

Ex situ stabilization limitations:

- Stabilization does not remove chemical contamination unless the contaminant undergoes a change in chemical composition. Radionuclides and metals may become part of a more stable complex, but they remain present in the soil.
- Transportation costs may be high if large volumes of stabilizer are needed.
- Soil volume typically increases due to mixing procedures and addition of stabilizers.

3.3.4.4 *Ex situ* Thermal Desorption

Thermal desorption is traditionally an *ex situ* remedial technology that uses heat to physically separate organic chemicals from excavated soils. Thermal desorption can be accomplished by processing contaminated soil through thermal desorption units or by desiccating contaminated soil using solar radiation. Thermal desorbers heat soils to temperatures that volatilize and desorb (i.e., physically separate) contaminants from soil. Although they are not designed to decompose organic constituents, thermal desorbers can, depending upon the specific organics present and the temperature of the desorber system, cause some of the constituents to completely or partially decompose.

The vaporized organic chemicals are generally treated in a secondary treatment unit (e.g., an afterburner, catalytic oxidation chamber, condenser or carbon adsorption unit) prior to discharge to the atmosphere. Afterburners and oxidizers destroy the organic constituents. Condensers and carbon adsorption units trap organic compounds for subsequent treatment or disposal.

VOCs can be desorbed from soil by desiccating thin layers of contaminated soil using solar radiation. Desiccation requires a relatively large unshaded land area to spread the soil and provide adequate exposure to solar radiation. The soil is overturned until VOC removal objectives are met.

Some pre- and post-processing of soil is necessary when using thermal desorption. Excavated soils are first screened to remove large (greater than two inches in diameter) objects. These may be sized (e.g., crushed or shredded) and then introduced back into the feed material. After desorption, soils are re-moistened to control dust and stabilized (if necessary) to prepare them for disposal/reuse. Treated soil may be redeposited on-site, used as cover in landfills or incorporated into asphalt.

Ex situ thermal desorption and desiccation advantages:

- *Ex situ* thermal desorption and desiccation equipment is readily available for on-site or off-site treatment.
- Most commercial thermal desorption systems are capable of over 25 tons per hour throughput.
- *Ex situ* thermal desorption and desiccation costs are competitive for large volumes (greater than 1,000 cubic yards) of soil.
- Treated soil can be reused on-site if permitted by overseeing regulatory agencies.
- *Ex situ* thermal desorption can consistently reduce the total organic chemical concentration below 10 parts per million.
- *Ex situ* thermal desorption equipment is applicable to constituents that are volatile at temperatures as great as 1,200 degrees Fahrenheit. Natural solar desiccation is applicable to VOCs.

Ex situ thermal desorption and desiccation limitations:

- Treatment is typically limited to soil within 25 ft of ground surface due to excavation limitations.
- Solar desiccation is not applicable to semi-volatile or heavy hydrocarbon compounds.
- *Ex situ* thermal desorption equipment and soil stockpiles require significant land area for on-site treatment. Solar desiccation requires larger areas of land.
- Transportation costs may make off-site treatment and disposal expensive.
- Wet soil must be dewatered prior to treatment.
- Gravel and cobbles must be crushed or removed from soil before it is processed.
- Cohesive soil may require shredding or blending with more friable soil or other amendments (e.g., gypsum).
- State and local regulations may require pilot testing before *ex situ* thermal desorption can be implemented.
- Air quality permits are required and source monitoring must be implemented to operate *ex situ* thermal desorption equipment.

3.3.4.5 *Ex situ* Shallow-Rooted Phytoremediation

The basic concept of phytoremediation is presented in Section 3.3.3.2. In situations where deep contamination exceeds root depths, soil can be excavated and graded into a shallow bed constructed at the surface. Typically, the bed is lined with plastic or other low-permeability material to prevent downward or lateral migration of contaminants. Soil amendments and irrigation may be employed to optimize contaminant removal. Contaminated plants are harvested and disposed or treated.

Ex situ shallow-rooted phytoremediation advantages:

- Uses standard agricultural techniques and equipment.
- Treatment times are relatively short.
- Can be combined with other technologies to improve contaminant mass removal rates and efficiency.

Ex situ shallow-rooted phytoremediation limitations:

- May not be applicable where high levels of contamination are present.
- Direct human and ecological exposure to surface contamination and storm water/irrigation runoff must be controlled.
- Contaminated plant and storm water runoff mass and/or volume may exceed soil volumes if removal efficiency is low or if deployed in an area of high rainfall.
- Requires relatively large land areas.
- May be infeasible to conduct remediation in winter month or in areas with high rainfall.

3.3.5 Removal and Reuse/Disposal

Removal by excavation and disposal at a waste facility is conceptually the most straightforward approach to soil cleanup. However, as discussed under removal and *ex situ* treatment, excavation decisions are data intensive, costly when large volumes are involved, and can become considerably more complicated and expensive when the area must be backfilled before confirmation data are received. If large volumes of soil are involved, *in situ* options should be exhausted before excavation is considered.

3.3.5.1 Excavation

Excavation was discussed in Section 3.3.4.1. There are no additional aspects involved in excavation when disposal is selected rather than *ex situ* treatment as a general response action.

3.3.5.2 Soil Reuse/Disposal

Soil may be reused on-site if it meets acceptable risk and ground water resource protection criteria. Uncontaminated and slightly contaminated soil was excavated to access deeper contamination during past RAs in DOE areas at LEHR. Future cleanup activities may involve clean soil excavation. Decisions to reuse previously removed soil would be based on comparisons of soil characterization sample results to the reuse criteria. If the reuse criteria are not exceeded and the LEHR RPMs agree to on-site reuse, the soil would be used for backfill, as needed.

Uncontaminated or slightly contaminated soil could be shipped to an off-site facility if it meets the acceptance criteria and can be used at that facility. Slightly contaminated WDPs gravel was shipped for reuse to the Nevada Test Site in 2003 and 2004 because it met the site material usage criteria.

Often, the only cost-effective option for managing small and medium volumes of contaminated soil is to dispose it at an off-site landfill facility. Waste characterization samples are collected from the contaminated soil stockpile and analyzed by a laboratory for comparison to the disposal facility waste acceptance criteria. When the waste characterization data indicate the criteria are met, the facility will issue documentation accepting the waste. If waste acceptance criteria are not met, the excavated waste may be treated on-site to meet facility criteria or profiled for disposal at an alternative facility. The waste must be packaged and transported to the disposal facility according to all state and federal requirements.

Reuse/disposal advantages:

- Transportation and disposal costs are avoided when soil is reused on site. Disposal costs are avoided when soil is reused off site.
- Disposal is accomplished in the short term.
- Disposal is cost-effective when the volume of contaminated material is relatively small (<100 cubic yards).
- Reuse is cost-effective for larger volumes.
- Reuse/disposal applies to all classes of contamination.

Reuse/disposal limitations:

- Transportation costs may limit off-site reuse.
- Material with a slight amount of radiological contamination that has been released from radiological controls may not be accepted for off-site reuse.
- DOE maintains long-term liability for the material.
- Disposal costs are often prohibitive for large soil volumes.

3.3.6 Containment

Containment can be implemented to prevent contaminant migration and/or direct contact with contaminated soil. Caps and infiltration controls are capable of preventing contaminants from migrating to ground water because they prevent infiltration water from entering the soil column. A cap can prevent subsurface vapor releases to indoor or outdoor air, and it can be a physical barrier to prevent dermal contact and ingestion of contaminated soil.

3.3.6.1 Infiltration Control

The purpose of infiltration control is to prevent vadose zone contamination from impacting ground water. Infiltration is the primary transport mechanism that causes contamination to migrate from a vadose zone source to the water table. Infiltration is the downward flow of water through an unsaturated soil column due to the force of gravity. When infiltration water passes through contaminated sediments, contaminants can partition out of soil and are carried downward by infiltration water. Contaminants that readily partition into water and sorb poorly to soil migrate more quickly by infiltration. Contaminant migration rates also increase with the amount of infiltration water passing through a soil column.

Infiltration is a function of the amount of surface water applied to a soil column and the permeability of sediments within the column. Most infiltration control techniques involve reducing or preventing surface water from entering the soil column. Surface covers, evapotranspiration enhancements, runoff engineering/diversion and irrigation water controls are techniques used to control the amount of infiltration water entering a soil column. Typical surface cover materials consist of clay, concrete, asphalt, plastic sheeting or spray-on membranes.

Evapotranspiration is a mechanism that removes water from shallow sediments in the soil column. Evapotranspiration occurs when plants extract water from the soil and evaporate it at the surface of their leaves. Cultivating plants with high evapotranspiration rates and/or applying a layer of soil that has high evapotranspiration can reduce infiltration.

Improvements in surface water runoff rates can reduce infiltration. A site can be graded to quickly divert surface water into paved ditches that will carry surface water away before it has time to infiltrate.

Irrigation water can add to the infiltration rate. Irrigation rates can be minimized or eliminated to decrease the total amount of infiltration water.

Infiltration is also a function of soil permeability. Low-permeability sediment layers can significantly reduce the infiltration rate and retard contaminant migration long enough to allow natural processes to degrade or remove contamination before it reaches the water table.

Engineered infiltration measures are usually implemented at the surface. Permeability adjustments are not made to sediments located bgs because surface water control is less expensive and achieves the same objective. However, documentation of low-permeability native sediments may be all that is necessary to demonstrate acceptably low levels of infiltration. Native sediment permeability should be considered before implementing surface water controls. Low-permeability native sediments are sometimes sufficient to adequately retard downward contaminant migration.

Infiltration control advantages:

- Infiltration control is an *in situ* approach that avoids human exposure to contaminated materials during installation.
- Materials and techniques of infiltration control are readily available.
- Low-permeability sediments may already be impermeable enough to adequately limit infiltration.
- No added waste disposal or air emissions control/permitting are necessary.

Infiltration control limitations:

- Infiltration control measures are usually implemented for the long term.
- New building or facility construction may require removal of the infiltration control layer. Disposal of the layer materials will have a cost impact. Infiltration control must be part of the building or facility design unless alternative remedial technologies are implemented.
- Engineered infiltration controls must be maintained and monitored until remedial action goals are achieved.
- Land-use restrictions are necessary to prevent human exposure or damage to the infiltration control measure.

3.3.6.2 Caps

Containment caps typically consist of material layers placed on top of waste or contaminated native soil to prevent releases to the surface or migration to ground water. Cap materials typically consist of low-permeability and high-permeability soils and low-permeability geosynthetic products. The low-permeability materials divert water and prevent its passage into the contamination. The high-permeability materials carry percolation water away.

The most critical components of a cap are the barrier layer and the drainage layer. The barrier layer can be low-permeability soil and/or geosynthetic clay liners. A flexible geomembrane liner is typically placed on top of the barrier layer. Geomembranes are usually polymer sheets supplied in large rolls and are available in several thicknesses (20 to 140 mil).

Soil barrier materials generally consist of clays that are compacted to a hydraulic conductivity no greater than 1×10^{-6} centimeters per second (cm/sec). Compacted soil barriers are generally installed in 6-inch minimum lifts to achieve a thickness of two ft or more. A composite barrier uses both soil and a geomembrane, taking advantage of the properties of each. The geomembrane is essentially impermeable, but if it develops a leak, the underlying low-permeability soil layer prevents significant leakage into the underlying waste.

A RCRA Subtitle C multilayered landfill cap is a baseline design that is suggested for use in RCRA hazardous waste applications. These caps generally consist of an upper vegetative (topsoil) layer, a drainage layer, and a low-permeability layer which consists of a synthetic liner over two ft of compacted clay. The compacted clay liners are effective if they retain optimal moisture content, but are susceptible to cracking if the clay material is desiccated. As a result, alternate cap designs are usually considered for arid environments.

A RCRA Subtitle D cap design fulfills the requirements for non-hazardous waste landfills. RCRA Subtitle D cap design is generally dictated by the presence or absence of a bottom liner system and/or the permeability of natural subsoils present. The cover must meet the following specifications:

- The material must have a permeability no greater than 10^{-5} cm/sec, or equivalent permeability of any bottom liner or natural subsoils present, whichever is less.
- The infiltration layer must contain at least 45 cm (1.5 ft) of earthen material.
- The erosion control layer must be at least 15 cm (0.5 ft) of earthen material capable of sustaining native plant growth.

Capping advantages:

- Caps protect ground water resources and above-ground receptors.
- Capping is a widely used technology with readily available designs, materials, and equipment.
- A wide variety of contaminants can be treated.
- Initial investment costs are usually low compared to other shorter term remedial technologies.

Capping limitations:

- RCRA caps must conform to specific requirements.
- Treatment is long term.
- Contamination remains at the site and must be monitored to ensure no releases are occurring.
- Land-use restrictions must be implemented to prevent future site operations from impacting the cap.
- Cap materials require ongoing inspection and maintenance.
- A release from a ruptured cap may cause the overall cost to exceed shorter term remedial technology costs.

3.4 Evaluation and Screening of Remedial Technologies and Process Options

In accordance with US EPA guidance (US EPA, 1988), all potentially applicable remedial technologies and process options for each response action were initially evaluated with respect to their technical implementability. The potentially applicable technologies and process options are shown in Figure 3-1. All but two of the technologies/options were found implementable. The technologies and process options that could not be implemented were:

- Shallow-rooted phytoremediation (as an *in situ* treatment technology)—This technology can only be implemented on contamination located within a few inches to two ft bgs. Shallow-rooted phytoremediation does not apply to DOE areas contamination because it generally deeper than two ft bgs.
- Vegetation cover infiltration control—This technology relies on plant uptake shortly after precipitation events. The largest Davis area precipitation events occur during winter months when plant uptake is at a minimum. Plant uptake resumes in the spring, several weeks after peak rainfall events. This technology/option cannot be implemented on infiltration water from large winter precipitation events because plant uptake is inactive when the events occur.

The remaining process options were evaluated for their effectiveness, implementability and cost (Figure 3-2). The effectiveness evaluation focused on:

- Process reliability with respect to DOE area contaminants of concern and site conditions;
- The potential effectiveness of process options in handling the estimated mass of contamination and volumes of contaminated media;
- The ability to meet remediation goals identified in the RAOs; and
- Potential impacts to human health and the environment during process option construction and implementation.

The implementability criteria focused on:

- The availability of technology, equipment and skilled workers to implement the process option;
- The availability of university property for remedial activities;
- The ability to obtain necessary permits; and
- The availability of treatment, storage and disposal services (including capacity).

The cost criterion plays a limited role at this stage of the screening process. Engineering judgment was used to generally estimate the capital and operations and maintenance (O&M) costs relative to other process options (US EPA, 1988).

Figure 3-2 shows the technology options that were retained. The retained options and reasons they were retained are:

- No action—Several DOE areas do not pose significant risk to human or ecological receptors, and are not a threat to ground water quality. Also, the NCP requires that the no action alternative be considered as a baseline of comparison to other alternatives.
- Land-use restrictions—Human health risk assessment results indicated greater than 10^{-6} risk for residential receptors in the SWT area and DSS 4. Land-use restrictions can be placed on these areas to prevent residential use.
- Subsurface hazard notification (a specific land-use restriction)—Persons planning subsurface work in DOE areas should know the locations and levels of subsurface contamination to plan appropriate health and safety measures before starting work. In addition, persons managing and/or disposing materials excavated from DOE areas should know the residual contaminants and concentrations/activities. A notification system should be implemented to communicate the contaminants, their locations and concentrations/activities in DOE areas.
- Ground water monitoring—A monitoring program is necessary. Monitoring data would provide the information necessary to determine baseline conditions and identify changes in ground water quality. Monitoring data are necessary to reduce decision risks associated with no action or land-use restriction alternatives.
- Bioremediation—Nutrient injection is an innovative option for treating nitrate and possibly formaldehyde in the vadose zone. This option involves injecting a carbon-source solution (e.g., ethanol, glucose, lactate or sucrose in purified water) into contamination in the vadose zone and maintaining fully saturated anaerobic conditions.
- Excavation using conventional heavy equipment—Excavation is an effective and reliable cleanup method that has been successfully implemented in several DOE areas.
- Excavation using oversized augers—This technology has been successfully implemented at LEHR for removing small, deep volumes of contamination. Contamination that cannot be reached by conventional heavy equipment can be removed with an oversized auger rig.
- Excavation with natural *ex situ* solar desiccation (thermal desorption)—This option is expected to remove formaldehyde from DSS 3 soil. The contaminated soil could be spread over the WDPs area and processed during the dry season.
- Excavation with *ex situ* shallow-rooted phytoremediation—This option moves contaminated soil to a location where it can be spread out and made accessible to plant roots. Contaminant uptake is likely effective in a shallow treatment cell.

This form of *ex situ* treatment could reduce overall cost by avoiding off-site disposal costs.

- Removal with on-site reuse—This option is viable if clean soil will be removed and fill is needed at an on-site location. In 1999, clean soil cover was excavated from Ra/Sr Area 1 and later reused in Ra/Sr Area 2 in 2000.
- Removal with off-site reuse—Excavated materials should be reused off-site to reduce waste volume and disposal costs. This option was used effectively in 2003 when WDPs gravel was successfully shipped to the Nevada Test Site for reuse.
- Removal with off-site disposal—Most of the waste previously generated from DOE areas has been disposed off site. Off-site disposal is usually the final option when reuse, treatment, or containment is not viable or cost effective.
- Single-layer asphalt cap—A cap can mitigate human and ecological risks and provide an infiltration barrier to protect ground water resources. Asphalt caps are reasonably reliable and cost-effective. The cap would include a high-density polyethylene (HDPE) liner as a secondary barrier to infiltration water that may pass through the asphalt layer.

The remedial technology/process options that were eliminated and the reasons for elimination are:

- Deep tree planting—This patented option was considered potentially applicable to nitrate removal in vadose zone soil at the SWT area, Ra/Sr Treatment Systems area, and DSS 3. Although the technology vendor has several documented saturated zone case studies, the vendor did not have any vadose zone case study data. The vendor predicted low mass removal and low radius of influence in the vadose zone. Heavy, tight soil (deep soil) will limit root growth. Deep tree planting is effective at capturing dissolved contaminants in permeable saturated zone sediments. Contaminant capture depends on depressing the water table in the vicinity of the tree and inducing ground water flow towards the tree. This capture mechanism is not available in the vadose zone. Deep tree planting was eliminated due to low predicted radius of influence and low mass removal in the vadose zone. In addition, deep tree planting would restrict future land use and pose safety hazards due to open borings that contain the tree trunks. Deep tree planting effectiveness is limited by the time required for maturation to meet treatment design specifications.
- Bioventing—Bioventing was considered potentially applicable to treating formaldehyde at DSS 3 and PAHs at DSS 4. Bioventing was found ineffective for formaldehyde treatment was eliminated, because there are no laboratory or field data to demonstrate its effectiveness. Bioventing was eliminated for PAHs treatment at DSS 4 because the source is still buried in the leach trench (orangeburg pipe coated with PAH-bearing tar). Bioventing will be slow and ineffective for PAHs treatment as long as the pipe remains in the subsurface.

When the PAHs source (orangeburg pipe) is removed, bioventing will be relatively ineffective and expensive compared to removing the small volume of contaminated soil below the pipe.

- Oxygen or hydrogen injection—Hydrogen injection was eliminated because it is an ignition/explosion hazard in the vadose zone and is only applicable to saturated zone treatment. Oxygen injection was considered for formaldehyde and PAHs treatment, but was eliminated for the same reasons that bioventing was eliminated. Oxygen injection does not apply to any of the other DOE areas COCs. However, nutrient injection was retained since it could be effective if saturated conditions are obtained in the vadose zone during the injection process.
- Surfactant enhanced *in situ* flushing—This option is potentially applicable to all of the DOE areas COCs. Surfactant enhanced *in situ* flushing will mobilize contamination and natural metals down the vadose zone column to the water table. This option will also increase mobilization in the saturated zone. Surfactant enhanced *in situ* flushing was eliminated due to the risk of mobilizing natural metals into ground water and beyond the capture zone. In addition, the surfactants will increase contaminant and natural metal mobility for an unknown period. This option was undesirable for additional reasons, including surfactant recycling complexities, process sludge accumulation, a history of limited field implementation success and a 20-ft seasonal water table fluctuation at the LEHR site.
- Water-based *in situ* flushing—Water-based flushing was potentially applicable to mobile DOE areas contaminants (nitrate, formaldehyde and potentially C-14). This option was eliminated for similar reasons to surfactant-enhanced *in situ* flushing. Flushing mobilizes contamination to the water table and the contaminants may mobilize beyond the capture zone. Water-based *in situ* flushing is less risky than surfactant-based flushing, because water will not alter soil/water partitioning for natural metals in the vadose zone and saturated zone. However, water-based flushing has a history of limited field implementation success and would be extremely long term. In addition, this option would be difficult to implement at the LEHR site, because the seasonal water table fluctuation is approximately 20 ft.
- *In situ* stabilization—Stabilization was potentially applicable to nitrate treatment, but it was eliminated because nitrate is a common contaminant with no history of successful vadose zone treatment. In addition, nitrate contamination is known to extend at least 40 ft bgs at the SWT area, Ra/Sr Treatment Systems area, and DSS 3. *In situ* stabilizer mixing would be difficult to implement to the total depth of nitrate contamination. Auger mixing operations showed some promise, but complete mixing was a noted technical difficulty. Additionally, agents added to vadose zone soil will increase the soil volume at the Site, and may cause contamination from unforeseen chemical interactions between the stabilizers and native soil. The increased soil volume

from stabilizing additives would likely interfere with site activities. Site characterization data indicate that LEHR soil has significant stabilizing properties for metals, inorganic radionuclides and PAHs. Stabilizing agents would not likely improve on the natural stabilizing properties of LEHR soil. In addition, stabilizing agents are generally ineffective for VOCs (e.g., formaldehyde).

- *In situ* thermal desorption/soil vapor extraction—This patented technology is applicable to removing SVOCs from vadose zone soil and was considered for treating PAH contamination at DSS 4. *In situ* thermal desorption/soil vapor extraction was eliminated because the source of PAHs at DSS 4 is still buried in the leach trench (orangeburg pipe coated with PAH-bearing tar). *In situ* thermal desorption/soil vapor extraction will be slow and ineffective for PAHs treatment as long as the pipe remains in the subsurface. When the PAHs source (orangeburg pipe) is removed, *in situ* thermal desorption/soil vapor extraction will be relatively ineffective and expensive compared to removing the small volume of contaminated soil below the pipe. This technology does not apply to the DOE areas metals, nitrate, inorganic radionuclides and formaldehyde. The C-14 mass-based concentration was too low for this form of treatment (<0.1 micrograms per kilogram [µg/kg]).

- Excavation with soil washing (dissolution)—Soil washing is appropriate when most of the soil matrix consists of coarse-grained material and most of the contamination is sorbed to a small, fine-grained fraction of the soil matrix. This technology would perform poorly because LEHR DOE areas soil is primarily fine-grained. Soil washing was eliminated because the fine-grained DOE areas soil would overwhelm the processes and produce large volumes of fine-grained waste.

- Excavation with soil washing (i.e., particulate separation)—This technology was eliminated because the soil matrix requirements are the same as soil washing with fines separation. The fine-grained DOE areas soil would overwhelm the processes and produce large volumes of fine-grained waste.

- Excavation with engineered *ex situ* stabilization—This technology was potentially applicable to nitrate, metals, inorganic radionuclides, and PAHs treatment. Stabilizing agents are generally ineffective for VOCs (e.g., formaldehyde). Unlike *in situ* mixing, reliable *ex situ* additive mixing processes and equipment are available. However, unforeseeable interactions between additives and native soil chemistry could occur after reburial. Additives would increase the soil volume, which might interfere with current or future research facility land use. This option would increase human health risk at LEHR by bringing Sr-90-contaminated soil to the surface for processing. *Ex situ* stabilization would be difficult to implement due to soil management/handling logistics and interference with existing site activities conducted by university researchers.

- Excavation with *ex situ* thermal desorption—This technology was potentially applicable for PAHs treatment, but was eliminated because the PAHs-contaminated soil mass is too small. The volume of PAHs-contaminated soil (about 13 cubic yards) would not be enough to justify the cost of mobilizing thermal desorption equipment to the Site. Thermal desorption is not effective on metals, nitrate and inorganic radionuclides. The C-14 mass-based concentration is too low for thermal desorption (<0.1 μg/kg) and the formaldehyde concentration is likely too low (~1 milligrams per kilogram [mg/kg]).
- Surface water diversion to control infiltration—While this option appears technically sound, no case histories were identified to demonstrate its effectiveness. Surface water diversion would reduce infiltration, but not entirely prevent it. Infiltration would likely still be an active transport mechanism for mobile COCs (e.g., nitrate, formaldehyde). This option would limit University land use due to surface grading and drainage structure requirements.
- Clay and soil cap—A cap consisting of native soil and imported clay can prevent water infiltration. However, a clay and soil cap might fail to prevent infiltration if plants or animals rupture the clay layer. Holes or cracks in the clay layer may not be visible at the surface. Asphalt caps are no more expensive, and cracks/holes are easier to find and repair.
- Single layer concrete cap—A concrete cap can effectively prevent infiltration and/or exposure at the surface, but would be expensive to remove if the capped area is involved in future development. An asphalt cap would serve the same purpose and cost less to install, maintain and remove.
- RCRA multiple layer cap—A RCRA cap would prevent infiltration and/or exposure at the surface, but installation and maintenance costs are high. DOE areas contamination does not pose enough risk to human or biological receptors or ground water resources to justify RCRA cap costs.

DOE Area General Response Actions	Remedial Technology	Process Options	Description	Comments
No Further Action	No Further Action	N/A	No further action	Required for consideration by NCP and may be applicable for areas where removal actions have been completed and other low-risk areas
Institutional Controls	Land Use Controls	Property use restrictions	Restriction placed in deed to control land use	Potentially Applicable
		Subsurface hazard notification	Post signage to notify workers of subsurface hazards and removal restrictions	Potentially Applicable
	Monitoring	Ground water monitoring	Long-term ground water monitoring downgradient of source area	Potentially Applicable
In situ Treatment	Soil Vapor Extraction	Vadose zone well network	Use vacuum to induce vapor migration toward extraction wells	Potentially Applicable
	Phytoremediation	Shallow-rooted vegetation planting	Vegetation is planted in shallow soil to remove or mineralize contaminants	Not effective for remediating deep contamination
		Deep tree planting	Trees are planted in boreholes to remove or mineralize contaminants	Potentially Applicable
	Bioremediation	Bioventing	Air is delivered to vadose zone to enhance biodegradation of organic chemicals	Potentially Applicable
		Nutrient, O_2 or H_2 injection	Nutrient solution, oxygen or hydrogen delivered to enhance aerobic or anaerobic soil bioremediation	Potentially Applicable
	In situ Flushing	Surfactant enhanced	Inject or infiltrate surfactant-enhanced aqueous solution to leach contaminants from vadose zone into ground water for capture	Potentially Applicable
		Water only	Inject or infiltrate water to leach contaminants from vadose zone into ground water for capture	Potentially Applicable
	Stabilization	*In situ* additive mixing	A stabilizing agent is injected into the subsurface or applied on surface contamination	Potentially Applicable
	Thermal Desorption/ Soil Vapor Extraction	High temperature desorption with soil vapor extraction	Thermal wells heat soil to mobilize the contaminant vapors for extraction and treatment	Potentially Applicable

Legend

- Bioremediation (shaded box): Process Option Potentially Applicable
- Soil Vapor Extraction (unshaded box): Process Option Eliminated

Abbreviations

- DOE Department of Energy
- FT feet
- H_2 hydrogen gas
- N/A not applicable
- NCP National Oil and Hazardous Substances Pollution Contingency Plan
- O_2 oxygen
- RCRA Resource Conservation and Recovery Act
- UCD University of California, Davis

Figure 3-1. Initial Screening of Technologies and Process Options

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DOE Area General Response Actions	Remedial Technology	Process Options	Description	Comments
Removal / *Ex Situ* Treatment	Excavation	Excavate using conventional heavy equipment	Remove contaminated soil with excavators and loaders	Potentially Applicable
		Excavate using oversized auger	Remove contaminated soil with large diameter auger (greater than 3 ft)	Potentially Applicable
	Soil washing	Dissolution	Water-based media transfers soil contaminants into aqueous solution	Potentially Applicable
		Particle Separation	Water-based media transfer concentrates contaminant bearing particles through size & gravity separation for removal	Potentially Applicable
	Stabilization	*Ex situ* additive mixing	Apply via machine-mixing stabilizers into contaminated soil	Potentially Applicable
	Thermal Desorption	*Ex situ* thermal desorption	Thermal desorbers heat soil to temperatures that volatilize and desorb contaminants from soil	Potentially Applicable
	Phytoremediation	Shallow-rooted vegetation planting	Vegetation is planted in shallow soil to remove or mineralize contaminants	Potentially Applicable
Removal / Disposal	Excavation	Excavate using conventional heavy equipment	Remove contaminated soil with excavators and loaders	Potentially Applicable
		Excavate using oversized auger	Remove contaminated soil with excavators and loaders	Potentially Applicable
	Soil Reuse / Disposal	On-site reuse / disposal	Reuse or dispose material on site	Potentially Applicable
		Off-site reuse	Reuse material off site	Potentially Applicable
		Off-site Disposal	Dispose material at an appropriately permitted facility	Potentially Applicable
Containment	Infiltration Control	Surface Water Diversion	Grade surface to divert storm water runoff	Potentially Applicable
		Vegetation Cover	Cultivate plants with high evapotranspiration rates	Not effective in local climate
	Cap	Clay, single layer	Layer of compacted clay covered with soil over soil contamination	Potentially Applicable
		Asphalt, single layer	Layer of asphalt over soil contamination	Potentially Applicable
		Concrete, single layer	Layer of concrete over soil contamination	Potentially Applicable
		RCRA multiple layer		

Legend

Bioremediation — Process Option Potentially Applicable

Soil Vapor Extraction — Process Option Eliminated

Abbreviations

- DOE Department of Energy
- FT feet
- H_2 hydrogen gas
- N/A not applicable
- NCP National Oil and Hazardous Substances Pollution Contingency Plan
- O_2 oxygen
- RCRA Resource Conservation and Recovery Act
- UCD University of California, Davis

Figure 3-1. Initial Screening of Technologies and Process Options (continued)

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DOE Area General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost	Retained?
No Action	No Action	N/A	Uncertain effectiveness. Degradation, decay, dilution, adsorption may mitigate risks and ground water impacts.	Easily implemented	Negligible	Yes
	No Further Action	N/A	Effective for areas where removal actions have addressed principle risks; otherwise, uncertain. Degradation, decay, dilution, adsorption may mitigate risks and ground water impacts.	Easily implemented	Negligible	Yes
Institutional Control	Land Use Controls	Property use restrictions	Effective for preventing exposure to human health risk COCs (Sr-90, PAHs). Effectiveness depends on continued future implementation.	Readily implemented	Low capital	Yes
		Subsurface hazard notification	Effective for limiting exposure and restricting removal of contaminated soil if proper notification system is in place. Requires the installation and maintenance of signage with up-to-date contact information	Readily implemented	Negligible	Yes
	Ground water monitoring	Ground water monitoring	Monitors extent of ground water COCs, prevents exposure to contaminated ground water if proper notification system is in place. Contingent remedial action will be necessary if ground water monitoring shows ground water impacts.	Easily incorporated into existing ground water monitoring program. The difficulty of contingent remedial action varies with the selected technology	Low capital, and low O&M; medium capital if well installation becomes necessary; potential high captial and/or O&M costs if Contingent remedial action becomes necessary	Yes

Abbreviations

µg/kg	micrograms per kilogram
C-14	carbon-14
COCs	contaminants of concern
DOE	Department of Energy
FT	feet
H_2	hydrogen
HDPE	high-density polyethylene
NA	not applicable
O_2	oxygen
O&M	operation and maintenance
PAHs	polynuclear aromatic hydrocarbons
Ra-226	radium-226
RCRA	Resource Conservation and Recovery Act
Sr-90	Strontium-90

Legend

Stabilization (shaded box)	Process Option Retained
Excavation (unshaded box)	Process Option Not Retained

Figure 3-2. Evaluation of Process Options

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DOE Area General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost	Retained?
In-situ Treatment	Phytoremediation	Deep tree planting	Demonstrated for dissolved contaminants (typically nitrate) in permeable saturated zone sediments. Not a demonstrated technology for vadose zone contamination. Trees likely cannot easily capture vadose zone contamination.	Restricts future land use	Low capital and O&M	No
	Bioremediation	Bioventing	Bioventing is not applicable to inorganic COCs (nitrate, metals, radionuclides). PAHs mass is too small / localized. No laboratory or field data indicating that bioventing is effective on formaldehyde.	Easily implemented	Medium capital and O&M	No
		Nutrient, O_2 or H_2 injection	Nutrient injection is applicable to nitrate treatment and possibly formaldehyde treatment. H_2 injection is not applicable to vadose zone soil. O_2 injection has same effectiveness problems as bioventing.	Easily implemented	Medium capital and O&M	Yes (nutrient injection only)
	In situ Flushing	Surfactant enhanced	Introduces chemicals into the subsurface. Surfactant recovery is marginal due to the site's fine grained soil. Will release natural metals to ground water. Contaminants may mobilize beyond capture zone.	Difficult to implement due to fluctuations in the site's water table	Medium capital and O&M	No
		Water only	Moblizes contaminants into ground water. Contaminants may moblize beyond capture zone.	Difficult to implement due to fluctuations in the site's water table	Medium capital and O&M	No
	Stabilization	Additives mixed *in situ*	Unknown long-term effectiveness. No nitrate case histories for vadose zone. Not effective for mobile volatile organic compounds (e.g., formaldehyde). Stabilizing additives will not likely significantly improve metal and radionuclide stabilizing properties of LEHR soil.	Difficult to evenly mix additives; generates excess volume of soil that will interfere with site activities	High capital; low O&M	No
	Thermal Desorption/ Soil Vapor Extraction	High temperature desorption with soil vapor extraction	Potentially appicable to PAHs contamination, but PAHs mass is too small / localized. Not appicable to metals, inorganics, radionuclides. C-14 chemical concentration is too low (<0.1 µg/kg).	Only availble through one vendor who holds patents on technology	Medium capital and O&M	No
	Soil Vapor Extratction	Vadose zone well network	Not effective. Formaldehyde and potenially C-14 (organic chemical identity is unknown) are the only volatile organic compounds in DOE areas. Formaldehyde Henry's Constant is too low for air partitioning and C-14 chemical concentration is too low (<0.1 µg/kg).	Readily implementable	Medium capital and O&M	No

Legend

Stabilization (shaded box) — Process Option Retained
Excavation (unshaded box) — Process Option Not Retained

Abbreviations

µg/kg	micrograms per kilogram
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COCs	contaminants of concern
DOE	Department of Energy
FT	feet
H_2	hydrogen
HDPE	high-density polyethylene
NA	not applicable
O_2	oxygen
O&M	operation and maintenance
PAHs	polynuclear aromatic hydrocarbons
Ra-226	radium-226
RCRA	Resource Conservation and Recovery Act
Sr-90	Strontium-90

Figure 3-2. Evaluation of Process Options (continued)

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DOE Area General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost	Retained?
Removal	Excavation	Excavate using conventional heavy equipment	Effective and reliable for localized PAHs contamination. May increase Sr-90 human health risk by bringing contamination to surface. Less effective for randomly distributed contamination (Ra-226) or dispersed contamination (nitrate, formaldehyde, C-14).	Readily implementable to 20 ft, deeper excavation has reduced implementability; cannot be used under structures / buildings	Very high capital; low O&M	Yes
Removal	Excavation	Excavate using oversized auger	Effective for removing deep contamination. May increase Sr-90 human health risk by bringing contamination to surface. Less effective for randomly distributed contamination (Ra-226) or dispersed contamination (nitrate, formaldehyde, C-14). Auger may deflect or refuse and miss target contamination.	Readily implementable to depths > 40 ft above the water table; cannot be used under structures / buildings	High capital; low O&M	Yes
Ex Situ Treatment	Soil washing	Dissolution	Effective on course-grained soil types. Not effective at removing any COCs from fine grained LEHR soil.	Difficult to implement on DOE area soil	Medium capital; low O&M	No
Ex Situ Treatment	Soil washing	Particulate separation	Effective on course-grained soil types. Not effective at removing any COCs from fine-grained LEHR soil.	Difficult to implement on DOE area soil	Medium capital; low O&M	No
Ex Situ Treatment	Stabilization	*Ex situ* additive mixing	More effective mixing than *in situ*. May reduce mobility of metals, organics, rads. May increase Sr-90 human health risk by bringing contaminaton to surface. Ineffective on formaldehyde.	Difficult to implement due to soil management logistics and interference with site activities	Medium capital; low O&M	No
Ex Situ Treatment	Thermal Desorption	*Ex situ* thermal desorption	Ineffective on metals, nitrate, inorganics,rads. C-14 concentration too low (<0.1 µg/kg). PAHs mass / volume too small.	Difficult to implement due to soil management logistics and interference with site activities	Medium capital; low O&M	Yes
Ex Situ Treatment	Phytoremediation	Shallow-rooted vegetation planting	Effective nitrate removal for shallow, wet treatment areas. Some plant species are effective at removing metals dissolved in ground water.	Readily implementable	Medium capital; low O&M	Yes

Legend

- Stabilization (shaded box): Process Option Retained
- Excavation (unshaded box): Process Option Not Retained

Abbreviations

µg/kg	micrograms per kilogram
C-14	carbon-14
COCs	contaminants of concern
DOE	Department of Energy
FT	feet
H_2	hydrogen
HDPE	high-density polyethylene
NA	not applicable
O_2	oxygen
O&M	operation and maintenance
PAHs	polynuclear aromatic hydrocarbons
Ra-226	radium-226
RCRA	Resource Conservation and Recovery Act
Sr-90	Strontium-90

Figure 3-2. Evaluation of Process Options (continued)

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DOE Area General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost	Retained?
Removal	Excavation	Excavate using conventional heavy equipment	Effective and reliable for small / localized PAHs contamination. May increase Sr-90 human health risk by bringing contamination to surface. Less effective for randomly distributed contamination (Ra-226) or dispersed contamination (nitrate, formaldehyde, C-14).	Readily implementable to 20 ft, deeper excavation has reduced implementability	High capital; low O&M	Yes
		Excavate using oversized auger	Effective for removing deep contamination. May increase Sr-90 human health risk by bringing contamination to surface. Less effective for randomly distributed contamination (Ra-226) or dispersed contamination (nitrate, formaldehyde, C-14). Auger may deflect or refuse and miss target contamination.	Readily implementable to depths > 40 ft above the water table	High capital; low O&M	Yes
Disposal	Soil Reuse / Disposal	Retained process option	Effective and reliable for uncontaminated overburden and fill	Readily implementable	Low capital and O&M	Yes
		Off-site reuse	Effective and reliable for uncontaminated overburden and fill	Acceptable for uncontaminated material	Low capital and O&M	Yes
		Off-site disposal	Effective and reliable for all COCs.	Readily implementable; landfills have capacity and will accept LEHR COCs / concentrations	High capital; low O&M	Yes

Legend

Stabilization — Process Option Retained

Excavation — Process Option Not Retained

Abbreviations

µg/kg	micrograms per kilogram
C-14	carbon-14
COCs	contaminants of concern
DOE	Department of Energy
FT	feet
H_2	hydrogen
HDPE	high-density polyethylene
NA	not applicable
O_2	oxygen
O&M	operation and maintenance
PAHs	polynuclear aromatic hydrocarbons
Ra-226	radium-226
RCRA	Resource Conservation and Recovery Act
Sr-90	Strontium-90

Figure 3-2. Evaluation of Process Options (continued)

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DOE Area General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost	Retained?
Containment	Infiltration Control	Surface water diversion	Mobile COCs (nitrate, formaldehyde) transport mechanism still active. Unproven effectiveness. Will not prevent all surface water from entering vadose zone.	Readily implementable; some limits on future land use due to drainage structures	Medium capital, low O&M	No
	Cap	Clay + soil	Bioturbation and weed control may reduce effectiveness. Capping will reduce contaminant transport for nitrate, formaldehyde (potentially C-14) by preventing infiltration. Minimal effect on metals, PAHs, radionuclide transport. Does not change Sr-90 risk in Southwest Trenches area.	Readily implementable; limits on future land use	Low capital, low O&M	No
		Asphalt, HDPE liner	Effective, but asphalt is susceptible to cracking and weathering. HDPE liner will prevent infiltration. Capping will reduce contaminant transport for nitrate, formaldehyde (potentially C-14) by preventing infiltration. Minimal effect on metals, PAHs, radionuclide transport. Does not change Sr-90 risk in Southwest Trenches area.	Readily implementable; limits future land use	Medium capital, moderate O&M	Yes
		Concrete, single layer	Effective, but susceptible to cracking and weathering. Capping will reduce contaminant transport for nitrate, formaldehyde (potentially C-14) by preventing infiltration. Minimal effect on metals, PAHs, radionuclide transport. Does not change Sr-90 risk in Southwest Trenches area.	Readily implementable; limits future land use	Medium capital, moderate O&M	No
		RCRA multiple layer	Effective and reliable. Capping will reduce contaminant transport for nitrate, formaldehyde (potentially C-14) by preventing infiltration. Minimal effect on metals, PAHs, radionuclide transport. Does not change Sr-90 risk in Southwest Trenches area.	Readily implementable; significantly limits future land use	High capital, moderate O&M	No

Legend

Stabilization — Process Option Retained
Excavation — Process Option Not Retained

Abbreviations

µg/kg	micrograms per kilogram
C-14	carbon-14
COCs	contaminants of concern
DOE	Department of Energy
FT	feet
H_2	hydrogen
HDPE	high-density polyethylene
NA	not applicable
O_2	oxygen
O&M	operation and maintenance
PAHs	polynuclear aromatic hydrocarbons
Ra-226	radium-226
RCRA	Resource Conservation and Recovery Act
Sr-90	Strontium-90

Figure 3-2. Evaluation of Process Options (continued)

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4. DESCRIPTION AND EVALUATION OF REMEDIAL ALTERNATIVES

4.1 Description and Evaluation Process

In this section, remedial alternatives for each of the DOE areas are developed from the retained remedial technologies identified in Section 3. Each alternative is assembled with the goal of achieving acceptable risk under CERCLA and meeting all ARARs. A detailed evaluation and comparison of the remedial alternatives is developed for each alternative using the nine criteria identified in the NCP, as outlined in Section 4.2. The general assumptions associated with the general response actions are presented in Section 4.3.

4.1.1 Remedial Alternative Development Process

Remedial alternatives are developed from the technologies and options retained in Section 3. The retained technologies/options are:

- No action;
- Land-use restrictions (including subsurface hazard notification);
- Ground water monitoring;
- Nutrient injection;
- Excavation using conventional heavy equipment;
- Excavation using oversized augers;
- *Ex situ* shallow-rooted phytoremediation;
- Thermal desorption;
- On-site reuse;
- Off-site reuse;
- Off-site disposal; and
- Single-layer asphalt cap with plastic liner.

Per US EPA guidance, a no action alternative is provided for each DOE area.

The Risk Assessment identified COCs that require FS remedial alternatives in the following DOE areas:

- Ra/Sr Treatment Systems;
- DSS 3;
- DSS 4;
- Dry Wells A-E;
- SWT; and
- EDPs.

Remedial alternatives were developed for each of these areas (FS areas) by assembling retained process options in a manner that addresses specific ARARs, NCP requirements and FS area conditions.

As shown in Table 4-1, ground water impacting COCs are present in all of the FS areas except the EDPs, and human health COCs are present in the DSS 4, SWT and EDPs areas. All of the FS areas contain at least one low-mobility constituent (e.g., Ra-226, Sr-90, PAHs or metals) and some of the FS areas contain localized areas of more mobile constituents (e.g., nitrate and formaldehyde). The former have no practical treatment options, while the latter are potentially treatable, both *in* and *ex situ.*

All of the FS areas potentially contain residual radionuclides above site background. With the exception of Sr-90 in the SWT and EDPs areas, these radionuclides do not result in unacceptable risk under CERCLA.

Application of State of California ground water protection ARARs, NCP requirements and information on site conditions resulted in a consistent set of alternatives that applied to all areas except the EDPs. These alternatives are:

- No action;
- Long-term ground water monitoring and contingent remedial action;
- Capping, long-term ground water monitoring and land-use restrictions; and
- Removal and off-site disposal.

In FS areas where nitrate and/or formaldehyde were present, additional *in* and *ex situ* treatment alternatives were developed (Table 4-1):

- Removal and on-site treatment; and
- *In situ* bioremediation.

The Risk Assessment identified that no COCs were present in the following DOE areas:

- DSS 1;

- DSS 5;
- DSS 6;
- DSS 7; and
- WDPs.

Area-specific descriptions and detailed evaluations of the alternatives are presented below.

4.2 Detailed Analysis of Alternatives Process

4.2.1 Overview of the National Contingency Plan Evaluation Criteria

A detailed analysis of the remedial alternatives for each DOE area was conducted. All of the remedial alternatives were evaluated using nine criteria identified in the NCP (40 CFR 300.430 (e)(9)(iii)). Per the NCP, these criteria are categorized into three groups:

Threshold Criteria:

- **Overall Protection of Public Health and the Environment**—Assesses the degree to which public health and the environment is protected from site risks. Draws on the assessment of the other evaluation criteria, particularly long-term effectiveness and permanence, short-term effectiveness and compliance with ARARs.
- **Compliance with ARARs**—Determines whether the alternative meets ARARs as described in Section 2 and if any waivers of these requirements are necessary.

Balancing Criteria:

- **Long-Term Effectiveness**—Evaluates the degree of permanence and certainty that the proposed alternative will be successful in maintaining risk mitigation.
- **Reduction in Toxicity, Mobility or Volume through Treatment**—Assesses the degree to which an alternative can reduce the toxicity, mobility or volume of contamination at the Site.
- **Short-Term Effectiveness**—Assesses the immediate impacts to the surrounding community, site workers and environment during implementation of the alternative. Also evaluates the time required to reach a protective state. Groundwater remedial actions will be considered protective when background is achieved for all COCs, or, if background is shown to be technically or economically infeasible to achieve, when the lowest applicable water quality objectives are achieved.

- **Implementability**—Evaluates whether the alternative can be implemented based on the following criteria:
  - **Technical Feasibility**—Evaluates whether the remedial technology will be a technically reliable remedy.
  - **Administrative Feasibility**—Assesses the degree of difficulty of obtaining the necessary permits or regulatory approvals for the alternative.
  - **Availability of Services and Material**—Assesses the degree of difficulty of obtaining necessary products or services needed to complete the remedy.
- **Cost**—Estimates the monetary cost of each alternative expressed as the net present worth. Costs were developed for the following categories, as applicable:
  - **Capital Costs—**Includes direct costs for field labor, equipment and material. Subcontracted tasks supporting field activities (i.e., analytical lab services and land surveyors) are also included. Includes indirect costs for project management, permitting, engineering and design.
  - **Annual O&M Cost—**O&M costs include treatment system operation, monitoring, sampling, testing and analysis.
  - **Periodic Cost—**Includes all future costs that may not occur on a regular annual basis, such as repairs every 10 years or decommissioning costs at the end of a project.

Modifying Criteria:

- **State Acceptance**—Documents the state's concern and position. Developed after comments on the FS are received.
- **Community Acceptance**—Documents the community's concern and position. This process may not be completed until comments on the proposed plan are received.

As indicated in the NCP, all selected alternatives must meet the threshold criteria. The other criteria are considered by the lead agency and other decision-makers in selecting remedial alternatives for the site.

4.3 Assumptions

The general assumptions used to evaluate the remedial alternatives are provided below. Detailed cost assumptions are provided in Appendix A.

4.3.1 Land-Use/Institutional Control

1. Land-use restrictions would consist of implementing a codified land-use restriction in coordination with the UC Office of the President, Real Estate Services Group and the UC Davis Office of Resource Management and Planning (ORMP). A deed modification would be recorded with Solano County.

2. Subsurface hazard notification would consist of metal signs on posts.

4.3.2 Long-Term Monitoring

1. Monitoring wells UCD1-021, UCD1-054 and UCD1-023 (Figure 4-1) have been designated to monitor ground water downgradient of the Ra/Sr Treatment Systems, Dry Wells A-E and the SWT areas, respectively.

2. Monitoring wells will be installed in hydrostratigraphic unit (HSU)-1 at locations downgradient of DSS 3, DSS 4 and the SWT areas.

3. Full-suite ground water samples will be collected quarterly for one year in the new wells.

4. Ground water COC samples will be collected annually for 30 years in selected monitoring wells. The 30-year time period is recommended by US EPA for the cost comparison of alternatives (US EPA, 1988). Based on historical ground water monitoring at the Site, most wells do not show significant seasonal variation. The actual monitoring frequency and duration may be shorter or longer, depending on site-specific conditions, data trends and other factors, as determined in the remedial action work plan. The monitoring well locations presented in the FS report are conceptual. Final well locations and design specifications will be developed in the Remedial Action Work Plan.

5. The ground water monitoring results will be summarized in the UC Davis annual ground water monitoring reports.

6. Remedial alternatives for groundwater will be evaluated and the preferred alternative implemented if four consecutive ground water sample results from a designated DOE area ground water monitoring well exceed site background and show an increasing or constant concentration trend.

7. If monitoring data trigger an evaluation of remedial options, an addendum to the Remedial Action Work Plan will be prepared. The Remedial Action Work Plan addendum will present a plan to address data gaps, if necessary, an engineering evaluation of remedial options and the preferred remedial option. The evaluation will be designed to meet the substantive requirements of CERCLA and applicable DOE

requirements. RPM review and approval of the Remedial Action Work Plan addendum will be required.

4.3.3 Removal and Disposal

1. At a minimum, the following elements are included in the removal and disposal alternatives:
   - Prepare a detailed construction work plan;
   - Remove and package contaminated material;
   - Characterize and profile waste for off-site disposal;
   - Ship waste material containing above-background radioactivity to a permitted low-level radioactive waste repository;
   - Ship waste material that does not contain above-background radioactivity to a Class II industrial waste landfill;
   - Collect confirmation samples;
   - Evaluate confirmation data and produce a confirmation report; and
   - Backfill and compact excavation.
2. Excavation will remove all soil containing COC concentrations above the remediation goals shown in Tables 2-1 and 2-2, respectively.
3. All clean material located above the contaminated soil will be returned to the excavation without testing. Testing is not necessary because the clean fill, which was characterized before placement, has not been in contact with the contaminated soil. Geotextile liners separate the clean soil from the contaminated soil below. Furthermore, the clean soil will be stockpiled separately from all other excavation soil.
4. No hazardous or mixed waste will be generated.
5. All low-level radioactive waste will be disposed at Envirocare of Utah. Alternate permitted disposal facilities may be used when the work is conducted.

4.3.4 Removal and On-Site Treatment

1. This alternative is the same as removal and disposal, except a fraction of the soil is treated on-site in a treatment cell.

2. Phytoremediation will be conducted in an on-site treatment cell located in the WDPs area for three annual growing seasons using a grass species suited to a warm climate. The treatment cell will be decommissioned at the end of the third year and the treated soil will be left in place.

3. The treatment cell will be lined with a single sheet of welded HDPE plastic to prevent contaminating underlying soil. The cell will be graded to prevent ponding during the rainy season, and covered with plastic sheeting during the rainy season to prevent transfer of the contaminants to storm water runoff.

4. The plants will uptake the nitrate contamination, which will be harvested when the grass is trimmed during the growing seasons. The trimmings will be dried and stored until cleanup is complete and then disposed with the liner and water delivery system when the phytoremediation system is decommissioned. A Class III landfill will accept the cuttings and used system components.

4.3.5 Asphalt Cap

1. The asphalt cap will consist of four inches of standard asphalt underlain with eight inches of gravel base material and a 40-mil welded HDPE liner.

2. The asphalt will be inspected annually for signs of deterioration. Minor repairs will be made, as necessary.

3. A two-inch thick asphalt overlay will be installed over the cap every ten years for thirty years.

4.3.6 In Situ *Bioremediation*

1. Carbon-source solution injection will be used to saturate the vadose zone and obtain anaerobic conditions that will reduce nitrate and formaldehyde to innocuous compounds.

2. Bench-scale pilot tests will be used to determine the feasibility and optimal conditions for each treatment area.

3. A carbon source solution delivery system will be constructed of injection wells and construction materials commonly used in soil and ground water remediation systems.

4. A system of monitoring wells and piezometers will be used to monitor system performance and determine whether contamination is stable and not migrating beyond the treatment area.

5. Treatment will be conducted for two years.

4.3.7 Cost

1. The net present worth of a future payment is the actual value that will be disbursed, discounted at an appropriate rate of interest. The present value for the annual costs is calculated using a multi-year discount rate of 3.1 percent to derive the discount factor in accordance with US EPA guidance (US EPA, 2000a).

2. Detailed cost assumptions for each alternative are presented in Appendix A.

4.4 Radium/Strontium Treatment Systems

4.4.1 Nature and Extent of Contaminants of Concern

The Ra/Sr Treatment Systems area has no human health risk COCs; nitrate, C-14 and Ra-226 are ground water impact COCs (Tables 2-1 and 2-2).

4.4.1.1 Nitrate in Soil

A significant fraction of the nitrate results exceeded background (29 of 126, or 23 percent) in the Ra/Sr Treatment Systems area. The elevated results ranged from 36.1 mg/kg to 304 mg/kg and were clustered in the vicinity of the three former dry wells, Domestic Septic Tank (DST) No. 2 and the northern Ra-226 leach trench (Figure 4-2). The background concentration for nitrate in LEHR soil is 36 mg/kg. Nitrate was below background throughout the southern Ra-226 leach trench, Sr-90 leach field, and Sr-90 and Ra-226 treatment tank areas. Most of the nitrate contamination is distributed vertically between four and 20 ft bgs. However, two of three samples collected at 42.5 ft bgs had nitrate concentrations above background. Intervals from one to three ft bgs and 21 to 29 ft bgs were below background. The area of nitrate contamination appears to be approximately 25 ft wide with a small leg extending north along the northern Ra-226 leach trench, and 20 ft deep with potential deeper contamination (Figure B-1, Appendix B).

4.4.1.2 Carbon-14 in Soil

Only six out of 103 soil sample results (6 percent) exceeded background for C-14 in the Ra/Sr Treatment Systems area. The elevated results were located in the Ra-226 leach trench at depths ranging between 5.5 and 13.5 ft bgs. Two of the samples had relatively high concentrations (2.38 ± 0.115 picoCuries per gram [pCi/g] and 2.41 ± 0.112 pCi/g) compared to background (0.13 pCi/g). The two elevated samples (SSRSC019 and SSRSC020) were clustered at the southern end of the Ra-226 leach trench. Soil boring samples were collected at these two sample locations at depths ranging from 13 to 33.5 ft bgs. C-14 concentrations were consistent with background in the soil boring samples. C-14 concentrations in the other four elevated sample results were significantly lower (0.173 ± 0.0606 pCi/g to 0.404 ± 0.0634 pCi/g) and randomly distributed across the Ra-226 leach trench. These data suggest that any residual C-14 is limited in extent and is not actively releasing C-14 to ground water.

4.4.1.3 Radium-226 in Soil

The spatial distribution of above-background Ra-226 is limited. Only five out of 106 (5 percent) of the Ra/Sr Treatment Systems area soil samples exceeded background. The samples with elevated concentrations were located at depths ranging between 15 ft bgs and 42.5 ft bgs. Three of the samples were located below the southern Ra-226 leach trench, and two were inside the southern and middle dry wells. Deeper soil samples were collected below each of these locations and their results were below background. The extent and mass of Ra-226 appears limited to depths below 15 ft bgs in the vicinity of the former southern leach trench and dry wells.

4.4.1.4 Ground Water

Ground water that is downgradient of the Ra/Sr Treatment Systems area has been monitored for COPCs between 1987 and the present. Ground water from HSU1 has been sampled in wells UCD1-006, UCD1-022, UCD1-005 and UCD1-021 (listed with increasing distance from the Ra/Sr Treatment Systems area). Figure 4-1 shows the relative locations of these wells to the Ra/Sr Treatment Systems area. Wells UCD1-006 and UCD1-022 are adjacent to each other, but are screened at different intervals: UCD1-006 is screened from 40 to 50 feet bgs, whereas the deeper UCD1-022 is screened from 57 to 72 feet bgs. Similarly, wells UCD1-005 and UCD1-021 are adjacent to each other but are also screened at different intervals: UCD1-005 is screened from 38 to 48 feet bgs, whereas the deeper UCD1-021 is screened from 57 to 72 feet bgs. Ground water from HSU2 has been sampled in wells UCD2-007 and UCD2-036 (listed with increasing distance from the Ra/Sr Treatment Systems area) (Figure 4-1). Graphs illustrating the concentrations of COCs in these six wells through time are in Appendix F, with the exception of those graphs that would show fewer than five detected results and no detected results greater than MCLs. Included in each graph is a simple linear regression calculation, represented by a dashed line, to assist the reader in evaluating the overall trend of the COC in ground water.

The concentration of nitrate in HSU1 downgradient of the Ra/Sr Treatment Systems area is variable through both time and space, and in some cases exceeds the MCL of 10,000 µg/L. In the nearest well, UCD1-006, the concentration of nitrate in a recent sample was 43,000 µg/L (June 15, 2006). Before this, nitrate had not been analyzed for in this well since 1987, when the concentration of nitrate was reported at 90,000 µg/L (Wahler Associates, 1989). In the adjacent well, UCD1-022, the nitrate concentration has been consistently below the MCL of 10,000 µg/L, except in one sample with an anomalously high concentration of 18,000 µg/L (Figure F-12). This anomalously high concentration forces the simple regression calculation to reflect an increasing nitrate concentration, but without this high concentration such a calculation would probably reflect what appears to be an overall decreasing trend. The discrepancy between the higher nitrate concentrations in the shallower well UCD1-006, and the lower concentrations in the deeper well UCD1-022, suggest that the wells monitor hydrostratigraphic units that are hydrogeologically separated. Further downgradient, in well UCD1-005, the concentration of nitrate in a recent sample was 18,000 µg/L (June 14, 2006). Before this, nitrate had not been analyzed for in this well since 1987, when the concentration of nitrate was reported at 48,000 µg/L (Wahler Associates, 1989). In well UCD1-021, which is near well UCD1-005, the concentration of nitrate has consistently been above the MCL, although that concentration may have been decreasing since 1999 (Figure F-10). Nevertheless, the most recent samples collected from UCD1-021 have concentrations of nitrate above the MCL of 10,000 µg/L (ranging from 34,000-42,000 µg/L over the past two years). Again, the discrepancy between nitrate concentrations in these latter two wells may be due to heterogeneities in HSU1. In summary, the concentration of nitrate in HSU1 downgradient of the Ra/Sr Treatment Systems area is variable through both time and space. Through time, nitrate generally seems to be decreasing in concentration. In space, there may be hydrogeological heterogeneity in HSU1 that affects nitrate concentration.

Nitrate concentrations in HSU2 downgradient of the Ra/Sr Treatment Systems area have either almost always been below the MCL or have decreased with time to concentrations below the MCL. Specifically, in well UCD2-007, nitrate concentrations have steadily decreased for the last 16 years, and for the last two years have been below the MCL (Figure F-24). In well UCD2-036, nitrate concentrations have been highly variable through time but, with only a single exception in 1999, have consistently been below the MCL (Figure F-36).

C-14 has not been detected at concentrations above its MCL of 2,000 pCi/L downgradient of the Ra/Sr Treatment Systems area in either HSU1 or HSU2. The highest detected concentration in HSU1 was 177 ± 69 pCi/L in well UCD1-021. The highest detected concentration in HSU2 was 640 ± 20.4 pCi/L in well UCD2-007. In well UCD2-036, the only downgradient well from which there have been more than four detections of C-14, the concentration of C-14 has consistently been below 20 pCi/L since 1999 (Figure F-34).

Ra-226 has not been detected at concentrations greater than its MCL of 5 pCi/L in HSU1 downgradient of the Ra/Sr Treatment Systems area, aside from one outlier in well UCD1-022 that is probably be erroneous (Figure F-11). In this well, Ra-226 has been increasing through time, although it has not exceeded the MCL. The most recent sample from well UCD1-022 had a concentration of Ra-226 of 4.21 ± 1.05 pCi/L. In well UCD1-021, 13 primary and five duplicate samples have been analyzed for Ra-226. Of these, two samples contained detectible concentrations of Ra-226 in 1999 and 2006 (2.38 ± 0.832 pCi/L and 2.65 ± 0.701 pCi/L, respectively). In HSU2, the concentration of Ra-226 downgradient of the Ra/Sr Treatment Systems area is yet to be fully understood. In well UCD2-007 (Figure F-23), the concentration of Ra-226 has been below 2 pCi/L, except for an outlier identical to the one in well UCD1-022. In well UCD2-036, the most recent sample had a significantly elevated concentration of Ra-226 at 8.83 ± 1.2 pCi/L (Figure F-35). It is possible that this result is erroneous, which is an explanation that is supported by the facts that no previous sample from this well has had concentrations of Ra-226 greater than 2 pCi/L, and that those previous results follow a decreasing, not increasing, trend. This well will be resampled for Ra-226 in the near future, and the recent elevated concentration will be reevaluated then.

4.4.2 Description of Remedial Alternatives

4.4.2.1 Alternative 1—No Action

A no action alternative was developed for the Ra/Sr Treatment Systems area to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.4.2.2 Alternative 2—Long-Term Ground Water Monitoring and Contingent Remedial Action

The second alternative developed for the Ra/Sr Treatment Systems area consists of implementing long-term ground water monitoring to determine if remedial action is warranted.

Ground water monitoring will consist of sampling well UCD1-021 (Figure 4-1) for C-14, nitrate and Ra-226 on an annual basis. A new well will be installed downgradient of DSS 4 (Figures 4-1 and 4-14) and used to monitor DSS 4 COCs and C-14 from the southern portion of the Ra/Sr Treatment Systems area. Monitoring results will be reported in the UC Davis annual ground water monitoring reports and evaluated in CERCLA 5-year reviews. Four consecutive ground water sample results that exceed site background and show an increasing or constant concentration trend would trigger an evaluation of remedial options. Wells UCD1-5, UCD1-21 and the new DSS4 well (Figure 4-1) are the proposed compliance monitoring wells.

Cost:

- Capital Cost: $108,000
- Present Worth O&M Cost: $128,000
- Periodic Costs: $10,000
- Total Present Worth Cost: $246,000

4.4.2.3 Alternative 3—Cap, Long-Term Ground Water Monitoring and Land-Use Restrictions

In addition to long-term ground water monitoring described above, Alternative 3 includes capping to prevent the downward migration of residual contaminants through the vadose zone to ground water. Capping will eliminate ground water infiltration, which is currently the primary mechanism for downward contaminant migration.

The cap will be constructed of asphalt surface, gravel base and a HDPE liner overlying a 14,079 square ft area located in the western half of the Ra/Sr Treatment Systems area (Figure 4-3). The cap will cover Ra/Sr Treatment Systems Area 1 and extend west of the fence line into the adjacent storm water drainage ditch along Old Davis Road. The cap will cover the storm water drainage ditch to prevent infiltration of storm water runoff that tends to pond in the ditch. Because Ra/Sr Treatment Systems Area 1 is used for service vehicle traffic, the eastern portion of the cap (east of the fence line) will be designed according to UC Davis Campus Standard 02500, Paving (UC Davis, 1995). Asphalt and gravel base will be removed from the cap area that is currently a service route. The asphalt and gravel will be reused and/or disposed at a Class III landfill along with import fill soil that was previously placed within the 1999 Area 1 excavation. Native soil will be moved into the excavation and compacted. The cap will consist of a 40-mil HDPE liner overlaid by eight inches of compacted gravel base material and four inches of asphalt pavement. The liner and pavement will be sloped to direct storm water runoff away from the area. The cap's condition will be visually inspected on an annual basis and maintenance (i.e., asphalt overlay) is expected every 10 years. A land-use restriction will be recorded to document the cap area and to prohibit site development activities that would affect the cap's performance.

Long-term ground water monitoring and cap maintenance will be performed for 30 years.

Cost:

- Capital Cost: $462,000

- Present Worth O&M Cost: $149,000
- Periodic Costs: $35,000
- Total Present Worth Cost: $646,000

4.4.2.4 Alternative 4a—Removal and Off-Site Disposal

Alternative 4a removes a range of contaminated soil volumes from the Ra/Sr Treatment Systems area based on achieving either background- or MCL-based remediation goals (Table 2-2). In some cases, the remediation goal for soil is below its site background concentration. In these cases, the soil background concentration was selected as the remediation goal.

The areas of nitrate, C-14 and Ra-226 contamination that are above the remediation goals are enclosed by the excavation limits shown on Figure 4-4. Contaminated soil will be removed using conventional excavation (e.g., backhoe) at the shallower excavations (< 20 ft bgs), and oversized auger drilling (4 to 8 ft diameter) will be used in areas where the excavation depth exceeds 20 ft bgs.

Most of the excavation areas (Figure 4-4) underlie portions of the 1999 Area 1 removal action. Previously imported clean fill removed from Area 1 during the new excavation will be stored for reuse as backfill material. The overburden soil interval located between ground surface and 5 ft bgs was assumed clean, because it would not have come in contact with effluent from the Ra-226 leach trench. Contaminated soil below 5 ft bgs would be removed, stockpiled separately, sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. Soil from the 5 to 20 ft bgs interval would likely be classified as low-level radioactive waste that would be disposed at Envirocare of Utah. Soil from the 20 to 50 ft bgs interval was assumed to contain no above-background radiological activity and would be disposed at a Class II industrial waste landfill.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. Locations that require oversize auger excavation will be filled with controlled-density fill (e.g., low-strength concrete). The strength of controlled-density fill is low enough that it can be excavated like soil, but it does not require compaction. Locations that would be excavated using conventional equipment will receive clean soil backfill and compaction to the engineered specification. The surface of the Ra/Sr Treatment Systems area will be repaved and restored to its current condition after backfilling and compaction are complete.

The confirmation sample results were assumed to demonstrate that all COC concentrations will be below the selected cleanup goals and no further action would be required when the RA is complete. All of the costs are expected to occur in the present time frame and no annual or periodic costs were assumed. No land-use restrictions are required. A cost range was determined based on removal volumes derived from the background- and MCL-based soil to ground water remediation goals (Table 2-2 and Appendix B).

Cost:

- Capital Cost: $3,335,000 to $5,052,000
- Present Worth O&M Cost: $0

- Periodic Costs: $0
- Total Present Worth Cost: $3,335,000 to $5,052,000

4.4.2.5 Alternative 4b—Removal and On-Site Treatment

Alternative 4b involves removing the same volumes of soil and achieving the same remediation goals as Alternative 4a, and treating a portion of the nitrate-contaminated soil on site using phytoremediation. Some of the nitrate-contaminated soil would not be treated on site, because it contains Sr-90 contamination that would pose greater than 10^{-6} risk. The Sr-90 risk soil would be disposed as low-level waste at Envirocare of Utah.

Nitrate phytoremediation would involve excavating nitrate-impacted soil from the Ra/Sr Treatment Systems area, moving it to the WDPs area and planting a crop of warm-season grass to remove excess nitrate. A plastic liner would be installed under the nitrate-contaminated soil to prevent contact with the existing WDPs soil. The contaminated soil would be covered with plastic sheets during the rainy season to prevent storm water contamination. The WDPs area would be graded to prevent pond formation.

The plastic under liner would consist of a single welded sheet of HDPE. The contaminated soil would be placed evenly throughout the lined area and mixed with amendments to facilitate optimal crop growth. A timed sprinkler system would be installed to maintain proper irrigation.

The treatment cell crop would be seeded in spring and grown through early fall. The grass would be regularly trimmed, and the trimmings would be dried and stored for disposal upon decommissioning. The irrigation system and liner would be inspected regularly. Soil and grass samples would be collected from the treatment cell at the end of each growing season before covering the cell with plastic sheets. The sample data would be evaluated and reported in an annual treatment system performance report.

When annual data indicate nitrate remediation is complete, a round of confirmation samples will be collected. A random grid confirmation sampling design will be used. The confirmation sampling results will be presented in a remedial action confirmation report. After the RPMs agree that remediation is complete, the liner, sprinkler system and accumulated grass cuttings will be sampled and profiled for disposal, and an authorized release report will be prepared. The liner, sprinkler system and waste cuttings are assumed to be disposed at a Class II landfill.

All of the excavation and soil disposal costs are expected to occur in the present time frame. A cost range was determined based on removal volumes derived from the background- and MCL-based soil to ground water remediation goals (Table 2-2 and Appendix B). Phytoremediation costs are assumed to occur over three years (three growing seasons).

Cost:

- Capital Cost: $2,135,000 to $3,006,000
- Present Worth O&M Cost: $93,000

- Periodic Costs: $135,000
- Total Present Worth Cost: $2,363,000 to $3,234,000

4.4.2.6 Alternative 4c—Limited Removal, Off-Site Disposal and Long-Term Ground Water Monitoring

Alternative 4c will remove and dispose of soil containing nitrate, C-14 and Ra-226 that is present above a depth of 20 ft using conventional excavation equipment such as a backhoe. In addition, long-term ground water monitoring will be performed as described in Alternative 2.

The lateral excavation limits are the same as Alternative 4a and are shown on Figure 4-5. Most of the excavation areas underlie portions of the 1999 Area 1 RA. Previously imported clean fill that is delineated by a geotextile would be removed from Area 1 during the new excavation and stored for reuse as backfill material. In undisturbed areas, overburden soil located between ground surface and 5 ft bgs was assumed clean, because it would not have come in contact with effluent from the former Ra-226 leach trench or dry wells. Soil from the 5 to 20 ft bgs interval would likely be classified as low-level radioactive waste that would be disposed at Envirocare of Utah.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. Clean fill from the 1999 Area 1 RA and new import fill from an off-site source would be used to backfill the excavation. The area will be paved to restore it to its current condition.

Excavation, disposal and well installation capital costs are expected to occur in the present time frame. A cost range was determined based on removal volumes derived from the background- and MCL-based soil to ground water remediation goals (Table 2-2 and Appendix B). Annual monitoring costs are expected to occur for 30 years, and one periodic cost is expected after 30 years to demolish the monitoring well.

Cost:

- Capital Cost: $1,953,000 to $2,354,000
- Present Worth O&M Cost: $128,000
- Periodic Costs: $10,000
- Total Present Worth Cost: $2,091,000 to $2,492,000

4.4.2.7 Alternative 5—*In situ* Bioremediation and Long-Term Ground Water Monitoring

In addition to implementing long-term ground water monitoring, as described in Alternative 2, Alternative 5 includes pilot testing, installation, and O&M of an *in situ* microbial denitrification system, an innovative technology for the vadose zone. Anaerobic denitrification occurs during microbial respiration in the absence of oxygen and presence of a carbon source (e.g., ethanol, glucose, lactate or sucrose in purified water). The *in situ* microbial denitrification system would inject a carbon-source solution into nitrate-contaminated vadose zone soil. The injection system would fully saturate vadose zone soil in the vicinity of nitrate contamination. This will result in a ground water mound, which will drive nitrate and the injected carbon source downward and outward from the area of contamination. It is expected that vadose zone nitrate will be mobilized and some of the nitrate treatment would extend into HSU-1 ground water below the treated area.

Indigenous aerobic bacteria in the vadose zone would use the carbon source as an electron donor and existing oxygen as the electron acceptor. Denitrification will begin when the existing oxygen is depleted. When the carbon source remains in excess, indigenous denitrifying bacteria proliferate and reduce the nitrate contamination to nitrogen gas. Induced denitrification has been successfully demonstrated extensively in ground water. Deployment in the vadose zone is innovative and unproven. Prior to implementation, the site-specific effectiveness will need to be further evaluated in a bench- and field-scale pilot testing.

Pilot testing would involve collecting two continuous core samples in the contaminated vadose zone and testing the core samples for hydraulic properties, nitrate concentration profile, bench-scale denitrification and biological and geochemical parameters. A hydrologic testing laboratory will determine hydraulic properties of the soil core, such as the lateral and vertical hydraulic conductivity and porosity. A field infiltration test would be conducted in one of the boreholes to verify the hydraulic parameters determined in the laboratory. The hydraulic data will be used to determine the pressure and flow rate of the carbon-source solution delivery system. The most recent samples of the Ra/Sr Treatment Systems area nitrate profile were collected in 2001, but should be verified by analyzing core samples. The screened interval of the carbon-source solution delivery system will depend on the current vertical location of nitrate contamination. Bench-scale tests of denitrification will be conducted on a section of contaminated core. The core will be sampled and analyzed for nitrate, plate count and geochemical parameters before conducting the bench test. The geochemical parameters that will be tested are: alkalinity, pH, dissolved oxygen, oxidation/reduction potential, total iron, soluble iron, sulfate and total organic carbon. Various carbon-source solutions and amendments will be applied to selected contaminated core samples in dynamic soil column tests to determine optimal denitrification conditions. A pilot test report will be prepared to present the results and any carbon-source solution and augmentation recommendations that should be used to implement the final *in situ* microbial denitrification system.

A treatment system design will be prepared and approved by the UC Davis ORMP and the LEHR RPMs. The treatment system design is assumed to consist of a vadose zone well field spaced on 10-ft centers (Figure 4-6) that are manifolded into a carbon-source solution holding tank. A metered pump between the delivery tank and manifold would control the total carbon-source solution delivery rate. The manifold would be designed with pressure and flow control valves to adjust carbon-source solution delivery to individual wells. The carbon-source solution would be mixed on site by an automated metering system that would combine filtered tap water with concentrated carbon-source solution. The concentrated carbon-source solution would be stored in a separate tank and metered into the filtered water when the low-level switch is activated in the solution storage tank. The tap water will be treated with carbon filtration to remove any impurities or trihalomethane compounds generated in the municipal water supply disinfection process. The tanks, metering systems, manifold valving, filtration system and electrical control panel will be installed on a concrete slab within a fenced compound. The tanks and equipment will be anchored to the slab with seismic anchorage to prevent overturning in the event of an earthquake. Electrical power will be supplied to the compound via underground conduit. A treatment system construction report will be prepared to document the as-built system design.

A treatment system manual will be prepared containing instructions for system startup, O&M and performance parameter collection. The manual will contain copies of the as-built system design, component diagrams and vendor contact information. System startup will consist of turning the system on, measuring and adjusting flow rates at the pumps and valves, and collecting samples of the carbon-source solution. Clustered piezometers will be used to measure the level of hydraulic saturation in the vadose zone and the carbon-source solution concentration and nitrate concentration at distances away from the injection wells. Monitoring wells will be used to measure nitrate concentrations in ground water below the source and approximately 20 ft from the source perimeter. The piezometer and monitoring well configurations are shown in Figure 4-6.

System startup is expected to include daily field measurements from the delivery system, piezometers and monitoring wells for three weeks of operation. A startup report will be prepared and the recommended optimal adjustments will be added to the treatment system manual. System O&M will be conducted periodically thereafter according to a schedule determined by the system engineer and field technicians. The treatment system O&M schedule is assumed to consist of bi-weekly visits for the first month, weekly visits for the second month and bi-monthly visits thereafter.

All of the pilot testing, installation and startup costs are expected to occur in the present time frame. O&M is assumed to occur over two years. A decommissioning cost is expected to occur at the end of two years.

Cost:

- Capital Cost: $703,000
- Present Worth O&M Cost: $316,000
- Periodic Costs: $187,000
- Total Present Worth Cost: $1,206,000

4.4.3 Analysis of Remedial Alternatives

Table 4-2 summarizes the analysis of remedial alternatives. The detailed analysis is presented below.

4.4.3.1 Alternative 1—No Action

4.4.3.1.1 Overall Protection of Public Health and the Environment

Alternative 1 does not address future protection of ground water. Previous RAs have addressed principal threats to human health and the environment, but some minor residual contaminants remain in soil and ground water. There are no significant human health risk exposure pathways to these contaminants, and risks are below CERCLA risk thresholds. Ground water modeling results (WA, 2003) suggest that nitrate in unsaturated soil has the potential to impact ground water above the California MCL, C-14 could impact ground water above the federal MCL-based limit and Ra-226 in unsaturated soil has the potential to impact ground water above site background. Recent monitoring results for ground water from UCD1-006 (Figure 4-1) show that nitrate concentrations exceed the MCL, and monitoring results from UCD1-022 (Figure 4-1) suggest that Ra-226 activities may exceed background and, based on limited data, show an increasing trend (Appendix F, Figure F-11). C-14 and Ra-226 will not degrade significantly in the near term due to radioactive decay half-lives of 5,730 years and 1,600 years, respectively. Nitrate is not expected to degrade significantly under the expected aerobic conditions in Site ground water. However, due to the low mass of these contaminants in the vadose zone, the areas of impact are estimated to be limited (Table 1-1).

4.4.3.1.2 Compliance with ARARs

Alternative 1 may not comply with the State's Anti-Degradation Policy and Basin Plan since it does not provide ground water monitoring to verify the limited impact predictions.

4.4.3.1.3 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long term since localized known ground water impacts will not be monitored. The magnitude of ground water impacts is expected to be limited. In addition, future local use of HSU-1 ground water is unlikely due to the low yield of HSU-1. Current significant ground water impacts associated with the Ra/Sr Treatment Systems appear to be limited to nitrate and possibly Ra-226. This is notable, given that releases from the Ra/Sr leach fields occurred up to 47 years ago and persisted for more than 20 years. This observation reflects the low mobility and/or low mass of most of the contaminants released. Additionally, the majority of the residual mass of contaminants was removed during the CERCLA RAs conducted in 1999 and 2000. However, Alternative 1 does not provide adequate management and monitoring controls to confirm long-term effectiveness.

4.4.3.1.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 1, toxicity, mobility or volume are not reduced.

4.4.3.1.5 Short-Term Effectiveness

Alternative 1 has no short-term impacts, since there are no current risks to the public and no remedial actions are included.

4.4.3.1.6 Implementability

There are no barriers to implementing Alternative 1.

4.4.3.1.7 Cost

The cost of Alternative 1 is $0.

4.4.3.1.8 State Acceptance

The State of California has not accepted Alternative 1 as a viable alternative.

4.4.3.1.9 Community Acceptance

The Draft Feasibility Study was submitted to the Davis South Campus Superfund Oversight Committee (DSCSOC) for their review and comment. The public at large will have the opportunity to comment on their non-acceptance of this alternative during the public comment period for the Proposed Plan.

4.4.3.2 Alternative 2—Long-Term Ground Water Monitoring and Contingent Remedial Action

4.4.3.2.1 Overall Protection of Public Health and the Environment

Alternative 2 provides ground water monitoring near the source area to confirm ground water protection. If future monitoring indicates that conditions are not protective, contingent remedial actions could be undertaken, such as ground water extraction and treatment.

4.4.3.2.2 Compliance with ARARs

Alternative 2 complies with ARARs.

4.4.3.2.3 Long-Term Effectiveness and Permanence

The collection of ground water data from monitoring well UCD1-021 for the next 30 years allows continued long-term evaluation of ground water impacts. This will be applicable for nitrate and C-14, for which the travel time from the Ra/Sr Treatment Systems area to well UCD1-021 is approximately between 12 and 48 years. For Ra-226, however, calculated travel times to this well are greater than 10,000 years. The travel-time calculations assume a relatively high hydraulic conductivity (1×10^{-4} cm/sec), an effective porosity of 20 percent and a gradient between 0.01 and 0.04.

Ground water plume sizes were estimated based on complete transfer of contaminant mass to HSU-1. The estimated plume areas and diameters are summarized in Table 1-1. Based on these estimates, the Ra-226 plume will be very small. The estimated C-14 plume exceeding the background concentration could occupy an area between one and two acres, but the estimated plume size exceeding the four mrem/year federal MCL (US EPA, 2000b) would occupy much less than one acre. The nitrate plume ranges from 1.3 acres to 3.6 acres for concentrations equal to ground water background and the California MCL, respectively. The ground water plume calculations are presented in Appendix E.

This alternative is effective for the residual Ra-226, C-14 and nitrate present in vadose zone soil due to their limited mass. Effectiveness will be confirmed by monitoring concentrations in ground water and applying management controls including quality assurance and routine reporting.

4.4.3.2.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 2, toxicity, mobility or volume are not reduced.

4.4.3.2.5 Short-Term Effectiveness

No short-term risks to the public or to the environment are anticipated. The ongoing effectiveness of this alternative will be confirmed by long-term ground water monitoring. However, if monitoring results trigger an evaluation of remedial alternatives, the time until each alternative is protective will be presented in an addendum to the Remedial Action Work Plan.

Contingent remedial action will be considered protective when groundwater is cleaned up to background concentrations, or if background concentrations are not technically or economically feasible, water quality objectives protective to one-in-a-million cancer risk or the lowest water quality objective applicable for the constituent/s of concern.

4.4.3.2.6 Implementability

Alternative 2 uses standard ground water monitoring systems and techniques that are currently deployed at the Site. From an administrative standpoint, standard records management and database activities will be required. The required services and materials are readily obtainable.

Land-use restrictions are not proposed under this alternative, but land-use restrictions may be a component of future remedial action, if required. Additionally, intervening site development could limit access to areas requiring remedial action.

4.4.3.2.7 Cost

The anticipated capital and O&M costs for Alternative 2 are $246,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.4.3.2.8 State Acceptance

The State of California has accepted Alternative 2 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.4.3.2.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.4.3.3 Alternative 3—Cap, Long-Term Ground Water Monitoring and Land-Use Restrictions

4.4.3.3.1 Overall Protection of Public Health and the Environment

To mitigate future impacts to ground water, Alternative 3 includes capping to reduce the rate at which contaminants reach HSU-1 and ground water monitoring near the source area to confirm long-term effectiveness. Additionally, deed restrictions maintain and prevent disturbances of the cap.

4.4.3.3.2 Compliance with ARARs

Alternative 3 complies with ARARs Alternative 3 includes a program to actively monitor ground water for 30 years. The monitoring program will reduce the uncertainties in predicting the potential impact to ground water.

4.4.3.3.3 Long-Term Effectiveness and Permanence

Because the contamination is already at a minimal level, Alternative 3 should be effective in the long term. The addition of a surface cap will mitigate ground water impacts related to the entrainment of residual contaminants in infiltrating meteoric water. Infiltration is currently the primary transport mechanism for contaminants in the vadose zone to reach ground water. After the cap is installed, diffusion processes will continue, but the transport rates should be markedly reduced. Institutional controls will be required to maintain the cap’s integrity over time. Effectiveness is confirmed by monitoring and management controls, including quality assurance and routine reporting.

4.4.3.3.4 Reduction of Toxicity, Mobility or Volume

Mobility of the residual contamination through surface water infiltration is substantially reduced by the cap. However, some contaminant migration to the water table will still occur through diffusion. Contaminant mass and volume are not reduced.

4.4.3.3.5 Short-Term Effectiveness

Alternative 3 involves the installation of asphalt pavement. There are minor environmental and health risks associated with the manufacture, transportation and installation of asphalt. Additional short-term risks to the community and to workers include relatively short-term noise and heavy equipment use. Deployment of the cap system is rapid, since it relies on established engineering design and materials. The cap may restrict site development and affect aesthetics. The estimated time to design and install a cap is approximately one year.

4.4.3.3.6 Implementability

The paving procedures for implementing Alternative 3 are routine and technically feasible. There are no physical barriers to mobilizing the paving equipment to the Site. This alternative can be implemented with established engineering design and materials. A small amount of clean soil will be disposed under this alternative, but suitable landfill space or reuse options are available within

30 miles of the Site. Paving equipment and labor are generally available on relatively short notice between the months of May and November in the Davis area.

Permission will need to be granted by the University of California Office of the President (UCOP) to implement land-use restrictions. UC Davis has indicated that land-use restrictions are acceptable under a specific set of conditions (UC Davis, 2006a). Discussions between DOE and UCOP may be required to address the effort required to administer and implement the land-use restrictions.

The monitoring wells are expected to remain operable for the duration of this alternative. Standard records management and database activities are required.

4.4.3.3.7 Cost

The anticipated capital and O&M costs for Alternative 3 are $646,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.4.3.3.8 State Acceptance

The State of California has accepted Alternative 3 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.4.3.3.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.4.3.4 Alternative 4a—Removal and Off-Site Disposal

4.4.3.4.1 Overall Protection of Public Health and the Environment

Alternative 4a is fully protective, since all soil with contaminant concentrations greater than the cleanup-goal concentrations is removed and disposed off site. However, off-site disposal will generate environmental impacts including the long-term transfer of risk to the disposal site, as well as short-term transportation risks, including highway accidents and vehicular air emissions.

4.4.3.4.2 Compliance with ARARs

Because the contaminated soil is removed under Alternative 4a, this alternative complies with all ARARs.

4.4.3.4.3 Long-Term Effectiveness and Permanence

Because all of the contamination in soil at concentrations greater than the remediation goal is expected to be removed under Alternative 4a, this alternative is permanently effective. However, this alternative requires auger excavation over a large area and contamination may be missed if the auger deflects or is not properly located during use. Risk associated with the contaminated soil is transferred to the disposal site; however, contaminant levels are low and should be easily controlled in a permitted facility.

4.4.3.4.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4a, nearly all contaminated soil is removed and toxicity, mobility and contaminated soil volumes are greatly reduced to negligible quantities by transferring contaminated soil to the land disposal site.

4.4.3.4.5 Short-Term Effectiveness

Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal sites. The local community will be impacted by the transport of more than 680 truckloads of soil over a period of several months. Off-site disposal has several negative impacts associated with it, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 1.17×10^{-2}. The estimated risk of a fatality due to waste transport air emissions is 2.58×10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.43 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these impacts are described in Section 5.

Additionally, localized noise and vibration impacts at the Site will persist for several months during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. The time to complete the excavation is uncertain due to the depth and non-standard techniques required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent in any deep excavation.

The estimated time required to remove and dispose the contaminated soil is approximately one year.

4.4.3.4.6 Implementability

The excavation methods are technically feasible and are used in the construction of deep foundations. However, the use of large-diameter augers to conduct mass excavations has not been conducted at the Site at the scale proposed and may fail to remove all contaminated soil. Thus, unanticipated conditions or engineering issues may extend the project's schedule and cost. Significant site preparations are required, including re-routing a sanitary sewer line before excavation begins. Transportation and disposal of the contaminated soil will require an involved waste acceptance process, as some of the waste will be shipped to Envirocare of Utah. Suitable landfill space is expected to remain available during the remedial action.

This alternative can be implemented with established engineering design and materials. Standard records management and database activities are required.

4.4.3.4.7 Cost

The anticipated capital and O&M costs are between $3,335,000 and $5,052,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.4.3.4.8 State Acceptance

The State of California has accepted Alternative 4a as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.4.3.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.4.3.5 Alternative 4b—Removal and On-Site Treatment

Alternative 4b is similar to Alternative 4a, except that some of the contaminated soil will be treated on site.

4.4.3.5.1 Overall Protection of Public Health and the Environment

Alternative 4b is fully protective, since all soil with contaminant concentrations greater than the remediation goals is removed and either disposed off site or treated on site in a lined treatment cell. Under Alternative 4b, less of the risk is transferred off site, because a smaller volume of contaminated soil will be disposed and fewer truckloads will be hauled. The number of truckloads is significantly reduced to 46, compared to 683 for Alternative 4a. Local risk reduction is offset by the transfer of risk to the disposal site. There are short-term risks associated with transportation accidents, vehicular air emissions and on-site treatment operations.

4.4.3.5.2 Compliance with ARARs

Because the contaminated soil is removed and disposed or treated under Alternative 4, this alternative complies with all ARARs..

4.4.3.5.3 Long-Term Effectiveness and Permanence

Alternative 4b is expected to be effective for long-term nitrate remediation at the Site. The risk will be transferred off site for the fraction of contaminated soil that would be disposed. However, the permitted landfill facilities have sufficient capacity and controls to manage the risk from the excavated soil. As stated above, this alternative potentially transfers some limited ground water impact risk from the Ra/Sr Treatment Systems area to the WDPs.

4.4.3.5.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4b, the toxicity and volume of nitrate contamination at the Site will be reduced through phytoremediation and disposal. The mobility of nitrate that will be transferred to the phytoremediation treatment cell will be controlled with a HDPE liner. The toxicity and volume of all contaminants in the disposed soil will be transferred to the disposal site. The permitted disposal site will have engineering controls to mitigate contaminant mobility.

4.4.3.5.5 Short-Term Effectiveness

The local community will be minimally impacted by the transport of approximately 46 truckloads of soil over a period of about a month. Off-site disposal impacts will include transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 1.88×10^{-3}. The estimated risk of a fatality due to waste transport air emissions is 4.14×10^{-4}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.24 mrem/year which is not significant. The procedures used to estimate these negative impacts are described in Section 5. Localized noise and vibration impacts at the Site will persist for several months during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. The time to complete the excavation is uncertain due to the depth and non-standard techniques required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent in any deep excavation.

Workers will be exposed to heavy equipment hazards during construction and decommissioning of the phytoremediation system. The on-site treatment component of this alternative is expected to take three years, which is the estimated time for grass crops to consume the nitrate. The phytoremediation treatment cell is expected to prevent contaminant migration to ground water, because a plastic barrier will be placed underneath the cell. Airborne contamination is expected to be minimal, because the treatment cell will be fully covered with grass, irrigated frequently during the growing season and covered with plastic between growing seasons. No risk of transferring contamination to surface water is expected, because the treatment cell will be covered during the rainy season and graded to prevent ponding.

The estimated time required to remove the contaminated soil and install a phytoremediation treatment cell is approximately one year. The cell is expected to achieve cleanup goals within three growing seasons. The total estimated time for short-term effectiveness is four years.

4.4.3.5.6 Implementability

The excavation methods are technically feasible and are used in the construction of deep foundations. However, the use of large-diameter augers to conduct mass excavations has not been conducted at the Site at the scale proposed and may fail to remove all contaminated soil. Thus, unanticipated conditions or engineering issues may extend the project's schedule and cost. Significant site preparations are required, including re-routing a sanitary sewer line before excavation begins. Transportation and disposal of the contaminated soil will require an involved waste acceptance process, as some of the waste will be shipped to Envirocare of Utah. Suitable landfill space is expected to remain available during the remedial action.

This alternative can be implemented with established engineering design and materials. Standard records management and database activities are required.

Phytoremediation requires a flat parcel of land to spread the soil over a thin layer that will be accessible to plant roots. The WDPs area was identified as a potential location for the treatment cell. This alternative would be difficult to implement if the university decided to use the WDPs area for purposes that are incompatible with phytoremediation. No other suitable locations were identified for phytoremediation at the Site. The UC Davis ORMP must approve the treatment cell design before it can be constructed. Standard services and mostly standard materials would be used to install, operate, maintain and decommission the treatment system.

4.4.3.5.7 Cost

The anticipated capital, O&M and decommissioning costs are between $2,363,000 and $3,234,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.4.3.5.8 State Acceptance

The State of California has accepted Alternative 4b as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.4.3.5.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.4.3.6 Alternative 4c—Limited Removal, Off-Site Disposal and Long-Term Ground Water Monitoring

4.4.3.6.1 Overall Protection of Public Health and the Environment

To mitigate future impacts to ground water, Alternative 4c includes limited removal of contaminated soil, followed by ground water monitoring near the source area to confirm long-term effectiveness. Based on existing data, all soil with C-14 concentrations greater than the remediation goal would be removed and disposed off site. Residual nitrate and Ra-226 would remain in soil deeper than 20 ft bgs at concentrations which could impact limited quantities of ground water.

Off-site disposal will generate environmental impacts and risks associated with the long-term transfer of risk to the disposal site, as well as short-term transportation risks, including highway accidents and vehicular air emissions.

4.4.3.6.2 Compliance with ARARs

Alternative 4c complies with ARARs since it provides data to evaluate any impact to ground water.

4.4.3.6.3 Long-Term Effectiveness and Permanence

This alternative is permanently effective for C-14. All of the C-14 contamination in soil at concentrations greater than the remediation goal is expected to be removed under Alternative 4c. Nitrate and Ra-226 remaining deeper than 20 ft bgs will continue to migrate to ground water, but the mass of nitrate contamination arriving in ground water should be markedly reduced. The mass of Ra-226 is so small and the travel time is so long (greater than 10,000 years) that ground water impact is unlikely. The effectiveness of this alternative will be confirmed with monitoring. Part of the risk associated with this alternative is transferred to the disposal site, but contaminant levels are low and should be easily controlled in a permitted facility.

4.4.3.6.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4c, C-14 toxicity, mobility and contaminated soil volume is greatly reduced, since the C-14-contaminated soil is removed and disposed off site. A large fraction of the nitrate and Ra-226 contamination will be removed and disposed off site. Nitrate and Ra-226 mobility are not reduced.

4.4.3.6.5 Short-Term Effectiveness

Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal site in Utah. The local community will be impacted by the transport of more than 193 truckloads of soil over a period of several weeks. Off-site disposal has several negative impacts, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 7.89×10^{-3}. The estimated risk of a fatality due to waste transport air emissions is 1.74×10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.43 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Additionally, localized noise and vibration impacts at the Site will persist during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent to excavation.

The estimated time required to perform limited removal and disposal of the contaminated soil is approximately one year.

4.4.3.6.6 Implementability

The excavation methods for implementing Alternative 4c are routine and technically feasible. Significant site preparations are required, including re-routing a sanitary sewer line before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process, as the material will be shipped to Envirocare of Utah. Suitable landfill space is expected to remain available during the remedial action.

This alternative can be implemented with established engineering design and materials. Standard records management and database activities are required.

4.4.3.6.7 Cost

The anticipated capital and O&M costs for Alternative 4c are between $2,091,000 and $2,492,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.4.3.6.8 State Acceptance

The State of California has accepted Alternative 4c as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.4.3.6.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.4.3.7 Alternative 5—*In Situ* Bioremediation and Ground Water Monitoring

4.4.3.7.1 Overall Protection of Public Health and the Environment

Alternative 5 protects potential future beneficial use of ground water by treating the nitrate contamination *in situ* with bioremediation. C-14 and Ra-226 would not be treated and long-term monitoring will be required to evaluate potential ground water contamination from these constituents. Ground water monitoring would also be used to verify treatment system effectiveness and monitor the position and movement of contamination. Several monitoring wells would be installed and sampled on a frequent basis to ensure contamination does not spread due to saturation of the vadose zone with carbon-source solution. Soil data indicate that the mass of Ra-226 contamination is small and relatively immobile and, as a result, will not likely spread due to entrainment by the infiltrating carbon-source solution. The C-14 mass is small and is located more than 100 ft from the nitrate treatment area. Although the C-14 is assumed to mobilize during *in situ* bioremediation treatment, the random spatial distribution and small mass of C-14 within the treatment area will preclude any C-14 impact to ground water. The chemical form of C-14 at the Site is not known and is technically infeasible to characterize.

4.4.3.7.2 Compliance with ARARs

Alternative 5 complies with the ARARs for nitrate, because it will be reduced to nitrogen gas, and other constituents left untreated (Ra-226 and C-14) are not predicted to significantly impact ground water. Additionally, ground water monitoring would be used to confirm the environmental fate of C-14 and Ra-226.

4.4.3.7.3 Long-Term Effectiveness and Permanence

Alternative 5 reduces the threat to ground water by removing nitrate in the vadose zone using *in situ* bioremediation. Alternative 5 does not treat C-14 or Ra-226, but it does include long-term ground water monitoring for these contaminants, as described above. This alternative is effective due to the negligible mass and toxicity of residual contaminants in soil. The pilot test, monitoring and management controls will confirm effectiveness.

4.4.3.7.4 Reduction of Toxicity, Mobility or Volume

Alternative 5 is expected to reduce the toxicity and volume of nitrate through *in situ* bioremediation. Alternative 5 would temporarily increase nitrate mobility due to saturating the vadose zone with carbon-source solution, but the nitrate mass is expected to quickly degrade before mobilizing out of the source area. Most of the C-14 mass is located away from the treatment area and would not come in contact with the carbon-source solution. The Ra-226 mass co-located with the nitrate is small and will not likely move appreciably (< 1 cm) during the nitrate treatment period (approximately two years).

4.4.3.7.5 Short-Term Effectiveness

Alternative 5 adds only minor short-term risks to the public, workers or the environment. Construction will involve heavy equipment risks and mechanical injury risks from drilling several wells and piezometers; installing a concrete slab; anchoring holding tanks, pumps and treatment system controls to the slab; and trenching and installing subsurface piping to the injection wells. The drilling and trenching work will result in some minor noise impacts to the Site. The treatment system O&M period is expected to be two years. Deployment of the system is rapid, since it relies on established engineering design and materials. Design, installation and system startup tasks can be completed in one year, and the system is expected to achieve the remediation goals after two years of operation. Thus, the predicted time to reach protectiveness is three years. The treatment system may interfere with site activities or development.

4.4.3.7.6 Implementability

A site-specific pilot test will be required to confirm technical feasibility. The methods for constructing and operating the treatment system are well established. A service vehicle route crosses over the area of nitrate contamination. Traffic would need to be redirected during construction and demolition, and while collecting measurements and samples at the injection wells, monitoring wells and piezometers. The UC Davis ORMP would have to approve the treatment system construction plans before installation. From an administrative standpoint, standard records management and database activities will be required.

4.4.3.7.7 Cost

The anticipated capital and O&M costs for Alternative 5 are $1,206,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.4.3.7.8 State Acceptance

The State of California has accepted Alternative 5 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.4.3.7.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.4.4 Comparative Evaluation of Remedial Alternatives

4.4.4.1 Overall Protection of Public Health and the Environment

Currently, public health is protected under all of the alternatives because residual vadose zone contamination does not pose a human health risk (WA, 2005). Ground water is currently impacted by nitrate and possibly Ra-226, but neither the public nor ecological receptors are currently exposed to this ground water.

Future ground water impact is anticipated based on predictions from modeling of current conditions (WA, 2003). Ra-226 is limited in mass and should only impact ground water in the immediate vicinity of the contaminated soil. Model results (WA, 2003) suggest that future nitrate ground water impacts could be more extensive than present, but within the concentration range for existing regional nitrate concentrations in shallow ground water. Plume size estimates indicate potentially measurable impact from nitrate and C-14 (Table 1-1). The impact from Ra-226 is expected to be insignificant.

Therefore, under Alternatives 1 and 2, for which no remedial action is taken, beneficial use of ground water may be locally impacted. Alternative 3 actively protects ground water by reducing the potential for contaminant migration. Alternatives 2, 3, 4c and 5 include ground water monitoring to evaluate their long-term effectiveness. Alternative 5 also includes frequent monitoring from several wells surrounding the nitrate source area while the system is operating. If impacts were detected, responses could be implemented to prevent ingestion of contaminated ground water though administrative and/or engineering controls, such as extraction and treatment. Thus, the monitoring program in these alternatives maintains the current level of protection to human health. Alternatives 4a and 4b remove all soil with contamination at concentrations greater than cleanup-goal concentrations, and therefore mitigate further loss of beneficial use of ground water. Under Alternatives 4a and 4b, the contaminant mass is reduced to negligible levels with a high level of certainty, but protection of public health and the environment at the Site is offset by the transfer of risk to the disposal site, the addition of transportation risks and the emission of air pollutants from trucks that ship the waste for distances up to 700 miles from the Site. Under Alternative 4c, the C-14 contaminant mass is reduced to negligible levels, but contaminated soil containing nitrate and Ra-226 is left in place. Risk is transferred to the disposal site under Alternative 4c. Alternative 5 protects ground water by converting the nitrate contamination to nitrogen gas using *in situ* bioremediation, but does not reduce future ground water impacts from C-14 and Ra-226.

4.4.4.2 Compliance with ARARs

Alternatives 2, 3, 4a, 4b, 4c and 5 comply with ARARs. Under Alternatives 1 and 2, HSU-1 might be impacted in a limited way, as predicted by the modeling results (WA, 2003 and Table 1-1). C-14 may impact ground water above background concentrations and the federal MCL. Ra-226 may impact ground water above background concentrations, but that impact would be below the California MCL and would be highly localized due to the limited mass of Ra-226 present and its relative immobility. As discussed above, nitrate may impact the ground water above background and the California MCL, but this release of nitrate would only affect a small area under a worst case scenario.

Alternatives 2, 3, 4c and 5 include long-term ground water monitoring. Alternative 3 involves installing a cap to reduce contaminant mobility and improves the assurance of long-term compliance with the State's Anti-Degradation Policy and Basin Plan. Because the contaminant mass is not removed, however, the contamination may eventually impact ground water. Alternatives 4a and 4b remove all soil with contamination above the remediation goals, and comply with all ARARs. Alternative 4c removes some of the soil with contamination above the remediation goals to further deplete the low mass of contaminants present. Alternative 5 treats the nitrate contamination but does not address potential ground water impacts from C-14 and Ra-226.

4.4.4.3 Long-Term Effectiveness and Permanence

All of the alternatives, except alternative 1, are likely to be effective given the low mass and toxicity of the residual contamination. Alternative 1 is not effective with respect to long-term effectiveness since localized known ground water impacts will not be monitored. Alternatives 2, 3, 4c and 5 include monitoring and other management controls to confirm effectiveness. Alternative 3 includes a cap to enhance the long-term effectiveness. Alternative 4a is a permanent solution for all COCs. Alternative 4c is a permanent solution for C-14, but requires long-term monitoring for nitrate and Ra-226. Alternative 5 is a potentially permanent solution for nitrate, and relies on long-term monitoring to manage potential C-14 and Ra-226 contamination. However, site-specific pilot tests are required to confirm the technical feasibility of Alternative 5.

4.4.4.4 Reduction of Toxicity, Mobility or Volume

There is no direct reduction of toxicity, mobility or volume under either Alternatives 1 or 2, but the slow-moving Ra-226 will decay significantly before it reaches the nearest well, reducing its toxicity and volume. The toxicity and volume of C-14 is small, but C-14 is assumed to be mobile and may not decay appreciably before reaching the nearest well. Under Alternative 3, mobility of the residual vadose-zone contamination is reduced substantially by the cap. A cap will allow more time for natural decay of the radionuclides. Although capping (Alternative 3) is not a treatment technology, it can reduce contaminant mobility by preventing infiltration. Under Alternatives 4a and 4b, all of the toxicity and volume of soil with contaminant concentrations greater than cleanup-goal concentrations is removed from the Site. Alternative 5 converts the nitrate volume to nitrogen gas, but may slightly increase the mobility of Ra-226 and may increase the mobility of a small fraction of the C-14 contamination that is co-located with the nitrate. Contaminant mobility in the nitrate cleanup area would be closely monitored under Alternative 5.

4.4.4.5 Short-Term Effectiveness

Neither Alternatives 1 nor 2 would add any short-term impacts to the public, or to workers or to the environment. Alternative 3 involves the installation of asphalt pavement and a plastic liner. There are minor environmental and health risks associated with air emissions during the manufacture, transportation and installation of asphalt. Additional short-term risks to the community and to workers include relatively short-term noise and heavy equipment use. Deployment of the cap system is rapid, since it relies on established engineering design and materials. Infiltration of water would be prevented from entering the vadose zone immediately upon installation of the cap.

Alternatives 4a, 4b, and 4c produce the most severe impact in the short term. Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal sites. Transportation impacts include local traffic congestion, air emissions and the risk of highway accidents. Site construction impacts, including localized noise and ground vibrations, will persist for several months during the remedial action. Air monitoring, dust control and personal protective equipment are required. The exact time to complete the work for Alternatives 4a and 4b is uncertain due to the depth and non-standard excavation techniques required. Workers will also be exposed to heavy equipment, fall hazards and burial hazards inherent in any deep excavation. Alternative 4b will require an additional estimated three years to complete on-site treatment of nitrate in soil. Additional risks associated with heavy equipment usage will be encountered during the installation and decommissioning of the phytoremediation cell.

Alternative 5 will involve relatively minor short-term risks to the public, workers or the environment. The *in situ* bioremediation system construction will result in some limited mechanical injury risks during the installation of monitoring wells and equipment. The work will result in some minor vibration and noise impacts to the Site. The *in situ* bioremediation system is expected to operate for two years.

The period to achieve short-term effectiveness is not applicable to Alternative 1 because there is no metric to evaluate its effectiveness. Alternative 2 appears to be effective in the short term based on current site data. The ongoing effectiveness of Alternative 2 will be confirmed by long-term ground water monitoring. Alternatives 3, 4a and 4c are expected to meet their objectives in approximately one year because they use proven rapid construction technology. Alternative 4b is predicted to take four years based on three phytoremediation growing seasons to achieve cleanup goals, while Alternative 5 is expected to take three years (one year installation, two years operation).

4.4.4.6 Implementability

There are no barriers to implementing Alternative 1. From an administrative standpoint, standard records management and database activities will be required for Alternative 2. Land-use restrictions included in Alternative 3 require acceptance by UCOP. There are numerous issues related to this acceptance, including, but not limited to, increased site maintenance and development costs, loss of development potential and long-term monitoring costs that need to be negotiated by DOE and UCOP.

The paving procedures for implementing Alternative 3 are routine and technically feasible. Access is available to paving equipment, with only a minor barrier presented by a chain-link fence. A small amount of clean soil will be disposed under this alternative, but suitable landfill space is available within 30 miles of the Site. The monitoring wells have been, and are expected to remain, operable for the duration of this alternative. Paving equipment and labor are generally available on relatively short notice between May and November.

Alternatives 4a, 4b and 4c require significant site preparations, including re-routing a sanitary sewer line before excavation begins. For Alternatives 4a and 4b, the excavation methods are the same as those used in the construction of deep foundations. However, the use of large-diameter augers to conduct mass excavations has not been conducted at the Site at the scale proposed. Thus, implementation problems may reduce the effectiveness of the soil removal and extend the project's schedule and cost. Although the excavation methods are routinely used for foundation construction, the availability of the requisite specialized equipment and labor at any particular time is not guaranteed. Transportation and disposal of the contaminated material will require an involved waste acceptance process, as a large fraction the material will be shipped to Envirocare of Utah.

The phytoremediation cell in Alternative 4b would be constructed and maintained using standard services and mostly standard materials. The plastic under-liner would be fabricated into an uncommonly large, single waterproof sheet, which is subject to damage by high winds. This alternative would be difficult to implement if the university decided to use the WDPs area for purposes that are incompatible with phytoremediation.

The conventional excavation procedures for implementing Alternative 4c are routine and technically feasible. The ground water monitoring portion of Alternative 4c takes advantage of the same in-place systems that Alternative 2 uses.

The methods for constructing and operating the *in situ* bioremediation system in Alternative 5 are well established. From an administrative standpoint, standard records management and database activities will be required.

4.4.4.7 Costs

The anticipated capital and O&M costs for the alternatives are:

- Alternative 1 (no action): $0
- Alternative 2 (ground water monitoring): $246,000
- Alternative 3 (cap, long-term ground water monitoring and land-use restrictions): $646,000
- Alternative 4a (removal and disposal): $3,335,000 to $5,052,000
- Alternative 4b (removal and on-site treatment): $2,363,000 to $3,234,000

- Alternative 4c (limited removal, disposal and long-term ground water monitoring): $2,091,000 to $2,492,000
- Alternative 5 (*in situ* bioremediation and ground water monitoring): $1,206,000

Detailed cost assumptions are presented in Appendix A.

4.4.4.8 State Acceptance

With the exception of the no action alternative, the State of California has accepted all the alternatives.

A preferred remedial alternative will be presented in the Draft Proposed Plan. State of California acceptance of the preferred remedial alternative will be provided after resolution of their comments on the Draft Proposed Plan.

4.4.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on the accepted alternatives during the public comment period for the Proposed Plan.

4.5 Domestic Septic System No. 1

4.5.1 Nature and Extent of Contaminants of Concern

DSS 1 has no human health or ground water-impact COCs (Tables 2-1 and 2-2).

4.5.2 Description of Remedial Alternatives

4.5.2.1 Alternative 1 – No Action

A no action alternative was developed for DSS 1 to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.5.3 Analysis of Remedial Alternatives

The evaluation summary is presented in Table 4-3.

4.5.3.1 Alternative 1—No Action

4.5.3.1.1 Overall Protection of Public Health and the Environment

Alternative 1 is protective of public health and the environment. DSS 1 has no human health or ground water COCs.

4.5.3.1.2 Compliance with ARARs

Alternative 1 complies with ARARs.

4.5.3.1.3 Long-Term Effectiveness and Permanence

There are no human health or ground water COCs; therefore, this criterion is not applicable.

4.5.3.1.4 Reduction of Toxicity, Mobility or Volume

There are no human health or ground water COCs; therefore, this criterion is not applicable.

4.5.3.1.5 Short-Term Effectiveness

There are no human health or ground water COCs; therefore, this criterion is not applicable.

4.5.3.1.6 Implementability

There are no human health or ground water COCs; therefore, this criterion is not applicable.

4.5.3.1.7 Cost

The cost of Alternative 1 is $0.

4.5.3.1.8 State Acceptance

The State of California has accepted Alternative 1 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

A preferred remedial alternative will be presented in the Draft Proposed Plan. State of California acceptance of the preferred remedial alternative will be provided after resolution of their comments on the Draft Proposed Plan.

4.5.3.1.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.6 Domestic Septic System No. 3

4.6.1 Nature and Extent of Contaminants of Concern

DSS 3 has no human health risk COCs, but has the ground water impact COCs formaldehyde, molybdenum and nitrate.

4.6.1.1 Formaldehyde in Soil

Formaldehyde was detected in 32 of 35 confirmation samples (91 percent) collected at DSS 3. All of the confirmation samples collected from the DSS 3 leach trench excavation had concentrations above the detection limit. Concentrations along the former leach trench centerline were generally above 1 mg/kg, but did not exceed 2.2 mg/kg. Samples collected along the north and south walls of the trench and at each end of the trench were generally below 1 mg/kg. However, wall samples at the west end of the leach line, near the first point of perforation, were above 1 mg/kg, indicating a broader area of contamination near the west end. Soil boring samples collected below the west end indicate formaldehyde concentrations of almost 1 mg/kg down to 20 ft bgs, and then attenuation to 0.19 mg/kg at 40 ft bgs. These data indicate that formaldehyde was released at DSS 3 and has spread laterally and vertically from the former leach trench.

4.6.1.2 Molybdenum in Soil

Molybdenum was above background in seven of fourteen soil sample results (50 percent) at DSS 3. The elevated concentrations were in samples of the DST contents, concrete at the bottom of the tank and in soil beneath the first point of perforation on the DSS 3 leach line. Molybdenum was below background and not detected in soil samples collected in areas adjacent to DST 3, around the distribution box and a few ft west of the leach field. Molybdenum was detected above background in soil boring samples collected at depths of 15, 20, 25 and 35 ft bgs beneath the first point of perforation on the DSS 3 leach line. The highest concentration of molybdenum at DSS 3 (2.5 mg/kg) was present in the soil boring sample collected at 36 ft bgs. Molybdenum was below background and not detected in the samples collected six ft above (30 ft bgs) and four ft below (40 ft bgs) the highest concentration. Based on these data, molybdenum was released to soil below the former DSS 3 leach line and has migrated to a depth below 35 ft in the soil column.

4.6.1.3 Nitrate in Soil

Nitrate was above background in seven of 41 soil sample results (17 percent) at DSS 3. The elevated results were located in soil below the former leach line and in one excavation sidewall sample positioned a few ft north of the leach line. The highest nitrate concentration in soil (106 mg/kg) was located beneath the first point of perforation on the DSS 3 leach line at 12.5 ft bgs. All but one of the excavation trench sidewall samples and all of the samples collected at the east and west ends of the excavation were below background. All of the samples collected near the distribution box and DST (Figure 4-7) were below background. The soil boring samples collected beneath the first point of perforation on the DSS 3 leach line were below background. The shallowest soil boring sample, collected at 15 ft bgs, contained 33.2 mg/kg of nitrate, which was slightly below the background screening value (36 mg/kg). The other five soil boring samples, collected between 20 and 40 ft bgs, had concentrations below 11 mg/kg. Based on these data, nitrate was released to subsurface soil below the former leach line, but the contamination is very limited in lateral and vertical extent.

4.6.1.4 Ground Water in Soil

Ground water that is downgradient of the DSS 3 area has been sampled for COCs between October 1990 and the present. Ground water from HSU1 has been sampled from well UCD1-024, and ground water from HSU2 has been sampled from well UCD2-039. Figure 4-1 shows the relative locations of wells to the DSS 3 area. Graphs illustrating the concentrations of COCs in these two wells through time are in Appendix F, with the exception of those graphs that would show fewer than five detected results and no detected results greater than MCLs. Included in each graph is a simple linear regression calculation, represented by a dashed line, to assist the reader in evaluating the overall trend of the COC in ground water.

Formaldehyde has not been detected in well UCD1-024, and was not analyzed for in well UCD2-039.

Molybdenum concentrations in HSU1 downgradient of the DSS 3 area have only been higher than the PRG of 180 µg/L in the very earliest samples. In well UCD1-024, molybdenum has either been detected at only very low concentrations since 1990 or, as shown in the most recent sample, not detected at all (Figure F-18). Molybdenum concentrations in HSU2 downgradient of the DSS 3 area have been far below the PRG, as shown by the concentrations reported in well UCD2-039 (Figure F-43).

Nitrate concentrations in HSU1 downgradient of the DSS 3 area have been very high, only rarely below the MCL of 10,000 µg/L. In well UCD1-024, the peak concentrations occurred approximately eight or nine years ago, and may have been decreasing since then; currently, nitrate concentrations are still above the MCL (Figure F-16). In contrast, in HSU2 downgradient of the DSS 3 area, nitrate has been almost exclusively below the MCL. In well UCD2-039, nitrate concentrations appears to have peaked five or six years ago and have decreased since (Figure F-41).

4.6.2 Description of Remedial Alternatives

4.6.2.1 Alternative 1—No Action

A no action alternative was developed for DSS 3 to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no further action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.6.2.2 Alternative 2—Long-Term Ground Water Monitoring and Contingent Remedial Action

The second alternative developed for DSS 3 consists of installing a downgradient HSU-1 monitoring well at the location shown in Figures 4-1 and 4-8 and performing long-term ground water monitoring. Quarterly ground water samples will be collected from the new well for one year and analyzed for a full suite of analytes. Annual sampling will be conducted for nitrate, formaldehyde and molybdenum thereafter. Monitoring results will be reported in the UC Davis annual ground water monitoring reports and evaluated during CERCLA five-year reviews. Four consecutive ground water sample results that exceed site background and show an increasing or constant concentration trend would trigger an evaluation of remedial options. The new DSS 3 monitoring well (Figure 4-1) is the proposed compliance monitoring well.

Cost:

- Capital Cost: $108,000
- Present Worth O&M Cost: $103,000
- Periodic Costs: $10,000
- Total Present Worth Cost: $221,000

4.6.2.3 Alternative 3—Cap, Long-Term Ground Water Monitoring and Land-Use Restrictions

In addition to long-term ground water monitoring as described above, Alternative 3 includes capping the leach field and surrounding area to prevent downward migration of residual contaminants through the vadose zone to ground water. Capping will eliminate surface water infiltration, which is the primary mechanism for downward contaminant migration. Subsurface diffusion will become the primary contaminant transport mechanism in the absence of infiltration.

The cap will be constructed of asphalt, gravel base and a HDPE liner overlying a 2,500 square ft area (Figure 4-9). Since this area is used for service vehicle traffic and/or parking, it will be designed to be consistent with the UC Davis Campus Standard 02500, Paving (UC Davis, 1995). Existing asphalt pavement gravel base and soil will be removed from the Site to prepare for installation of the cap. Import fill soil that was previously placed within the leach field excavation will be removed and recycled or disposed off site at a Class III landfill. Native soil will be moved into the excavation and compacted. The cap will consist of a 40-mil HDPE liner overlain by eight inches of compacted gravel base material and four inches of asphalt pavement. The liner and pavement will be sloped to direct storm water runoff away from the area. The cap's condition will be visually inspected on an annual basis and maintenance (i.e., asphalt overlay) is expected every 10 years. Signage will be posted to ensure that the cap is not disturbed. A land-use restriction will be recorded to document the cap area and to prohibit site development activities that would affect the cap's performance.

Long-term ground water monitoring and cap maintenance will be performed for 30 years.

Cost:

- Capital Cost: $327,000
- Present Worth O&M Cost: $124,000
- Periodic Costs: $17,000
- Total Present Worth Cost: $468,000

4.6.2.4 Alternative 4a—Removal and Off-Site Disposal

Alternative 4a will remove all of the soil in DSS 3 that contains concentrations of formaldehyde, molybdenum and nitrate that are above the cleanup goals. The lateral excavation limits to remove this contamination are shown on Figure 4-10. Contaminated soil will be removed using oversized auger drilling (4 to 8 ft diameter) to the seasonal low-water table at approximately 50 ft bgs.

The excavation area (Figure 4-10) surrounds and underlies the 2002 leach field excavation. Clean fill from the leach field excavation would be stored for reuse as backfill material. The overburden soil located between ground surface and 4 ft bgs in areas that were not removed in 2002 will be managed as clean soil because it overlies the drain tile where waste water from the DSS was discharged. Contaminated soil below 4 ft bgs would be removed, stockpiled separately, sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. Based on DSS 3 confirmation data, low levels of Sr-90 (<2 pCi/g) remained in the 2002 excavation floor and sidewalls. The Sr-90 contamination is assumed confined between 4 ft and 20 ft bgs. Soil from the 4 to 20 ft bgs interval would likely be classified as low-level radioactive waste that would be disposed at Envirocare of Utah. Soil from the 20 to 50 ft bgs interval was assumed to contain no added radionuclides and would be disposed at a Class II industrial waste landfill.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. The auger holes will be filled with controlled-density fill between 8 and 50 ft bgs. Clean fill from the 2002 leach field excavation, the overburden and new import fill from an off-site source would be used in the upper 8 ft of each auger hole. The soil in each auger hole will be individually compacted before moving to the next auger location. A fraction of the controlled-density fill and compacted soil would be re-removed at overlapping areas of adjacent auger holes. The area will be paved to restore it to its current condition. No land-use restrictions are required.

All of the costs are expected to occur in the present time frame and no annual or periodic costs were assumed.

Cost:

- Capital Cost: $4,562,000
- Present Worth O&M Cost: $0
- Periodic Costs: $0
- Total Present Worth Cost: $4,562,000

4.6.2.5 Alternative 4b—Removal and On-Site Treatment

Alternative 4b involves removing the same volume of soil as Alternative 4a and treating a portion of the contaminated soil on site with thermal desorption (desiccation) and phytoremediation. Some of the contaminated soil would not be treated on site, because it contains Sr-90 contamination that would pose greater than 10^{-6} risk. The Sr-90-bearing soil would be disposed as low-level radioactive waste at Envirocare of Utah.

Soil drying and phytoremediation would involve spreading contaminated soil over a plastic liner in the WDPs area and desiccating the soil to remove formaldehyde. After the formaldehyde is removed, phytoremediation will be used to remove excess nitrate. The thermal desorption procedure will require notification to the California Air Resources Board.

A plastic liner would be installed to prevent contact between the contaminated soil and the existing WDPs soil. The contaminated soil would be graded to prevent ponding and be covered with plastic sheets during the rainy season to prevent storm water contamination.

The plastic under liner would consist of a single sheet of welded HDPE. The contaminated soil would be placed evenly throughout the lined area and allowed to dry throughout the summer season after the soil is removed. The soil would then be mixed with amendments to facilitate optimal crop growth during the following growing season. A timed sprinkler system would be installed to maintain proper irrigation.

The treatment cell crop will be seeded in spring and grown through early fall. The grass would be regularly trimmed, dried and stored for disposal upon decommissioning. The irrigation system and liner will be inspected regularly. Soil and grass samples would be collected from the treatment cell at the end of each growing season before covering the cell with plastic sheets. The sample data would be evaluated and reported in an annual treatment system performance report.

When annual data indicate remediation is complete confirmation samples will be collected using a random grid approach. After the RPMs agree that remediation is complete, the liner, sprinkler system and accumulated grass cuttings will be sampled and profiled for disposal. The liner, sprinkler system and cuttings waste are assumed to be disposed at a Class II landfill.

All of the excavation, soil disposal, soil drying and treatment cell installation costs are expected to occur in the present time frame. Phytoremediation O&M costs are assumed to occur over three years (i.e., three growing seasons). Decommissioning costs are expected at the end of the third year.

Cost:

- Capital Cost: $4,243,000
- Present Worth O&M Cost: $93,000
- Periodic Costs: $135,000
- Total Present Worth Cost: $4,471,000

4.6.2.6 Alternative 4c-Limited Removal, Off-Site Disposal and Long-Term Ground Water Monitoring

Alternative 4c will remove and dispose of soil that can be accessed using conventional excavation equipment such as a backhoe. In addition, long-term ground water monitoring will be performed as described in Alternative 2. The depth limit of conventional excavation is approximately 20 ft bgs. Soil containing concentrations of COCs that are above the ground water cleanup goals will be removed unless located deeper than 20 ft bgs. Soil deeper than 20 ft bgs will remain in place.

The lateral excavation limits are the same as Alternatives 4a and 4b, and are shown on Figure 4-11. The excavation area surrounds and underlies the 2002 leach field excavation. Clean fill from the leach field excavation would be stored for reuse as backfill material. The overburden soil located between ground surface and 4 ft bgs in areas that were not removed in 2002 will be managed as clean soil, because it overlies the drain tile where waste water from the DSS was discharged. Contaminated soil below 4 ft bgs would be removed, stockpiled separately, sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. Based on DSS 3 confirmation data, low levels of Sr-90 (<2 pCi/g) remained in the 2002 excavation floor and sidewalls. The Sr-90 contamination is assumed confined between 4 ft and 20 ft bgs. Soil from the 4 to 20 ft bgs interval would likely be classified as low-level radioactive waste that would be disposed at Envirocare of Utah.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. Clean fill from the 2002 leach field excavation, the overburden and new import fill from an off-site source would be used to backfill the excavation. The area will be paved to restore it to its current condition. Monitoring well installation and long-term ground water monitoring will be required as described in Alternative 2 above.

Excavation, disposal and well installation capital costs are expected to occur in the present time frame. Annual monitoring costs are expected to occur for 30 years, and one periodic cost is expected after 30 years to demolish the monitoring well.

Cost:

- Capital Cost: $2,046,000
- Present Worth O&M Cost: $103,000
- Periodic Costs: $10,000
- Total Present Worth Cost: $2,159,000

4.6.2.7 Alternative 5—*In Situ* Bioremediation and Long-Term Ground Water Monitoring

In addition to implementing long-term ground water monitoring and hazard notification signage, as described in Alternative 2, Alternative 5 includes pilot testing, installation and O&M of an *in situ* microbial denitrification and formaldehyde biodegradation system, an innovative technology for vadose zone remediation.

The nitrate treatment process will consist of induced anaerobic denitrification, which occurs during microbial respiration in the absence of oxygen and presence of a carbon source (e.g., ethanol, glucose, lactate or sucrose in purified water). The *in situ* microbial denitrification system would inject a carbon-source solution into nitrate-contaminated vadose zone soil. The injection system would fully saturate vadose zone soil in the vicinity of nitrate contamination. This will result in a ground water mound, which will drive nitrate, the injected carbon source, and formaldehyde downward and outward from the area of contamination. It is expected that some of the nitrate and formaldehyde may enter ground water below the treated area.

Indigenous aerobic bacteria in the vadose zone would use the carbon source as an electron donor and existing oxygen as the electron acceptor. Denitrification will begin when the existing oxygen is depleted. When the carbon source remains in excess, indigenous denitrifying bacteria will proliferate and reduce nitrate to nitrogen gas.

Although formaldehyde is biocidal to many microorganisms due to its nonspecific reactivity with proteins and nucleic acids, aerobic microorganisms such as methylotrophic bacteria or pseudomonads are capable of degrading formaldehyde. Methylotrophic microorganisms are distinguished by their ability to utilize reduced one-carbon compounds such as formaldehyde as sources of carbon and energy (Chongcharoen et al., 2005). The energy metabolism and production of biomass contribute to the detoxification of formaldehyde. During the energy metabolism, methylotrophs take up formaldehyde, which is oxidized to formate and ultimately carbon dioxide (CO_2). Additionally, formaldehyde and formate enter the assimilatory pathway, where they are converted into biomass (Mitsui et al., 2003). Chongcharoen et al. reported that methylotrophs were capable of using formaldehyde as their principal growth substrate up to a concentration of at least 1,700 mg/L, and were able to survive at concentrations of up to 3,000 mg/L (Chongcharoen et al., 2005). A study by Glancer-Soljan et al. indicated that pseudomonads aerobically degraded formaldehyde concentrations as high as 1,000 mg/L. During the aerobic degradation, formic acid developed as an intermediate product, which was also used as carbon source for growth and biomass formation (Glancer-Soljan et al., 2001). Formaldehyde is also degradable under anaerobic conditions in aqueous and soil media by non-methylotrophic bacteria such as *Escherichia coli* (Goenrich et al., 2002). Eiroa et al. showed that concentrations of up to 260 mg/L were biodegraded under denitrification conditions (Eiroa et al., 2005). Degradation of formaldehyde in wastewaters at concentrations of 220 to 4,000 mg/L was observed under anoxic conditions, while formaldehyde served as the electron donor by biomass during denitrification of the nitrate (Garrido et al., 2000). Houbron et al. also reported that denitrification rates in anaerobic environments have been found to be directly dependent on methanotrophic activities, where formaldehyde or formate served as electron donors by anaerobic microorganisms (Houbron et al., 1999).

Induced denitrification has been successfully demonstrated extensively in ground water. Deployment of this technology in the vadose zone is innovative and unproven. The deployment of bioremediation of formaldehyde in these conditions is even more uncertain. The formaldehyde concentration in DSS 3 vadose zone soil ranges between 0.2 mg/kg to 2.2 mg/kg, which would partition to approximately 2 mg/l to 20 mg/l under saturated conditions. The presence of residual formaldehyde for more than 30 years after its release suggests that degradation in the vadose zone is very slow or non-existent. However, available Site formaldehyde ground water concentrations suggest that it readily biodegrades once it reaches the saturated zone. Moreover, formaldehyde might induce degradation of nitrate in DSS site ground water, since formaldehyde can serve as the electron donor during denitrification. Prior to implementation, the site-specific effectiveness of bioremediation will need to be further evaluated by bench- and field-scale pilot testing.

Pilot testing would involve collecting two continuous core samples in the contaminated vadose zone and testing the core samples for hydraulic properties, nitrate and formaldehyde concentration profile, bench-scale denitrification and formaldehyde biodegradation and biological and geochemical parameters. A hydrologic testing laboratory will determine hydraulic properties of the soil core, such as the lateral and vertical hydraulic conductivity and porosity. A field infiltration test would be conducted in one of the boreholes to verify the hydraulic parameters determined in the laboratory. The hydraulic data will be used to determine the pressure and flow rate of the carbon/nutrient-source solution delivery system. The most recent samples of the nitrate and formaldehyde profile at DSS 3 were collected in 2002, but should be verified by analyzing core samples. The screened interval of the carbon/nutrient-source solution delivery system will depend on the current vertical location of nitrate and formaldehyde contamination. Bench-scale tests of denitrification and formaldehyde biodegradation will be conducted on sections of contaminated core. The cores will be sampled and analyzed for nitrate, formaldehyde, plate count and geochemical parameters before conducting the bench test. The geochemical parameters that will be tested are: alkalinity, pH, dissolved oxygen, oxidation/reduction potential, total iron, soluble iron, sulfate and total organic carbon. Various carbon/nutrient-source solutions and amendments will be applied to selected contaminated core samples to determine optimal denitrification and formaldehyde biodegradation conditions. A pilot test report will be prepared to present the results and any carbon/nutrient-source solution and augmentation recommendations that should be used to implement the final *in situ* microbial denitrification and formaldehyde biodegradation system.

A treatment system design will be prepared and approved by the UC Davis ORMP and the RPMs. The treatment system design is assumed to consist of a vadose zone well field spaced on 10-ft centers (Figure 4-12) that are manifolded into a carbon/nutrient-source solution holding tank. A metered pump between the delivery tank and manifold would control the total carbon/nutrient-source solution delivery rate. The manifold would be designed with pressure and flow control valves to adjust carbon/nutrient-source solution delivery to individual wells. The carbon/nutrient-source solution would be mixed on site by an automated metering system that would combine filtered tap water with concentrated carbon/nutrient-source solution. The concentrated carbon/nutrient-source solution would be stored in a separate tank and metered into the filtered water when the low-level switch is activated in the solution storage tank. The tap water will be treated with carbon filtration to remove any impurities or trihalomethane compounds generated in the municipal water supply disinfection process. The tanks, metering systems, manifold valving, filtration system and electrical control panel will be installed on a concrete slab within a fenced compound. The tanks and equipment will be anchored to the slab with seismic anchorage to prevent overturning in the event of an earthquake. Electrical power will be supplied to the compound via underground conduit. A treatment system construction report will be prepared to document the as-built system design.

A treatment system manual will be prepared containing instructions for system startup, O&M and performance parameter collection. The manual will contain copies of the as-built system design, component diagrams and vendor contact information. System startup will consist of turning the system on and measuring and adjusting flow rates at the pumps and valves, and collecting samples of the carbon/nutrient-source solution. Clustered piezometers will be used to measure the level of hydraulic saturation in the vadose zone, and the carbon/nutrient-source solution, nitrate and formaldehyde concentrations at distances away from the injection wells. Monitoring wells will be used to measure nitrate and formaldehyde concentrations in ground water below the source and approximately 20 ft from the source perimeter. The piezometer and monitoring well configurations are shown in Figure 4-12.

System startup is expected to include daily field measurements from the delivery system, piezometers and monitoring wells for three weeks of operation. A startup report will be prepared and the recommended optimal adjustments will be added to the treatment system manual. System O&M will be conducted periodically thereafter according to a schedule determined by the system engineer and field technicians. The treatment system O&M schedule is assumed to consist of bi-weekly visits for the first month, weekly visits for the second month and bi-monthly visits thereafter.

All of the pilot testing, installation and startup costs are expected to occur in the present time frame. O&M is assumed to occur over two years. A decommissioning cost is expected to occur at the end of two years.

Cost:

- Capital Cost: $722,000
- Present Worth O&M Cost: $404,000
- Periodic Costs: $193,000
- Total Present Worth Cost: $1,319,000

4.6.3 Analysis of Remedial Alternatives

Table 4-4 summarizes the analysis of remedial alternatives. A comprehensive analysis is presented below.

4.6.3.1 Alternative 1—No Action

4.6.3.1.1 Overall Protection of Public Health and the Environment

Alternative 1 does not address the future protection of ground water. The RA has addressed principal threats to human health and the environment, but residual formaldehyde, molybdenum and nitrate remain in soil at concentrations which may impact ground water over limited areas. Ground water modeling results (WA, 2003) suggest that residual COCs have the potential to impact limited amounts of ground water above background and MCLs (WA, 2003). The concentrations of formaldehyde and molybdenum in ground water in downgradient well UCD1-024 are currently below background thresholds. Nitrate from this area may be impacting ground water concentrations in UCD1-023 and UCD1-024; however, these concentrations show a declining trend over time

(Appendix F). The total mass of nitrate present in the DSS 3 area is about 203 pounds, and the total mass of nitrate that could be released to ground water annually is estimated to be less than 39 pounds.

4.6.3.1.2 Compliance with ARARs

Alternative 1 complies with most ARARs if natural attenuation and dispersion act to mitigate the transport of residual soil contaminants to ground water and/or reduce contaminant concentrations in ground water to background in a reasonable time frame. As described above, the worst case (i.e., no degradation) predicted impacts are expected to be relatively small. However, this alternative does not provide a means to verify these predictions and compliance with the State's Anti-Degradation Policy and Basin Plan.

4.6.3.1.3 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long-term since localized known ground water impacts will not be monitored. Future local use of HSU-1 ground water is unlikely due to the low yield of HSU-1. The majority of the residual mass of contaminants was removed during the CERCLA RA conducted in 1999 and 2000. However, Alternative 1 does not provide adequate management and monitoring controls to confirm long-term effectiveness.

4.6.3.1.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 1, toxicity, mobility or volume are not reduced.

4.6.3.1.5 Short-Term Effectiveness

Alternative 1 has no short-term impacts, since there are no current risks and no remedial actions are included.

4.6.3.1.6 Implementability

There are no barriers to implementing Alternative 1.

4.6.3.1.7 Cost

The cost of Alternative 1 is $0.

4.6.3.1.8 State Acceptance

The State of California has not accepted Alternative 1 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.6.3.1.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their non-acceptance of this alternative during the public comment period for the Proposed Plan.

4.6.3.2 Alternative 2—Long-Term Ground Water Monitoring and Contingent Remedial Action

4.6.3.2.1 Overall Protection of Public Health and the Environment

Alternative 2 addresses uncertainties associated with future impacts to ground water by employing ground water monitoring near the source area to confirm long-term effectiveness and protection. If future monitoring indicates that conditions are not protective, remedial actions could be undertaken, such as ground water extraction and treatment.

4.6.3.2.2 Compliance with ARARs

Alternative 2 complies with ARARs if natural attenuation and dispersion act to mitigate the transport of residual soil contaminants to ground water and/or reduce contaminant concentrations in ground water to background in a reasonable time frame. As noted above, if significant ground water impacts are observed, additional remedial measures may be required.

4.6.3.2.3 Long-Term Effectiveness and Permanence

Ground water plume predictions were prepared to evaluate long-term effectiveness under Alternative 2. The plume size estimates were based on complete contaminant transfer to HSU-1. The estimated plume areas and diameters are summarized in Table 1-1 and the calculations are presented in Appendix E. Formaldehyde plumes were predicted to range from 5.1 acres to 20 acres based on ground water background and the California State Action Level, respectively. However, formaldehyde was not detected in ground water samples collected downgradient of DSS 3 on June 13, 2006. The absence of downgradient formaldehyde suggests that DSS 3 formaldehyde contamination may be undergoing biodegradation as it reaches ground water. As described in Section 4.6.2.7, dissolved formaldehyde is readily degradable under aerobic and anaerobic subsurface conditions. Additionally, it is suspected that formaldehyde is used as an electron donor by indigenous organisms under anaerobic conditions, to denitrify nitrate in ground water. Molybdenum and nitrate plumes are predicted to occupy less than one acre (Table 1-1). Alternative 2 is effective for molybdenum and nitrate given the low mass of the residual contamination.

Under this alternative, a new monitoring well will be located less than 100 ft northeast (downgradient) of the DSS 3 area (Figure 4-8) and would be used to verify that formaldehyde, molybdenum and nitrate are either degrading or not being released to ground water. Monitoring and management controls are provided by this alternative to confirm effectiveness. The collection of ground water data for the next 30 years allows continued long-term evaluation of ground water impacts.

4.6.3.2.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 2, toxicity, mobility or volume are not reduced.

4.6.3.2.5 Short-Term Effectiveness

No short-term risks to the public or to the environment are anticipated. The drilling procedures to install the new monitoring well may restrict parking access and create a local noise disturbance for nearby site occupants for a period of one to two days.

The ongoing effectiveness of this alternative will be confirmed by long-term ground water monitoring. However, if monitoring results trigger an evaluation of remedial alternatives, the time until each alternative is protective will be presented in an addendum to the Remedial Action Work Plan.

Contingent remedial action will be considered protective when groundwater is cleaned up to background concentrations, or if background concentrations are not technically or economically feasible, water quality objectives protective to one-in-a-million cancer risk or the lowest water quality objective applicable for the constituent/s of concern.

4.6.3.2.6 Implementability

This alternative utilizes standard monitoring techniques currently deployed at the Site, and relies on standard services and materials. Standard records management and database activities are required.

Land-use restrictions are not proposed under this alternative, but land-use restrictions may be a component of future remedial action, if required. Additionally, intervening site development could limit access to areas requiring remedial action.

4.6.3.2.7 Cost

The anticipated capital and O&M costs for Alternative 2 are $221,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.6.3.2.8 State Acceptance

The State of California has accepted Alternative 2 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.6.3.2.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.6.3.3 Alternative 3—Cap, Long-Term Ground Water Monitoring and Land-Use Restrictions

4.6.3.3.1 Overall Protection of Public Health and the Environment

To mitigate future impacts to ground water, Alternative 3 includes capping to reduce the rate at which contaminants reach HSU-1, and ground water monitoring near the source area to confirm long-term effectiveness. If future monitoring indicates that the cap has not been protective, other remedial actions could be undertaken, such as ground water extraction and treatment. Additional deed restrictions maintain and prevent disturbances of the cap.

4.6.3.3.2 Compliance with ARARs

Alternative 3 complies with ARARs. Alternative 3 includes a program to actively monitor ground water.

4.6.3.3.3 Long-Term Effectiveness and Permanence

Because the residual soil contamination is already at a minimal level, Alternative 3 should be effective in the long term. The addition of a surface cap will mitigate ground water impacts related to the entrainment of residual contaminants in infiltrating meteoric water. Infiltration is currently the primary transport mechanism for contaminants in the vadose zone to reach ground water. After the cap is installed, diffusion processes will continue, but the transport rates should be markedly reduced. Institutional controls will be required to maintain the cap's integrity over time. The effectiveness of these controls over long periods of time is uncertain. If the controls are ineffective and the cap is allowed to deteriorate, the long-term effectiveness and permanence of Alternative 3 is the same as Alternative 2. Effectiveness is confirmed with monitoring and management controls such as quality assurance and routine reporting.

4.6.3.3.4 Reduction of Toxicity, Mobility or Volume

Mobility of the residual contamination is substantially reduced by the cap, since it eliminates surface water infiltration. Some contaminant migration to the water table will still occur through diffusion. Contaminant mass and volume are not reduced.

4.6.3.3.5 Short-Term Effectiveness

Alternative 3 involves the installation of asphalt pavement. There are discernable environmental and health risks associated with the manufacture, transportation and installation of asphalt. Additional short-term risks to the community and to workers include relatively short-term noise and heavy equipment use. Deployment of the cap system is rapid, since it relies on established engineering design and materials. The impact to site occupants due to the installation of the well, as described under Alternative 2, are relatively minor. The cap may restrict site development and affect aesthetics. The estimated time to design and install a cap is approximately one year.

4.6.3.3.6 Implementability

The paving procedures for implementing Alternative 3 are routine and technically feasible. There are no physical barriers to mobilizing the paving equipment to the Site. This alternative can be implemented with established engineering design and materials. A small amount of clean soil will be disposed under this alternative, but suitable landfill space or reuse options are available within 30 miles of the Site. Paving equipment and labor are generally available on relatively short notice between the months of May and November in the Davis area.

Permission will need to be granted by UCOP to implement land-use restrictions. Negotiations between DOE and UCOP may be required to address the effort required to administer and implement the land-use restrictions.

The monitoring wells are expected to remain operable for the duration of this alternative. Standard records management and database activities are required.

4.6.3.3.7 Cost

The anticipated capital and O&M costs for Alternative 3 are $468,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.6.3.3.8 State Acceptance

The State of California has accepted Alternative 3 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.6.3.3.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.6.3.4 Alternative 4a—Removal and Off-Site Disposal

4.6.3.4.1 Overall Protection of Public Health and the Environment

Alternative 4a is protective of ground water at the Site since all soil with contaminant concentrations greater than the remediation goals is removed and disposed off site. However, off-site disposal will generate environmental impacts and risks associated with the long-term transfer of risk to the disposal site, as well as short-term transportation risks, including highway accidents and vehicular air emissions.

4.6.3.4.2 Compliance with ARARs

Because all contaminated soil is removed under Alternative 4a, this alternative complies with all ARARs.

4.6.3.4.3 Long-Term Effectiveness and Permanence

Because all of the contamination in soil at concentrations greater than remediation goals is expected to be removed under Alternative 4a, this alternative is permanently effective. However, this alternative requires auger excavation over a large area, and contamination may be missed if the auger deflects or is not properly located during use. The risk associated with this alternative is transferred to the disposal site, but contaminant levels are low and should be easily controlled in a permitted facility.

4.6.3.4.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4, toxicity, mobility and contaminated soil volumes are greatly reduced, since nearly all the contaminated soil is removed and disposed off site.

4.6.3.4.5 Short-Term Effectiveness

Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal site in Utah. The local community will be impacted by the transport of more than 645 truckloads of soil over a period of several months. Off-site disposal has several negative impacts, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 1.05×10^{-2}. The estimated risk of a fatality due to waste transport air emissions is 2.31×10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.21 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Additionally, localized noise and vibration impacts at the Site will persist for several months during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. The time to complete the excavation is uncertain due to the depth and non-standard techniques required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent to any deep excavation.

The estimated time required to remove and dispose the contaminated soil is approximately one year.

4.6.3.4.6 Implementability

The excavation methods are technically feasible and are used in the construction of deep foundations. However, the use of large-diameter augers to conduct mass excavations has not been conducted at the Site at the scale proposed and may fail to remove all contaminated soil. Thus, unanticipated conditions or engineering issues may extend the project's schedule and cost. Site preparations are relatively minor and mainly involve removing chain-link fencing before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process, as the material will be shipped to Envirocare of Utah. Suitable landfill space is expected to remain available during the remedial action.

This alternative can be implemented with established engineering design and materials. Standard records management and database activities are required.

4.6.3.4.7 Cost

The anticipated capital and O&M costs are $4,562,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.6.3.4.8 State Acceptance

The State of California has accepted Alternative 4a as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.6.3.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.6.3.5 Alternative 4b—Removal and On-Site Treatment

Alternative 4b is identical to Alternative 4a, except that instead of disposing all excavated soil as in Alternative 4a, some of the soil will be treated on site. Because these two alternatives are otherwise identical, this section will only discuss the on-site treatments aspects of Alternative 4b.

4.6.3.5.1 Overall Protection of Public Health and the Environment

Alternative 4b protects the beneficial use of ground water at the Site, since all soil with contaminant concentrations greater than the remediation goals is removed and either disposed off site or treated on site in a lined treatment cell. Under Alternative 4b, less of the risk is transferred off site, because a smaller volume of contaminated soil will be disposed, and fewer truckloads will be hauled. Local risk reduction is offset by the transfer of risk to the disposal site. There are short-term risks associated with transportation accidents, vehicular air emissions and on-site treatment operations.

4.6.3.5.2 Compliance with ARARs

This alternative complies with all ARARs. During periods when the crops are not established and/or when mechanical tilling is taking place, engineering controls will be required to mitigate dust and air emissions.

4.6.3.5.3 Long-Term Effectiveness and Permanence

Because all of the contamination in soil at concentrations greater than cleanup-goal concentrations is expected to be removed and treated or disposed under Alternative 4b, this alternative is permanently effective. However, this alternative requires auger excavation over a large area, and contamination may be missed if the auger deflects or is not properly located during use.

Nevertheless, the volume of potentially missed contamination is expected to be relatively small. Confirmation sample data will be used to confirm effectiveness of the phytoremediation. Risk associated with this alternative is transferred to the disposal site, but contaminant levels are low and should be easily controlled in a permitted facility.

4.6.3.5.4 Reduction of Toxicity, Mobility or Volume

Alternative 4b reduces toxicity, mobility and volume to negligible quantities by on-site treatment and the off-site disposal of soil containing added radioactivity.

4.6.3.5.5 Short-Term Effectiveness

Because fewer truckloads will be transported off site, the community will be less impacted by vehicular traffic under Alternative 4b than under Alternative 4a. In addition, Alternative 4b transfers less risk, air emissions and potential highway accidents off site. Localized noise and vibration impacts at the Site will persist for several months during the remedial action, and on-site research activities may be impacted. The estimated risk of a traffic fatality due to waste transport under this alternative is 8.71×10^{-3}. The estimated risk of a fatality due to waste transport air emissions is 1.92×10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.21 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Air monitoring, dust control and personal protective equipment are required. The time to complete the excavation is uncertain due to the depth and non-standard techniques required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent in any deep excavation.

Alternative 4b will release formaldehyde to the atmosphere; however, these emissions are expected to be negligible. Development of the WDPs area will not be possible during the three-year treatment period.

The estimated time required to remove the contaminated soil and install a phytoremediation treatment cell is approximately one year. The cell is expected to achieve cleanup goals within three growing seasons. The total estimated time for short-term effectiveness is four years.

4.6.3.5.6 Implementability

The use of a large-diameter auger to conduct mass excavation has not been conducted at LEHR at the scale proposed and may fail to remove all contaminated soil. Thus, unanticipated conditions may reduce the effectiveness of the soil removal and extend the project's schedule and cost. This alternative relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.

The thermal desorption and phytoremediation methods are technically feasible. There is available space at the WDPs area for spreading the soil to be treated. The agricultural techniques involve standard methods. Standard records management and database activities are required.

4.6.3.5.7 Cost

The anticipated capital and O&M costs are $4,471,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.6.3.5.8 State Acceptance

The State of California has accepted Alternative 4b as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.6.3.5.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.6.3.6 Alternative 4c—Limited Removal, Off-Site Disposal and Long-Term Ground Water Monitoring

4.6.3.6.1 Overall Protection of Public Health and the Environment

To mitigate future impacts to ground water, Alternative 4c includes limited removal of contaminated soil followed by ground water monitoring near the source area to confirm long-term effectiveness. Based on existing data, all soil with nitrate concentrations greater than the remediation goal would be removed and disposed off site. Residual formaldehyde and molybdenum would remain in soil deeper than 20 ft bgs at concentrations which may impact ground water. If future monitoring indicates that limited removal has not been protective, other remedial actions could be undertaken, such as ground water extraction and treatment.

Off-site disposal will generate environmental impacts and risks associated with the long-term transfer of risk to the disposal site, as well as short-term transportation risks, including highway accidents and vehicular air emissions.

4.6.3.6.2 Compliance with ARARs

Alternative 4c complies with ARARs. Alternative 4c includes a program to actively monitor ground water for 30 years. This program will provide data to evaluate any impact to the ground water which may require additional remedial measures.

4.6.3.6.3 Long-Term Effectiveness and Permanence

This alternative is permanently effective for nitrate. All of the nitrate contamination in soil at concentrations greater than the remediation goal is expected to be removed under Alternative 4c. Formaldehyde and molybdenum remaining deeper than 20 ft bgs will continue to migrate to ground water, but the mass of contamination arriving in ground water should be markedly reduced. The effectiveness of this alternative will be confirmed with monitoring. Part of the risk associated with this alternative is transferred to the disposal site, but contaminant levels are low and should be easily controlled in a permitted facility.

4.6.3.6.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4c, nitrate toxicity, mobility and contaminated soil volume is greatly reduced, since nearly all the nitrate-contaminated soil is removed and disposed off site. A large fraction of the formaldehyde and molybdenum contamination will be removed and disposed off site. Formaldehyde and molybdenum mobility are not reduced.

4.6.3.6.5 Short-Term Effectiveness

Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal site in Utah. The local community will be impacted by the transport of more than 148 truckloads of soil over a period of several weeks. Off-site disposal has several negative impacts, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 6.05×10^{-3}. The estimated risk of a fatality due to waste transport air emissions is 1.33×10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.21 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5.

Additionally, localized noise and vibration impacts at the Site will persist for several months during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent to excavation.

The estimated time required to remove and dispose the contaminated soil is approximately one year.

4.6.3.6.6 Implementability

The excavation methods for implementing Alternative 4c are routine and technically feasible. Site preparations are relatively minor and mainly involve removing chain-link fencing before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process, as the material will be shipped to Envirocare of Utah. Suitable landfill space is expected to remain available during the remedial action.

This alternative can be implemented with established engineering design and materials. Standard records management and database activities are required.

4.6.3.6.7 Cost

The anticipated capital and O&M costs for Alternative 4c are $2,159,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.6.3.6.8 State Acceptance

The State of California has accepted Alternative 4c as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.6.3.6.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.6.3.7 Alternative 5—*In Situ* Bioremediation and Long-Term Ground Water Monitoring

4.6.3.7.1 Overall Protection of Public Health and the Environment

Alternative 5 protects against the potential future loss of beneficial use of ground water by treating the nitrate and formaldehyde contamination *in situ* with bioremediation. This treatment will be carefully monitored, using five wells to monitor ground water concentration trends of COCs near the source area and verify the effectiveness of the method. The treatment system will only treat nitrate and formaldehyde, leaving molybdenum in the vadose zone as a potential ground water contaminant. As described above under Alternative 1, the impact to ground water from molybdenum is likely to be only localized, as predicted from NUFT modeling results.

4.6.3.7.2 Compliance with ARARs

Alternative 5 complies with all ARARs. The potential contamination of the ground water by nitrate will be mitigated by the *in situ* treatment. Upon completion of the treatment, only molybdenum has the potential to impact ground water. As described above, the potential impact is expected to be only minor and the uncertainty in this expectation can be evaluated by the new monitoring well.

4.6.3.7.3 Long-Term Effectiveness and Permanence

In the current conditions at the Site, Alternative 5 is likely to be effective in mitigating future ground water impacts due to the negligible mass and toxicity of residual contaminants in soil. Alternative 5 removes nitrate and formaldehyde contamination through *in situ* bioremediation. Alternative 5 does not treat the molybdenum contamination, but it does allow for long-term monitoring, as described above. Effectiveness will be confirmed with a pilot test, monitoring and management controls.

4.6.3.7.4 Reduction of Toxicity, Mobility or Volume

Alternative 5 reduces the toxicity and volume of nitrate and formaldehyde through *in situ* bioremediation. The mobility of the nitrate and formaldehyde will be increased as a result of water added to the vadose zone. As planned, however, the nitrate and formaldehyde will biodegrade to innocuous compounds locally within the vadose zone and ground water. This method does not, however, treat molybdenum and may increase its mobility.

4.6.3.7.5 Short-Term Effectiveness

Alternative 5 adds only minor short-term risks associated with the bioremediation system installation and operation to the public, workers or the environment. Construction of a concrete slab to hold the tank for injection, as well as drilling of 33 holes, will be required. This will result in some vibration and noise impacts to the community. Standard field work hazards will be present. The *in situ* remediation is expected to take two years. Deployment of the system is rapid, since it relies on established engineering design and materials. Design, installation and system startup tasks can be completed in one year, and the system is expected to achieve the remediation goals after two years of operation. Thus, the predicted time to achieve protectiveness is three years. The treatment system may interfere with site activities or development.

4.6.3.7.6 Implementability

Alternative 5 is technically feasible, as it relies on standard services and materials. The methods for installing the wells and injecting the sucrose water are well established. The Site presents no physical barriers for drilling and construction equipment. From an administrative standpoint, standard records management and database activities will be required. A site-specific pilot test is required to confirm feasibility.

4.6.3.7.7 Cost

The anticipated capital and O&M costs for Alternative 5 are $1,319,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.6.3.7.8 State Acceptance

The State of California has accepted Alternative 5 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.6.3.7.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.6.4 Comparative Evaluation of Remedial Alternatives

4.6.4.1 Overall Protection of Public Health and the Environment

Alternative 1 takes no active steps to verify ground water protection in the future, and as such, may result in a future loss of beneficial use of ground water. Alternatives 2 and 3 are more protective of public health and the environment since long-term ground water monitoring will help ensure that contaminated ground water is not a threat to the public or ecological receptors, and allows for the evaluation of additional remedial measures, if necessary. Alternative 3 actively protects the beneficial use of ground water and human health by reducing contaminant migration to ground water. Alternatives 4a and 4b remove all soil with contamination at concentrations greater than cleanup-goal concentrations, and therefore, remove risk to human health altogether. Alternative 4c removes some of the soil with contamination above the cleanup goals and reduces the potential for future ground water impacts. Under Alternatives 4a and 4b, contaminant masses are reduced to negligible levels and these mass reductions will be achieved with a high level of certainty. However, alternative 4a's protection of public health and the environment at the Site is offset by the transfer of risk to the disposal site, the addition of transportation risks and the emission of air pollutants from trucks. Under Alternative 4c, contaminant mass is not completely removed and the risk reduction is offset by transportation risk, truck emissions and risk transfer. The transfer of risk, additional transportation risk and added emissions are less for Alternatives 4b and 4c than for Alternative 4a. Alternative 5 achieves nearly the same level of overall protection as Alternatives 4a and 4b, as key contaminants are transformed into non-toxic constituents, while eliminating the need to remove the soil for off-site disposal or on-site *ex situ* treatment. All of the alternatives, except Alternative 4a, result in some residual site contamination.

4.6.4.2 Compliance with ARARs

Alternative 1 does not comply with ground water protection ARARs, while Alternatives 2, 3, 4a, 4b, 4c and 5 comply with ARARs. Alternative 1 does not provide a monitoring system to confirm the predicted limited impacts of the COCs on ground water. Alternative 2 complies with ARARs because the COCs are unlikely to impact ground water, and in the unlikely event that an impact occurs, remedial action will be taken. The remaining masses of molybdenum and nitrate are very low, so the resulting sizes of any potential plumes are also very small (Table 1-1); formaldehyde exists in moderate quantities in soil, but appears to naturally attenuate in ground water (in downgradient well UCD1-024, formaldehyde has never been detected; the concentration of formaldehyde in well UCD2-007 is reported in Figure F-24). Long-term ground water monitoring will permit evaluation of any possible non-compliance with ARARs. Contingent remedial action will address any potential non-compliance. Alternative 3 involves installing a cap to reduce contaminant mobility and improve assurance that compliance with the State's Anti-Degradation Policy and Basin Plan is maintained. Because the contaminant mass is not removed, however, the contamination may eventually impact ground water. Alternatives 4a and 4b comply with all ARARs because all of the contaminant mass is removed. Alternative 4c would remove some, but not all, of the contaminant mass; the remaining mass of contaminants would, as with Alternative 2, comply with ARARs. Alternative 5 complies with all ARARs by removing contaminant mass and monitoring with contingent remedial action. Under this Alternative, nitrate and formaldehyde are removed by *in situ* treatment. The remaining mass of molybdenum would, as with Alternative 2, comply with ARARs.

4.6.4.3 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long term since localized known ground water impacts will not be monitored. Alternatives 2, 3 and 4c include monitoring and other management controls to confirm effectiveness. Alternative 3 includes a cap to enhance the long-term effectiveness and Alternative 4c permanently removes most of the contaminant mass. Alternatives 4a and 4b are permanent solutions for all COCs. Alternative 5 is an innovative technology and, as such, there is uncertainty about its effectiveness. The completion of bench- and field-scale testing will be required to reduce this uncertainty. In the event the remediation fails, the nutrient injection may mobilize vadose zone contaminants into ground water.

4.6.4.4 Reduction of Toxicity, Mobility or Volume

There is no direct reduction of toxicity, mobility or volume under either Alternatives 1 or 2. Under Alternative 3, mobility of the residual vadose zone contamination is reduced substantially by the cap. Although capping (Alternative 3) is not a treatment technology, it should still be evaluated for this criterion because capping can reduce contaminant mobility by preventing infiltration. Under Alternatives 4a and 4b, all soil with contaminant concentrations greater than cleanup-goal concentrations is completely excavated. Most of the contamination is removed under Alternative 4c. Under Alternatives 4a and 4c, the reduction of toxicity, mobility or volume is accomplished by off-site removal. Under Alternative 4b, the reduction of toxicity, mobility or volume is accomplished partially by off-site removal and partially by on-site treatment. Alternative 5 converts nitrate and formaldehyde to innocuous substances. Molybdenum's toxicity, mobility or volume will not be reduced.

4.6.4.5 Short-Term Effectiveness

Neither Alternatives 1 nor 2 would add any short-term impacts to the public, workers or the environment. The impact of installing a new monitoring well is relatively minor.

Alternative 3 involves the installation of asphalt pavement. There are minor environmental and health risks associated with air emissions during the manufacture, transportation and installation of asphalt. Additional short-term impacts to the community and to workers include noise and heavy equipment use. Deployment of the cap system is rapid, since it relies on established engineering design and materials.

Alternatives 4a, 4b and 4c produce the most severe short-term impacts. Discernable short-term risks to the public and the environment are associated with the transport of contaminated soil to the waste disposal site in Utah. Transportation impacts include local traffic congestion, air emissions and the risk of highway accidents. Site construction impacts, including localized noise and ground vibrations, will persist for several months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment, fall hazards and burial hazards inherent in excavation. The exact time to complete the work for Alternatives 4a and 4b is uncertain due to the depth and non-standard excavation techniques required. Alternatives 4b and 4c create less off-site risk than Alternative 4a. The length of time required to complete Alternative 4b is three years longer than Alternative 4a.

Alternative 5 has increased short-term impacts over Alternative 2 and possibly Alternative 3, since a substantial number of wells, above-ground tanks, piping and electrical equipment need to be installed.

The period to achieve short-term effectiveness is not applicable to Alternative 1 because there is no metric to evaluate its protectiveness. Alternative 2 appears to be effective in the short term based on current site data. The ongoing effectiveness of Alternative 2 will be confirmed by long-term ground water monitoring. Alternatives 3, 4a and 4c are expected to meet their protectiveness objectives in approximately one year, because they use proven construction technologies. Alternative 4b is predicted to take four years based on three phytoremediation growing seasons to achieve protectiveness, while Alternative 5 is expected to take three years (one year installation, two years operation).

4.6.4.6 Implementability

There are no barriers to implementing Alternative 1. From an administrative standpoint, standard records management and database activities will be required for Alternative 2. The ground water monitoring portions of Alternative 3 take advantage of the same in-place systems that Alternative 2 uses.

The paving procedures for implementing Alternative 3 are routine and technically feasible. Access is available to paving equipment. Land-use restrictions included in Alternative 3 require acceptance by UCOP. There are numerous issues related to this acceptance including, but not limited to, increased site maintenance and development costs, loss of development potential and long-term monitoring costs that need to be negotiated by DOE and UCOP. A small amount of clean soil will be disposed under Alternative 4a, but suitable landfill space is available within 30 miles of the Site. The monitoring wells have been and are expected to remain operable for the duration of this alternative. Paving equipment and labor are generally available on relatively short notice between May and November. Site preparations and restoration include removing and replacing a chain-link fence.

The conventional excavation procedures for implementing Alternative 4c are routine and technically feasible. The ground water monitoring portion of Alternative 4c takes advantage of the same in-place systems that Alternative 2 uses.

For Alternatives 4a and 4b, the excavation methods are technically feasible and are used in the construction of deep foundations. However, the use of large-diameter augers to conduct mass excavations has not been conducted at the Site at the scale proposed. Thus, unanticipated conditions may reduce the effectiveness of the soil removal and extend the project's schedule and cost. Minor site preparation and restoration include removing and replacing a chain-link fence before excavation begins. Although the excavation methods are routinely used for foundation construction, the availability of the requisite specialized equipment and labor at any particular time is not guaranteed. Transportation and disposal of the contaminated material will require an involved permitting process, as a large fraction of the material will be shipped to Envirocare of Utah.

The phytoremediation involved in Alternative 4b is technically feasible, involving well-established construction and agricultural techniques. There is space available for this in the WDPs area.

Alternative 5 may restrict parking and vehicular travel in the southern portion of the Site for several years. Otherwise, it relies on standard well installation and mechanical systems. The carbon source is a non-hazardous material.

4.6.4.7 Costs

The anticipated capital and O&M costs for the alternatives are:

- Alternative 1 (no action): $0
- Alternative 2 (ground water monitoring): $221,000
- Alternative 3 (cap, long-term ground water monitoring and land-use restrictions): $468,000
- Alternative 4a (removal and off-site disposal): $4,562,000
- Alternative 4b (removal and on-site treatment): $4,471,000
- Alternative 4c (limited removal, off-site disposal and long-term ground water monitoring) $2,159,000
- Alternative 5 (*in situ* bioremediation and long-term ground water monitoring): $1,319,000

Detailed cost assumptions are presented in Appendix A.

4.6.4.8 State Acceptance

With the exception of the no action alternative, the State of California has accepted all of the alternatives.

A preferred remedial alternative will be presented in the Draft Proposed Plan. State of California acceptance of the preferred remedial alternative will be provided after resolution of their comments on the Draft Proposed Plan.

4.6.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on the accepted alternatives during the public comment period for the Proposed Plan.

4.7 Domestic Septic System No. 4

4.7.1 Nature and Extent of Contaminants of Concern

Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene contained in soil are human health risk COCs, and selenium is a ground water impact COC at DSS 4 (Tables 2-1 and 2-2).

4.7.1.1 Polynuclear Aromatic Hydrocarbons in Soil

The COCs benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene are commonly referred to as PAHs, which are a typical mixture of SVOCs present in some petroleum products or can be produced by various combustion processes. All of the referenced PAHs were detected in the composite samples (field duplicates SSD4C002A/B and SSD4C003A/B) collected beneath the first points of perforation of the two leach lines at 4.2 ft bgs. All of the referenced PAHs, except indeno(1,2,3-cd)pyrene, were detected in a sample (SSD4C004) collected at 7.75 ft bgs beneath the first point of perforation of the western leach line. All of the referenced PAHs, except dibenzo(a,h)anthracene, were detected in sample SSD4C005 collected beneath the mid-point of the southern leach line at 4.2 ft bgs. No PAHs were detected in the remaining three samples (LEHR-S-T401, LEHR-S-T402 and SSD4C001). Samples LEHR-S-T401, LEHR-S-T402 and SSD4C001 were collected at depths of 5.5, 8 and 7.8 ft, respectively.

Field duplicate samples (SSD4C002A/B and SSD4C003A/B) had the highest PAH concentrations. There appears to be a trend of decreasing PAH concentrations in the leach field with increased distance from the distribution box. However, it is likely that PAHs persist in the unsampled portions of the leach field, which includes the area beneath Building H-215 (Figure 4-13). However, given the low solubility and high sorptivity of the PAHs, they are not likely to have migrated significantly past the gravel fill in the leach field under Building H-215. A single data point (sample SSD40C001) at the junction between the septic tank and vitrified clay pipe distribution line suggests that no PAHs have been released in this area.

4.7.1.2 Selenium in Soil

Three of thirteen selenium soil results (23 percent) exceeded site background at DSS 4. One of the elevated results was in the composite soil sample collected beneath the first points of perforation on the southern and western leach lines. Another elevated sample was collected beneath the mid-point of the southern leach line. The third elevated sample was collected from the soil boring at the first point of perforation on the western leach line at a depth of 18 ft bgs. The selenium concentration was equal to the background screening value (1.2 mg/kg) in the soil boring sample collected at 13 ft bgs. Selenium was below background in the soil boring samples collected between 23 ft bgs and 38 ft bgs, and at the effluent connection to the DSS. The data indicate that selenium may have been released to soil below the DSS 4 leach lines and may have migrated as deep as 18 ft bgs. The maximally detected concentration was 2 mg/kg.

4.7.1.3 Ground Water

Ground water that is downgradient of the DSS 4 area has been sampled for COCs between October 1990 and the present. Ground water from HSU1 has been sampled in wells UCD1-024 and UCD1-020 (listed with increasing distance from the DSS 4 area). Ground water from HSU2 has been sampled in well UCD2-039. Figure 4-1 shows the relative locations of wells to the DSS 4 area. Graphs illustrating the concentrations of COCs in these three wells through time are in Appendix F, with the exception of those graphs that would show fewer than five detected results and no detected results greater than MCLs. Included in each graph is a simple linear regression calculation, represented by a dashed line, to assist the reader in evaluating the overall trend of the COC in ground water.

Selenium concentrations in both HSU1 and HSU2 downgradient of the DSS 4 area have been far below the MCL of 50 µg/L. In well UCD1-020, selenium has been detected only four times, with the highest concentration at 5 µg/L. In wells UCD1-024 and UCD2-039, selenium concentrations have consistently been below 8 µg/L (Figures F-20 and F-45).

4.7.2 Description of Remedial Alternatives

4.7.2.1 Alternative 1—No Action

A no action alternative was developed for DSS 4 to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.7.2.2 Alternative 2—Long-Term Ground Water Monitoring, Land-Use Restrictions and Contingent Remedial Action

The second alternative developed for DSS 4 consists of long-term ground water monitoring and land-use restrictions. Long-term ground water monitoring involves installing a downgradient well near DSS 4 at the location shown on Figure 4-14. Quarterly ground water samples will be collected for a period of one year after the new well is installed. The quarterly samples will be analyzed for a full suite of analytes. Annual selenium sampling will be conducted thereafter. Monitoring results will be reported in the UC Davis annual ground water monitoring reports and evaluated in CERCLA five-year reviews. Four consecutive ground water sample results that exceed site background and show an increasing or constant concentration trend would trigger an evaluation of remedial options. The new DSS 4 monitoring well (Figure 4-1) is the proposed compliance monitoring well.

Land-use restrictions will be necessary along with long-term ground water monitoring to prevent future residential construction at locations where risks exceed 10^{-6} for hypothetical residents. The residential risk at DSS 4 is due to concentrations of PAHs in soil below the leach trenches, which extend west of the distribution box and are partially covered by Building H-215. A residential property restriction and a restriction on soil removal (e.g., soil management plan) for this location would be recorded with Solano County by the UC Davis ORMP. The legal description would include a parcel map showing exclusion areas where residential risk is greater than 10^{-6}. The portion of the leach trenches located under and to the west of Building H-215 has not been sampled, but is assumed to contain PAH contamination and would be shown on the parcel map as an exclusion area. A California-registered land surveyor will survey the Site features and exclusion areas and prepare the parcel map. The UC Davis ORMP will also maintain records of the site contamination data. It is expected that UC Davis will maintain control of the Site for the foreseeable future, as stated in the UC Davis 2003 Long-Range Development Plan (LRDP) (UC Davis, 2003). However, land-use covenants would be drafted by DTSC and recorded with Solano County. Since contact with PAHs in this area also poses a risk to construction workers, signage would be posted to identify the potential subsurface hazards and contact information.

Ground water monitoring and institutional controls will be performed for 30 years.

Cost:

- Capital Cost: $158,000
- Present Worth O&M Cost: $92,000
- Periodic Costs: $10,000
- Total Present Worth Cost: $260,000

4.7.2.3 Alternative 3—Cap, Long-Term Ground Water Monitoring and Land-Use Restrictions

In addition to implementing long-term ground water monitoring and land-use restrictions as described in Alternative 2, Alternative 3 will include capping the DSS 4 leach trench and distribution box area to prevent the downward migration of selenium through the vadose zone to ground water and to protect workers from exposures to PAH contamination. There are two areas to be capped, one each on the west and east sides of Building H-215 (Figure 4-15). The proposed cap areas cover the extent of the leach trenches, the assumed source of contamination, that is outside the footprint of Building H-215. Contamination has been confirmed east of the building, but no samples have been collected west of the building to confirm or refute contamination there. If Alternative 3 is selected for the DSS 4 area, DOE would likely propose that additional samples be collected on the west side of the building before the cap was placed.

The cap will consist of an asphalt surface, gravel base and an underlying HDPE liner that will cover a 702-square ft area (Figure 4-15). Surface soil will be removed from the Site to prepare for installation of the asphalt and gravel base materials. The removed soil will be sampled and profiled for disposal. The waste will likely be accepted by a Class III landfill, because it will originate from overburden that has not come in contact with DSS 4 leachate. The cap will consist of a 40-mil HDPE liner overlain by eight inches of compacted gravel base material and four inches of asphalt pavement. The liner and pavement will be sloped to direct storm water runoff away from the area. The cap's condition will be visually inspected on an annual basis and maintenance (i.e., asphalt overlay) is expected every 10 years. A land-use restriction will be recorded to document the cap area and to prohibit site development activities that would affect the cap's performance.

Institutional controls will be maintained indefinitely. Long-term ground water monitoring and cap maintenance will be performed for 30 years.

Cost:

- Capital Cost: $302,000
- Present Worth O&M Cost: $113,000
- Periodic Costs: $17,000
- Total Present Worth Cost: $432,000

4.7.2.4 Alternative 4—Removal, Off-Site Disposal and Institutional Controls

The scope of Alternative 4 is to remove and dispose of the accessible contaminated soil at the DSS 4 leach field (Figure 4-16). The accessible contamination lies outside the footprint of Building H-215. The portion of the leach field that underlies Building H-215 will not be removed. The distribution box will be removed to access contamination below it. The areas to be excavated are on both the west and east sides of Building H-215 (Figure 4-16). Contamination has been confirmed east of the building, but no samples have been collected west of the building to confirm or refute contamination there. If Alternative 4 is selected for the DSS 4 area, DOE would likely propose that additional samples be collected on the west side of the building before the excavation was begun.

Land-use restrictions will be implemented for the inaccessible portions of the leach trenches that extend below Building H-215. These trench sections have not been sampled, but are assumed to contain PAH contamination at levels that exceed 10^{-6} risk to residential receptors. A deed property restriction would be recorded with Solano County using a surveyed map showing the restricted area in the parcel's legal description and the inaccessible trench.

The overburden that lies above the accessible leach trenches is assumed to be clean, and will be removed and stored for reuse as backfill material. The distribution box and contaminated soil will then be removed and stockpiled separately. The distribution box will be rubblized on site and the contaminated soil and distribution box will be sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. DSS 4 sample data indicate that the distribution box and contaminated soil do not contain added radioactivity and could be disposed at a Class II industrial waste landfill.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. The excavation will be filled and compacted with the overburden and imported fill from an off-site source.

All of the costs are expected to occur in the present time frame and no annual or periodic costs were assumed.

Cost:

- Capital Cost: $547,000
- Present Worth O&M Cost: $0
- Periodic Costs: $0
- Total Present Worth Cost: $547,000

4.7.3 Analysis of Remedial Alternatives

Table 4-5 summarizes the analysis of remedial alternatives. The detailed analysis of remedial alternatives is presented below.

4.7.3.1 Alternative 1—No Action

4.7.3.1.1 Overall Protection of Public Health and the Environment

Under no action, the residential risk greater than 10^{-4} is not addressed. However, the construction worker risk, which is slightly above 10^{-6}, falls within the CERCLA acceptable range (i.e., 10^{-4} to 10^{-6}).

The PAH contamination is believed to originate from a tar coating on the drain tile in the DSS 4 leach trench. The mass of contamination is likely small and is not expected to have migrated significantly below the pipe, because PAHs are relatively immobile compounds in soil due to their high soil/water partitioning coefficient (K_d).

The ground water COC, selenium, is present above background in soil and has been detected infrequently in downgradient HSU-1 ground water. Under no action, future selenium ground water concentration trends will not be monitored.

4.7.3.1.2 Compliance with ARARs

Alternative 1 may not comply with the State's Anti-Degradation Policy and Basin Plan, since this alternative does not address future ground water protection. As discussed above, this area is a possible source of contaminants currently present in ground water.

4.7.3.1.3 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long term, because the estimated risk to hypothetical future residential receptors is currently greater than 10^{-4} and localized known ground water impacts will not be monitored. However, the risk to the hypothetical construction worker is slightly above 10^{-6} and falls within the CERCLA acceptable range (i.e., 10^{-4} to 10^{-6}).

The PAHs, which drive this human health risk, are not likely to degrade significantly without intervention, because the source (tar-coated drain tile) has not been removed. Selenium is a ground water COC that is not predicted to impact ground water based on the NUFT modeling results. The soil and ground water data indicate the long-term selenium impact will be small or none. Without ground water monitoring, it is impossible to confirm these predictions.

4.7.3.1.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 1, toxicity, mobility or volume is not reduced. The COCs will not degrade significantly in a reasonable amount of time.

4.7.3.1.5 Short-Term Effectiveness

Alternative 1 adds no short-term impacts to the community, workers or the environment. The estimated human health risk is for hypothetical future residential receptors and construction workers. The Site is currently used as a research facility, and UC Davis does not have any short-term plans for residential land use or construction projects in the vicinity of DSS 4 PAH contamination.

4.7.3.1.6 Implementability

There are no barriers to implementing Alternative 1.

4.7.3.1.7 Cost

The cost of Alternative 1 is $0.

4.7.3.1.8 State Acceptance

The State of California has not accepted Alternative 1 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.7.3.1.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their non-acceptance of this alternative during the public comment period for the Proposed Plan.

4.7.3.2 Alternative 2—Long-Term Ground Water Monitoring, Land-Use Restrictions and Contingent Remedial Action

4.7.3.2.1 Overall Protection of Public Health and the Environment

Alternative 2 protects the public from exposure to PAHs by implementing land-use restrictions to prevent residential and construction worker exposure to subsurface soil contamination at the Site. The effectiveness of land-use restrictions depends on the reliability of continued future implementation.

As with Alternative 1, Alternative 2 may result in ground water impacts. Alternative 2 manages the potential future loss of beneficial use of ground water by installing a nearby downgradient well and implementing a ground water monitoring program. The new well would detect any ground water impact earlier than the existing downgradient wells and provide better data for comparison to the NUFT model predictions. If future monitoring indicates that conditions are not protective, other remedial actions could be undertaken, such as ground water extraction and treatment.

4.7.3.2.2 Compliance with ARARs

Alternative 2 complies with ARARs. The ground water monitoring program provided in Alternative 2 is designed to confirm whether selenium impacts are continuing, and provide data to assess whether additional remedial measures are required.

4.7.3.2.3 Long-Term Effectiveness and Permanence

Alternative 2's long-term effectiveness in protecting human health depends largely on successful future implementation of the land-use restrictions. Although the restrictions on residential construction are intended to be permanent, these restrictions may fail if the restrictions are overlooked.

Alternative 2 is effective in protecting ground water due to the negligible mass and toxicity of residual selenium in soil. NUFT modeling results predict selenium will not impact ground water, and the soil and ground water data do not indicate significant impact. Ground water plume predictions were prepared to evaluate long-term effectiveness under Alternative 2. The plume size estimates were based on complete contaminant transfer to HSU-1. The estimated plume areas and diameters are summarized in Table 1-1, and the calculations are presented in Appendix E. The calculations indicate that the selenium plume would be much less than an acre in area. Effectiveness will be confirmed with monitoring and management controls. The long-term ground water monitoring program would be used to evaluate any potential impacts and remedial measures would be implemented if ground water contamination was verified.

4.7.3.2.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 2, toxicity, mobility or volume is not reduced.

4.7.3.2.5 Short-Term Effectiveness

Except for minimal disturbance due to the installation of a new well, Alternative 2 results in no impacts to the community, workers or the environment. The land-use restrictions will likely be effective at preventing residential development in the near future.

The ongoing effectiveness of this alternative will be confirmed by long-term ground water monitoring. However, if monitoring results trigger an evaluation of remedial alternatives, the time until each alternative is protective will be presented in an addendum to the Remedial Action Work Plan.

Contingent remedial action will be considered protective when groundwater is cleaned up to background concentrations, or if background concentrations are not technically or economically feasible, water quality objectives protective to one-in-a-million cancer risk or the lowest water quality objective applicable for the constituent/s of concern.

4.7.3.2.6 Implementability

Permission will need to be granted by UCOP to implement land-use restrictions. UC Davis has indicated that land-use restrictions are acceptable under a specific set of conditions (UC Davis, 2006a). Discussions between DOE and UCOP may be required to address the effort required to administer and implement the land-use restrictions. The UC Davis ORMP would implement the land-use restrictions. The restriction on residential development due to contamination is not an established practice for the UC Davis ORMP, but no barriers to implementing the land-use restrictions were identified.

Alternative 2 utilizes standard monitoring techniques that are currently deployed at the Site and relies on standard services and materials. Standard records management and database activities are required.

4.7.3.2.7 Cost

The anticipated capital and O&M costs for Alternative 2 are $260,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.7.3.2.8 State Acceptance

The State of California has accepted Alternative 2 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.7.3.2.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.7.3.3 Alternative 3—Cap, Long-Term Ground-Water Monitoring and Land-Use Restrictions

4.7.3.3.1 Overall Protection of Public Health and the Environment

The beneficial use of ground water is protected by limiting meteoric water infiltration through surface capping and monitoring ground water near the source area. The physical barrier and development restrictions provided by the cap mitigate direct worker exposure to underlying contaminants. The cap is expected to mitigate ground water impacts by reducing selenium mobility in the vadose zone. A new monitoring well would be used to confirm the long-term effectiveness of the cap. The cap would be regularly inspected and periodically maintained to ensure its protectiveness over time. If future monitoring indicates that the cap has not been protective, other remedial actions could be undertaken, such as *in situ* treatment or extraction and treatment.

Alternative 3 protects hypothetical future residential receptors and construction workers from human health risk by implementing land-use restrictions. Deed restrictions maintain and prevent disturbances of the cap.

4.7.3.3.2 Compliance with ARARs

Alternative 3 complies with ARARs. A monitoring program will be used to confirm the cap's performance over time.

4.7.3.3.3 Long-Term Effectiveness and Permanence

Alternative 3 is effective in protecting ground water due to the negligible mass and toxicity of residual contamination in soil. Effectiveness is confirmed with monitoring and management controls.

Alternative 3 is expected to be effective in the long term for protecting ground water from selenium contamination. The installation of a surface cap will mitigate ground water impacts related to the entrainment of residual contaminants in infiltrating meteoric water. Infiltration is currently the primary transport mechanism for contaminants in the vadose zone to reach ground water. After the cap is installed, diffusion processes will continue, but the transport rates should be markedly reduced. Regular inspections and periodic maintenance will be required to ensure long-term performance of the cap. Implementation of inspections and maintenance over long periods of time is uncertain. If the cap is allowed to deteriorate, the long-term effectiveness and permanence of Alternative 3 is the same as Alternative 2.

The long-term effectiveness of Alternative 3 for protecting human health is identical to Alternative 2, except that the cap provides slightly more protection by providing a physical barrier that makes contact with the PAHs more difficult.

4.7.3.3.4 Reduction of Toxicity, Mobility or Volume

Although technically not a treatment technology, mobility of the residual contamination is substantially reduced by the cap, which eliminates the infiltration of surface water. Some contaminant migration to the water table will still occur through diffusion. The toxicity and volume of COCs, however, are not reduced.

4.7.3.3.5 Short-Term Effectiveness

Alternative 3 involves the installation of asphalt pavement. There are discernable environmental and health risks associated with the manufacture, transportation and installation of asphalt. Additional short-term risks to the community and to workers include relatively short-term noise and heavy equipment use. Deployment of the cap system is rapid, since it relies on established engineering design and materials. The impacts to the site personnel due to the installation of the well, as described under Alternative 2, are relatively minor. The land-use restrictions will likely be effective at preventing residential development in the near future. The cap may restrict site development and affect aesthetics. The estimated time to design and install a cap is approximately one year.

4.7.3.3.6 Implementability

The paving procedures for implementing Alternative 3 are routine and technically feasible. There are no physical barriers to mobilizing the paving equipment to the Site. This alternative can be implemented with established engineering design and materials. A small amount of clean soil will be disposed under this alternative, but suitable landfill space or reuse options are available within 30 miles of the Site. Paving equipment and labor are generally available on relatively short notice between the months of May and November in the Davis area.

Permission will need to be granted by UCOP to implement land-use restrictions. UC Davis has indicated that land-use restrictions are acceptable under a specific set of conditions (UC Davis, 2006a). Discussions between DOE and UCOP may be required to address the effort required to administer and implement the land-use restrictions.

The monitoring wells are expected to remain operable for the duration of this alternative. Standard records management and database activities are required.

4.7.3.3.7 Cost

The anticipated capital and O&M costs for Alternative 3 are $432,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.7.3.3.8 State Acceptance

The State of California has accepted Alternative 3 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.7.3.3.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.7.3.4 Alternative 4—Removal, Off-Site Disposal, and Land-Use Restrictions

4.7.3.4.1 Overall Protection of Public Health and the Environment

Alternative 4 protects the beneficial use of ground water by removing all of the accessible soil with PAH concentrations greater than the cleanup-goal concentrations from the Site. The accessible contamination lies in the parts of the leach trenches that are outside the footprint of Building H-215. The portion of the leach trenches that underlie Building H-215 (Figure 4-13) will not be removed, but the risk from this inaccessible contamination will be managed with land-use restrictions.

Off-site disposal will transfer risk to the disposal site and result in some minor short-term transportation risks, including highway accidents and vehicular air emissions. However, the volume of soil that will be disposed is small and the transferred risk to an off-site disposal site is minimal.

The excavation will also remove selenium mass, and the excavation confirmation sampling will provide additional selenium data to better evaluate potential selenium impact. The excavation will remove all of the soil that contained selenium above the background screening value, except one sample location that had 1.3 mg/kg of selenium at 17.8 ft bgs. However, this remaining selenium concentration is only slightly above the soil background screening value (1.2 mg/kg) and likely represents natural conditions. Based on the NUFT model results, the cleanup goal (background impact) to protect ground water from selenium is 4.0 mg/kg (Table 2-2).

4.7.3.4.2 Compliance with ARARs

Alternative 4 is expected to comply with all ARARs. All of the accessible soil that poses human health risk due to PAH contamination will be removed. Risk due to inaccessible PAH-contaminated soil will be managed with land-use restrictions. The excavation will remove selenium in soil and confirmation sampling will verify whether selenium concentrations are present above site background levels.

4.7.3.4.3 Long-Term Effectiveness and Permanence

Alternative 4 is permanently effective for accessible selenium and PAH contamination, because all of the soil at concentrations greater than remediation goals will be removed. The contaminant mass is small and should be easily controlled in a permitted disposal facility. Inaccessible PAH contamination below Building H-215 will be managed using land-use restrictions, which may fail over time as discussed under Alternative 2 (Section 4.7.3.2.3).

4.7.3.4.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4, the toxicity and volume of nearly all of the accessible soil with contaminant concentrations greater than cleanup-goal concentrations are removed. The toxicity and volume of inaccessible PAH-contaminated soil will not be reduced. However, the exposure and mobility of inaccessible contamination is currently minimized due to surface coverage by the Building H-215 foundation.

4.7.3.4.5 Short-Term Effectiveness

Minor short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal site. The local community would only be impacted by two truckloads of soil over a short period (1 or 2 days). Off-site disposal has some negative impacts, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 8.18×10^{-6}. The estimated risk of a fatality due to waste transport air emissions is 1.8×10^{-6}. The radiation dose to the public was not estimated because radiological constituents are below Site background at DSS 4. The procedures used to estimate these negative impacts are described in Section 5. Localized noise and vibration impacts at the Site would last a few weeks during the remedial action and on-site research activities may be slightly impacted. Air monitoring, dust control and personal protective equipment are required. The time to complete the excavation is fairly certain due to the relatively shallow depth and standard excavation techniques required. Workers will be exposed to heavy equipment hazards, and fall and burial hazards inherent to any excavation. The institutional controls will likely be effective at preventing residential development at the location of inaccessible PAHs in the near future.

The estimated time required to remove and dispose the contaminated soil is approximately one year.

4.7.3.4.6 Implementability

The excavation and disposal methods are technically feasible and are used routinely in construction. Excavation equipment is readily available. Site preparations are minimal; underground sewer and electrical conduits are located nearby, but should only be minimally affected by the excavation activities. Transportation and disposal of the contaminated material will require routine waste acceptance, as the material is not radioactive, and therefore can be shipped to a local landfill. Suitable landfill space is expected to remain available during the remedial action. Standard records management and database activities are required.

The UCOP would need to approve the land use restrictions as discussed in Alternative 2 (Section 0). Deed restrictions would be recorded with Solano County and the UC Davis ORMP would implement a restriction on residential development at the locations of PAH contamination that will be left in place.

4.7.3.4.7 Cost

The anticipated capital and O&M costs are $547,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.7.3.4.8 State Acceptance

The State of California has accepted Alternative 4 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.7.3.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.7.4 Comparative Evaluation of Remedial Alternatives

4.7.4.1 Overall Protection of Public Health and the Environment

Alternative 1 is not protective of public health, because it does not address the risk to hypothetical future site residents and construction workers. The estimated risk is greater than 10^{-6} due to concentrations of PAHs in soil below the DSS 4 leach trench. Additionally, Alternative 1 doesn't address the potential loss of beneficial use of ground water from residual selenium.

Alternatives 2 and 3 provide markedly more protection than Alternative 1 by including ground water monitoring and land-use restrictions. Land-use restrictions and signage are used to restrict future exposure to residual contamination by prohibiting access to the public (residents and construction workers). A new monitoring well would detect local ground water impact and produce data to verify the ground water model's predictions of no impact.

Alternative 3 provides additional protection for ground water over Alternative 2 by reducing selenium mobility in the vadose zone. There are also slight improvements for human health protection over Alternative 2, since the cap provides a physical barrier above the subsurface contaminants. However, Alternative 2 provides contingent remediation if additional protection is deemed necessary based on future monitoring results.

Alternative 4 does not rely on land-use restrictions and permanently protects human health from the accessible PAH contamination by removing all of the accessible contaminated soil. The inaccessible PAH contamination located below Building H-215 will not be removed, but the risk from this contamination will be managed with land-use restrictions. The excavation activities will remove selenium and only background levels will likely remain in accessible areas.

4.7.4.2 Compliance with ARARs

Alternatives 1, 2, 3 and 4 comply with the State's Anti-Degradation Policy and Basin Plan because the only potential ground water impact constituent, selenium, has little potential to significantly impact ground water. In general, Alternatives 2 through 4 provide progressively greater protection to ground water. However, it is possible that the current conditions are already protective. Alternative 3 involves installing a cap to reduce contaminant mobility and improve assurance of compliance with the State's Anti-Degradation Policy and Basin Plan. Because the contaminant mass is not removed, however, the contamination may eventually impact ground water.

4.7.4.3 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long term, because localized known ground water impacts will not be monitored and it does nothing to manage or reduce human health risk. In contrast, Alternatives 2, 3 and 4 reduce risk by implementing land-use restrictions. Alternative 4 achieves greater permanence that Alternatives 2 and 3 since accessible contamination is removed.

Based on the NUFT model results for selenium, and the concentrations of selenium in soil and ground water, all of the alternatives are likely to protect ground water. Alternatives 2 and 3 will provide added ground water protection through local monitoring. The cap in Alternative 3 will reduce the migration rate of selenium toward ground water, but will not provide a long-term advantage over Alternative 2 if the cap is not maintained. Alternative 4 is likely a permanent solution for selenium in accessible areas, because the excavation will remove all but one location that was slightly above the background screening value. However, there are no data to confirm that selenium is not present beneath Building H-215.

4.7.4.4 Reduction of Toxicity, Mobility or Volume

There is no direct reduction of toxicity, mobility or volume under either Alternatives 1 or 2. Although capping (Alternative 3) is not a treatment technology, it should still be evaluated for this criterion because capping will reduce selenium mobility by preventing infiltration. Under Alternative 4, the toxicity and volume of selenium and accessible PAHs will be reduced by removal. The toxicity and volume of inaccessible selenium and PAHs will not change under Alternative 4, but the mobility of the inaccessible selenium and PAHs will be reduced as long as Building H-215 remains, since it limits the infiltration of meteoric water.

4.7.4.5 Short-Term Effectiveness

Neither Alternatives 1 nor 2 result in any significant short-term impacts to the public, workers or the environment.

Alternative 3 involves the installation of asphalt pavement. There are minor environmental and health risks associated with air emissions during the manufacture, transportation and installation of asphalt. Additional short-term impacts to the community and to workers include noise and heavy equipment use over a period of approximately two weeks. Deployment of the cap system is rapid, since it relies on established engineering design and materials.

Alternative 4 produces the most significant short-term impact, but they remain relatively minor. Construction activities are expected to take about three weeks, followed by two days of waste shipping. The local community would only be impacted by the shipment of two truckloads of soil. Off-site disposal has negative impacts associated with it, including transfer of risk, air emissions and potential highway accidents. Localized noise and vibration impacts at the Site would last a few weeks during the remedial action, and on-site research activities may be slightly impacted. Air monitoring, dust control and personal protective equipment are required. The time to complete the excavation is fairly certain due to the relatively shallow depth and standard excavation techniques required. Workers will be exposed to heavy equipment hazards, and fall and burial hazards inherent to any excavation.

The period to achieve short-term effectiveness is not applicable to Alternative 1 because there is no metric to evaluate its effectiveness. Alternative 2 appears to be effective in the short term based on current site data. The ongoing effectiveness of Alternative 2 will be confirmed by long-term ground water monitoring. Alternatives 3 and 4 are expected to meet their objectives in approximately one year, because they use proven rapid construction technologies.

4.7.4.6 Implementability

There are no barriers to implementing Alternative 1. From an administrative standpoint, standard records management and database activities will be required for Alternatives 2 and 3. Alternative 3's cap installation and Alternative 4's excavation of contaminated soil are routine and technically feasible. Alternatives 2, 3 and 4 restrict site development, which will require negotiations between DOE and UCOP.

4.7.4.7 Costs

The anticipated capital and O&M costs for the alternatives are:

- Alternative 1 (no action): $0
- Alternative 2 (ground water monitoring and land-use restrictions): $260,000
- Alternative 3 (cap, long-term ground water monitoring and land-use restrictions): $432,000
- Alternative 4 (removal, off-site disposal and land-use restrictions): $547,000

Detailed cost assumptions are presented in Appendix A.

4.7.4.8 State Acceptance

With the exception of the no action alternative, the State of California has accepted all of the alternatives.

A preferred remedial alternative will be presented in the Draft Proposed Plan. State of California acceptance of the preferred remedial alternative will be provided after resolution of their comments on the Draft Proposed Plan.

4.7.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on the accepted alternatives during the public comment period for the Proposed Plan.

4.8 Domestic Septic System No. 5

4.8.1 Nature and Extent of Contaminants of Concern

DSS 5 has no human health or ground water-impact COCs (Tables 2-1 and 2-2).

4.8.2 Description of Remedial Alternatives

4.8.2.1 Alternative 1—No Action

A no action alternative was developed for DSS 5 to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.8.3 Analysis of Remedial Alternatives

The remedial alternative for DSS 5 was evaluated against the nine criteria described in Section 4.2.1 of the text. The evaluation of individual remedial alternatives is identical to the evaluation conducted for DSS 1 in Section 4.5.3. The evaluation summary is presented in Table 4-6.

4.9 Domestic Septic System No. 6

4.9.1 Nature and Extent of Contaminants of Concern

DSS 6 was located east of Animal Hospitals 1 and 2 (Figure 1-2) and consisted of a septic tank attached to a distribution box with two effluent lines leading north and south to perforated pipes set in gravel. Analytical results for site characterization samples collected from the DSS 6 area before the removal action indicated mercury was the primary contaminant of concern. Mercury was above background and the site-specific PRG in 31 of 34 soil samples and its concentration ranged from 0.13 to 101 mg/kg. Some of the pre-removal action soil samples collected at DSS 6 also indicated concentrations of hexavalent chromium, barium and copper slightly above background and the site-specific PRGs.

In 2002, a removal action was conducted according to an approved work plan (WA, 2002a) to reduce the mercury, hexavalent chromium, barium and copper contamination that potentially posed a human health risk. During the removal action all effluent lines associated with DSS 6 were removed, along with the perforated pipe and leach trench gravel. Approximately one foot of soil was removed from the trench floor and sidewalls. The excavation depth ranged from six to seven feet bgs and was 11 feet wide by 105 feet long. The DSS 6 Septic Tank and attached distribution box were not removed, because the concrete sample collected from the bottom of the tank showed no significant contamination. Approximately 215 cubic yards of piping, gravel and underlying soil were shipped for off-site disposal.

Twenty-three confirmation grid samples and four discretionary samples were collected from the DSS 6 excavation and analyzed for hexavalent chromium, barium, copper and mercury. The highest remaining mercury concentration was 8.0 mg/kg beneath the former northeastern leach line. After the removal action the 95 % upper confidence limit for mercury was 1.85 mg/kg. Concentrations of hexavalent chromium, barium and copper were lower after the removal action. The sample results representing post-removal action conditions, including the mercury, hexavalent chromium, barium and copper data, were used in the Site-Wide Risk Assessment to determine human health risk, ecological risk and ground water impacts. The risk assessment results were evaluated in the approved Risk Characterization Report (WA, 2005) and showed DSS 6 does not pose significant risk to human health or ecological receptors and there are no current or predicted ground water impacts. Mercury, hexavalent chromium, barium and copper are no longer COCs at DSS 6, and DSS 6 has no COCs for evaluation in the Feasibility Study.

4.9.2 Description of Remedial Alternatives

4.9.2.1 Alternative 1—No Action

A no action alternative was developed for DSS 6 to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no further action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.9.3 Analysis of Remedial Alternatives

The remedial alternative for DSS 6 was evaluated against the nine criteria described in Section 4.2.1 of the text. The evaluation of the individual remedial alternative is identical to the evaluation conducted for DSS 1 in Section 4.5.3. The evaluation summary is presented in Table 4-7.

4.10 Domestic Septic System No. 7

4.10.1 Nature and Extent of Contaminants of Concern

DSS 7 has no human health or ground water-impact COCs (Tables 2-1 and 2-2).

4.10.2 Description of Remedial Alternatives

4.10.2.1 Alternative 1—No Action

A no action alternative was developed for DSS 7 to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.10.3 Analysis of Remedial Alternatives

The remedial alternative for DSS 7 was screened against the nine criteria described in Section 4.2.1 of the text. The evaluation of the individual remedial alternative is identical to the evaluation conducted for DSS 1 in Section 4.5.3. The evaluation summary is presented in Table 4-8.

4.11 Domestic Septic System Nos. 1 and 5 Leach Field (Dry Wells A through E)

4.11.1 Nature and Extent of Contaminants of Concern

Chromium, Cr-VI, mercury, molybdenum, silver, Cs-137 and Sr-90 contained in soil are ground water COCs (Table 2-2). No human health risk COCs were identified.

4.11.1.1 Chromium in Soil

Total chromium was above background in one of 41 soil sample results (2.4 percent) in the Dry Wells A-E area. The elevated sample (245 mg/kg) was collected next to Dry Well C (Figure 4-17) at a depth of 40 ft bgs. The background screening value for chromium is 181 mg/kg. The lateral and vertical spatial distribution appears random (WA, 2005). With the exception of one elevated result at 40 ft bgs, the chromium concentration profile does not appear to vary significantly throughout the total depth explored (5 ft to 40 ft bgs). The chromium background study results indicated that chromium concentrations decrease with depth. Dry Wells A-E chromium data do not reflect the expected natural decrease in chromium concentration with depth. Deep Dry Wells A-E area soil is likely contaminated with chromium.

Hexavalent chromium was above background in two of 32 soil sample results (6 percent) in the Dry Wells A-E area. The two elevated samples were collected next to Dry Wells C and E, and had Cr-VI concentrations of 1.62 mg/kg and 1.37 mg/kg, respectively. The elevated concentrations were only slightly above the background screening value of 1.3 mg/kg. The lateral spatial distribution appears random, but Cr-VI concentrations appear to increase slightly with depth. The highest detected concentration was located at 32 ft bgs, and the next-highest concentration was located at 40 ft bgs.

4.11.1.2 Mercury in Soil

Mercury was above background in nine of 41 soil sample results (22 percent) in the Dry Wells A-E area. Samples with elevated mercury results were located next to Dry Wells A, C and D. Mercury was below the background screening value (0.63 mg/kg) at Dry Wells B and E, and the distribution box and piping. The highest reported mercury concentration was 5.3 mg/kg in sample SSSTC007 located at Dry Well D at a depth of 20 ft bgs. Four of the elevated concentrations were located deeper than 30 ft bgs. The background study results indicated that mercury concentrations decrease with depth. Dry Wells A-E mercury concentrations do not reflect the expected natural decrease in concentrations with depth. The data indicate mercury contamination in deep subsurface soil.

4.11.1.3 Molybdenum in Soil

Twenty-nine of 37 molybdenum results (78 percent) were above background in the Dry Wells A-E area. Elevated concentrations were found in soil samples collected at all of the Dry Wells

A-E area features. The highest molybdenum concentration was 1.3 mg/kg in sample SSDWC033 collected next to Dry Well D at a depth of 40 ft bgs. The vertical profile of molybdenum concentrations is uniform between 5 ft and 20 ft bgs, and then increases slightly with depth down to 40 ft bgs. Molybdenum contamination is present throughout the subsurface soil column.

4.11.1.4 Silver in Soil

Silver was above background in 28 of 41 soil sample results (68 percent) at the Dry Wells A-E area. Elevated concentrations were found in soil samples collected at all of the Dry Wells A-E area features, except the piping. The highest silver concentration was 53.8 mg/kg in sample SSDWC013 collected next to Dry Well C at a depth of 40 ft bgs. Twelve of the elevated results (6.4 mg/kg to 53.8 mg/kg) were more than an order of magnitude above the background screening value for silver (0.55 mg/kg). The vertical profile of silver concentrations is uniform between 5 ft and 20 ft bgs, and then decreases between 20 ft and 40 ft bgs. The exception in this vertical profile is the maximum concentration, which stands out as a single elevated result located at 40 ft bgs. Based on the soil concentrations, silver contamination is present in deep subsurface soil. However, most of the silver contamination is located in the vadose zone (<20 ft bgs).

4.11.1.5 Cesium in Soil

Sixteen of 32 Cs-137 results (50 percent) were above background in the Dry Wells A-E area. Elevated concentrations were found in soil samples collected at each dry well. Cs-137 was below background in soil samples collected at the distribution box and piping. The highest Cs-137 concentration was 0.191 ± 0.0078 pCi/g in sample SSDWC008 collected next to Dry Well A at a depth of 40 ft bgs. The vertical profile of Cs-137 concentrations is lowest at 20 ft bgs, and higher at the top and bottom of the soil column. The two highest Cs-137 concentrations (0.161 ± 0.0163 pCi/g and 0.191 ± 0.0078 pCi/g) were in soil samples located at 40 ft bgs.

4.11.1.6 Strontium-90 in Soil

Sr-90 was above background in thirteen of 28 soil sample results (46 percent) at the Dry Wells A-E area. Elevated concentrations were found in soil samples collected at Dry Wells A, B, C, E and the distribution box. Sr-90 was below background (0.056 pCi/g) in soil samples collected at Dry Well D. The highest Sr-90 concentration was 0.176 ± 0.0132 pCi/g in sample SSDWC013 collected next to Dry Well C at a depth of 40 ft bgs. The vertical profile of Sr-90 concentrations appears nearly uniform in the vertical plane throughout the total depth explored (5 ft to 40 ft bgs).

4.11.1.7 Ground Water

A ground water investigation was conducted at the Dry Wells Area in December of 2003. Grab ground water samples were collected at downgradient locations from HSU 1 and HSU 2 and analyzed for chromium, Cr-VI, mercury, molybdenum, silver, Cs-137 and Sr-90. Mercury and molybdenum were the only constituents detected above background in the grab ground water samples. However, the mercury result was likely biased high because it was not filtered prior to analysis. Well UCD1-054 was installed in February 2004, and ground water monitoring samples were collected during all four quarters of 2004. Molybdenum was the only COC detected above background in the ground water monitoring samples. The Dry Wells ground water investigation report is provided in Appendix C.

Ground water that is downgradient of the Dry Wells A-E area has been sampled for COCs between October 1990 and the present. Ground water from HSU1 has been sampled in well UCD1-054 since 2004. Ground water from HSU2 has been sampled in wells UCD2-007 and UCD2-036 (listed with increasing distance from the Dry Wells A-E area). Figure 4-1 shows the relative locations of wells to the Dry Wells A-E area. Graphs illustrating the concentrations of COCs in these three wells through time are in Appendix F, with the exception of those graphs that would show fewer than five detected results and no detected results greater than MCLs. Included in each graph is a simple linear regression calculation, represented by a dashed line, to assist the reader in evaluating the overall trend of the COC in ground water.

Chromium concentrations in HSU1 downgradient of the Dry Wells A-E area has generally been far below the MCL of 50 µg/L. In well UCD1-054, chromium has historically been at concentrations below 6 µg/L (Figure F-21). Three samples collected in the summer of 2006, however, yielded highly variable results, including one result greater than 100 µg/L. This well will be resampled for chromium in the near future, and these highly variable concentrations will be reevaluated then. In HSU2, chromium concentrations downgradient of the Dry Wells A-E area are higher than they are in HSU1. In UCD2-007, the concentration of chromium has been somewhat variable through time, often exceeding the MCL (Figure F-26). In the last five years, however, exceedence of the MCL has been rare, restricted to two extremely high concentrations in 2004 and one in the summer of 2006. These exceedences force the simple linear regression calculation to indicate that chromium concentrations are increasing through time. In well UCD2-036, the concentration of chromium has consistently been below the MCL (Figure F-37). The chromium concentration appears to have peaked in late 2001, after which it appears to have been decreasing. The increasing trend prior to 2001 is probably what forces the simple linear regression calculation to reflect an overall increasing trend.

Hexavalent chromium has not been detected at concentrations greater than its MCL of 50 µg/L in HSU1 downgradient of the Dry Wells A-E area. In well UCD1-054, there has been only one detection, at a concentration of 7.35 µg/L. In HSU2, the concentration of hexavalent chromium is different in the two downgradient wells. In well UCD2-007, the concentration of hexavalent chromium has been highly variable through time, often exceeding the MCL (Figure F-27). In well UCD2-036, the concentration of hexavalent chromium has consistently been below the MCL (Figure F-38). Although the simple linear regression calculation reflects an increasing trend through time in this latter well, this result is caused by the concentrations in recent samples; these concentrations were higher than the average concentrations historically, but still within the range of historical hexavalent chromium concentrations.

Molybdenum concentrations in HSU1 and HSU2 downgradient of the Dry Wells A-E area are far below the PRG of 180 µg/L (Figures F-22, F-28 and F-39). Furthermore, the simple linear regression calculations reflect decreasing concentrations of molybdenum in both hydrostratigraphic units.

Mercury, silver, Cs-137 and Sr-90 have not been detected at concentrations greater than their respective MCLs, in either HSU1 or HSU2 downgradient of the Dry Wells A-E area. Mercury has been detected only once in the downgradient wells, at 0.68 µg/L in well UCD2-007. The MCL for mercury is 2 µg/L. Silver has been detected only once in the downgradient HSU1 well, at 2.5 µg/L. The highest detection of silver in a downgradient HSU2 well was 20 µg/L in well UCD2-007. The Secondary MCL for silver is 100 µg/L. Cs-137 has been detected only once in the downgradient HSU1 well, at 2.15 ± 1.44 pCi/L. Cs-137 has not been detected in the downgradient HSU2 well. The MCL for Cs-137 is 200 pCi/L. Sr-90 has been detected only once in the downgradient HSU1 well, at 0.51 ± 0.282 pCi/L. The highest detection of Sr-90 in a downgradient HSU2 well was 5.7 ± 0.9 pCi/L in well UCD2-007. The MCL for Sr-90 is 8 pCi/L.

4.11.2 Description of Remedial Alternatives

4.11.2.1 Alternative 1—No Action

A no action alternative was developed for the Dry Wells A through E area to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no further action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.11.2.2 Alternative 2—Long-Term Ground Water Monitoring and Contingent Remedial Action

The second alternative developed for the Dry Wells A through E area consists of performing long-term ground water monitoring. Ground water monitoring will consist of annually sampling well UCD1-054 (Figure 4-1) for chromium, Cr-VI, mercury, molybdenum, silver, Cs-137 and Sr-90. Monitoring results will be reported in the UC Davis annual ground water monitoring reports and evaluated in CERCLA five-year reviews. Four consecutive ground water sample results that exceed site background and show an increasing or constant concentration trend would trigger an evaluation of remedial options. Well UCD1-54 (Figure 4-1) is the proposed compliance monitoring well.

Costs:

- Capital Cost: $10,000
- Present Worth O&M Cost: $125,000
- Periodic Costs: $10,000
- Total Present Worth Cost: $145,000

4.11.2.3 Alternative 3—Cap, Long-Term Ground Water Monitoring and Land-Use Restrictions

In addition to long-term ground water monitoring described in Alternative 2, the third alternative includes capping the Dry Wells area to inhibit downward migration of residual contaminants through the vadose zone to ground water. Capping will eliminate surface water infiltration, which is the primary mechanism for downward contaminant migration. Subsurface diffusion will become the primary contaminant transport mechanism in the absence of infiltration.

The cap will consist of an asphalt surface, gravel base and an underlying HDPE liner that will cover a 3,567 square ft area (Figure 4-18). The cap will cover the Dry Wells area and extend west of the fence line into the adjacent storm water drainage ditch. The cap will cover the storm water drainage ditch to prevent infiltration of storm water runoff that tends to pond in the ditch. Because the Dry Wells area is used for service vehicle traffic and parking, the eastern portion of the cap (east of the fence line) will be designed to comply with UC Davis Campus Standard 02500, Paving (UC Davis, 1995). Asphalt and gravel base will be removed from the cap area that is currently a parking lot and service route. Soil will also be removed from the Site to prepare for installation of the cap. Import fill soil that was previously placed within the 1999 Dry Wells area excavation will be removed, and reused on site or disposed off site at a Class III landfill. Native soil will be moved into the excavation and compacted. The cap will consist of a 40-mil HDPE liner overlaid by eight inches of compacted gravel base material and four inches of asphalt pavement. The liner and pavement will be sloped to direct storm water runoff away from the area. The cap's condition will be visually inspected on an annual basis and maintenance (i.e., asphalt overlay) is expected every 10 years. A land-use restriction will be recorded to document the cap area and to prohibit site development activities that would affect the cap's performance.

Long-term ground water monitoring and cap maintenance will be performed for 30 years.

Costs:

- Capital Cost: $241,000
- Present Worth O&M Cost: $146,000
- Periodic Costs: $17,000
- Total Present Worth Cost: $404,000

4.11.2.4 Alternative 4a—Removal and Off-Site Disposal

Alternative 4a removes and disposes all of the soil in the Dry Wells area that contains concentrations of chromium, Cr-VI, mercury, molybdenum, silver, Cs-137 and Sr-90 that are above the cleanup goals. The areas of known contamination that are above the remediation goals are enclosed by the excavation limits shown on Figure 4-19. Contaminated soil in the vicinity of the former distribution box will be removed using conventional excavation (e.g., backhoe). The dry well structures are approximately 30 inches in diameter and will be excavated using 8-ft diameter auger drilling.

Clean fill from the 1999 RA will be removed and stored for reuse as backfill material. The contaminated soil will be removed, stockpiled separately, sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. All of the contaminated soil is assumed to be low-level radioactive waste that would need to be disposed at Envirocare of Utah.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. The dry well excavations will be filled with controlled-density fill (e.g., low-strength concrete). The distribution box excavation will be filled and compacted with clean soil.

All of the costs are expected to occur in the present time frame and no annual or periodic costs were assumed.

Cost:

- Capital Cost: $1,201,000
- Present Worth O&M Cost: $0
- Periodic Costs: $0
- Total Present Worth Cost: $1,201,000

4.11.2.5 Alternative 4b—Limited Removal, Off-Site Disposal and Long-Term Ground Water Monitoring

Alternative 4b will remove and dispose of soil that can be accessed using conventional excavation equipment such as a backhoe. The depth limit of conventional excavation is approximately 20 ft bgs. Soil containing concentrations of chromium, Cr-VI, mercury, molybdenum, silver, Cs-137 and Sr-90 that are above the ground water cleanup goals will be removed unless located deeper than 20 ft bgs. Soil deeper than 20 ft bgs will remain in place.

The lateral excavation limits are the same as Alternative 4a and are shown on Figure 4-20. Clean fill from the 1999 RA will be removed and stored for reuse as backfill material. The contaminated soil will be removed, stockpiled separately, sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. All of the contaminated soil is assumed to be low-level radioactive waste that would need to be disposed at Envirocare of Utah.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. Clean fill from the 1999 RA and new import fill from an off-site source would be used to backfill the excavation. The area will be paved to restore it to its current condition.

Excavation and disposal capital costs are expected to occur in the present time frame. Annual monitoring costs are expected to occur for 30 years, and one periodic cost is expected after 30 years to demolish the monitoring well.

Cost:

- Capital Cost: $708,000
- Present Worth O&M Cost: $125,000
- Periodic Costs: $10,000
- Total Present Worth Cost: $843,000

4.11.3 Analysis of Remedial Alternatives

Table 4-9 summarizes the analysis of remedial alternatives. The detailed analysis of alternatives is presented below.

4.11.3.1 Alternative 1—No Action

4.11.3.1.1 Overall Protection of Public Health and the Environment

Alternative 1 may allow the loss of beneficial use of ground water. Ground water modeling results (WA, 2003) suggest that chromium, Cr-VI, mercury, and silver have the potential to impact ground water above California MCLs, and that molybdenum, Cs-137, and Sr-90 in unsaturated soil have the potential to impact ground water above site background. Predicted molybdenum impacts are below the PRG, predicted Cs-137 impacts are below the federal MCL and predicted Sr-90 impacts are below the California MCL. However, these predicted impacts, with the exception of molybdenum, have not been observed after four quarters of monitoring well UCD1-054, located immediately downgradient of the Dry Wells A-E area. Additionally, the estimated mass of contaminants present is very low and the plume sizes are estimated to be very small (Table 1-1)

4.11.3.1.2 Compliance with ARARs

Alternative 1 does not provide monitoring to demonstrate compliance with the State's Anti-Degradation Policy and Basin Plan.

4.11.3.1.3 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long term since localized known ground water impacts will not be monitored. This alternative lacks management controls to confirm ground water protection.

4.11.3.1.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 1, toxicity, mobility or volume are not significantly reduced. The mass of Cs-137 and Sr-90 will attenuate slowly due to radioactive decay.

4.11.3.1.5 Short-Term Effectiveness

Alternative 1 has no short-term impacts, since there are no current risks and no remedial actions are included. Current ground water monitoring is showing no impacts above MCLs or PRGs.

4.11.3.1.6 Implementability

There are no barriers to implementing Alternative 1.

4.11.3.1.7 Cost

The cost of Alternative 1 is $0.

4.11.3.1.8 State Acceptance

The State of California has not accepted Alternative 1 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.11.3.1.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their non-acceptance of this alternative during the public comment period for the Proposed Plan.

4.11.3.2 Alternative 2—Ground Water Monitoring

4.11.3.2.1 Overall Protection of Public Health and the Environment

Alternative 2 addresses uncertainties associated with future impacts to ground water by monitoring ground water to assess the long-term effectiveness of this alternative. If future monitoring indicates that conditions are not protective, other remedial actions could be undertaken, such as *in situ* treatment or extraction and treatment.

4.11.3.2.2 Compliance with ARARs

Alternative 2 complies with ARARs. Alternative 2 includes monitoring ground water for 30 years to provide data on any future impacts to ground water.

4.11.3.2.3 Long-Term Effectiveness and Permanence

Ground water plume predictions were prepared to evaluate long-term effectiveness under Alternative 2. The plume size estimates were based on complete contaminant transfer to HSU-1. The estimated plume areas and diameters are summarized in Table 1-1 and the calculations are presented in Appendix E. The results indicate that silver is the only COC that might impact HSU-1 over an area greater than one acre. None of the COCs are expected to impact ground water above the MCL (or PRG if no MCL was available) over more than one acre. Predicted plume sizes for hexavalent chromium, molybdenum, Cs-137 and Sr-90 are much less than one acre in area.

Alternative 2 will likely be effective given the limited area of impact for all COCs. The ground water monitoring data indicate molybdenum contamination in the vicinity of Dry Wells A-E. However, the calculated mass of molybdenum contamination and estimated plume area indicate that the long-term molybdenum impact should be insignificant. The collection of ground water data for next 30 years allows continued long-term evaluation of ground water impacts. Ground water monitoring would be conducted at well UCD1-054, which is located immediately downgradient of Dry Wells D and E (Figure 4-1).

4.11.3.2.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 2, toxicity, mobility or volume are not significantly reduced. The mass of Cs-137 and Sr-90 will attenuate slowly to due to radioactive decay.

4.11.3.2.5 Short-Term Effectiveness

No short-term risks to the public or to the environment are anticipated. The ongoing effectiveness of this alternative will be confirmed by long-term ground water monitoring. However, if monitoring results trigger an evaluation of remedial alternatives, the time until each alternative is protective will be presented in an addendum to the Remedial Action Work Plan.

Contingent remedial action will be considered protective when groundwater is cleaned up to background concentrations, or if background concentrations are not technically or economically feasible, water quality objectives protective to one-in-a-million cancer risk or the lowest water quality objective applicable for the constituent/s of concern.

4.11.3.2.6 Implementability

Alternative 2 uses standard ground water monitoring techniques that are currently deployed at the Site. From an administrative standpoint, standard records management and database activities will be required.

4.11.3.2.7 Cost

The anticipated capital and O&M costs for Alternative 2 are $145,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.11.3.2.8 State Acceptance

The State of California has accepted Alternative 2 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.11.3.2.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.11.3.3 Alternative 3—Cap, Long-Term Ground Water Monitoring and Land-Use Restrictions

4.11.3.3.1 Overall Protection of Public Health and the Environment

Alternative 3 includes capping to reduce the rate at which contaminants reach HSU-1. Deed restrictions are included to ensure that the cap is maintained over time. If future monitoring indicates that the cap has not been protective, other remedial actions could be undertaken, such as ground water extraction and treatment.

4.11.3.3.2 Compliance with ARARs

Alternative 3 complies with ARARs. The monitoring component of this alternative will be used to evaluate cap effectiveness.

4.11.3.3.3 Long-Term Effectiveness and Permanence

The addition of a surface cap will mitigate ground water impacts related to the entrainment of residual vadose zone contamination in infiltrating surface water. However, most of the soil contamination at Dry Wells A-E is already at or below the seasonal high-water table depth (about 20 ft bgs) and may be mobilized when the water table rises seasonally. Institutional controls will be required to maintain the cap's integrity over time. The effectiveness of these controls over long periods of time is uncertain.

4.11.3.3.4 Reduction of Toxicity, Mobility or Volume

The cap should reduce the mobility of the residual vadose zone contamination to ground water by eliminating surface water infiltration. Some contaminant migration will still occur through diffusion processes. The cap will not reduce contaminant mass and volume.

4.11.3.3.5 Short-Term Effectiveness

Alternative 3 involves the installation of asphalt pavement. There are minor short-term environmental and health risks associated with the manufacture, transportation and installation of asphalt. Deployment of the cap system is rapid, since it relies on established engineering design and materials. The estimated time to design and install a cap is approximately one year.

4.11.3.3.6 Implementability

The paving procedures for implementing Alternative 3 are routine and technically feasible. There are no physical barriers to mobilizing the paving equipment to the Site. Permission will need to be granted by UCOP to implement land-use restrictions. Negotiations between DOE and UCOP may be required to address the effort required to administer and implement the land-use restrictions. Additionally, the storm water drainage ditch west of the fence line is on Solano County property. Permission must be obtained from the county prior to implementation. A small amount of clean soil will be disposed under this alternative, but suitable landfill space or reuse options are available within 30 miles of the Site. Paving equipment and labor are generally available on relatively short notice between the months of May and November in the Davis area.

4.11.3.3.7 Cost

The anticipated capital and O&M costs for Alternative 3 are $404,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.11.3.3.8 State Acceptance

The State of California has accepted Alternative 3 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.11.3.3.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.11.3.4 Alternative 4a—Removal and Off-Site Disposal

4.11.3.4.1 Overall Protection of Public Health and the Environment

Alternative 4a protects the beneficial use of ground water since all soil with contaminant concentrations greater than the remediation goal is removed and disposed off site. However, off-site disposal will result in transfer of risk to the disposal site and result in short-term transportation risks, including highway accidents and vehicular air emissions.

4.11.3.4.2 Compliance with ARARs

Because the contaminated soil is removed under Alternative 4a, this alternative complies with all ARARs.

4.11.3.4.3 Long-Term Effectiveness and Permanence

Because all of the contamination in soil at concentrations greater than cleanup-goal concentrations is expected to be removed under Alternative 4a, this alternative is permanently effective. The risk associated with the disposed soil should be adequately controlled by standard engineering controls in place at a permitted facility, since contaminant levels are low.

4.11.3.4.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4a, nearly all contaminated soil is removed and transferred to a land disposal site. The residual site toxicity, mobility and contaminated soil volumes should reach negligible levels.

4.11.3.4.5 Short-Term Effectiveness

Discernable short-term risks to the public and the environment are associated with the transport of contaminated soil to the waste disposal site. This alternative will require the transport of more than 63 truckloads of soil over a period of several months. Off-site disposal has several negative impacts associated with it, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 2.58×10^{-3}. The estimated risk of a fatality due to waste transport air emissions is 5.67×10^{-4}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.057 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Additionally, localized noise and vibration impacts at the Site will persist for several months during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent to any deep excavation.

The estimated time required to remove and dispose the contaminated soil is approximately one year.

4.11.3.4.6 Implementability

The excavation methods are technically feasible and are used in the construction of deep foundations. The use of large-diameter augers to conduct dry well excavations has been successfully conducted at the Site at the scale proposed. Significant site preparations are required, including rerouting a sanitary sewer line before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process.

4.11.3.4.7 Cost

The anticipated capital and O&M costs are $1,201,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.11.3.4.8 State Acceptance

The State of California has accepted Alternative 4a as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.11.3.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.11.3.5 Alternative 4b—Limited Removal, Off-Site Disposal and Long-Term Ground Water Monitoring

4.11.3.5.1 Overall Protection of Public Health and the Environment

To mitigate future impacts to ground water, Alternative 4b includes limited removal of contaminated soil followed by ground water monitoring near the source area to confirm long-term effectiveness. Based on existing data, some of the soil with chromium, mercury, molybdenum, silver, Cs-137 and Sr-90 concentrations greater than the remediation goal would be removed and disposed off site. All of the soil containing Cr-VI above the remediation goal would remain because the Cr-VI contamination is located deeper than 20 ft bgs.

Off-site disposal will generate environmental impacts and risks associated with the long-term transfer of risk to the disposal site, as well as short-term transportation risks, including highway accidents and vehicular air emissions.

4.11.3.5.2 Compliance with ARARs

Alternative 4b complies with ARARs. Alternative 4b includes a program to actively monitor ground water for 30 years.

4.11.3.5.3 Long-Term Effectiveness and Permanence

Alternative 4b is not likely to be effective given the presence of deep soil contamination that will remain after excavation. The collection of ground water data for the next 30 years would allow continued long-term evaluation of ground water impacts. Part of the risk associated with this alternative is transferred to the disposal site, but contaminant levels are low and should be easily controlled in a permitted facility.

4.11.3.5.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4b, Cr-VI toxicity, mobility and contaminated soil volume is unchanged, since the Cr-VI-contaminated soil will remain after excavation. A minor reduction of toxicity, mobility and contaminated soil volume will be achieved for chromium, mercury, molybdenum, silver, Cs-137 and Sr-90 toxicity, due to their partial removal.

4.11.3.5.5 Short-Term Effectiveness

Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal site in Utah. The local community will be impacted by the transport of more than 27 truckloads of soil over a period of a few weeks. Off-site disposal has several negative impacts, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 1.1×10^{-3}. The estimated risk of a fatality due to waste transport air emissions is 2.43×10^{-4}. The estimated radiation dose to the maximally exposed public individual (a truck driver) under this alternative is 0.024 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Additionally, localized noise and vibration impacts at the Site will persist for several weeks during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent to excavation.

4.11.3.5.6 Implementability

The excavation methods for implementing Alternative 4b are routine and technically feasible. Significant site preparations are required, including rerouting a sanitary sewer line before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process, as the material will be shipped to Envirocare of Utah. Suitable landfill space is expected to remain available during the remedial action.

This alternative can be implemented with established engineering design and materials. Standard records management and database activities are required.

4.11.3.5.7 Cost

The anticipated capital and O&M costs for Alternative 4b are $843,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.11.3.5.8 State Acceptance

The State of California has accepted Alternative 4b as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.11.3.5.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.11.4 Comparative Evaluation of Remedial Alternatives

4.11.4.1 Overall Protection of Public Health and the Environment

Under Alternative 1, for which no remedial action is taken, some minor ground water impacts may occur. Alternative 3 only marginally reduces contaminant migration to ground water, and therefore is not significantly more protective of ground water than Alternatives 1 and 2. Alternatives 2 and 3 include ground water monitoring to evaluate their long-term effectiveness. If impacts were detected, responses could be implemented to protect ground water though administrative and/or engineering controls, such as ground water extraction and treatment. Alternative 4a removes all soil with contamination at concentrations greater than remediation goals, and therefore fully protects the ground water. Alternative 4b removes some of the contaminated soil but is only slightly more protective of ground water than Alternatives 1, 2 and 3 due to deep concentration. Alternatives 4a and 4b's protection of ground water is offset by the transfer of risk to the disposal site, the addition of transportation risks and the emission of air pollutants from trucks.

4.11.4.2 Compliance with ARARs

Alternatives 1, 2, 3, 4a and 4b comply with ARARs HSU-1 might be locally impacted, as predicted by fate and transport modeling (WA, 2003) and ground water monitoring results.

Alternatives 2, 3 and 4b include long-term ground water monitoring to evaluate any possible non-compliance with ARARs. Alternative 3 involves installing a cap to reduce contaminant mobility and improve assurance of complying with the State's Anti-Degradation Policy and Basin Plan. Under Alternative 4a, all soil with contamination concentrations greater than the remediation goals concentrations is removed, and therefore, this alternative complies with all ARARs.

4.11.4.3 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long term since localized known ground water impacts will not be monitored. Alternatives 2, 3 and 4b may be effective based on current monitoring data showing that only minor molybdenum ground water contamination has resulted from releases that occurred decades ago. Under Alternative 4a, all soil with contamination concentrations greater than the remediation goals concentrations is removed, and therefore, this alternative complies with all ARARs.

4.11.4.4 Long-Term Effectiveness and Permanence

Alternatives 1, 2, 3 and 4b may be effective based on current monitoring data showing that only minor molybdenum ground water contamination has resulted from releases that occurred decades ago. Alternative 4a is the only permanent solution.

4.11.4.5 Reduction of Toxicity, Mobility or Volume

There is no direct reduction of toxicity, mobility or volume under either Alternatives 1 or 2, but the radionuclide COCs, Cs-137 and Sr-90 will slowly decay with time, reducing their toxicity and volume. Under Alternative 3, mobility of the residual vadose zone contamination is marginally reduced by the cap, since most of the contamination is too deep to be influenced by the cap. Although capping (Alternative 3) is not a treatment technology, it should still be evaluated for this criterion because capping can reduce contaminant mobility by preventing infiltration. Under Alternative 4a, all soil with contaminant concentrations greater than the remediation goal is completely removed. Under Alternative 4b, some of the soil with contamination above the remediation goals is removed, but most of the contamination will remain.

4.11.4.6 Short-Term Effectiveness

Neither Alternatives 1 nor 2 would add any short-term impacts to the public, workers or the environment. Alternative 3 involves the installation of asphalt pavement. There are minor environmental and health risks associated with air emissions during the manufacture, transportation and installation of asphalt. Additional short-term impacts to the community and to workers include noise and heavy equipment use. Deployment of the cap system is rapid, since it relies on established engineering design and materials.

Alternatives 4a and 4b produce the most severe impact in the short term. Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal site in Utah. Transportation impacts include local traffic congestion, air emissions and the risk of highway accidents. Site construction impacts, including localized noise and ground vibrations, will persist for several weeks during the remedial action. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment, fall hazards and burial hazards inherent in excavation. The exact time to complete the work for Alternative 4a is uncertain due to the depth and non-standard extraction techniques required.

The period to achieve short-term effectiveness is not applicable to Alternative 1 because there is no metric to evaluate its effectiveness. Alternative 2 appears to be effective in the short term based on current site data. The ongoing effectiveness of Alternative 2 will be confirmed by long-term ground water monitoring. Alternatives 3, 4a and 4b are expected to meet their objectives in approximately one year, because they use proven rapid construction technologies.

4.11.4.7 Implementability

There are no barriers to implementing Alternative 1. There are also no barriers to implementing Alternative 2, as this alternative uses standard ground water monitoring systems and techniques that are currently deployed at the Site. From an administrative standpoint, standard records management and database activities will be required for Alternative 2. The ground water monitoring portions of Alternative 3 take advantage of the same in-place systems that Alternative 2 uses.

The paving procedures for implementing Alternative 3 are routine and technically feasible. Access is available to paving equipment, with only a minor barrier presented by a chain-link fence. To implement the land-use restrictions, permission must be obtained from the UCOP. The time required for this approval and whether or not it will be accepted by UCOP is uncertain. Alternative 3 will also affect future site development, since the area can only be used as an asphalt surface or for certain types of structures that would maintain the cap's purpose for restricting the infiltration of meteoric water. Aesthetics for the Site could be impacted, since in-ground landscaping would be prohibited. A small amount of clean soil will be disposed under this alternative, but suitable landfill space is available within 30 miles of the Site. Monitoring well UCD1-054 has been, and is expected to remain, operable for the duration of this alternative. Paving equipment and labor are generally available on relatively short notice between May and November.

For Alternative 4a, the excavation methods are technically feasible, and are used in the construction of deep foundations. The use of large-diameter augers to conduct dry well excavations has been conducted at the Site at the scale proposed. Unanticipated conditions are not likely, but may reduce the effectiveness of the soil removal and extend the project's schedule and cost. Significant site preparation includes rerouting a sanitary sewer line before excavation begins. Although the excavation methods are routinely used for foundation construction, the availability of the requisite specialized equipment and labor at any particular time is not guaranteed. Transportation and disposal of the contaminated material will require an involved permitting process, as a large fraction of the material will be shipped to Envirocare of Utah.

The excavation methods for implementing Alternative 4b are routine and technically feasible. The sanitary sewer line will also need to be rerouted during implementation of this alternative. The ground water monitoring portion of Alternative 4b takes advantage of the same in-place systems that Alternative 2 uses.

4.11.4.8 Costs

Costs:

- Alternative 1 (no action): $0
- Alternative 2 (ground water monitoring): $145,000
- Alternative 3 (cap, long-term ground water monitoring and land-use restrictions): $404,000
- Alternative 4a (removal and off-site disposal): $1,201,000
- Alternative 4b (limited removal, off-site disposal and long-term ground water monitoring): $843,000

Detailed cost assumptions are presented in Appendix A.

4.11.4.9 State Acceptance

With the exception of the no action alternative, the State of California has accepted all of the alternatives.

A preferred remedial alternative will be presented in the Draft Proposed Plan. State of California acceptance of the preferred remedial alternative will be provided after resolution of their comments on the Draft Proposed Plan.

4.11.4.10 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on the accepted alternatives during the public comment period for the Proposed Plan.

4.12 Southwest Trenches

4.12.1 Nature and Extent of Contaminants of Concern

Sr-90 is a human health risk COC, and nitrate and C-14 are ground water COCs.

4.12.1.1 Strontium-90 in Soil

Sr-90 is a human health risk COC in the SWT area (Figure 4-21). Sample SSDTC020, located near the southern boundary, had a measured concentration that corresponded to the 10^{-5} to 10^{-4} risk range. It is surrounded by non-detect samples with concentrations below background, indicating a limited extent of contamination. Although 18 samples had Sr-90 concentrations corresponding to 10^{-6} to 10^{-5} risk, ten of those sample results are from the 1996 data set, which, as discussed in the Risk Characterization (WA, 2005), has a positive bias for reported concentrations. Apart from these suspect results:

- Sample concentrations were below background throughout most of the central waste burial areas.
- Only three samples that are not from the suspect 1996 data set and that are outside of the northern waste burial area had concentrations that correspond to a risk greater than 10^{-6}.
- The northern quarter of the northern waste burial area has four closely clustered samples with concentrations in the 10^{-6} to 10^{-5} risk range. Two other samples in the northern waste burial area had concentrations in the 10^{-6} to 10^{-5} risk range.

Based on the spatial distribution of these data, Sr-90 concentrations exceed both background and the concentration equivalent to a risk of 10^{-6} in areas located in the northernmost and southern waste burial areas. Based on the 1996 data, sample concentrations may also exceed background and 10^{-6} risk in the southwest and southeast corners of the area, and near the former wash-down pad.

4.12.1.2 Nitrate in Soil

Nitrate is a ground water COC that was above background in 114 of 456 soil sample results (25 percent) in the SWT area. The elevated results were clustered in the central portion of the SWT area and cover the northern half of waste burial trenches W-8 and W-10. Nitrate was mostly below background in samples collected on the north, east and south sides of the central portion of the SWT area.

In the central portion of the SWT area, maximum nitrate concentrations are present at twelve ft bgs. Shallow samples collected between ground surface and two ft bgs, and deep samples collected between 21 ft and 30 ft bgs were mostly below the background screening value of 36 mg/kg. The nitrate concentration increases rapidly with depth starting at three ft bgs, peaks sharply at twelve ft bgs and declines rapidly to near background levels at 18.5 ft bgs.

4.12.1.3 Carbon-14 in Soil

C-14 is a ground water COC that was above background in 37 out of 105 soil sample results (35 percent) in the SWT area. Most of the soil samples from the southernmost disposal trench had elevated C-14 concentrations. A few samples containing slightly elevated C-14 concentrations are located at or near disposal trench T-3. The four highest detected concentrations (1.01 ± 0.129 pCi/g to 5.84 ± 0.25 pCi/g) were located between 2 ft and 3.5 ft bgs. C-14 concentrations were below 1 pCi/g between 4 ft and 44 ft bgs.

The chemical form of C-14 is not known due to technical limitations. There are no historical disposal records available. Presumably, the C-14 is an artifact of a radio isotope-labeled tracer compound. The highest C-14 activity in the SWT is 5.84 ± 0.25 pCi/g. Converting the maximum from pCi/g to µg/kg using the specific activity gives 0.0013 µg of C-14 per kg of soil (0.0013 parts per billion). Assuming the C-14 is in methanol (molecular weight 34 grams per mole), the methanol concentration would be 0.0032 µg/kg. Assuming the C-14 was used as a metabolic tracer in the form of aldrin (molecular weight 364.9 grams per mole), the aldrin concentration would be 0.034 µg/kg. These aldrin and methanol examples represent a reasonable range in molecular weights of reagents that may have been used in research laboratories, and their concentrations are two to three orders of magnitude lower than commercial analytical method detection limits.

4.12.1.4 Ground Water

Ground water that is downgradient of the Southwest Trenches area has been sampled for COCs between October 1990 and the present. Ground water from HSU1 has been sampled in wells UCD1-004 (southeast corner of the Southwest Trenches area) and UCD1-023 (northeast corner of the Southwest Trenches area). Ground water from HSU2 has been sampled in wells UCD2-015 and UCD2-039 (listed with increasing distance from the Ra/Sr Treatment Systems area). Figure 4-1 shows the relative locations of wells to the Southwest Trenches area. Graphs illustrating the concentrations of COCs in these four wells through time are in Appendix F, with the exception of those graphs that would show fewer than five detected results and no detected results greater than MCLs. Included in each graph is a simple linear regression calculation, represented by a dashed line, to assist the reader in evaluating the overall trend of the COC in ground water.

Nitrate concentrations in both HSU1 and HSU2 downgradient of the Southwest Trenches area have for several years been below the MCL of 10,000 µg/L and have been decreasing. In HSU1, the peak in the nitrate concentrations, which were slightly higher than the MCL, appears to have occurred approximately 10 years ago (Figures F-1 and F-14). In HSU2, the peak in nitrate concentrations, which also were slightly higher than the MCL, appears to have occurred approximately 5 years ago (Figures F-32 and F-41).

C-14 concentrations in both HSU1 and HSU2 downgradient of the Southwest Trenches area have consistently been far below the MCL of 2,000 pCi/L. In well UCD1-004, C-14 has been detected only once, at 57 ± 33 pCi/L. In well UCD1-023, C-14 concentrations have been decreasing; in the last two years, C-14 has not even been detected in samples from this well (Figure F-13). In well UCD2-015, C-14 has consistently been at either very low concentrations or not detected, aside from an anomalous concentration of 478 ± 19.7 pCi/L reported for a sample collected approximately

2 years ago (Figure F-31). This anomalously high concentration was still far below the MCL, and has not been corroborated by samples either before or after it. Similarly, in well UCD2-039, the concentration of C-14 has been consistently below 35 pCi/L except for one anomalous concentration of 74.7 ± 7.03 pCi/L (Figure F-40).

4.12.2 Description of Remedial Alternatives

4.12.2.1 Alternative 1—No Action

A no action alternative was developed for the SWT to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no further action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.12.2.2 Alternative 2a—Long-Term Ground Water Monitoring and Contingent Remedial Action

Alternative 2a involves installing a downgradient well at the location shown in Figures 4-1 and 4-22 and performing long-term ground water monitoring at the new well and existing well UCD1-023. Quarterly ground water samples will be collected from the new well for a period of one year. The quarterly samples will be analyzed for a full suite of analytes. Annual nitrate and C-14 sampling will be conducted at the new well and well UCD1-023 thereafter. Monitoring results will be reported in the UC Davis annual ground water monitoring reports and evaluated in the CERCLA five-year reviews. Four consecutive ground water sample results that exceed site background and show an increasing or constant concentration trend would trigger an evaluation of remedial options. Well UCD1-23 and the new SWT monitoring well (Figure 4-1) are the proposed compliance monitoring points.

Cost:

- Capital Cost: $108,000
- Present Worth O&M Cost: $199,000
- Periodic Costs: $15,000
- Total Present Worth Cost: $322,000

4.12.2.3 Alternative 2b—Long-Term Ground Water Monitoring, Land-Use Restrictions and Contingent Remedial Action

Alternative 2b consists of long-term ground water monitoring and land-use restrictions. Ground water monitoring and contingent remedial action would be identical to Alternative 2a.

Two institutional controls would be necessary along with long-term ground water monitoring:

1. A deed restriction preventing future residential development in areas where risks exceed 10^{-6} for hypothetical residents and a requirement to profile and dispose any contaminated soil from the area in accordance with applicable requirements at the time of disposal.
2. A communication system controlling future subsurface work in areas where added radioactivity was found to pose greater than 10^{-6} risk.

The land-use restrictions would be recorded with Solano County. The record would include a survey map and/or legal description defining the exclusion areas where residential risk is greater than 10^{-6} and references for site characterization data pertaining to the land-use restriction.

Institutional controls will be maintained indefinitely. Long-term ground water monitoring will be performed for 30 years.

Cost:

- Capital Cost: $158,000
- Present Worth O&M Cost: $199,000
- Periodic Costs: $15,000
- Total Present Worth Cost: $372,000

4.12.2.4 Alternative 3—Cap, Long-Term Ground Water Monitoring and Land-Use Restrictions

In addition to implementing long-term ground water monitoring, as described in Alternative 2a, and land-use restrictions, as described in Alternative 2b, Alternative 3 includes capping the SWT area to mitigate the downward migration of residual contaminants through the vadose zone to ground water.

The cap will consist of an asphalt surface, gravel base and an underlying HDPE liner, and will cover a 19,250-square ft area (Figure 4-23). In the event that this area is used for service vehicle traffic and/or parking, its design will be consistent with UC Davis Campus Standard 02500, Paving (UC Davis, 1995). Soil will be removed from the Site to prepare for installation of the asphalt and gravel base materials. Import fill soil that was previously placed within the 1998 excavations will be removed, and reused on site or disposed off site at a Class III landfill. Surrounding native soil will be moved into the excavations and compacted. The cap will consist of a 40-mil HDPE liner overlain by eight inches of compacted gravel base material and four inches of asphalt pavement. The liner and pavement will be sloped to direct storm water runoff to exiting catch basins to the north. The cap's condition will be visually inspected on an annual basis and maintenance (i.e., asphalt overlay) is expected every 10 years. A land-use restriction will be recorded to document the cap area and to prohibit site development activities that would affect the cap's performance.

Institutional controls will be performed indefinitely. Long-term ground water monitoring and cap maintenance will be performed for 30 years.

Cost:

- Capital Cost: $450,000
- Present Worth O&M Cost: $220,000
- Periodic Costs: $65,000
- Total Present Worth Cost: $735,000

4.12.2.5 Alternative 4a—Removal and Off-Site Disposal

Most of the SWT area contamination was removed in 1998 during the waste trenches RA. Alternative 4a removes and disposes a range of remaining contaminated soil volumes in the SWT area based on achieving a range of cleanup goals. As stated above, Sr-90, nitrate, and C-14 are the COCs in the SWT area. The SWT area remediation goals consist of a human health goal for Sr-90 (Table 2-1) and the ground water protection goals shown in Table 2-2. The ranges of ground water protection goals are based on achieving background- or MCL-based remediation goals.

The areas of Sr-90, nitrate, and C-14 contamination that are above the cleanup goals are enclosed by the excavation limits shown on Figure 4-24. Contaminated soil will be removed using conventional excavation (e.g., backhoe) at the shallower excavations (<20 ft bgs) and oversized auger drilling (4-to 8-ft diameter) will be used in areas where the excavation depth exceeds 20 ft bgs.

The excavation areas (Figure 4-24) underlie and surround the 1998 excavation. Clean fill that would be removed during the new excavation will be stored for reuse as backfill material. The contaminated soil would then be removed, stockpiled separately, sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. Waste soil removed between ground surface and 20 ft bgs was assumed to be low-level radioactive waste that would be disposed at Envirocare of Utah. Deep soil removed between 20 and 50 ft bgs was assumed to contain no added radioactivity and would be disposed at a Class II industrial waste landfill.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. Locations that require oversize auger excavation will be filled with controlled-density fill (e.g., low-strength concrete). The strength of controlled-density fill is low enough that it can be excavated like soil, but it does not require mechanical compaction. Conventional excavations will be filled and compacted with clean backfill from the 1998 RA and imported fill from an off-site source.

All of the costs are expected to occur in the present time frame and no annual or periodic costs were assumed. A cost range was determined based on removal volumes derived from the background- and MCL-based soil to ground water remediation goals (Table 2-2 and Appendix B).

Cost:

- Capital Cost: $7,271,000 to $8,831,000
- Present Worth O&M Cost: $0
- Periodic Costs: $0

- Total Present Worth Cost: $7,271,000 to $8,831,000

4.12.2.6 Alternative 4b—Removal, On-Site Treatment and Land-Use Restrictions

Alternative 4b involves removing the same volumes of soil and achieving the same remediation goals as Alternative 4a, and treating a portion of the nitrate-contaminated soil on site using phytoremediation. The *ex situ* treatment will require the use of shallow-rooted grass and due to the large area required, would be conducted in the WDPs area. Some of the nitrate-contaminated soil would not be treated on site because it contains Sr-90 contamination that showed greater than 10^{-6} risk. The Sr-90-contaminated soil would be disposed as low-level radioactive waste at Envirocare of Utah.

For the remaining soil, nitrate phytoremediation would involve planting a crop of warm-season grass in a treatment cell in the WDPs area to remove excess nitrate. A plastic liner would be installed under the nitrate-contaminated soil to prevent contact with the existing WDPs soil. The contaminated soil would be covered with a plastic tarp during the rainy season to prevent the entrainment of nitrate or sediment in storm runoff.

The plastic under liner would consist of a single welded sheet of HDPE. The contaminated soil would be placed evenly throughout the lined area and mixed with amendments to facilitate crop growth. A timed sprinkler system would be installed to maintain proper irrigation.

The treatment cell crop will be seeded in spring and grown through early fall. The grass would be regularly trimmed, dried and stored for disposal upon decommissioning. The irrigation system and liner will be inspected regularly. Soil and grass samples would be collected from the treatment cell at the end of each growing season before covering the cell with plastic sheets. The sample data would be evaluated and reported in an annual treatment system performance report.

When data indicate nitrate remediation is complete, a round of confirmation samples will be collected. A random-grid confirmation sampling design will be used. The confirmation sampling results will be presented in a remedial action confirmation report. After the RPMs agree that remediation is complete, the liner, sprinkler system and accumulated grass cuttings will be sampled, profiled for disposal and an authorized release report will be prepared. The liner, sprinkler system and waste cuttings are assumed to be disposed at a Class II landfill. The treated soil would be left in place.

All of the excavation and soil disposal costs are expected to occur in the present time frame. A cost range was determined based on removal volumes derived from the background- and MCL-based soil to ground water remediation goals (Table 2-2 and Appendix B). Phytoremediation costs are assumed to occur over three years (three growing seasons).

Cost:

- Capital Cost: $6,198,000 to $7,752,000
- Present Worth O&M Cost: $93,000

- Periodic Costs: $135,000
- Total Present Worth Cost: $6,426,000 to $7,980,000

4.12.2.7 Alternative 4c—Limited Removal, Off-Site Disposal and Long-Term Ground Water Monitoring

Alternative 4c will remove and dispose of soil that can be accessed using conventional excavation equipment such as a backhoe. In addition, long-term ground water monitoring and land-use restrictions will be performed as described in Alternatives 2a and 2b, respectively. This alternative removes a range of soil volumes based on achieving the practical range of remediation goals. As described above for Alternative 4a, these goals consist of 10^{-6} risk for Sr-90, soil background for nitrate, and the practical range of C-14 goals (soil background to the federal MCL). The depth limit of conventional excavation is approximately 20 ft bgs. Soil volumes containing concentrations of Sr-90, nitrate, and C-14 that are above the range of cleanup goals will be removed unless located deeper than 20 ft bgs. Soil deeper than 20 ft bgs will remain in place.

The lateral excavation limits are the same as Alternatives 4a and 4b, and are shown on Figure 4-25. The excavation area surrounds and underlies the 1998 excavation. Clean fill that would be removed during the new excavation will be stored for reuse as backfill material. The contaminated soil would then be removed, stockpiled separately, sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. Waste soil removed between ground surface and 20 ft bgs was assumed to be low-level radioactive waste that would be disposed at Envirocare of Utah.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. Clean fill from the 1998 RA and new import fill from an off-site source would be used to backfill the excavation. Monitoring well installation and long-term ground water monitoring will be required as described in Alternative 2a above.

Excavation, disposal, well installation and land-use restriction capital costs are expected to occur in the present time frame. A cost range was determined based on removal volumes derived from the background- and MCL-based soil to ground water remediation goals (Table 2-2 and Appendix B). Annual monitoring costs are expected to occur for 30 years, and one periodic cost is expected after 30 years to demolish the monitoring well.

Cost:

- Capital Cost: $4,422,000 to $4,969,000
- Present Worth O&M Cost: $199,000
- Periodic Costs: $15,000
- Total Present Worth Cost: $4,636,000 to $5,183,000

4.12.2.8 Alternative 5—*In Situ* Bioremediation, Long-Term Ground Water Monitoring and Land-Use Restrictions

In addition to implementing long-term ground water monitoring, as described in Alternative 2a, and institutional actions, as described in Alternative 2b, Alternative 5 includes pilot testing, installation, and O&M of an *in situ* microbial denitrification system. Anaerobic denitrification occurs during microbial respiration in the absence of oxygen and presence of a carbon source (e.g., ethanol, glucose, lactate or sucrose in purified water). The *in situ* microbial denitrification system would inject a carbon-source solution into nitrate-contaminated vadose zone soil. The injection system would fully saturate vadose zone soil in the vicinity of nitrate contamination. This will result in a ground water mound, which will drive nitrate and the injected carbon source downward and outward from the area of contamination. It is expected that some of the nitrate may enter and continue to be treated in ground water.

Indigenous aerobic bacteria in the vadose zone would use the carbon source as an electron donor and existing oxygen as the electron acceptor. Denitrification will begin when the existing oxygen is depleted. When the carbon source remains in excess, indigenous denitrifying bacteria proliferate and reduce the nitrate contamination to nitrogen gas.

Pilot testing would involve collecting four continuous core samples in the contaminated vadose zone and testing the core samples for hydraulic properties, nitrate concentration profile, bench-scale denitrification, and biological and geochemical parameters. A hydrologic testing laboratory will determine hydraulic properties of the soil core, such as the lateral and vertical hydraulic conductivity and porosity. A field infiltration test would be conducted in one of the boreholes to verify the hydraulic parameters determined in the laboratory. The hydraulic data will be used to determine the pressure and flow rate of the carbon-source solution delivery system. The nitrate profile was established in 1999, but should be verified by analyzing core samples. The screened interval of the carbon-source delivery system will depend on the current vertical location of nitrate contamination. Bench-scale tests of denitrification will be conducted on a section of contaminated core. The core will be sampled and analyzed for nitrate, plate count and geochemical parameters before conducting the bench test. The geochemical parameters that will be tested are: alkalinity, pH, dissolved oxygen, oxidation/reduction potential, total iron, soluble iron, sulfate and total organic carbon. Various carbon-source solutions and amendments will be applied to selected contaminated core samples to determine optimal denitrification conditions. A pilot test report will be prepared to present the results and any carbon-source solution and augmentation recommendations that should be used to implement the final *in situ* microbial denitrification system.

A treatment system design will be prepared and approved by the UC Davis ORMP and the LEHR RPMs. The design will not require approval by any other government agencies because UC Davis is its own entity with complete authority over all new construction. The treatment system design is assumed to consist of a vadose zone well field spaced on 10-ft centers (Figure 4-26) that are manifolded into a carbon-source solution holding tank. A metered pump between the delivery tank and manifold would control the total carbon-source solution delivery rate. The manifold would be designed with pressure and flow control valves to adjust carbon-source solution delivery to individual wells. The carbon-source solution would be mixed on site by an automated metering system that would combine filtered tap water with concentrated carbon-source solution. The concentrated carbon-source solution would be stored in a separate tank and metered into the filtered water when the low-level switch is activated in the solution storage tank. The tap water will be treated with carbon filtration to remove any impurities or trihalomethane compounds generated in the municipal water supply disinfection process. The tanks, metering systems, manifold valving, filtration system and electrical control panel will be installed on a concrete slab within a fenced compound. The tanks and equipment will be anchored to the slab with seismic anchorage to prevent overturning in the event of an earthquake. Electrical power will be supplied to the compound via underground conduit. A treatment system construction report will be prepared to document the as-built system design.

A treatment system manual will be prepared containing instructions for system startup, O&M, and performance parameter collection. The manual will contain copies of the as-built system design, component diagrams and vendor contact information. System startup will consist of turning the system on and measuring and adjusting flow rates at the pumps and valves, and collecting samples of the carbon-source solution. Clustered piezometers will be used to measure the level of hydraulic saturation in the vadose zone and the carbon-source solution and nitrate concentrations at distances away from the injection wells. Monitoring wells will be used to measure nitrate concentrations in ground water below the source and approximately 20 ft from the source perimeter. The piezometer and monitoring well configurations are shown in Figure 4-26.

System startup is expected to include daily field measurements from the delivery system, piezometers and monitoring wells for three weeks of operation. A startup report will be prepared and the recommended optimal adjustments will be added to the treatment system manual. System O&M will be conducted periodically thereafter according to a schedule determined by the system engineer and field technicians. The treatment system O&M schedule is assumed to consist of bi-weekly visits for the first month, weekly visits for the second month, and bi-monthly visits thereafter.

All of the pilot testing, installation and startup costs are expected to occur in the present time frame. O&M are assumed to occur over two years. A decommissioning cost is expected to occur at the end of two years.

Cost:

- Capital Cost: $739,000
- Present Worth O&M Cost: $378,000
- Periodic Costs: $181,000
- Total Present Worth Cost: $1,298,000

4.12.3 Analysis of Remedial Alternatives

Table 4-10 summarizes the analysis of remedial alternatives. The comprehensive analysis is presented below.

4.12.3.1 Alternative 1—No Action

4.12.3.1.1 Overall Protection of Public Health and the Environment

Alternative 1 results in a risk of 3 x 10^{-6}. This value only slightly exceeds the 10^{-6} CERCLA point of departure, but is well within the 10^{-4} to 10^{-6} CERCLA acceptable risk range. Alternative 1 also does not address ground water impacts. Ground water monitoring indicates that C-14 concentrations above site background, but well below the federal MCL, are present in ground water in the SWT area. Plume size estimates (Table 1-1) indicate potential nitrate and/or C-14 plumes larger than one acre. NUFT modeling results (WA, 2003) suggest that C-14 may impact ground water above background concentrations and the federal MCL, but that impact would be highly localized due to the limited mass of C-14 present. NUFT modeling results also suggest that nitrate may impact the ground water above background and the California MCL. However, available ground water monitoring data show that nitrate concentrations in monitoring wells UCD1-023 and UCD1-024 are declining over time (Appendix F). Similarly, C-14 activities are also declining in UCD1-023 (Appendix F). The total mass of nitrate present in the SWT area is about 600 pounds (WA, 2003), and the total mass of nitrate that could be released to ground water annually is estimated to be less than 190 pounds. Sr-90 is not a ground water-impact COC.

4.12.3.1.2 Compliance with ARARs

Alternative 1 may not comply with the State's Anti-Degradation Policy and Basin Plan. This area is a likely source of the C-14 currently present in ground water above site background but below the federal MCL. Available transport modeling results suggest that the COCs will result in very localized impacts above background and MCLs (Table 1-1).

4.12.3.1.3 Long-Term Effectiveness and Permanence

Plume size estimates (Table 1-1) indicate potential nitrate and/or C-14 plumes larger than one acre. Alternative 1 is not effective in the long term since localized known ground water impacts will not be monitored. Low mass is associated with the residual nitrate and C-14 in soil. Ground water concentrations of these constituents have indicated a declining trend downgradient of the area. This alternative lacks monitoring and management controls to confirm effectiveness.

4.12.3.1.4 Reduction of Toxicity, Mobility or Volume

Alternative 1 does not significantly reduce toxicity, mobility or volume. The radionuclides, Sr-90 and C-14, will naturally decay, reducing their toxicities and volumes. However, significant reductions will take hundreds or thousands of years, respectively, due to the relatively long half-lives of these isotopes.

4.12.3.1.5 Short-Term Effectiveness

Alternative 1 does not result in short-term impacts to the public, workers or the environment.

4.12.3.1.6 Implementability

There are no barriers to implementing Alternative 1.

4.12.3.1.7 Cost

The cost of Alternative 1 is $0.

4.12.3.1.8 State Acceptance

The State of California has not accepted Alternative 1 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.12.3.1.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their non-acceptance of this alternative during the public comment period for the Proposed Plan.

4.12.3.2 Alternative 2a—Long-Term Ground Water Monitoring and Contingent Remedial Action

4.12.3.2.1 Overall Protection of Public Health and the Environment

Alternative 2a should not impact public health, because the risk only slightly exceeds the 10^{-6} point of departure.

With respect to ground water, Alternative 2a is the same as Alternative 1 in that significant ground water impacts are unlikely. In contrast to Alternative 1, however, Alternative 2a addresses uncertainties associated with the predictions of the future impacts by implementing a ground water monitoring program If monitoring indicates that conditions are not protective, other remedial actions could be undertaken, such as ground water extraction and treatment.

4.12.3.2.2 Compliance with ARARs

Alternative 2a complies with ARARs. As described above, Alternative 2a reduces the uncertainties in future compliance with the State's Anti-Degradation Policy and Basin Plan by implementing a ground water monitoring program and contingent remediation.

4.12.3.2.3 Long-Term Effectiveness and Permanence

Ground water plume predictions were prepared to evaluate long-term effectiveness under Alternative 2a. The plume size estimates were based on complete contaminant transfer to HSU-1. The estimated plume areas and diameters are summarized in Table 1-1 and the calculations are presented in Appendix E. The results indicate that C-14 concentrations could exceed background over an area of up to 4.5 acres, but the 4 mrem/year federal MCL-based concentration (US EPA, 2000b) could occupy only a little more than one-tenth of an acre. Predicted nitrate plumes range from 0.88 acres to 2.4 acres for concentrations equal to ground water background and the California MCL, respectively.

Alternative 2a's effectiveness would be evaluated through monitoring and management controls.

4.12.3.2.4 Reduction of Toxicity, Mobility or Volume

Alternative 2a does not significantly reduce toxicity, mobility or volume of the contaminants.

4.12.3.2.5 Short-Term Effectiveness

Alternative 2a does not add short-term risks to the public, workers or the environment. The ongoing effectiveness of this alternative will be confirmed by long-term ground water monitoring. However, if monitoring results trigger an evaluation of remedial alternatives, the time until each alternative is protective will be presented in an addendum to the Remedial Action Work Plan.

Contingent remedial action will be considered protective when groundwater is cleaned up to background concentrations, or if background concentrations are not technically or economically feasible, water quality objectives protective to one-in-a-million cancer risk or the lowest water quality objective applicable for the constituent/s of concern.

4.12.3.2.6 Implementability

There are no significant barriers to implementing Alternative 2a. The alternative uses standard ground water monitoring techniques that are currently deployed at the Site. From an administrative standpoint, standard records management, database and contracting activities will be required.

Land-use restrictions are not proposed under this alternative, but land-use restrictions may be a component of future remedial action, if required. Additionally, intervening site development could limit access to areas requiring remedial action.

4.12.3.2.7 Cost

The anticipated capital and O&M costs for Alternative 2a are $322,000. The cost assumptions for this alternative are presented in Appendix A.

4.12.3.2.8 State Acceptance

The State of California has accepted Alternative 2a as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.12.3.2.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.12.3.3 Alternative 2b—Long-Term Ground Water Monitoring, Land-Use Restrictions and Contingent Remedial Action

4.12.3.3.1 Overall Protection of Public Health and the Environment

Alternative 2b protects the public from exposure to Sr-90 by prohibiting future residential development at the Site where risk is greater than 10^{-6}. The long-term effectiveness of these controls is uncertain.

With respect to ground water, Alternative 2b is the same as Alternative 1, in that significant ground water impacts are unlikely. In contrast to Alternative 1, however, Alternative 2b addresses uncertainties associated with the predictions of the future impacts by implementing a ground water monitoring program. If monitoring indicates that conditions are not protective, other remedial actions could be undertaken, such as ground water extraction and treatment.

4.12.3.3.2 Compliance with ARARs

Alternative 2b complies with ARARs, except possibly the State's Anti-Degradation Policy and Basin Plan. As described above, Alternative 2b reduces the uncertainties in future compliance with this ARAR by implementing a ground water monitoring program.

4.12.3.3.3 Long-Term Effectiveness and Permanence

Based on plume size estimates, additional remedial measures may not be necessary under Alternative 2b if the nitrate or C-14 contamination arrives in HSU-1. The ground water monitoring included in this alternative provides a means to confirm effectiveness over time. The effectiveness of the residential land-use restriction depends on continued future implementation.

4.12.3.3.4 Reduction of Toxicity, Mobility or Volume

Alternative 2b does not significantly reduce toxicity, mobility or volume of the contaminants.

4.12.3.3.5 Short-Term Effectiveness

Alternative 2b does not add short-term risks to the public, workers or the environment. Like Alternative 2a, the ongoing effectiveness of this alternative will be confirmed by long-term ground water monitoring and, if monitoring results trigger contingent remedial action, this alternative is expected to be protective within five years.

Contingent remedial action will be considered protective when groundwater is cleaned up to background concentrations, or if background concentrations are not technically or economically feasible, water quality objectives protective to one-in-a-million cancer risk or the lowest water quality objective applicable for the constituent/s of concern.

4.12.3.3.6 Implementability

There are no anticipated barriers to implementing Alternative 2b. The alternative uses standard ground water monitoring techniques that are currently deployed at the Site. From an administrative standpoint, standard records management, database and contracting activities will be required. In addition, cooperation with UCOP will be necessary for implementing the land-use restrictions on residential development. Although UCOP is the land owner and DOE may transfer procedural responsibilities to UC Davis or some other entity, DOE will retain ultimate responsibility for the integrity of the implementation.

Land-use restrictions are not proposed under this alternative, but land-use restrictions may be a component of future remedial action, if required. Additionally, intervening site development could limit access to areas requiring remedial action.

4.12.3.3.7 Cost

The anticipated capital and O&M costs for Alternative 2b are $372,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.12.3.3.8 State Acceptance

The State of California has accepted Alternative 2b as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.12.3.3.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.12.3.4 Alternative 3—Cap, Ground Water Monitoring and Land-Use Restrictions

4.12.3.4.1 Overall Protection of Public Health and the Environment

Alternative 3 protects the public from exposure to Sr-90 by using the same land-use restrictions implemented in Alternative 2b. Additionally, surface capping limits exposure to subsurface contaminants.

Alternative 3 protects against the potential future ground water impacts by eliminating the infiltration of surface water through contaminated soil. Contaminant transport due to diffusion processes will continue after the cap is installed, but the overall contaminant transport rates should be markedly reduced. To address uncertainties associated with future impacts to ground water, Alternative 3 retains ground water monitoring to confirm long-term effectiveness Institutional controls are included to ensure that the cap is maintained over time and that residential development is prohibited. If future monitoring indicates that conditions are not protective, other remedial actions could be undertaken, such as ground water extraction and treatment.

4.12.3.4.2 Compliance with ARARs

Alternative 3 complies with ARARs. As described above, the impermeable cap will reduce the transport rate of the vadose zone contaminants, thereby reducing the potential impact to ground water. The ground water monitoring program will provide data to evaluate the compliance with ARARs.

4.12.3.4.3 Long-Term Effectiveness and Permanence

Alternative 3 is effective in protecting human health in the long term as long as the land-use restrictions are effective. With respect to future potential impacts to ground water, Alternative 3 may result in the loss of beneficial use of ground water. Institutional controls will be required to maintain the cap's integrity over time. The effectiveness of these controls over long periods of time is uncertain.

4.12.3.4.4 Reduction of Toxicity, Mobility or Volume

Downward mobility of the residual contamination is substantially reduced by the cap, but otherwise Alternative 3 has no effect on contaminant mass and volume.

4.12.3.4.5 Short-Term Effectiveness

There are minor short-term risks to the public and the environment associated with the manufacture, transportation and installation of asphalt. Additional short-term risks to the community and to workers include relatively short-term noise and heavy equipment use. Deployment of the cap system is rapid, since it relies on established engineering design and materials. The estimated time to design and install a cap is approximately one year.

4.12.3.4.6 Implementability

The implementability of the land-use restrictions is identical to Alternative 2b. The paving procedures used in Alternative 3 are routine and technically feasible. There are no physical barriers to mobilizing paving equipment to the Site. Permission will need to be granted by UCOP to implement land-use restrictions. Negotiations between DOE and UCOP may be required to address the effort required to administer and implement the land-use restrictions. A small amount of clean soil will be disposed under this alternative, but suitable landfill space or reuse options are available within 30 miles of the Site. The monitoring wells are expected to remain operable for the duration of this alternative. Paving equipment and labor are generally available on relatively short notice between the months of May and November in the Davis area.

4.12.3.4.7 Cost

The anticipated capital and O&M costs for Alternative 3 are $735,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.12.3.4.8 State Acceptance

The State of California has accepted Alternative 3 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.12.3.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.12.3.5 Alternative 4a—Removal and Off-Site Disposal

4.12.3.5.1 Overall Protection of Public Health and the Environment

Alternative 4a is protective of human health and protects beneficial use of ground water by removing all soil with contaminant concentrations greater than the cleanup-goal concentrations and disposing it off site. The off-site disposal will transfer risk to the disposal site and result in short-term transportation risks, including highway accidents and vehicular air emissions.

4.12.3.5.2 Compliance with ARARs

Because the contaminated soil is removed under Alternative 4a, this alternative complies with all ARARs.

4.12.3.5.3 Long-Term Effectiveness and Permanence

Because all of the contamination in soil at concentrations exceeding the remediation goal is removed under Alternative 4a, this alternative effectively mitigates most, if not all, site risks and ground water impacts permanently. This alternative requires auger excavation over a large area, and some limited amounts of contamination may be missed if the auger deflects or is improperly located. Long-term risks are transferred to land disposal facilities that have been engineered and permitted to contain such waste.

4.12.3.5.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4a, nearly all toxicity, mobility and contaminated soil volumes are reduced through removal.

4.12.3.5.5 Short-Term Effectiveness

Discernable short-term risks to the public and environment are associated with the transport of more than 900 truckloads of contaminated soil over a period of several months. Off-site disposal has several negative impacts associated with it, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 2.15×10^{-2}. The estimated risk of a fatality due to waste transport air emissions is 4.75×10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.43 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Additionally, localized noise and vibration impacts at the Site will persist for several months during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. The time to complete the excavation is uncertain due to the depth and non-standard techniques required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent to any deep excavation.

The estimated time required to remove and dispose the contaminated soil is approximately one year.

4.12.3.5.6 Implementability

The excavation methods are technically feasible and are used in the construction of deep foundations. However, the use of large-diameter augers to conduct mass excavations has not been conducted at the Site at the scale proposed. Thus, unanticipated conditions or engineering issues may extend the project's schedule and cost. Site preparations are relatively minor and mainly involve removing chain-link fencing before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process.

4.12.3.5.7 Cost

The anticipated capital and O&M costs are between $7,271,000 and $8,831,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.12.3.5.8 State Acceptance

The State of California has accepted Alternative 4a as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.12.3.5.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.12.3.6 Alternative 4b—Removal and On-Site Treatment

Alternative 4b is identical to Alternative 4a, except that a large portion of the excavated soil will be treated and retained on site. Because these two alternatives are so similar, this section only discusses the aspects of Alternative 4b that differ from those of Alternative 4a.

4.12.3.6.1 Overall Protection of Public Health and the Environment

Under Alternative 4b, less of the risk is transferred off site, because a large volume of soil is treated on site and a smaller volume of contaminated soil will be disposed off site. The number of off-site shipments estimated for Alternative 4b is 359, as opposed to 905 for Alternative 4a. However, some risks are transferred from the SWT area to the phytoremediation treatment area in the WDPs.

4.12.3.6.2 Compliance with ARARs

This alternative complies with all ARARs. As discussed in Section 4.12.2.6, special engineering controls have been provided to mitigate compliance issues associated with storm water runoff and air emission.

4.12.3.6.3 Long-Term Effectiveness and Permanence

Because all of the contamination in soil at concentrations exceeding the remediation goal is removed under Alternative 4b, this alternative effectively mitigates most, if not all, site risks and ground water impacts permanently. This alternative requires auger excavation over a large area, and some limited amounts of contamination may be missed if the auger deflects or is improperly located. Long-term risks are transferred to land disposal facilities that have been engineered and permitted to contain such waste.

4.12.3.6.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4b, the toxicity and volume of nitrate is reduced through phytoremediation. The site toxicity, mobility, or volume of soil containing radionuclides is reduced by transferring it to an engineered and permitted disposal facility.

4.12.3.6.5 Short-Term Effectiveness

Because fewer truckloads will be transported off site, the community will be less impacted by vehicular traffic under Alternative 4b than under Alternative 4a. Nevertheless, the 359 trucks required for Alternative 4b are not insignificant, and discernable short-term risks to the public and environment will be associated with this alternative. Off-site disposal has several negative impacts associated with it, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 1.47×10^{-2}. The estimated risk of a fatality due to waste transport air emissions is 3.23×10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.43 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Additionally, localized noise and vibration impacts at the Site will persist for several months during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. The time to complete the excavation is uncertain due to the depth and non-standard techniques required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent to any deep excavation. The time estimated for the vegetation to consume the nitrate and to decommission the treatment cell is about three years.

The estimated time required to remove the contaminated soil and install a phytoremediation treatment cell is approximately one year. The cell is expected to achieve cleanup goals within three growing seasons. The total estimated time for short-term effectiveness is four years.

4.12.3.6.6 Implementability

The phytoremediation methods are technically feasible. However, the use of large-diameter augers to conduct mass excavations has not been conducted at the Site at the scale proposed. Thus, unanticipated conditions or engineering issues may extend the project's schedule and cost. Site preparations are relatively minor and mainly involve removing chain-link fencing before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process. Maintenance and operation of the on-site phytoremediation requires standard methods and equipment. There is available space at the WDPs area for spreading the soil to be treated. However, if multiple DOE areas utilize phytoremediation, there may be a space limitation, which would require that the process be conducted in batches that could significantly extend the overall site cleanup schedule.

4.12.3.6.7 Cost

The anticipated capital and O&M costs are between $6,426,000 and $7,980,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.12.3.6.8 State Acceptance

The State of California has accepted Alternative 4b as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.12.3.6.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.12.3.7 Alternative 4c—Limited Removal, Off-Site Disposal and Long-Term Ground Water Monitoring

4.12.3.7.1 Overall Protection of Public Health and the Environment

To protect human health and mitigate future impacts to ground water, Alternative 4c includes limited removal of contaminated soil and ground water monitoring near the source area to confirm long-term effectiveness. Nearly all of the soil with Sr-90 concentrations greater than the human health cleanup-goal concentration would be removed and disposed off site. Some of the nitrate and C-14 would remain in soil deeper than 20 ft bgs at concentrations which may impact ground water. If future monitoring indicates that limited removal has not been protective, other remedial actions could be undertaken, such as ground water extraction and treatment.

Off-site disposal will generate environmental impacts and risks associated with the long-term transfer of risk to the disposal site, as well as short-term transportation risks, including highway accidents and vehicular air emissions.

4.12.3.7.2 Compliance with ARARs

Alternative 4c complies with ARARs. Alternative 4c includes a program to actively monitor ground water for 30 years. This program will provide data to evaluate any impact to the ground water which may require additional remedial measures.

4.12.3.7.3 Long-Term Effectiveness and Permanence

This alternative is permanently effective for Sr-90. Nearly all of the Sr-90 contamination in soil at concentrations greater than the remediation goal is expected to be removed under Alternative 4c. Nitrate and C-14 remaining deeper than 20 ft bgs will continue to migrate to ground water, but the mass of contamination arriving in ground water should be markedly reduced. The effectiveness of this alternative will be confirmed with monitoring. Part of the risk associated with this alternative is transferred to the disposal site, but contaminant levels are low and should be easily controlled in a permitted facility.

4.12.3.7.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 4c, Sr-90 toxicity, mobility and contaminated soil volume is greatly reduced, since the Sr-90-contaminated soil is removed and disposed off site. A significant fraction of the nitrate and C-14 contamination will be removed and disposed off site. Nitrate and C-14 mobility are not reduced.

4.12.3.7.5 Short-Term Effectiveness

Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal site in Utah. The local community will be impacted by the transport of more than 460 truckloads of soil over a period of several weeks. Off-site disposal has several negative impacts, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 1.90×10^{-2}. The estimated risk of a fatality due to waste transport air emissions is 4.18 x 10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.43 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Additionally, localized noise and vibration impacts at the Site will persist during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment hazards, and fall and burial hazards inherent to excavation.

The estimated time required to remove and dispose the contaminated soil is approximately one year.

4.12.3.7.6 Implementability

The excavation methods for implementing Alternative 4c are routine and technically feasible. Site preparations are relatively minor and mainly involve removing chain-link fencing before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process, as the material will be shipped to Envirocare of Utah. Suitable landfill space is expected to remain available during the remedial action.

This alternative can be implemented with established engineering design and materials. Standard records management and database activities are required.

4.12.3.7.7 Cost

The anticipated capital and O&M costs for Alternative 4c are between $4,636,000 and $5,183,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.12.3.7.8 State Acceptance

The State of California has accepted Alternative 4c as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.12.3.7.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.12.3.8 Alternative 5—*In Situ* Bioremediation, Long-Term Ground Water Monitoring and Land-Use Restrictions

4.12.3.8.1 Overall Protection of Public Health and the Environment

Alternative 5 protects the public from exposure to Sr-90 by using the same land-use restrictions implemented by Alternative 2b.

Alternative 5 protects against potential ground water impacts by treating the nitrate contamination *in situ* using extant microbes. This approach uses innovative technology and pilot testing will be required to confirm its feasibility at the Site. This treatment will be carefully monitored, using five wells, to verify the effectiveness of the method. The treatment system will only treat nitrate, leaving the majority of the C-14 mass, which is located to the south of the nitrate-impacted area (Figure 4-21) in the vadose zone as a potential ground water contaminant. Limited amounts of C-14 that are co-located with the nitrate will likely be mobilized by the injected nutrient solution to the water table. As described above under Alternative 1, the impact to ground water from C-14 is likely to be only localized, as predicted from NUFT modeling results. Similarly, co-located Sr-90 would be mobilized by the injected nutrient solution. However, Sr-90's high soil-water partitioning coefficient and the predicted two-year injection duration should limit the migration of Sr-90, such that it is retained in the vadose zone. This alternative includes the installation of two monitoring wells that will monitor nitrate and C-14 concentrations during and after implementation of Alternative 5.

4.12.3.8.2 Compliance with ARARs

Alternative 5 relies on land-use restrictions and *in situ* treatment to comply with ARARs. As described above, the potential ground water impact from the untreated C-14 is expected to be minor, and Sr-90 should not be mobilized to ground water during the short injection phase. Two new monitoring wells will be installed under this alternative to monitor and confirm these expectations.

4.12.3.8.3 Long-Term Effectiveness and Permanence

In the current conditions at the Site, Alternative 5 is effective in protecting human health in the long term due to the negligible mass and toxicity of residual contaminants in soil. With respect to future potential impacts to ground water, Alternative 5 is expected to be capable of irreversibly transforming nitrate contamination into innocuous substances. However, this innovative approach will require a pilot test to confirm its feasibility at the Site. Alternative 5 does not treat the C-14 contamination, but it does allow for long-term monitoring of C-14 in ground water, as described above.

4.12.3.8.4 Reduction of Toxicity, Mobility or Volume

Alternative 5 does not significantly reduce the toxicity, mobility or volume of C-14 and Sr-90. However, Alternative 5 is expected to reduce the toxicity and volume of nitrate to negligible levels. The mobility of the nitrate will be increased as a result of water added to the vadose zone. As planned, the nitrate should continue to degrade if it migrates below the water table. The injection process may transport some of the C-14 from the vadose zone to ground water. However, the majority of the C-14 is not co-located with the nitrate to be bioremediated.

4.12.3.8.5 Short-Term Effectiveness

Minor short-term risks to the public and the environment are associated with the installation and operation of the bioremediation system. Construction of a concrete slab to hold the tank for injection, as well as drilling 33 holes, will be required. This will result in some vibration and noise impacts to the community. Standard fieldwork hazards will be present. The time to deploy the system is rapid, since it relies on established engineering design and materials. Design, installation and system startup tasks can be completed in one year, and *in situ* remediation is expected to take about two years. Thus, the predicted short-term effectiveness period is three years.

4.12.3.8.6 Implementability

Alternative 5 is implementable. The methods for installing the wells and injecting the carbon-source solutions are well established. Permission for drilling at the Site will be required from Solano County. The Site presents no access issues for drilling and construction equipment. From an administrative standpoint, standard records management and database activities will be required. In addition, cooperation with UCOP will be necessary for implementing the restrictions on residential development.

4.12.3.8.7 Cost

The anticipated capital and O&M costs for Alternative 5 are $1,298,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.12.3.8.8 State Acceptance

The State of California has accepted Alternative 5 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.12.3.8.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.12.4 Comparative Evaluation of Remedial Alternatives

4.12.4.1 Overall Protection of Public Health and the Environment

RAs in 1998 addressed the principal threats to human health and the environment, but residual contaminants remain in soil and possibly ground water. The eight alternatives address these residual contaminants. Currently, the human health risk is within the CERCLA acceptable risk range of 10^{-4} to 10^{-6}, and only slightly above the 10^{-6} point of departure. The risk is due to a single constituent (Sr-90). Thus, public health is protected under Alternatives 1 and 2a in which no action is proposed to address the risk due to Sr-90. Alternatives 2b, 3 and 5 implement land-use restrictions to address this marginal risk. Alternatives 4a, 4b and 4c excavate the Sr-90-contaminated soil and effectively mitigate Site risk by disposing the soil containing Sr-90 off site. The public is not currently exposed to ground water, which is currently impacted by C-14.

In the future, ground water may be further impacted if vadose zone contaminants migrate to HSU-1. Plume size estimates indicate that ground water impacts are possible without any remedial action (Alternatives 1 , 2a and 2b) and are anticipated based on predictions from NUFT modeling (WA, 2003). Nitrate may impact the ground water above background and the California MCL, but this release of nitrate is comparatively minor with respect to other nitrate releases to shallow ground water in the Davis area. However, ground water monitoring results indicate that current nitrate and C-14 ground water concentrations at the SWT area are low and declining (Appendix F). Alternative 3 actively reduces contaminant migration through the vadose zone to ground water, and therefore, reduces the future risk to human health relative to Alternatives 1, 2a and 2b. However, diffusion processes may still result in some future ground water impacts under Alternative 3. Alternatives 2a, 2b, 3, 4c and 5 include ground water monitoring to evaluate their long-term effectiveness. If impacts were detected, responses could be implemented to prevent ingestion of contaminated ground water though administrative and/or engineering controls. Alternatives 4a, 4b and 4c remove most soil with contamination at concentrations greater than Sr-90 remediation-goal concentrations, and therefore, remove most, if not all, risk to human health. Alternatives 4a and 4b protect the beneficial use of ground water. Alternative 4a reduces contaminant mass to negligible levels. These mass reductions will be achieved with a high level of certainty, but the protection provided at the Site is offset by the transfer of risk to the disposal site, the addition of transportation risks and the emission of air pollutants from trucks. These additional impacts are less severe for Alternatives 4b and 4c than for Alternative 4a. However, in the case of Alternative 4b, some risk is transferred to the WDPs area. Alternative 5 actively treats nitrate, a potential ground water contaminant, and implements a ground water monitoring program to monitor the effectiveness of the treatment and future ground water impacts from C-14 and Sr-90. However, the nitrate treatment process may mobilize C-14 and possibly Sr-90 from the vadose zone to ground water. Alternatives 2b, 3 and 5 all require administrative controls that prohibit residential development at the Site. All of the alternatives, except Alternative 4a, result in some residual site contamination. Only Alternatives 2a, 4a, 4b and 4c allow unrestricted land use.

4.12.4.2 Compliance with ARARs

Alternatives 2a, 2b, 3, 4a, 4b and 4c comply with ARARs. Alternatives 2a, 2b, 3 and 4c include long-term ground water monitoring to evaluate compliance with ARARs. Alternative 3 adds a cap to further assure compliance with the State's Anti-Degradation Policy and Basin Plan. Under Alternatives 4a and 4b, all soil with contamination concentrations greater than the cleanup-goal concentrations is removed, and therefore, this alternative complies with all ARARs. Alternative 4c removes a high percentage of the mass of residual nitrate, C-14 and Sr-90. However, long-term ground water monitoring is required to demonstrate the long-term compliance of this alternative with the State's Anti-Degradation Policy and Basin Plan. Alternative 5 treats nitrate vadose zone contamination to avoid future ground water contamination, monitors ground water for C-14 and Sr-90 impacts and evaluates the effectiveness of the nitrate treatment.

4.12.4.3 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long-term since localized known ground water impacts will not be monitored. Alternative 2a is more protective than Alternative 1. Alternative 2b provides additional safeguards over Alternatives 1 and 2a by restricting residential development. Alternative

3 is more protective of ground water than Alternatives 2a and 2b, but may not eliminate future ground water impacts. Alternatives 4a and 4b are permanent solutions for the Site with respect to human health and protection of ground water. However, these alternatives transfer risk to land disposal facilities or other areas at the Site. Alternative 4c is expected to reduce human health risk below 10^{-6} and significantly reduce the mass of potential ground water-impacting COCs, but will not remove all of the contaminants that are predicted to impact ground water. Alternative 5 is an innovative approach that has a greater degree of uncertainty with respect to its effectiveness compared to Alternatives 2a, 2b, 3, 4a and 4b. Available information suggests that Alternative 5 will be more effective than Alternatives 2a, 2b and 3 in reducing future ground water impacts from nitrate, and will perform similarly to Alternatives 2a and 2b for Sr-90 and C-14. With respect to C-14, Alternative 3 will be slightly more protective of ground water than Alternative 5.

4.12.4.4 Reduction of Toxicity, Mobility or Volume

There is no direct reduction of toxicity, mobility or volume under Alternatives 1, 2a or 2b, except radioactive decay of Sr-90 and C-14. The human health risk will decline below 1×10^{-6} due to the radioactive decay of Sr-90 in 43 years. It will take thousands of years to achieve significant reductions of C-14 by radioactive decay. Under Alternative 3, mobility of the residual vadose zone contamination is reduced by the cap. Although capping (Alternative 3) is not a treatment technology, it should still be evaluated for this criterion because capping can reduce contaminant mobility by preventing infiltration. Under Alternatives 4a and 4b, all soil with contaminant concentrations greater than cleanup-goal concentrations is completely excavated. All contamination is either removed off site or treated on site. Under Alternative 4c, all of the soil containing Sr-90 above the human health risk goal would be removed, and some of the soil with nitrate and C-14 above the ground water goals would be removed. Nitrate and C-14 mobility would not change under Alternative 4c. Alternative 5 reduces the toxicity and volume of nitrate, but not C-14. There is a risk that the mobility of nitrate and C-14 would increase under Alternative 5.

4.12.4.5 Short-Term Effectiveness

Alternatives 1, 2a nor 2b will not add any short-term impacts to the public, workers or the environment.

Alternative 3 involves the installation of asphalt pavement. There are minor environmental and health risks associated with air emissions during the manufacture, transportation and installation of asphalt. Additional short-term impacts to the community and to workers include noise and heavy-equipment use. Deployment of the cap system is rapid, since it relies on established engineering design and materials.

Alternatives 4a, 4b and 4c produce the most severe impact in the short term. Discernable short-term risks to the public and environment are associated with the transport of contaminated soil to the waste disposal site in Utah. Transportation impacts include local traffic congestion, air emissions and the risk of highway accidents. Site construction impacts, including localized noise and ground vibrations, will persist for several months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment, fall hazards and burial hazards inherent in any excavation. The exact time to complete the work for Alternatives 4a and 4b is uncertain due to the depth and non-standard extraction techniques required. Alternative 4b creates less off-site risk than Alternative 4a, but the length of time required to complete Alternative 4b is three years longer than Alternative 4a.

Alternative 5 adds minor short-term impacts to the public, workers and the environment by means of concrete slab construction, well-installations and field work hazards.

The period to achieve short-term effectiveness is not applicable to Alternative 1, because there is no metric to evaluate its effectiveness. Alternatives 2a and 2b appear to be effective in the short term based on current site data. The ongoing effectiveness of Alternative 2 will be confirmed by long-term ground water monitoring. Alternatives 3, 4a and 4c are expected to meet their objectives in approximately one year because they use proven rapid construction technology. Alternative 4b is predicted to take four years based on three phytoremediation growing seasons to achieve cleanup goals, while Alternative 5 is expected to take three years (one year installation, two years operation).

4.12.4.6 Implementability

There are no barriers to implementing Alternatives 1 and 2a. Land-use restrictions included in Alternatives 2b, 3, 4b and 5 require acceptance by UCOP. There are numerous issues related to this acceptance including, but not limited to, increased site maintenance and development costs, loss of development potential and long-term monitoring costs that need to be negotiated by DOE and UCOP. Alternatives 2a, 4a, 4b and 4c avoid this implementation issue.

The paving procedures for implementing Alternative 3 are routine and technically feasible. Access is available to paving equipment, with only a minor barrier presented by a chain-link fence. A small amount of clean soil will be disposed under this alternative, but suitable landfill space is available within 30 miles of the Site. The monitoring wells have been, and are expected to remain, operable for the duration of this alternative. Paving equipment and labor are generally available on relatively short notice between May and November. Site preparations and restoration include removing a chain-link fence.

For Alternatives 4a and 4b, the excavation methods are technically feasible and are used in the construction of deep foundations. However, the use of large-diameter augers to conduct mass excavations has not been conducted at the Site at the scale proposed. Thus, unanticipated conditions may reduce the effectiveness of the soil removal and extend the project’s schedule and cost. Minor site preparation and restoration include removing a chain-link fence before excavation begins. Although the excavation methods are routinely used for foundation construction, the availability of the requisite specialized equipment and labor at any particular time is not guaranteed. Transportation and disposal of the contaminated material will require an involved permitting process, as a large fraction the material will be shipped to Envirocare of Utah.

The phytoremediation in Alternative 4b is technically feasible, involving well-established soil movement procedures and agricultural techniques. There is space available for this at the WDPs area. However, if multiple DOE areas are treated using phytoremediation, the project’s overall cleanup schedule will be delayed by several years due to treatment space constraints.

The conventional excavation procedures for implementing Alternative 4c are routine and technically feasible. The ground water monitoring portion of Alternative 4c takes advantage of the same in-place systems that Alternative 2 uses.

Alternative 5 is technically feasible. The methods for installing the wells and introducing the nutrient are well-established. Permission to inject will be required from the CRWQCB.

4.12.4.7 Costs

Cost:

- Alternative 1 (no action): $0
- Alternative 2a (ground water monitoring): $322,000
- Alternative 2b (ground water monitoring and land-use restrictions): $372,000
- Alternative 3 (cap, long-term ground water monitoring and land-use restrictions): $735,000
- Alternative 4a (removal and off-site disposal): $7,271,000 to $8,831,000
- Alternative 4b (removal and on-site treatment): $6,426,000 to $7,980,000
- Alternative 4c (limited removal, off-site disposal and long-term ground water monitoring): $4,636,000 to $5,183,000
- Alternative 5 (*in situ* bioremediation): $1,298,000

Detailed cost assumptions are presented in Appendix A.

4.12.4.8 State Acceptance

With the exception of the no action alternative, the State of California has accepted all of the alternatives.

A preferred remedial alternative will be presented in the Draft Proposed Plan. State of California acceptance of the preferred remedial alternative will be provided after resolution of their comments on the Draft Proposed Plan.

4.12.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on the accepted alternatives during the public comment period for the Proposed Plan.

4.13 Western Dog Pens

4.13.1 Nature and Extent of Contaminants of Concern

Dogs that were exposed to radioactive substances during LEHR experiments were housed in two outdoor dog pen areas identified as the Eastern and Western Dog Pens (Figure 1-2). The Western Dog Pens were constructed between 1958 and 1968 and consisted of 320 individual concrete pens lined with gravel. In 1975, the gravel and interior curbing of 64 pens were removed for construction of the Cellular Biology Laboratory (Figure 1-2). All of the above-ground concrete pedestals and wooden barrels used to house the dogs were removed from the Eastern and Western Dog Pens in 1995 and 1996, and disposed as low-level radioactive waste at Hanford.

More than 200 surface and subsurface samples were collected at the Western Dog Pens prior to the removal action in 2001. Gravel, concrete and soil sample data indicated chlordane was above the site-specific PRG and Ra-226, Sr-90, mercury and hexavalent chromium were above background and the site-specific PRGs. The maximum Ra-226, Sr-90, mercury and chlordane concentrations were 5.11 pCi/g, 5.66 pCi/g, 5.1 mg/kg and 2,060 mg/kg, respectively. Mercury and chlordane attenuated quickly with depth. The maximum hexavalent chromium concentration was 1.02 mg/kg. Hexavalent chromium concentrations were not found to correlate with depth.

In 2001, a removal action was conducted according to an approved work plan (WA, 2001) to reduce the Ra-226, Sr-90, mercury, hexavalent chromium and chlordane contamination that potentially posed a human health risk. The dog pen curbing and gravel, asphalt aisles separating the rows of dog pens, and the chain link fence that enclosed the entire area were removed.

Following the removal action, 46 confirmation samples were collected, 22 samples at discretionary locations and 24 samples on a grid with a random start. Ra-226 activity-concentrations in all of the soil samples collected after the removal action were below background. The maximum reported Sr-90 activity-concentration was more than an order of magnitude lower after the removal action (0.491 pCi/g). Mercury and hexavalent chromium concentrations were 5.1 mg/kg and 1.17 mg/kg, respectively. The maximum chlordane concentration (2.12 mg/kg) was approximately three orders of magnitude lower than the pre-removal maximum. Samples collected one foot beneath the surface of Aisle 3 showed that chlordane concentrations quickly attenuated with depth.

The sample results representing post-removal action conditions in the Western Dog Pens were used in the Site-Wide Risk Assessment to determine human health risk, ecological risk and ground water impacts. The approved Risk Characterization (WA, 2005) indicated Ra-226, Sr-90, mercury, hexavalent chromium and chlordane were not COCs after the removal action.

Topographic depressions were left in the Western Dog Pens area from the 2001 removal action. The topographic depressions were backfilled with soil originating from the Southwest Trenches area and an off-site agricultural area. The Southwest Trenches area soil was overburden removed during a removal action in 1998. Sample data from the Southwest Trenches area soil and imported agricultural fill were combined with the Western Dog Pens post-removal action data to determine the risk after backfilling. The approved post-backfilling Risk Assessment (WA, 2007) indicated the Western Dog Pens does not pose significant risk to human health or ecological receptors and there are no current or predicted ground water impacts. The Western Dog Pens has no COCs for evaluation in the Feasibility Study.

4.13.2 Description of Remedial Alternatives

4.13.2.1 Alternative 1—No Action

A no action alternative was developed for the WDPs area to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no further action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.13.3 Analysis of Remedial Alternatives

The remedial alternatives for the WDPs area were evaluated against the nine criteria described in Section 4.2.1 of the text. The evaluation of individual remedial alternatives was identical to the evaluation conducted for DSS 1 in Section 4.5.3. The evaluation summary is presented in Table 4-11.

4.14 Eastern Dog Pens

4.14.1 Nature and Extent of Contaminants of Concern

Dieldrin and Sr-90 are human health risk COCs. In September and October of 2007, after the Site Wide Risk Assessment was completed, DOE conducted a maintenance activity involving off-site disposal of the concrete curbs from the EDPs. The representative strontium-90 concentration in EDPs soil/solids, without correction for contaminant loss due to radioactive decay, and before the concrete curbs were removed, was 0.62 pCi/g. Before the concrete was disposed the estimated human health risk to residential receptors in the EDPs due to strontium-90 was 2 x 10^{-6}. The radioactive decay half-life for strontium-90 is 28.79 years. After the EDPs concrete was disposed, and accounting for radioactive decay since the EDPs were last sampled in March of 1999, the representative strontium-90 concentration was 0.33 pCi/g. The potential residential receptor risk in the EDPs due to strontium-90 was estimated to be 1 x 10^{-6} at the time of this report. This representative concentration of strontium-90 is at the EDPs cleanup goal (Table 2-1). Disposal of the EDPs concrete did not change the representative dieldrin concentration or the residential receptor human health risk due to dieldrin. No significant degradation is expected for dieldrin in the EDPs. Sr-90 and Dieldrin are both persistent pollutants and can bioconcentrate.

4.14.1.1 Dieldrin in Soil

Dieldrin was detected in thirteen of 37 sample results (35%) in the EDPs area (Figure 4-27). The detected concentrations ranged from 0.76 µg/kg to 223 µg/kg. Dieldrin contamination was more frequently detected in the eastern half of the EDPs. The highest and most frequently detected dieldrin concentrations were located in the northeast corner of the area. The highest detected concentration (Sample ID SSDP0338, located in surface soil [0-0.5 ft] near the northeastern corner of the dog pens) was in the 10^{-5} to 10^{-4} risk range. Dieldrin was not detected in subsurface soil at the same location (two ft bgs in Sample SSDP0340). The second-highest sample concentration was in the 10^{-6} to 10^{-5} risk range (Sample ID SSDP0345) and is surrounded by samples showing risks below 10^{-6}. The rest of the detected dieldrin concentrations indicated risk below 10^{-6} and appear randomly distributed. Dieldrin was not detected in any of the samples collected in the southwest quarter of the area.

4.14.1.2 Strontium-90 in Soil

At three locations, the Sr-90 concentrations correspond to a risk range between 10^{-4} and 10^{-5}, and at three locations, the Sr-90 concentrations correspond to a risk range between 10^{-5} and 10^{-6}. Samples with concentrations indicating risk above 10^{-5} are from the 1996 pedestal data set. The 1996 data are potentially poorly representative of site conditions, since they were not collected under the CERCLA RI/FS Work Plan or other quality assurance protocols. Regardless, the selection of the 1996 pedestal sample locations was based on elevated surface radiation scans, and likely represent a reasonable upper bound for residual Sr-90 concentrations in the pens.

4.14.2 Description of Remedial Alternatives

4.14.2.1 Alternative 1—No Action

A no action alternative was developed for the EDPs area to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.14.2.2 Alternative 2—Land-Use Restrictions

1. Alternative 2 consists of permanent land-use restrictions. Institutional controls would consist of a deed restriction preventing future residential development in areas where risks exceed 10^{-6} for hypothetical residents, and a requirement to profile and dispose any contaminated soil from the area in accordance with applicable requirements at the time of disposal.

The land-use restriction would be recorded with Solano County. The record would include a survey map and/or legal description defining the exclusion areas where residential risk is greater than 10^{-6} and references for site characterization data pertaining to the land-use restriction.

The cost of institutional controls will occur in the present time frame, and their implementation will be permanent.

Cost:

- Capital Cost: $50,000
- Present Worth O&M Cost: $0
- Periodic Costs: $0
- Total Present Worth Cost: $50,000

4.14.2.3 Alternative 3—Removal and Off-Site Disposal

Alternative 3 removes and disposes all of the gravel and asphalt in the EDPs area. Soil containing concentrations of dieldrin above the cleanup goals will also be removed. Several elderberry shrubs, that represent potential habitat for the presently threatened Valley Elderberry Longhorn Beetle (VELB), will be removed. This potential loss of habitat will be mitigated by funding VELB habitat development at an off-site location.

Concentrations of dieldrin are below the cleanup goals in all of the asphalt and gravel in the EDPs area. Though not a CERCLA or State requirement, all gravel and asphalt will be removed to facilitate future land development. Based on previous experience at the WDPs area, gravel and asphalt removal will result in an average excavation depth of 1.5 ft bgs. The actual depth at which soil is encountered will vary. Soil is present almost up to ground surface in the asphalt paved areas.

The areas of dieldrin concentrations in soil that exceed the cleanup goals are enclosed by the excavation limits shown on Figure 4-28. However, as stated in the Risk Characterization (WA, 2005), there is some uncertainty associated with the sample collection procedures used for some of the EDPs soil characterization samples. To reduce this uncertainty, field screening samples would be collected on a 20-ft grid and analyzed for dieldrin prior to soil removal. For the purpose of preparing the cost estimate, a six-inch depth of soil was assumed to be removed within the lateral excavation limits shown on Figure 4-28.

The asphalt, gravel and soil would be stockpiled separately, sampled for disposal, profiled for waste designation and transported to an appropriate disposal facility. All of the asphalt, gravel and soil was assumed to be low-level radioactive waste that would be disposed at Envirocare of Utah.

Confirmation samples will be collected from the excavation floor and sidewalls prior to filling the excavation. The excavation will be filled and compacted with clean imported fill from an off-site source.

All of the costs are expected to occur in the present time frame and no annual or periodic costs were assumed.

Cost:

- Capital Cost: $1,626,000
- Present Worth O&M Cost: $0
- Periodic Costs: $0
- Total Present Worth Cost: $1,626,000

4.14.3 Analysis of Remedial Alternatives

Table 4-12 summarizes the analysis of remedial alternatives. The comprehensive analysis is presented below.

4.14.3.1 Alternative 1—No Action

4.14.3.1.1 Overall Protection of Public Health and the Environment

Alternative 1 results in a risk of 4×10^{-6} to hypothetical future residential receptors. This value only slightly exceeds the 10^{-6} CERCLA point of departure, and is within the 10^{-4} to 10^{-6} CERCLA acceptable risk range.

4.14.3.1.2 Compliance with ARARs

Alternative 1 complies with ARARs.

4.14.3.1.3 Long-Term Effectiveness and Permanence

Alternative 1 is effective in the long term because the hypothetical residential receptor risk is within the CERCLA acceptable risk range. However, residual COC concentrations are slightly above the cleanup goals (i.e., 1 x 10^{-6}). The Sr-90 exposure point concentration is 0.33 pCi/g and the cleanup goal is 0.3 pCi/g. The dieldrin exposure point concentration is 0.019 mg/kg and the cleanup goal is 0.006 mg/kg.

4.14.3.1.4 Reduction of Toxicity, Mobility or Volume

Alternative 1 does not reduce toxicity, mobility or volume. The representative concentration of strontium-90 is at the target cleanup goal. Dieldrin is not expected to undergo any natural reduction in toxicity, mobility or volume.

4.14.3.1.5 Short-Term Effectiveness

Alternative 1 does not result in short-term impacts to the public, workers or the environment.

4.14.3.1.6 Implementability

There are no barriers to implementing Alternative 1. The selection of this alternative would not preclude UC Davis from capping or consolidating the EDP materials as part of the CERCLA remedy for Landfill Disposal Unit No. 2.

4.14.3.1.7 Cost

The cost of Alternative 1 is $0.

4.14.3.1.8 State Acceptance

The State of California has accepted Alternative 1 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.14.3.1.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.14.3.2 Alternative 2—Land-Use Restrictions

4.14.3.2.1 Overall Protection of Public Health and the Environment

Alternative 2 protects the public from exposure to dieldrin by prohibiting future residential development at the Site where risk is greater than 10^{-6}. The long-term effectiveness of these controls is uncertain.

4.14.3.2.2 Compliance with ARARs

Alternative 2 complies with ARARs.

4.14.3.2.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of residential land-use restrictions depends on permanent implementation. Dieldrin is assumed to remain at its current concentration in soil indefinitely. This is due to dieldrin being a persistent contaminant. Since there is no monitoring in Alternative 2, it will not be possible to verify whether dieldrin in soil has degraded over time.

4.14.3.2.4 Reduction of Toxicity, Mobility or Volume

Alternative 2 does not reduce the toxicity, mobility or volume. The representative concentration of strontium-90 is at the cleanup goal. Dieldrin is not assumed to undergo any reduction in toxicity, mobility or volume.

4.14.3.2.5 Short-Term Effectiveness

Alternative 2 does not add short-term risks to the public, workers or the environment. The predicted time to negotiate and record land-use restrictions is less than one year.

4.14.3.2.6 Implementability

There are no significant anticipated barriers to implementing Alternative 2. UC Davis tentatively plans land-use controls for this area as part of the CERCLA remedial action for the underlying Landfill Disposal Unit. The selection of this alternative would not preclude UC Davis from capping or consolidating the EDP materials as part of the CERCLA remedy for Landfill Disposal Unit No. 2.

4.14.3.2.7 Cost

The anticipated capital costs for Alternative 2 are $50,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.14.3.2.8 State Acceptance

The State of California has accepted Alternative 2 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.14.3.2.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.14.3.3 Alternative 3—Removal and Off-Site Disposal

4.14.3.3.1 Overall Protection of Public Health and the Environment

Alternative 3 is protective of human health by removing all soil with contaminant concentrations greater than the cleanup-goal concentrations and disposing it off site. The off-site disposal will transfer risk to the disposal site and result in short-term transportation risks, including highway accidents and vehicular air emissions.

4.14.3.3.2 Compliance with ARARs

Alternative 3 complies with all ARARs.

4.14.3.3.3 Long-Term Effectiveness and Permanence

Because all of the contamination in soil at concentrations exceeding the remediation goals is removed under Alternative 3, this alternative permanently mitigates site risks. Long-term risks are transferred to land disposal facilities that have been engineered and permitted to contain such waste.

4.14.3.3.4 Reduction of Toxicity, Mobility or Volume

Under Alternative 3, nearly all toxicity, mobility and contaminated soil volumes are reduced through removal.

4.14.3.3.5 Short-Term Effectiveness

Discernable short-term risks to the public and environment are associated with the transport of more than 190 truckloads of contaminated soil over a period of a few weeks. Off-site disposal has several negative impacts associated with it, including transfer of risk, air emissions and potential highway accidents. The estimated risk of a traffic fatality due to waste transport under this alternative is 8.01×10^{-3}. The estimated risk of a fatality due to waste transport air emissions is 1.76×10^{-3}. The estimated radiation dose to the maximally exposed member of the public (a truck driver) under this alternative is 0.68 mrem/year, which is considered a *de minimus* exposure. The procedures used to estimate these negative impacts are described in Section 5. Additionally, localized noise and vibration impacts at the Site will persist for weeks during the remedial action, and on-site research activities may be impacted. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment hazards.

The estimated time required to remove and dispose the contaminated soil is approximately one year.

4.14.3.3.6 Implementability

The excavation methods for implementing Alternative 3 are routine and technically feasible. Site preparations are relatively minor and mainly involve removing chain-link fencing before excavation begins. Transportation and disposal of the contaminated material will require an involved waste acceptance process, as the material will be shipped to Envirocare of Utah. Suitable landfill space is expected to remain available during the remedial action.

This alternative can be implemented with established engineering design and materials. Standard records management and database activities are required.

The selection of this alternative would not preclude UC Davis from capping or consolidating the EDP materials as part of the CERCLA remedy for Landfill Disposal Unit No. 2.

4.14.3.3.7 Cost

The anticipated capital and O&M costs are $1,626,000. Detailed cost assumptions for this alternative are presented in Appendix A.

4.14.3.3.8 State Acceptance

The State of California has accepted Alternative 3 as a viable alternative. The State of California reviewed the Draft Feasibility Study, submitted comments and comment resolution was reached.

4.14.3.3.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on their acceptance of this alternative during the public comment period for the Proposed Plan.

4.14.4 Comparative Evaluation of Remedial Alternatives

4.14.4.1 Overall Protection of Public Health and the Environment

Currently, the human health risk is within the CERCLA acceptable risk range of 10^{-4} to 10^{-6}, and only slightly above the 10^{-6} point of departure. The representative concentration of strontium-90 is at the target cleanup goal (Table 2-1) and the estimated strontium-90 risk is 1×10^{-6}. EDPs risk is primarily due to dieldrin (3×10^{-6}). Thus, public health is protected under Alternative 1 in which no action is proposed to address the risk due to dieldrin and Sr-90. Alternative 2 implements land-use restrictions to address this marginal risk. Alternative 3 excavates the contaminated soil and effectively mitigates Site risk by disposing the contaminated soil off site.

Risk reductions at the Site under Alternative 3 will be offset by the transfer of risk to the disposal site, the addition of transportation risks and the emission of air pollutants from trucks. Alternatives 2 requires administrative controls that prohibit residential development at the Site. All of the alternatives, except Alternative 3, result in some residual site contamination. Only Alternatives 1 and 3 allow unrestricted land use.

4.14.4.2 Compliance with ARARs

All of the alternatives currently comply with the ARARs.

4.14.4.3 Long-Term Effectiveness and Permanence

Alternative 1 is effective in the long term, since the residual risk to the hypothetical resident is within the CERCLA acceptable risk range. However, Alternative 1 lacks permanent management controls to protect potential future residents from COCs left in place above the cleanup goals. UC Davis will likely apply land-use controls for this area as part of the CERCLA remedial action for the underlying landfill. Alternative 2 provides the management controls to protect potential future residents by permanently restricting residential development. Alternative 3 is a permanent solution for the Site with respect to human health but transfers risk to a land disposal facility and to the public through potential traffic- and emission-related fatalities. Sr-90 and Dieldrin are both persistent pollutants and can bioconcentrate.

4.14.4.4 Reduction of Toxicity, Mobility or Volume

There is no reduction of toxicity, mobility or volume under Alternatives 1 or 2. The residential human health risk from Sr-90 is currently at 1×10^{-6}. Dieldrin is assumed to not degrade. Under Alternative 3, all soil with contaminant concentrations greater than cleanup-goal concentrations is completely excavated.

4.14.4.5 Short-Term Effectiveness

Alternatives 1 and 2 will not add any short-term impacts to the public, workers or the environment. Alternative 3 produces the most severe impact in the short term. Discernable short-term risks to the public and environment are associated with the transport of contaminated soil, gravel and asphalt to the waste disposal site in Utah. Transportation impacts include local traffic congestion, air emissions and the risk of highway accidents. Site construction impacts, including localized noise and ground vibrations, will persist for a few weeks during the remedial action. Air monitoring, dust control and personal protective equipment are required. Workers will also be exposed to heavy equipment.

Alternative 1 is currently protective. Alternative 2 is expected to require less than one year to negotiate and record the land use restrictions. Alternative 3, is expected to meet its objectives in approximately one year because it uses proven rapid construction technology.

4.14.4.6 Implementability

There are no barriers to implementing Alternative 1. Land-use restrictions included in Alternative 2 require acceptance by UCOP. There should be no land-use restriction implementation issues since UC Davis tentatively plans to restrict land use in this area as part of the CERCLA remedial action for the underlying municipal landfill unit. All of the alternatives are compatible with future capping or consolidation remedies that may be implemented by UC Davis.

For Alternative 3, the excavation methods are routine and technically feasible. Under Alternative 3, routine and readily available shaker screen equipment would be used to separate soil and gravel. Minor site preparation and restoration include removing a chain-link fence before excavation begins. Transportation and disposal of the contaminated material will require an involved permitting process, as all of the waste will be shipped to Envirocare of Utah.

4.14.4.7 Costs

Cost:

- Alternative 1 (no action): $0
- Alternative 2 (land-use restrictions): $50,000
- Alternative 3 (removal and off-site disposal): $1,626,000

Detailed cost assumptions are presented in Appendix A.

4.14.4.8 State Acceptance

The State of California has accepted all of the alternatives.

A preferred remedial alternative will be presented in the Draft Proposed Plan. State of California acceptance of the preferred remedial alternative will be provided after resolution of their comments on the Draft Proposed Plan.

4.14.4.9 Community Acceptance

The Draft Feasibility Study was submitted to DSCSOC for their review and comment. The public at large will have the opportunity to comment on the accepted alternatives during the public comment period for the Proposed Plan.

4.15 DOE Disposal Box

4.15.1 Nature and Extent of Contaminants of Concern

The DOE Disposal Box (Figure 1-2) was a repository used by the LEHR facility for disposal of miscellaneous low-level radioactive research waste, including syringes, bottles, vials and gravel. Ra-226 and Sr-90 were above background and the site-specific PRG in the DOE Disposal Box area prior to the 1996 removal action. The maximum Ra-226 and Sr-90 activity-concentrations in soil were 9.7 pCi/g and 36.7 pCi/g, respectively.

In 1996, a time-critical removal action was conducted at the DOE Disposal Box area to remove the Ra-226 and Sr-90 contamination that potentially posed a human health risk. Approximately 110 cubic yards of waste were removed, including soil, gravel, steel runway matting, plywood, syringes, bottles and vials. Following removal of the waste matrix, the area was over-excavated to remove approximately six inches of native soil from the excavation bottom and sidewalls. The excavation was lined with 20-mil high-density polyethylene and backfilled with clean fill. The DOE Disposal Box area waste was shipped to the DOE Hanford site for disposal in 1997.

Following the 1996 time-critical removal action, confirmation samples were collected from the excavation. The majority of the radionuclide concentrations in the confirmation samples were below their respective minimum detectable concentrations. There were no radionuclides detected at concentrations significantly above their respective background. However, the confirmation sampling plan design was not statistically based, and the confirmation samples were analyzed for a limited suite of analytes. In spring 2002, a second confirmation sampling event was conducted following an approved work plan (WA, 2001d) to obtain data that was sufficient for proper closure of the DOE Disposal Box area. The second round of confirmation sampling consisted of 30 soil samples collected on a random grid. The post removal action soil samples data indicated a more than five-fold decrease in the maximum Ra-226 activity-concentration (1.41 pCi/g) and a 500-fold decrease in the maximum Sr-90 activity-concentration (0.0721 pCi/g).

The sample results representing post-removal action conditions at the DOE Disposal Box area were used in the Site-Wide Risk Assessment. The risk assessment results were evaluated in the approved Risk Characterization Report (WA, 2005) and showed the DOE Disposal Box area does not pose significant risk to human health or ecological receptors and there are no current or predicted ground water impacts. Ra-226 and Sr-90 are no longer COCs at the DOE Disposal Box area and the DOE Disposal Box area has no COCs for evaluation in the Feasibility Study.

4.15.2 Description of Remedial Alternatives

4.15.2.1 Alternative 1—No Action

A no action alternative was developed for the DOE Disposal Box area to determine the potential effects and costs associated with leaving residual contaminants in place. Under this alternative, no further action, including environmental monitoring, will be performed. There is no cost to implement this alternative.

4.15.3 Analysis of Remedial Alternatives

The remedial alternatives for the DOE Disposal Box area were evaluated against the nine criteria described in Section 4.2.1 of the text. The evaluation of individual remedial alternatives was identical to the evaluation conducted for DSS 1 in Section 4.5.3. The evaluation summary is presented in Table 4-13.

Table 4-1. Summary of Constituents of Concern and Remedial Alternatives for the Department of Energy Areas

DOE Area[1]	COC	COC Type	Receptor Type	Alternatives
Ra/Sr Treatment Systems	Nitrate Carbon-14 Radium-226	GW GW GW	N/A N/A N/A	Alternative 1—No action Alternative 2—Long-term ground water monitoring and contingent remedial action Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring, and land-use restrictions Alternative 4a—Removal and off-site disposal Alternative 4b—Removal and on-site treatment Alternative 4c—Limited removal, off-site disposal and long-term ground water monitoring Alternative 5—*In situ* bioremediation and long-term ground water monitoring
Domestic Septic System No. 3	Formaldehyde Molybdenum Nitrate	GW GW GW	N/A N/A N/A	Alternative 1—No action Alternative 2—Long-term ground water monitoring and contingent remedial action Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions Alternative 4a—Removal and off-site disposal Alternative 4b—Removal and on-site treatment Alternative 4c—Limited removal, off-site disposal and long-term ground water monitoring Alternative 5—*In situ* bioremediation and long-term ground water monitoring
Domestic Septic System No. 4	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene	HH HH HH HH HH HH	R R, C R R R R	Alternative 1—No action Alternative 2—Long-term ground water monitoring, land-use restrictions and contingent remedial action Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions Alternative 4—Removal, off-site disposal and land-use restrictions

Table 4-1. Summary of Constituents of Concern and Remedial Alternatives for the Department of Energy Areas (continued)

DOE Area[1]	COC	COC Type	Receptor Type	Alternatives
	Selenium	GW	N/A	
Dry Wells A-E Area	Chromium	GW	N/A	Alternative 1—No action
	Hexavalent Chromium	GW	N/A	Alternative 2—Long-term ground water monitoring and contingent remedial action
	Mercury	GW	N/A	Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions
	Molybdenum	GW	N/A	Alternative 4a—Removal and off-site disposal
	Silver	GW	N/A	Alternative 4b—Limited removal, off-site disposal and long-term ground water monitoring
	Cesium-137	GW	N/A	
	Strontium-90	GW	N/A	
Southwest Trenches	Strontium-90+Daughter	HH	R	Alternative 1—No action
	Nitrate	GW	N/A	Alternative 2a—Long-term ground water monitoring and contingent remedial action
	Carbon-14	GW	N/A	Alternative 2b—Long-term ground water monitoring, land-use restrictions and contingent remedial action
				Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions
				Alternative 4a—Removal and off-site disposal
				Alternative 4b—Removal and on-site treatment
				Alternative 4c—Limited removal, off-site disposal and long-term ground water monitoring
				Alternative 5—*In situ* bioremediation, long-term ground water monitoring and land-use restrictions
Eastern Dog Pens	Dieldrin	HH	R	Alternative 1—No action
	Strontium-90+Daughter	HH	R	Alternative 2—Land-use restrictions
				Alternative 3—Removal and off-site disposal

Note
[1] No COCs were identified for Domestic Septic Systems 1,5,6 and 7 and the Western Dog Pens.

Table 4-1. Summary of Constituents of Concern and Remedial Alternatives for the Department of Energy Areas (continued)

Abbreviations

C	construction worker receptor
COC	constituent of concern
DOE	United States Department of Energy
GW	ground water
HH	human health
HDPE	high-density polyethylene
N/A	not applicable (to human health receptor)
No.	number
R	residential receptor
Ra/Sr	Radium/Strontium

Table 4-2. Evaluation Summary for Radium/Strontium Treatment Systems Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs[3]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[2]	
Alternative 1: No action	Removal actions have successfully addressed the principle threats to public health and the environment. This alternative does not address future ground water protection.	This alternative may not comply with the State's Anti-Degradation Policy and Basin Plan.	Not effective due to localized known ground water impacts that will not be monitored. Lacks management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Does not reduce TMV.	No short-term risks to the public	N/A	N/A	N/A	The State of California has not accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$ 0
Alternative 2: Long-term ground water monitoring and contingent remedial action	Protects the beneficial use of ground water by monitoring ground water near the source area. If deemed not protective in the future, remedial action may be implemented.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Includes monitoring and management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Does not reduce TMV.	No short-term risks to the public and environment. Ongoing effectiveness will be confirmed by long-term ground water monitoring.	Utilizes standard monitoring techniques currently deployed at the Site. Site development could limit access to areas requiring future remedial action.	Standard records management and database activities required. Land-use restrictions may be a component of future remedial action, if required.	Relies on standard services and materials.	The State of California has accepted Alternative 2 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$246,000
Alternative 3: Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions	Protects beneficial use of ground water through surface capping and monitoring ground water near the source area.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Cap will reduce the flux of contaminants to ground water, if maintained. Includes monitoring and management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Reduces mobility of residual soil contamination by eliminating surface water infiltration. Some contaminant migration to the water table will still occur through diffusion. Does not reduce contaminant mass and volume.	Minor short-term risks to the public and environment are associated with the manufacture, transport and installation of asphalt. The risk of a fatality from implementing this alternative is approximately zero. Cap may restrict site development and aesthetics. Time to deploy is rapid since the cap relies on established engineering design and materials. Predicted to be protective in approximately 1 year.	Relies on established engineering design and materials.	Standard records management and database activities required. Land-use restrictions require approval by UCOP.	Relies on standard services and materials.	The State of California has accepted Alternative 3 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$646,000
Alternative 4A: Removal and off-site disposal	Protects beneficial use of ground water by removing the contaminated soil. Local risk reduction offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents and vehicular air emissions.	Compliant with ARARs.	Effective since virtually all residual contamination is removed. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	Reduces TMV to negligible quantities by transferring contaminated soil to land disposal site.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 1.17×10^{-2}. Emissions fatality risk = 2.58×10^{-3}. Potential radiation dose to maximum exposed member of public = 0.43 mrem/yr. Localized noise and vibration impacts will persist for months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year. Time to complete is uncertain and may exceed 1 year due to the depth and techniques required to excavate the contaminated soil.	The use of large diameter augers to conduct mass excavation has not been conducted at LEHR at the scale proposed and may fail to remove all contaminated soil, and/or extend the project's schedule and costs.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4a as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$3, 335,000 - $5,052,000

Table 4-2. Evaluation Summary for Radium/Strontium Treatment Systems Remedial Alternatives (continued)

Evaluation Criteria	Effectiveness					Implementability					Total Costs[3]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[2]	
Alternative 4B: Removal and on-site treatment	Protects beneficial use of ground water by removing the contaminated soil and treating it in a lined treatment cell and disposing soil containing added radioactivity at permitted landfills. Local risk reduction offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents, vehicular air emissions, and on-site treatment operations.	Compliant with ARARs.	Effective since virtually all residual contamination is removed and treated or disposed. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	Reduces TMV to negligible quantities by on-site treatment and transferring soil containing added radioactivity to land disposal site.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 1.88 x 10^{-3}. Emissions fatality risk = 4.14 x 10^{-4}. Potential radiation dose to maximum exposed member of public = 0.24 mrem/yr. Localized noise and vibration impacts will persist for months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Time to complete removal action is uncertain due to the depth and techniques required to excavate the contaminated soil. Predicted to be protective in approximately 4 years.	The use of large diameter augers to conduct mass excavation has not been conducted at LEHR at the scale proposed and may fail to remove all contaminated soil, and/or extend the project's schedule and costs.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action. On-site treatment requires the use of the Western Dog Pens area.	The State of California has accepted Alternative 4b as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$2,363,000 - $3,234,000
Alternative 4C: Limited Removal, off-site disposal and Long-term ground water monitoring	Protects beneficial use of ground water by removing some contaminated soil and monitoring ground water near the source area.	Compliant with ARARs.	Effective reduction in mass and toxicity due to partial removal of residual contaminants in soil. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	Reduces toxicity and volume by transferring a limited volume of contaminated soil to land disposal site. No change in mobility.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 7.89 x 10^{-3}. Emissions fatality risk = 1.74 x 10^{-3}. Potential radiation dose to maximum exposed member of public = 0.43 mrem/yr. Localized noise and vibration impacts will persist for several weeks during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year.	Utilizes standard excavation and disposal techniques.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4c as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$2,091,000 - $2,492,000
Alternative 5: *In situ* bioremediation and long-term ground water monitoring	Protects beneficial use of ground water by treating nitrate-contaminated soil and monitoring ground water near the source area.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Includes pilot test, monitoring and management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Reduces nitrate TMV to negligible quantities. Should have no effect on the negligible quantity of co-located radium-226. Will not effect carbon-14 which is not co-located with the nitrate. Does not reduce TMV of carbon-14 and radium-228.	Minor short-term risks to the public and environment are associated with the installation and operation of a bioremediation system. The risk of a fatality from implementing this alternative is approximately zero. The treatment system may interfere with site activities or development. Time to deploy can be rapid since the system relies on established engineering design and materials. Predicted to be protective in approximately 3 years.	A site-specific pilot test is required to confirm technical feasibility.	Standard records management and database activities required.	Relies on standard services and materials.	The State of California has accepted Alternative 5 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$1,206,000

Notes
[1]State acceptance will be assessed after comments on the feasibility study are resolved.
[2]Community acceptance will be determined after comments on the proposed plan are resolved.
[3]Net present value of capital and operation and maintenance costs.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
HDPE	high density polyethylene
N/A	not applicable
TMV	toxicity, mobility, or volume
UCOP	University of California Office of the President

Table 4-3. Evaluation Summary for Domestic Septic System No. 1 Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance	Community Acceptance	
Alternative 1: No action	Protective. The SWRA did not identify any current or potential future impacts to public health or ground water	Compliant with ARARs.	N/A	N/A.	N/A	N/A	N/A	N/A	The State of California has accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$0

Abbreviations
ARARs Applicable or Relevant and Appropriate Requirements
N/A not applicable
No. number
SWRA Site-Wide Risk Assessment
TMV toxicity, mobility or volume

Table 4-4. Evaluation Summary for Domestic Septic System No. 3 Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs[3]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[2]	
Alternative 1: No action	Removal actions have successfully addressed the principle threats to public health and the environment. This alternative does not address future ground water protection.	May not comply with the State's Anti-Degradation Policy. This area is a possible source of contaminants currently present in ground water.	Not effective due to localized known ground water impacts that will not be monitored. Lacks management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Does not reduce TMV.	No short-term risks to the public	N/A	N/A	N/A	The State of California has not accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$ 0
Alternative 2: Long-term ground water monitoring and contingent remedial action	Protects the beneficial use of ground water by monitoring ground water near the source area. If deemed not protective in the future, remedial action may be implemented.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Includes monitoring and management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Does not reduce TMV.	No short-term risks to the public and environment. Ongoing effectiveness will be confirmed by long-term ground water monitoring.	Utilizes standard monitoring techniques currently deployed at the Site. Site development could limit access to areas requiring future remedial action.	Standard records management and database activities required. Land-use restrictions may be a component of future remedial action, if required.	Relies on standard services and materials.	The State of California has accepted Alternative 2 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$221,000
Alternative 3: Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions	Protects beneficial use of ground water through surface capping, and monitoring ground water near the source area.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Cap will reduce the flux of contaminants to ground water, if maintained. Includes monitoring and management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Reduces mobility of residual soil contamination by eliminating surface water infiltration. Some contaminant migration to the water table will still occur through diffusion. Does not reduce contaminant mass and volume.	Minor short-term risks to the public and environment are associated with the manufacture, transport and installation of asphalt. The risk of a fatality from implementing this alternative is approximately zero. Cap may restrict site development and aesthetics. Time to deploy is rapid, since the cap relies on established engineering design and materials. Predicted to be protective in approximately 1 year.	Relies on established engineering design and materials.	Standard records management and database activities required. Land-use restrictions require approval by UCOP.	Relies on standard services and materials.	The State of California has accepted Alternative 3 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$468,000
Alternative 4A: Removal and off-site disposal	Protects beneficial use of ground water by removing the contaminated soil. Local risk reduction offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents and vehicular air emissions.	Compliant with ARARs.	Effective since virtually all residual contamination is removed. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	Reduces TMV to negligible quantities by transferring contaminated soil to land disposal site.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 1.05×10^{-2}. Emissions fatality risk = 2.31×10^{-3}. Potential radiation dose to maximum exposed member of public = 0.21 mrem/yr. Localized noise and vibration impacts will persist for months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year. Time to complete is uncertain and may exceed 1 year due to the depth and techniques required to excavate the contaminated soil.	The use of large-diameter augers to conduct mass excavation has not been conducted at LEHR at the scale proposed and may fail to remove all contaminated soil, and/or extend the project's schedule and costs.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4a as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$4,562,000

Table 4-4. Evaluation Summary for Domestic Septic System No. 3 Remedial Alternatives (continued)

Evaluation Criteria	Effectiveness					Implementability					Total Costs[3]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[2]	
Alternative 4B: Removal, and on-site treatment	Protects beneficial use of ground water by removing the contaminated soil and treating it in a lined treatment cell and disposing soil containing added radioactivity at permitted landfills. Local risk reduction offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents, vehicular air emissions, and onsite treatment operations.	Compliant with ARARs.	Effective since virtually all residual contamination is removed and treated or disposed. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	Reduces TMV to negligible quantities by on-site and transferring containing added radioactivity to land disposal site.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 8.71 x 10^{-3}. Emissions fatality risk = 1.92 x 10^{-3}. Potential radiation dose to maximum exposed member of public = 0.21 mrem/yr. Localized noise and vibration impacts will persist for months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Time to complete removal action is uncertain due to the depth and techniques required to excavate the contaminated soil. Predicted to be protective in approximately 4 years.	The use of large-diameter augers to conduct mass excavation has not been conducted at LEHR at the scale proposed and may fail to remove all contaminated soil, and/or extend the project's schedule and costs.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action. On-site treatment requires the use of the Western Dog Pens area.	The State of California has accepted Alternative 4b as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$4,471,000
Alternative 4C: Limited Removal, off-site disposal and Long-term ground water monitoring	Protects beneficial use of ground water by removing some contaminated soil and monitoring ground water near the source area.	Compliant with ARARs.	Effective reduction in mass and toxicity due to partial removal of residual contaminants in soil. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	Reduces toxicity and volume by transferring a limited volume of contaminated soil to land disposal site. No change in mobility.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 6.05 x 10^{-3}. Emissions fatality risk = 1.33 x 10^{-3}. Potential radiation dose to maximum exposed member of public = 0.21 mrem/yr. Localized noise and vibration impacts will persist for several weeks during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year.	Utilizes standard excavation and disposal techniques.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4c as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$2,159,000
Alternative 5: *In situ* bioremediation and long-term ground water monitoring	Protects beneficial use of ground water by treating nitrate and formaldehyde-contaminated soil and monitoring ground water concentration trends of COCs near the source area.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Includes pilot test, monitoring and management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Reduces nitrate and formaldehyde TMV to negligible quantities. Does not treat and may increase the mobility of molybdenum.	Minor short-term risks to the public and environment are associated with the installation and operation of a bioremediation system. The risk of a fatality from implementing this alternative is approximately zero. The treatment system may interfere with site activities or development. Time to deploy can be rapid, since the system relies on established engineering design and materials. Predicted to be protective in approximately 3 years.	A site-specific pilot test is required to confirm technical feasibility.	Standard records management and database activities required.	Relies on standard services and materials.	The State of California has accepted Alternative 5 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$1,319,000

Notes
[1]State acceptance will be assessed after comments on the feasibility study are resolved.
[2]Community acceptance will be determined after comments on the Proposed Plan are resolved.
[3]Net present value of capital and operation and maintenance costs.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
COCs	contaminants of concern
HDPE	high-density polyethylene
LEHR	Laboratory for Energy-Related Health Research
N/A	not applicable
No.	number
TMV	toxicity, mobility or volume
UCOP	University of California Office of the President

Table 4-5. Evaluation Summary for Domestic Septic System No. 4 Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs[2]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	Residual soil contaminants pose a risk to hypothetical site residents. The risk to construction workers falls within the acceptable CERCLA risk range but slightly exceeds 1E-6. This alternative does not address future ground water protection.	This alternative may not comply with the State's Anti-Degradation Policy and Basin Plan.	Not effective due to localized known ground water impacts that will not be monitored and the potential risk to hypothetical site residents and construction workers. Hypothetical site resident risk = 5×10^{-4}. Construction worker risk = 1×10^{-6}.	Does not reduce TMV.	No short-term risks to the public. Residential receptors do not currently occupy the site. No construction projects are currently planned in the DSS 4 area.	N/A	N/A	N/A	The State of California has not accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$ 0
Alternative 2: Long-term ground water monitoring, contingent remedial action and land-use restrictions	Prevents site residential and construction worker exposure to subsurface soil contamination by implementing land-use restrictions that prevent residential use and unsafe worker exposure. Manages potential future loss of beneficial use of ground water by monitoring ground water near the source area. If deemed not protective of ground water in the future, other remedial actions may be undertaken.	Compliant with ARARs.	Effective in protecting human health if land-use restrictions are maintained. Human health risk less than 10^{-6}. Effective in protecting ground water due to the negligible mass and toxicity of residual contaminants in soil. Includes monitoring and management controls to confirm effectiveness of ground water protection.	Does not reduce TMV.	No short-term risks to the public and environment. Ongoing effectiveness will be confirmed by long-term ground water monitoring.	Utilizes standard monitoring techniques currently deployed at the Site. Site development could limit access to areas requiring future remedial action.	Standard records management and database activities required. Land-use restrictions require approval by the UCOP. Additional land-use restrictions may be a component of future remedial action, if required.	Relies on standard services and materials.	The State of California has accepted Alternative 2 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$260,000
Alternative 3: Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions	Prevents site resident exposure to subsurface soil contamination by implementing land-use restrictions that prevent residential use and unsafe worker exposure. Deed restrictions prevent disturbances of the cap. The physical barrier and development restrictions provided by the cap mitigate direct worker exposure to the underlying contaminants. Protects beneficial use of ground water by limiting meteoric water infiltration through surface capping, and monitoring ground water near the source area.	Compliant with ARARs.	Effective in protecting human health if land-use restrictions are maintained. Human health risk less than 10^{-6}. Effective in protecting ground water due to the negligible mass and toxicity of residual contaminants in soil. Cap will reduce the flux of contaminants to ground water, if maintained. Includes monitoring and management controls to confirm effectiveness of ground water protection.	Cap reduces mobility of residual soil contamination by eliminating the infiltration of surface water. Some contaminant migration to the water table will still occur through diffusion. Does not reduce contaminant mass and volume.	Minor short-term risks to the public and environment are associated with the manufacture, transport and installation of asphalt. The risk of a fatality from implementing this alternative is approximately zero. Cap may restrict site development and aesthetics. Time to deploy is rapid, since the cap relies on established engineering design and materials. Predicted to be protective in approximately 1 year.	Relies on established engineering design and materials.	Standard records management and database activities required. Land-use restrictions require approval by UCOP.	Relies on standard services and materials.	The State of California has accepted Alternative 3 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$432,000

Table 4-5. Evaluation Summary for Domestic Septic System No. 4 Remedial Alternatives (continued)

Evaluation Criteria	Effectiveness					Implementability					Total Costs[2]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 4: Removal, off-site disposal and land-use restrictions	Protects beneficial use of ground water by removing the accessible contaminated soil and disposing it. Local risk reduction is offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents and vehicular air emissions. Prevents residential receptor exposure to currently inaccessible subsurface soil contamination (beneath Building H-215) by implementing land-use restrictions that prevent residential land use.	Compliant with ARARs.	Effective for accessible contamination. Risk transferred to disposal site, but contaminant mass is small and should be easily controlled in a permitted facility. Effectiveness of land-use restrictions for inaccessible contamination depends on continued future implementation. Human health risk less than 10^{-6}.	Accessible contamination TMV reduced to negligible quantities by transferring contaminated soil volume to land disposal site. However, exposure and mobility of inaccessible contamination is currently minimized due to area coverage by Building H-215.	Minor short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 8.2×10^{-6}. Emissions fatality risk = 1.8×10^{-6}. Localized noise will persist for a few weeks during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year.	Utilizes standard excavation and disposal techniques.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$547,000

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.
[2]Net present value of capital and operation and maintenance costs.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
DSS	Domestic Septic System
HDPE	high-density polyethylene
N/A	not applicable
No.	number
TMV	toxicity, mobility or volume
UCOP	University of California Office of the President

Table 4-6. Evaluation Summary for Domestic Septic System No. 5 Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	Protective. The SWRA did not identify any current or potential future impacts to public health or ground water	Compliant with ARARs.	N/A	N/A	N/A	N/A	N/A	N/A	The State of California has accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$0

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
N/A	not applicable
No.	number
SWRA	Site-Wide Risk Assessment
TMV	toxicity, mobility or volume

Table 4-7. Evaluation Summary for Domestic Septic System No. 6 Remedial Alternatives

Evaluation Criteria	Effectiveness				Implementability					Total Costs
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	Protective. The SWRA did not identify any current or potential future impacts to public health or ground water.	Compliant with ARARs.	N/A	N/A	N/A	N/A	N/A	N/A	The State of California has accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$0

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.

Abbreviations

ARARs Applicable or Relevant and Appropriate Requirements
N/A not applicable
No. number
SWRA Site-Wide Risk Assessment
TMV toxicity, mobility or volume

Table 4-8. Evaluation Summary for Domestic Septic System No. 7 Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	Protective. The SWRA did not identify any current or potential future impacts to public health or ground water.	Compliant with ARARs.	N/A	N/A	N/A	N/A	N/A	N/A	The State of California has accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$0

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
N/A	not applicable
No.	number
SWRA	Site-Wide Risk Assessment
TMV	toxicity, mobility or volume

Table 4-9. Evaluation Summary for Domestic Septic System Nos. 1 and 5 Leach Field (Dry Wells A through E) Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs[2]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	This alternative does not address future ground water protection.	This alternative may not comply with the State's Anti-Degradation Policy and Basin Plan.	Not effective due to localized known ground water impacts that will not be monitored. Lacks management controls to protect ground water. Human health risk less than 10^{-6}.	Does not reduce TMV.	No short-term risks to the public. Current ground water monitoring is showing no significant impacts.	N/A	N/A	N/A	The State of California has not accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$ 0
Alternative 2: Long-term ground water monitoring and contingent remedial action	Protects the beneficial use of ground water by monitoring ground water near the source area. If deemed not protective in the future, remedial action may be implemented.	Compliant with ARARs	Effective due to the limited mass of contaminants in the vadose zone and the inclusion of monitoring and management controls to initiate future remedial actions if necessary. Human health risk less than 10^{-6}.	Does not reduce TMV.	No short-term risks to the public and environment. Current ground water monitoring is showing no significant impacts. Ongoing effectiveness will be confirmed by long-term ground water monitoring.	Utilizes standard monitoring techniques currently deployed at the Site. Site development could limit access to areas requiring future remedial action.	Standard records management and database activities required. Land-use restrictions may be a component of future remedial action, if required.	Relies on standard services and materials.	The State of California has accepted Alternative 2 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$145,000
Alternative 3: Asphalt /HDPE cap, and long-term ground water monitoring and land-use restrictions	Protects beneficial use of ground water by limiting surface water infiltration through surface capping, and monitoring ground water near the source area. Deed restrictions will mitigate disturbances of the cap.	Compliant with ARARs.	Effective due to the limited mass of contaminants in the vadose zone. Additionally, cap will reduce the flux of contaminants to ground water, if maintained. Includes monitoring and management controls to confirm effectiveness. Human health risk less than 10^{-6}.	Reduces mobility of residual soil contamination by eliminating surface water infiltration. Some contaminant migration to the water table will still occur through diffusion. Does not reduce contaminant mass and volume.	Minor short-term risks to the public and environment are associated with the manufacture, transport and installation of asphalt. The risk of a fatality from implementing this alternative is approximately zero. Cap may restrict site development and aesthetics. Time to deploy is rapid, since the cap relies on established engineering design and materials. Predicted to be protective in approximately 1 year.	Relies on established engineering design and materials	Standard records management and database activities required. Land-use restrictions require approval by UCOP.	Relies on standard services and materials.	The State of California has accepted Alternative 3 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$404,000

Table 4-9. Evaluation Summary for Domestic Septic System Nos. 1 and 5 Leach Field (Dry Wells A through E) Remedial Alternatives (continued)

Evaluation Criteria	Effectiveness					Implementability					Total Costs[2]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 4A: Remove and dispose soil above the cleanup goals	Protects beneficial use of ground water by removing the contaminated soil and disposing it at permitted landfills. Local protection offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents and vehicular air emissions.	Compliant with ARARs.	Effective since virtually all residual contamination is removed. Risk transferred to disposal site but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	TMV reduced to negligible quantities by transferring contaminated soil to land disposal site.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 2.58×10^{-3}. Emissions fatality risk = 5.67×10^{-4}. Potential radiation dose to maximum exposed member of public = 0.057 mrem/yr. Localized noise and vibration impacts will persist for weeks during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year.	The use of large-diameter augers to conduct dry well excavation has been successfully conducted at LEHR.	Standard records management and database activities required.	Relies on standard services and materials Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4a as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$1,201,000
Alternative 4B: Limited Removal, off-site disposal and Long-term ground water monitoring	Protects beneficial use of ground water by removing some contaminated soil and monitoring ground water near the source area.	Compliant with ARARs.	Effective due to the limited mass of contaminants in the vadose zone. Additional mass reduction due to partial removal of residual contaminants in soil. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	Reduces toxicity and volume by transferring a limited volume of contaminated soil to land disposal site. No change in mobility.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 1.10×10^{-3}. Emissions fatality risk = 2.43×10^{-4}. Potential radiation dose to maximum exposed member of public = 0.024 mrem/yr. Localized noise and vibration impacts will persist for a few weeks during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year.	Utilizes standard excavation and disposal techniques.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4b as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$843,000

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.
[2]Net present value of capital and operation and maintenance costs.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
HDPE	high-density polyethylene
LEHR	Laboratory for Energy-Related Health Research
N/A	not applicable
UCOP	University of California Office of the President

Table 4-10. Evaluation Summary for Southwest Trenches Remedial Alternatives

Evaluation Criteria	Effectiveness				Implementability					Total Costs[2]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	Residual soil contaminants pose a marginal (3E-6) risk to hypothetical residential receptors. Residual soil contaminants in the vadose zone may result in a loss of beneficial use of ground water.	This alternative may not comply with the State's Anti-Degradation Policy and Basin Plan.	Not effective due to localized known ground water impacts that will not be monitored. Lacks management controls to confirm effectiveness. Hypothetical site resident risk = 3 x 10^{-6}.	Does not reduce TMV.	No short-term risks to the public. Residential receptors do not currently occupy the Site.	N/A	N/A	N/A	The State of California has not accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$ 0
Alternative 2a: Long-Term Ground Water Monitoring and Contingent Remedial Action	Identifies marginal risk (3E-6) to the hypothetical resident as acceptable Protects the beneficial use of ground water by monitoring ground water near the source area. If deemed not protective in the future, remedial action may be implemented.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Includes monitoring to confirm effectiveness of ground water protection. Hypothetical site resident risk = 3 x 10^{-6}.	Does not reduce TMV.	No short-term risks to the public and environment. Ongoing effectiveness will be confirmed by long-term ground water monitoring.	Utilizes standard monitoring techniques currently deployed at the Site. Site development could limit access to areas requiring future remedial action.	Standard records management and database activities required. Land-use restrictions may be a component of future remedial action, if required.	Relies on standard services and materials.	The State of California has accepted Alternative 2a as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$322,000
Alternative 2b: Long Term Ground Water Monitoring, Land Use Restrictions and Contingent Remedial Action	Mitigates marginal residential receptor risk by implementing land-use controls that prevent residential land use. Protects the beneficial use of ground water by monitoring ground water near the source area. If deemed not protective in the future, remedial action may be implemented.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Includes monitoring and management controls to confirm effectiveness of ground water protection. Effectiveness of land-use restrictions depends on continued future implementation. Human health risk less than 10^{-6}.	Does not reduce TMV.	No short-term risks to the public. Protective within 1 year if monitoring indicates achievement of cleanup goals. Protective within approximately 5 years if monitoring indicates contingency remediation is necessary.	Utilizes standard monitoring techniques currently deployed at the Site. Site development could limit access to areas requiring future remedial action.	Standard records management and database activities required. Land-use restrictions require approval by the UCOP. Additional land-use restrictions may be a component of future remedial action, if required.	Relies on standard services and materials.	The State of California has accepted Alternative 2b as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$372,000

Table 4-10. Evaluation Summary for Southwest Trenches Remedial Alternatives (continued)

Evaluation Criteria	Effectiveness					Implementability					Total Costs[2]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 3: Asphalt /HDPE cap, long-term ground water monitoring and land-use restrictions	Mitigates marginal residential receptor risk and protects beneficial use of ground water through surface capping and monitoring ground water near the source area. Deed restrictions will mitigate disturbances of the cap.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Cap will reduce the flux of contaminants to ground water, if maintained. Includes monitoring and management controls to confirm effectiveness of ground water protection. Effectiveness of land-use depends on continued future implementation. Human health risk less than 10^{-6}.	Cap reduces mobility of residual soil contamination by eliminating the infiltration of surface water. Some contaminant migration to the water table will still occur through diffusion. Does not reduce contaminant mass and volume.	Minor short-term risks to the public and environment are associated with the manufacture, transport and installation of asphalt. The risk of a fatality from implementing this alternative is approximately zero. Cap may restrict site development and aesthetics. Time to deploy is rapid, since the cap relies on established engineering design and materials. Predicted to be protective in approximately 1 year.	Relies on established engineering design and materials	Standard records management and database activities required. Land-use restrictions require approval by UCOP.	Relies on standard services and materials.	The State of California has accepted Alternative 3 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$735,000
Alternative 4a: Removal and off-site disposal	Mitigates marginal residential receptor risk and protects beneficial use of ground water by removing the contaminated soil. Local risk reduction is offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents and vehicular air emissions.	Compliant with ARARs.	Effective since virtually all residual contamination is removed. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	TMV reduced to negligible quantities by transferring contaminated soil to land disposal site.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 2.15 x 10^{-2}. Emissions fatality risk = 4.75 x 10^{-3}. Potential radiation dose to maximum exposed member of public = 0.43 mrem/yr. Localized noise and vibration impacts will persist for months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year. Time to complete is uncertain and may exceed 1 year due to the depth and techniques required to excavate the contaminated soil.	The use of large-diameter augers to conduct mass excavation has not been conducted at LEHR at the scale proposed and may result in a failure to remove all contaminated soil, and/or extend the project's schedule and costs.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4a as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$7,271,000 - $8,831,000
Alternative 4b: Removal and on-site treatment	Mitigates marginal residential receptor risk and protects beneficial use of ground water by removing the contaminated soil and treating it to acceptable levels or disposing it off site. Local risk reduction offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents, vehicular air emissions, and onsite treatment operations.	Compliant with ARARs.	Effective since virtually all residual contamination is removed and treated or disposed. Some risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	TMV reduced to negligible quantities by on-site treatment and transferring soil containing added radioactivity to land disposal site.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 1.47 x 10^{-2}. Emissions fatality risk = 3.23 x 10^{-3}. Potential radiation dose to maximum exposed member of public = 0.43 mrem/yr. Localized noise and vibration impacts will persist for months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Time to complete removal action is uncertain due to the depth and techniques required to excavate the contaminated soil. On-site treatment cell could rupture and release contaminants. Predicted to be protective in approximately 4 years.	The use of large-diameter augers to conduct mass excavation has not been conducted at LEHR at the scale proposed and outcomes may fail to remove all contaminated soil, and/or extend the project's schedule and costs.	Standard records management and database activities required.	Relies on standard services and materials Suitable landfill space is expected to remain available during the remedial action. On-site treatment requires the use of the Western Dog Pens area.	The State of California has accepted Alternative 4b as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$6,426,000 - $7,980,000

Table 4-10. Evaluation Summary for Southwest Trenches Remedial Alternatives (continued)

Evaluation Criteria	Effectiveness					Implementability					Total Costs[2]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 4c: Limited Removal, off-site disposal and Long-term ground water monitoring	Mitigates marginal residential receptor risk by removing soil containing Sr-90 contamination above the risk goal. Protects beneficial use of ground water by removing some contaminated soil and monitoring ground water near the source area.	Compliant with ARARs.	Effective reduction in mass and toxicity due to partial removal of residual contaminants in soil. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	Reduces toxicity and volume by transferring a limited volume of contaminated soil to land disposal site. No change in mobility.	Discernable short-term risks to the public are associated with the transport of contaminated soil to off-site disposal facilities. Traffic fatality risk = 1.90 x 10^{-2}. Emissions fatality risk = 4.18 x 10^{-3}. Potential radiation dose to maximum exposed member of public = 0.43 mrem/yr. Localized noise and vibration impacts will persist for months during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year.	Utilizes standard excavation and disposal techniques.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 4c as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$4,636,000 - $5,183,000
Alternative 5: *In situ* bioremediation, long-term ground water monitoring and land-use restrictions	Mitigates marginal residential receptor risk by implementing land-use restrictions that prevent residential land use. Protects beneficial use of ground water by treating nitrate-contaminated soil and monitoring ground water near the source area.	Compliant with ARARs.	Effective due to the negligible mass and toxicity of residual contaminants in soil. Includes pilot test, monitoring and management controls to confirm effectiveness of ground water protection. Effectiveness of land-use restrictions for residential receptors depends on continued future implementation. Human health risk less than 10^{-6}.	Reduces nitrate TMV to negligible quantities. Does not reduce or effect TMV of strontium-90. May mobilize some carbon-14 to ground water. However, the majority of the carbon-14 is not co-located with nitrate.	Minor short-term risks to the public and environment are associated with the installation and operation of the bioremediation system. The risk of a fatality from implementing this alternative is approximately zero. The treatment system may interfere with site activities or development. Time to deploy can be rapid, since the system relies on established engineering design and materials. Predicted to be protective in approximately 3 years.	A site-specific pilot test is required to confirm technical feasibility.	Standard records management and database activities required. Land-use restrictions require approval by the UCOP.	Relies on standard services and materials.	The State of California has accepted Alternative 5 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$1,298,000

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.
[2]Net present value of capital and operation and maintenance costs.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
HDPE	high density polyethylene
LEHR	Laboratory for Energy-Related Health Research
N/A	not applicable
UCOP	University of California Office of the President

Table 4-11. Evaluation Summary for Western Dog Pens Area Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	Protective. The SWRA did not identify any current or potential future impacts to public health or ground water.	Compliant with ARARs.	N/A	N/A	N/A	N/A	N/A	N/A	The State of California has accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$0

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
N/A	not applicable
SWRA	Site-Wide Risk Assessment
TMV	toxicity, mobility or volume

Table 4-12. Evaluation Summary for Eastern Dog Pens Area Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs[2]
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	Residual soil contaminants pose a marginal (4E-6) risk to hypothetical residential receptors. Risk is within the CERCLA acceptable risk range.	Compliant with ARARs.	Effective due to hypothetical site resident risk (4×10^{-6}) within the CERCLA acceptable risk range.	Does not reduce TMV.	No short-term risks to the public. Residential receptors do not currently occupy the Site.	N/A	N/A	N/A	The State of California has accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$ 0
Alternative 2: Land-use restrictions	Mitigates marginal residential receptor risk by implementing permanent land-use controls that prevent residential land use.	Compliant with ARARs.	Effectiveness of land-use restrictions depends on continued future implementation. Human health risk less than 10^{-6}.	Does not reduce TMV.	No short-term risks to the public. Predicted to be protective within 1 year.	N/A	Standard records management. Land-use restrictions require approval by the UCOP.	N/A	The State of California has accepted Alternative 2 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$50,000
Alternative 3: Removal and off-site disposal	Mitigates marginal residential receptor risk by removing the contaminated soil. Local risk reduction is offset by the transfer of risk to the disposal site(s), and short-term risks from transportation accidents and vehicular air emissions.	Compliant with ARARs.	Effective since virtually all residual contamination is removed. Risk transferred to disposal site, but contaminant levels are low and should be easily controlled in a permitted facility. Human health risk less than 10^{-6}.	TMV reduced to negligible quantities by transferring contaminated soil to land disposal site.	Discernable short-term risks to the public are associated with the transport of contaminated materials to off-site disposal facilities. Traffic fatality risk = 8.01×10^{-3}. Emissions fatality risk = 1.76×10^{-3}. Potential radiation dose to maximum exposed member of public = 0.68 mrem/yr. Localized noise and vibration impacts will persist for weeks during the remedial action. Air monitoring, dust control and personal protective equipment are required. Predicted to be protective in approximately 1 year.	Utilizes standard excavation and disposal techniques.	Standard records management and database activities required.	Relies on standard services and materials. Suitable landfill space is expected to remain available during the remedial action.	The State of California has accepted Alternative 3 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$1,626,000

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.
[2]Net present value of capital and operation and maintenance costs.

Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements
LEHR	Laboratory for Energy-Related Health Research
N/A	not applicable
UCOP	University of California Office of the President
TMV	toxicity, mobility or volume

Table 4-13. Evaluation Summary for DOE Disposal Box Area Remedial Alternatives

Evaluation Criteria	Effectiveness					Implementability					Total Costs
	Overall Protection of Public Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume (TMV)	Short-Term Effectiveness	Technical Feasibility	Administrative Feasibility	Availability of Services and Materials	Regulatory Acceptance[1]	Community Acceptance[1]	
Alternative 1: No action	Protective. The SWRA did not identify any current or potential future impacts to public health or ground water.	Compliant with ARARs.	N/A	N/A	N/A	N/A	N/A	N/A	The State of California has accepted Alternative 1 as a viable alternative.	The public at large will have the opportunity to comment on this alternative during the public comment period for the Proposed Plan.	$0

Notes
[1]State and community acceptance will be assessed after comments on the feasibility study are resolved.

Abbreviations
ARARs Applicable or Relevant and Appropriate Requirements
DOE United States Department of Energy
N/A not applicable
SWRA Site-Wide Risk Assessment
TMV toxicity, mobility or volume

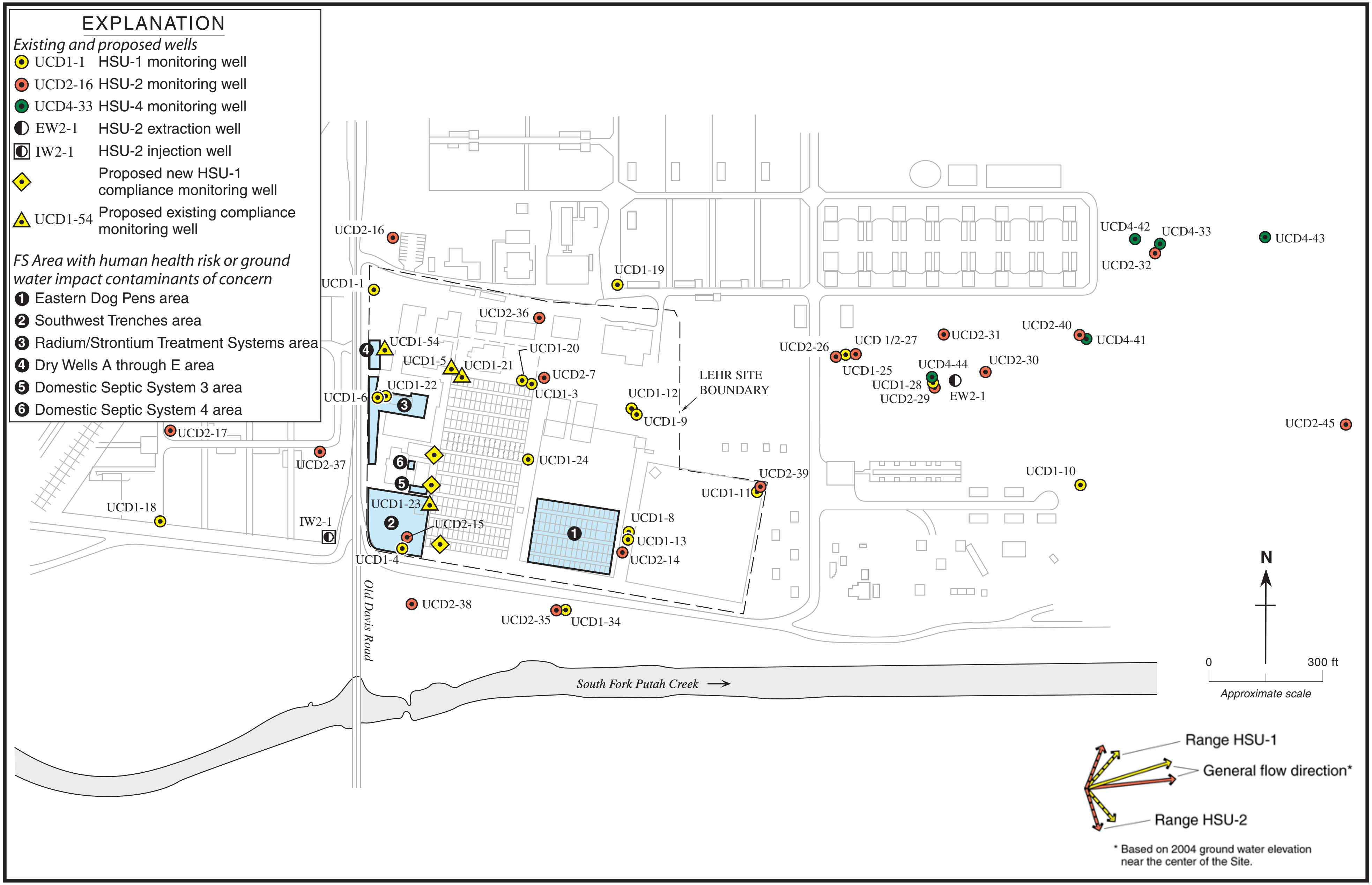

Figure 4-1. Existing and Proposed Ground Water Monitoring Well Locations, Laboratory for Energy-Related Health Research, UC Davis, California

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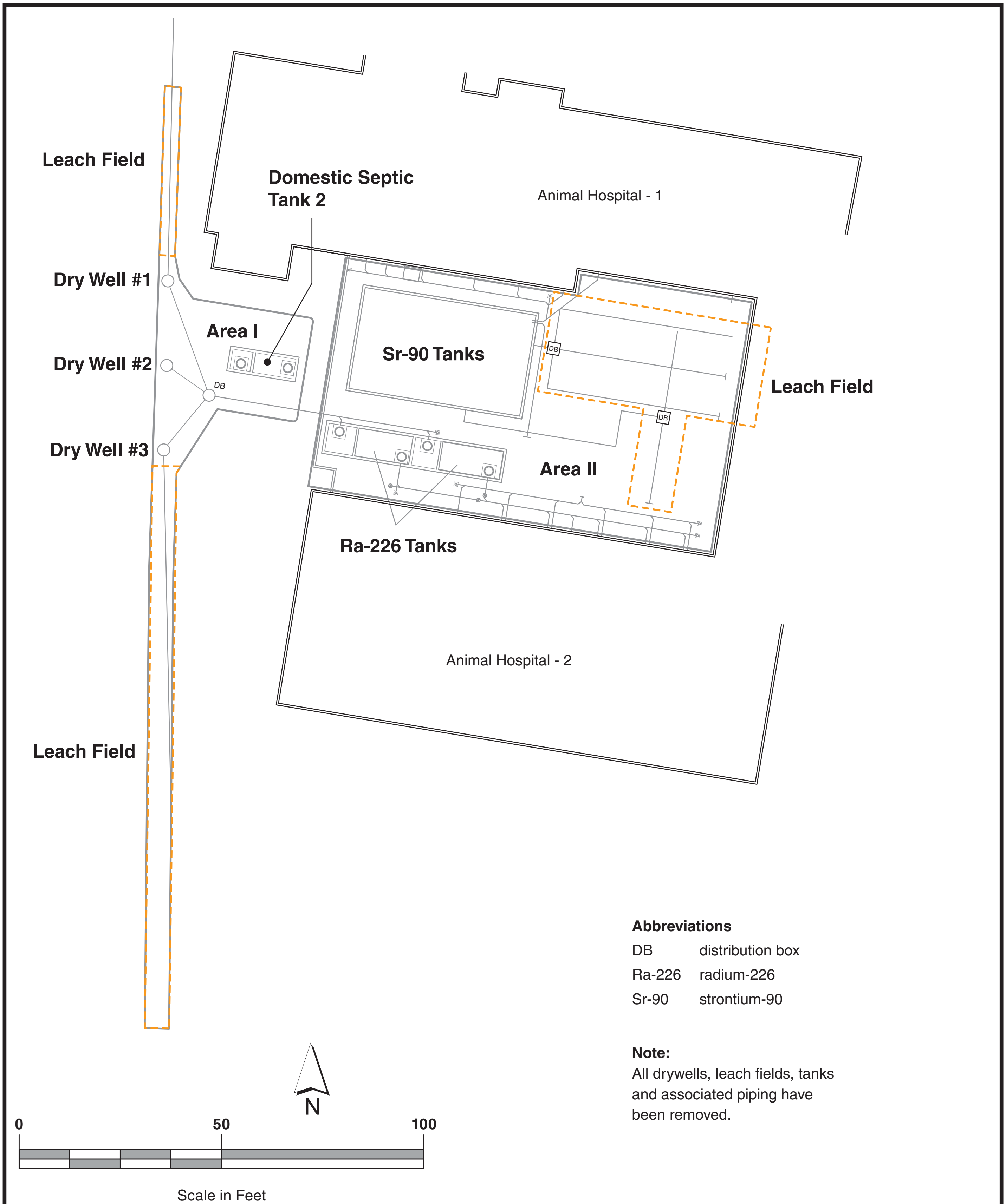

Abbreviations

DB distribution box
Ra-226 radium-226
Sr-90 strontium-90

Note:
All drywells, leach fields, tanks and associated piping have been removed.

Figure 4-2. Radium/Strontium Treatment Systems Area Features

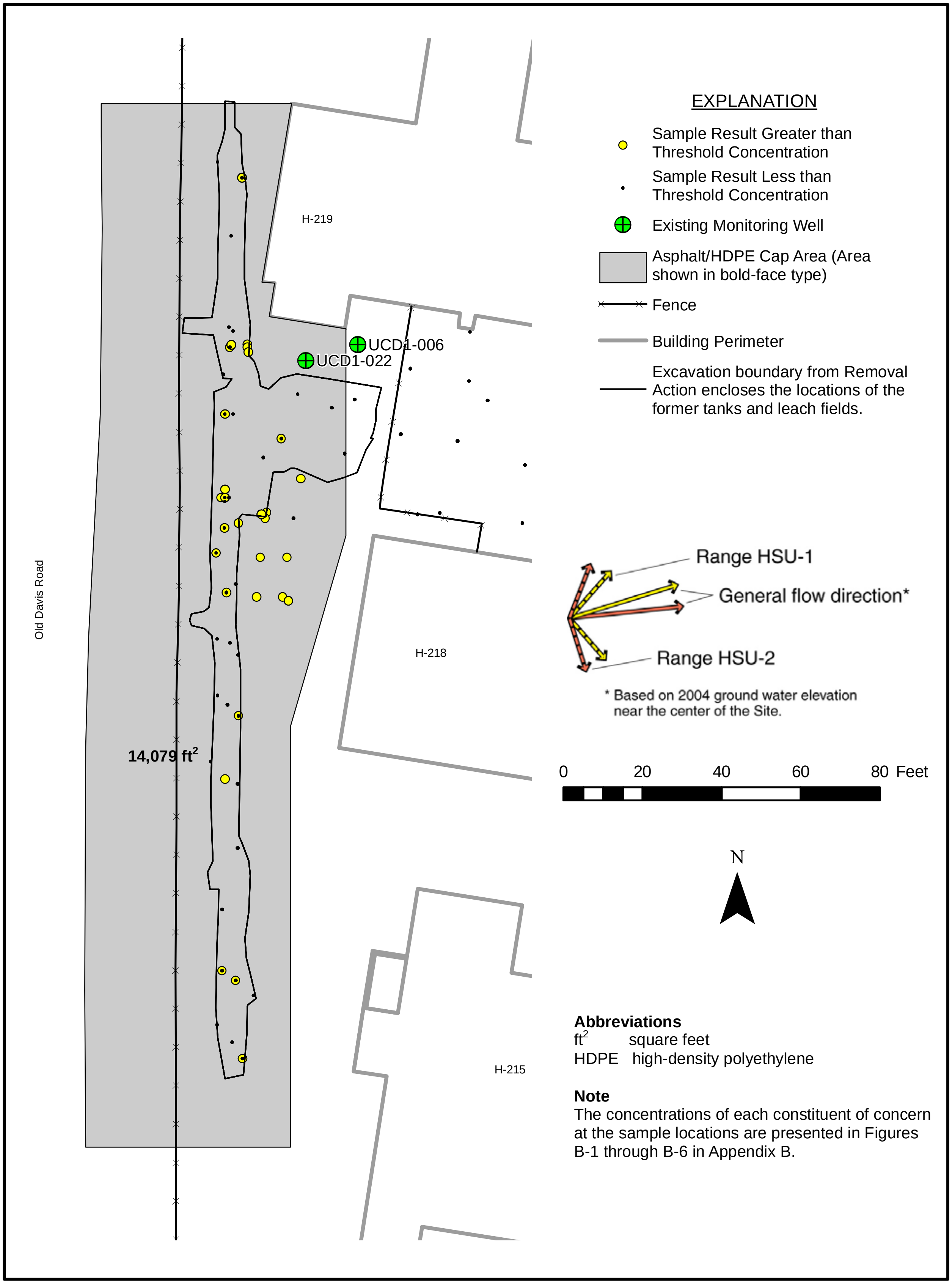

Figure 4-3. Alternative 3 at the Radium/Strontium Treatment Systems Area: Asphalt/High-Density-Polyethylene Cap Area

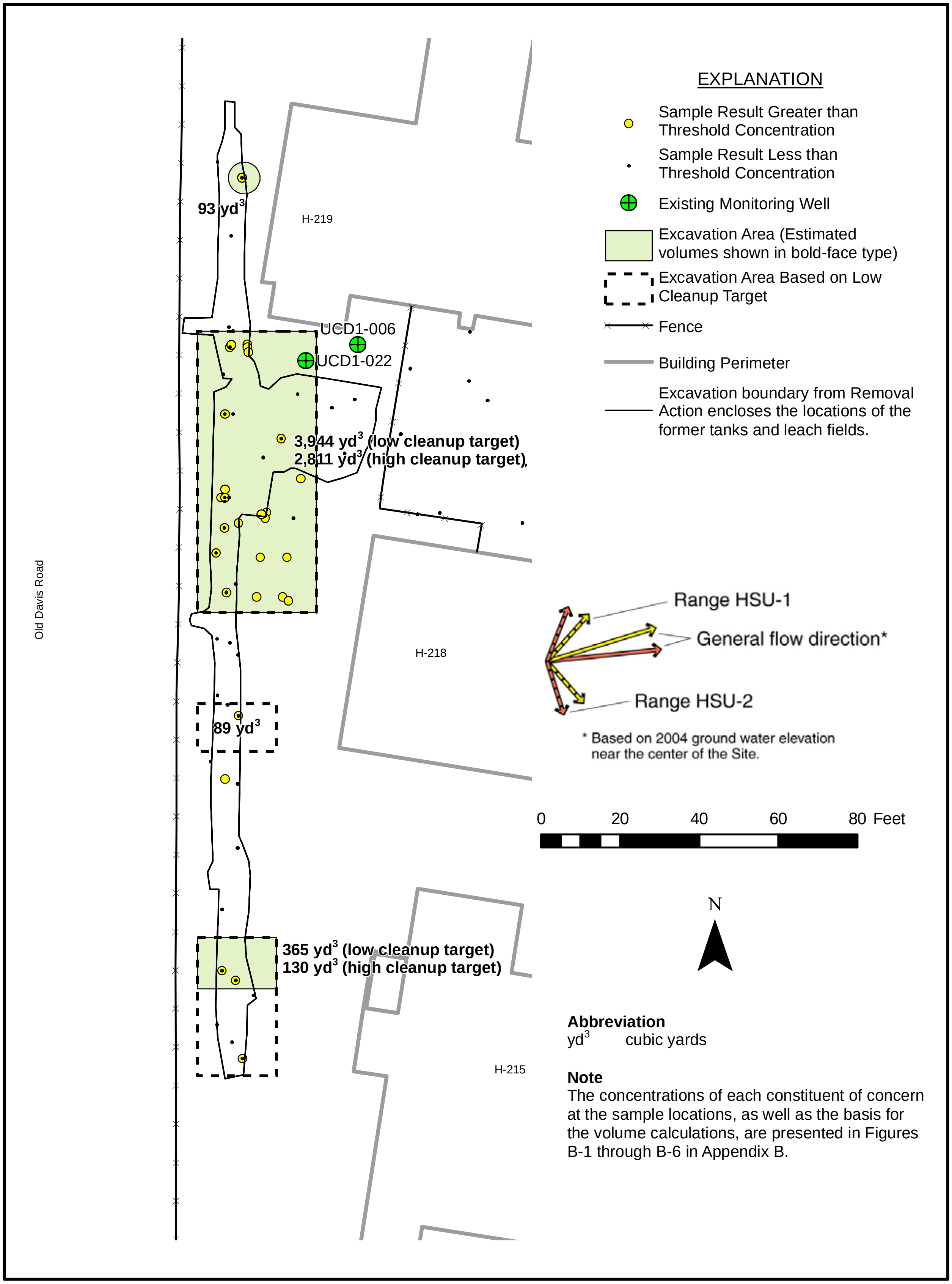

Figure 4-4. Alternative 4a/4b at the Radium/Strontium Treatment Systems Area: Excavation Areas

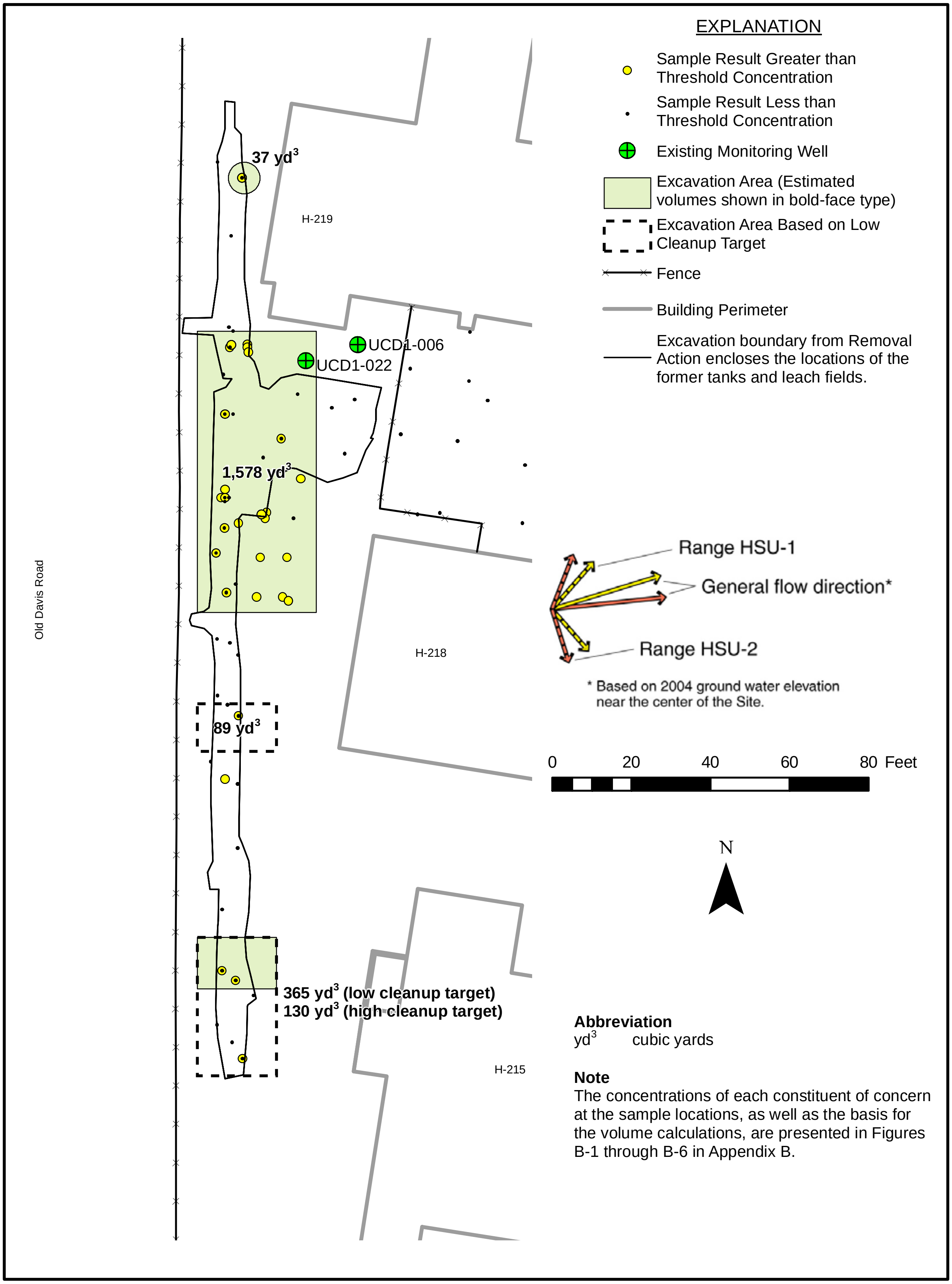

Figure 4-5. Alternative 4c at the Radium/Strontium Treatment Systems Area: Excavation Areas

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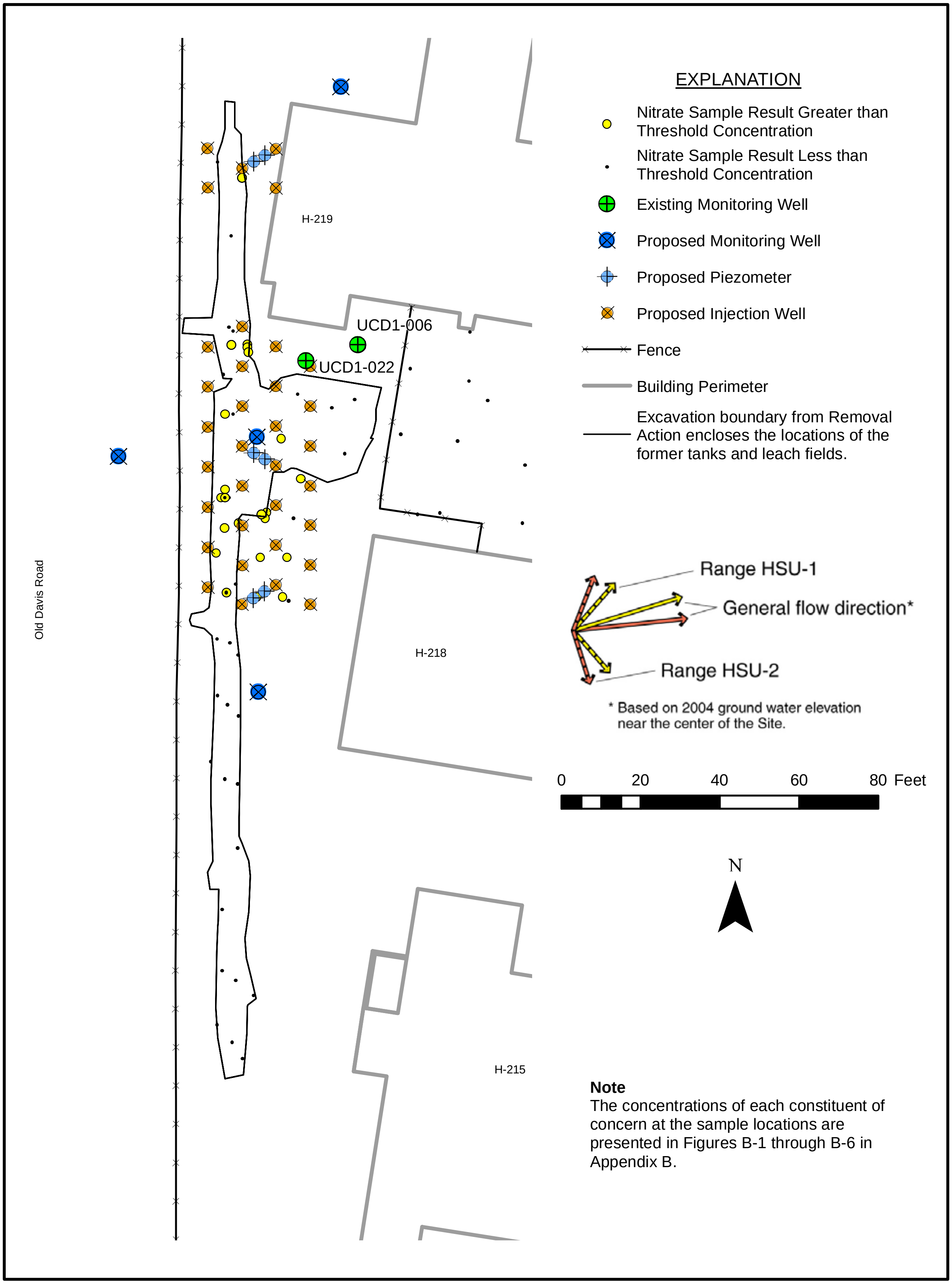

Figure 4-6. Alternative 5 at the Radium/Strontium Treatment Systems Area: Injection and Monitoring Wells

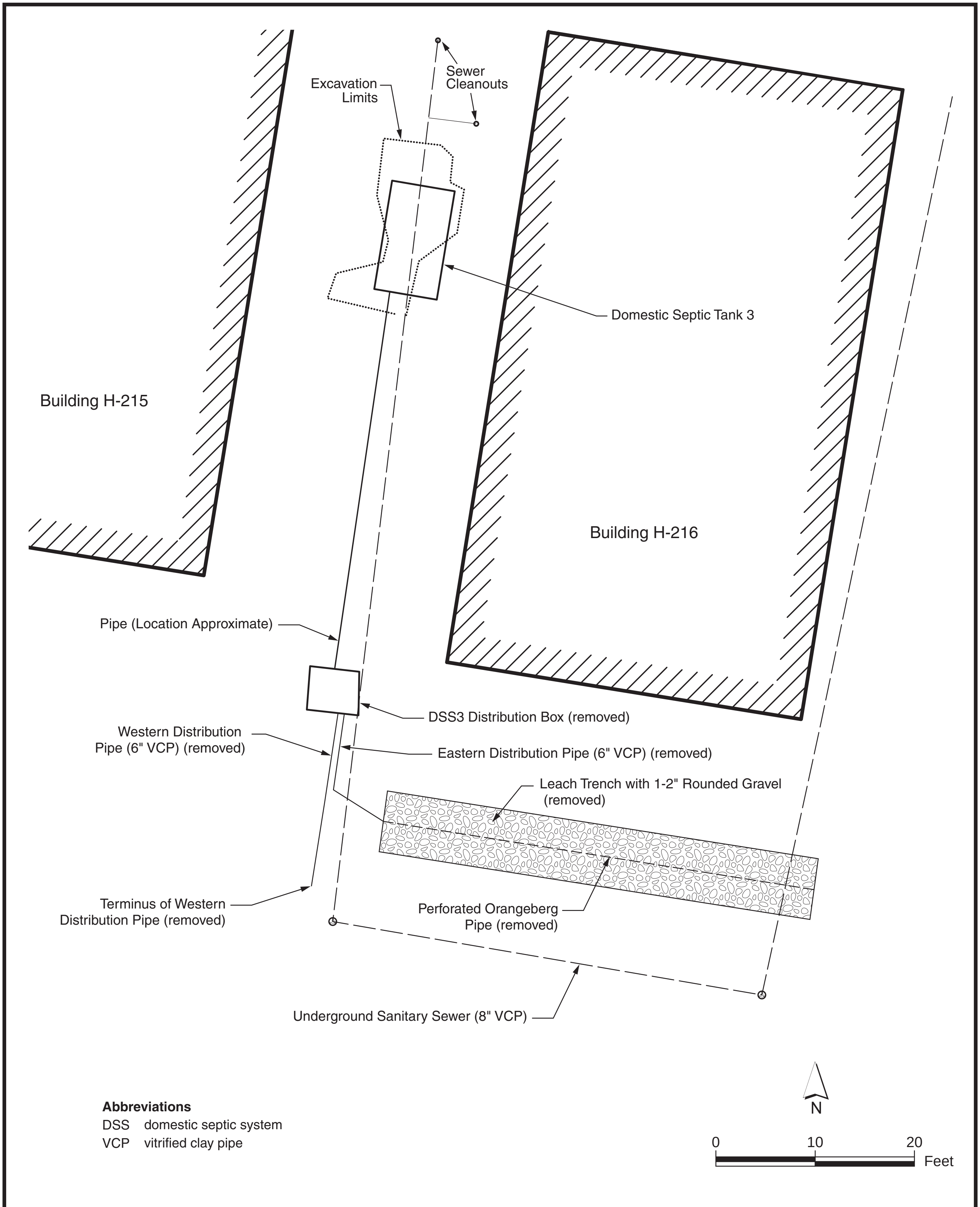

Figure 4-7. Domestic Septic System No. 3 Features

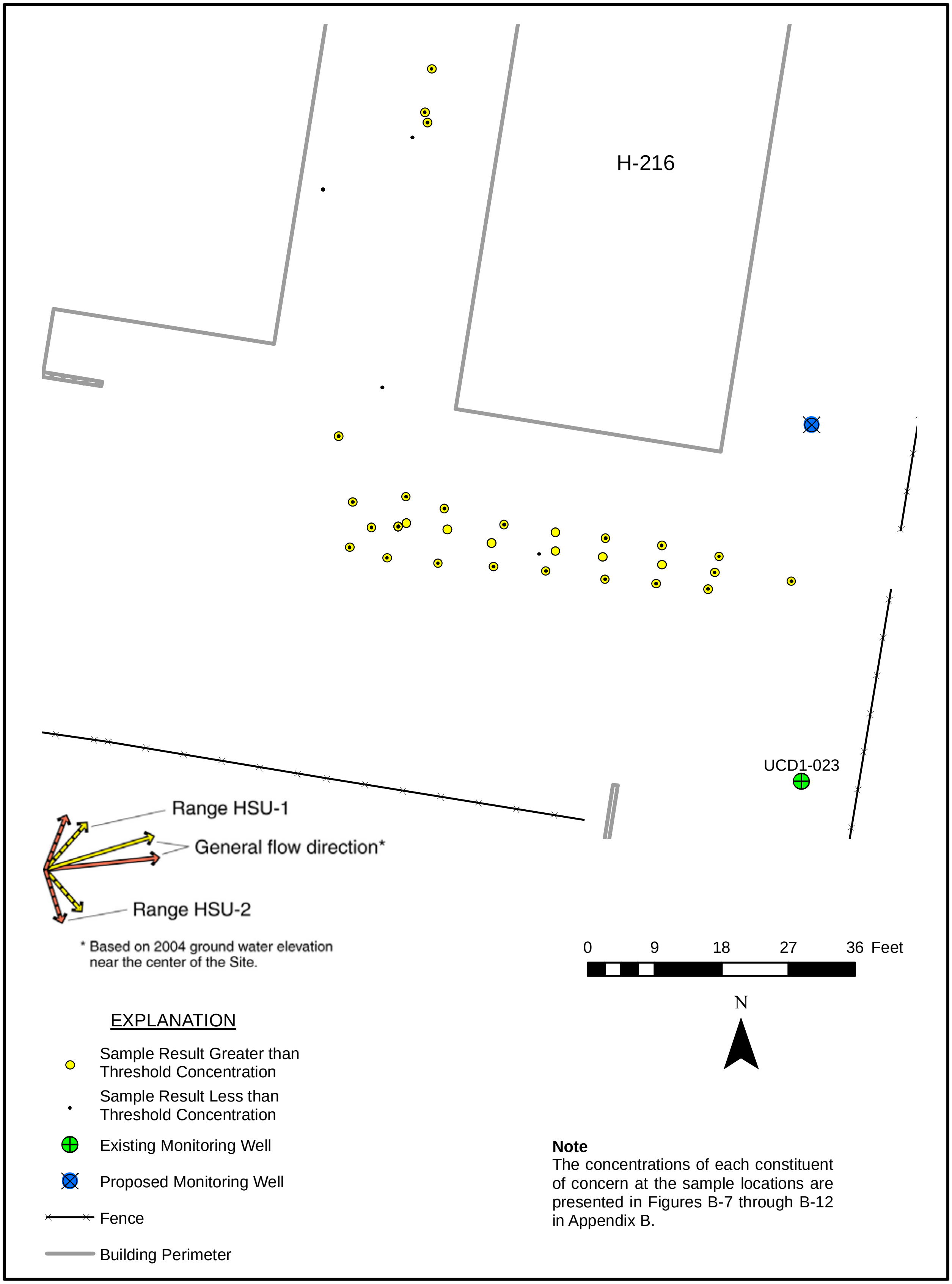

Figure 4-8. Alternative 2 at the Domestic Septic System No. 3 Area: Monitoring Well Location

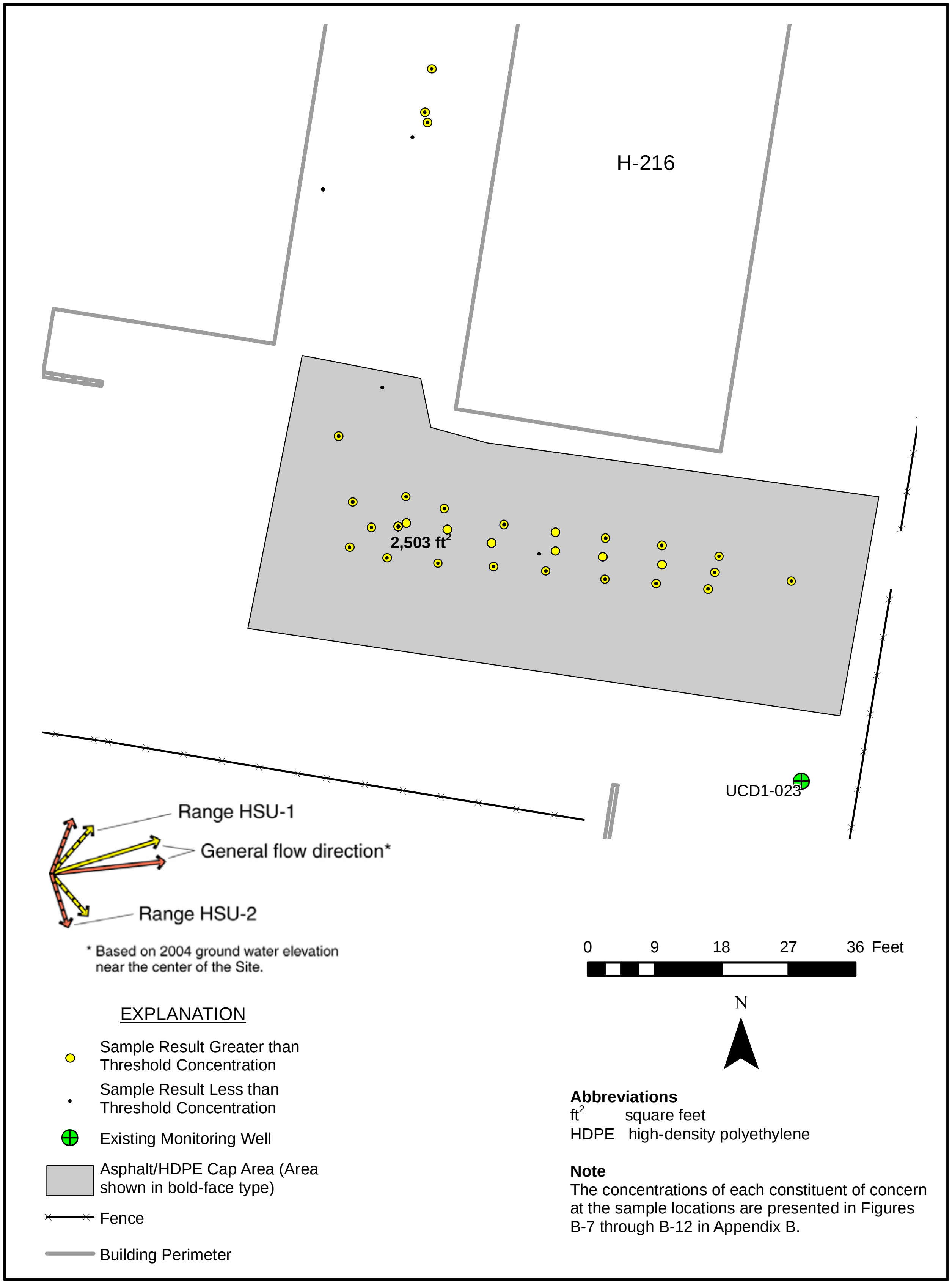

Figure 4-9. Alternative 3 at the Domestic Septic System No. 3 Area: Asphalt/High-Density-Polyethylene Cap Area

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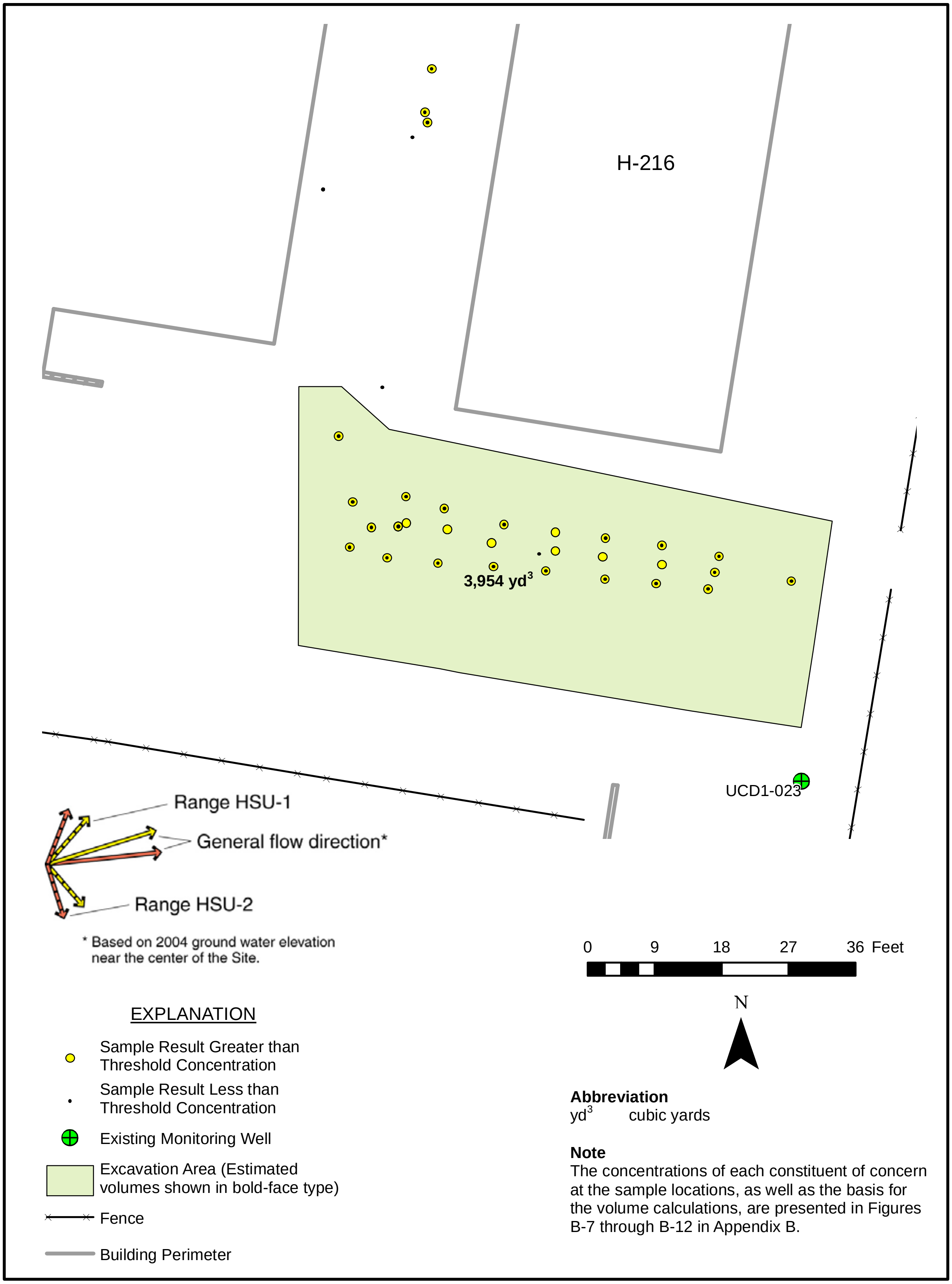

Figure 4-10. Alternative 4a/4b at the Domestic Septic System No. 3 Area: Excavation Area

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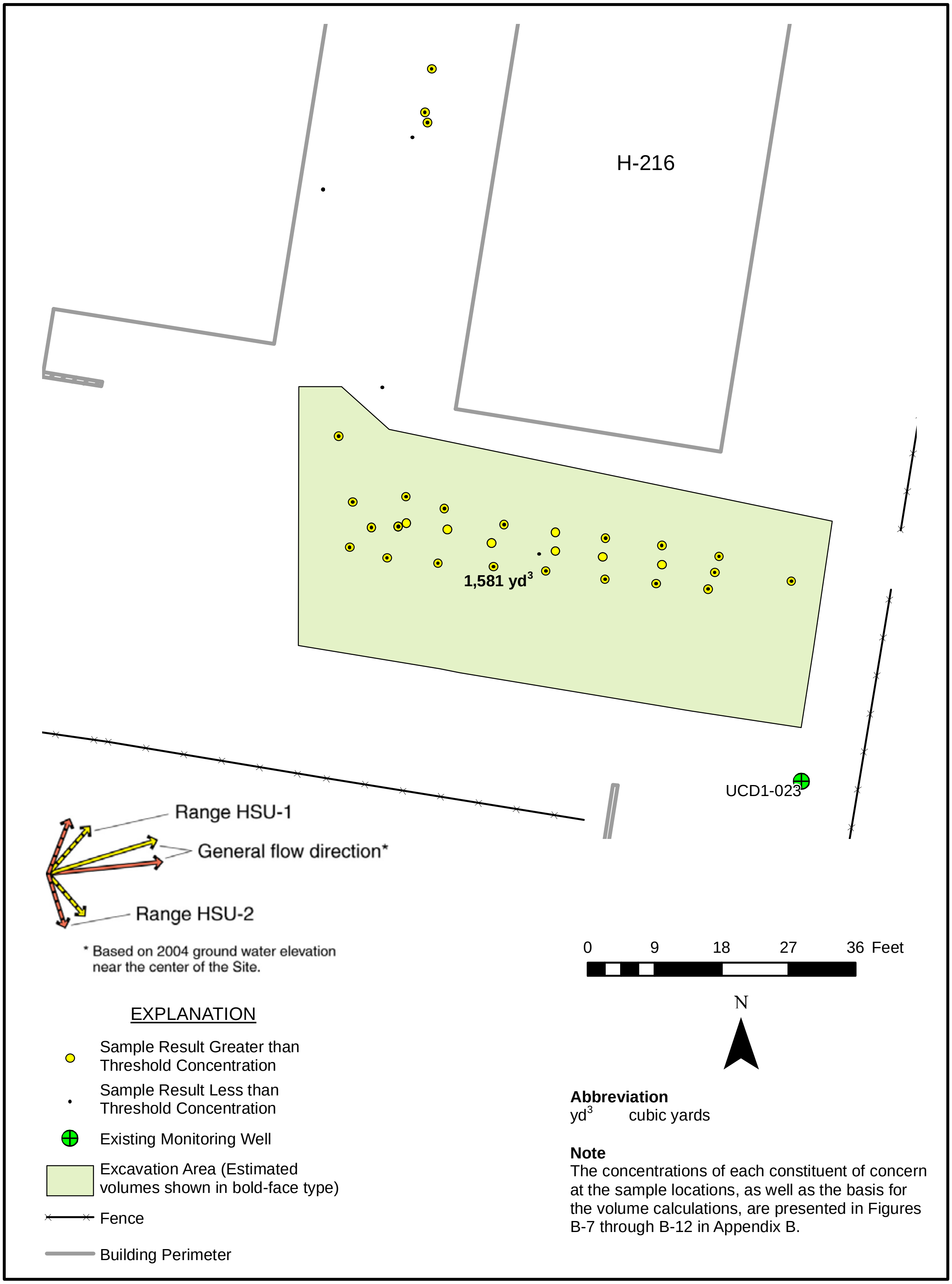

Figure 4-11. Alternative 4c at the Domestic Septic System No. 3 Area: Excavation Area

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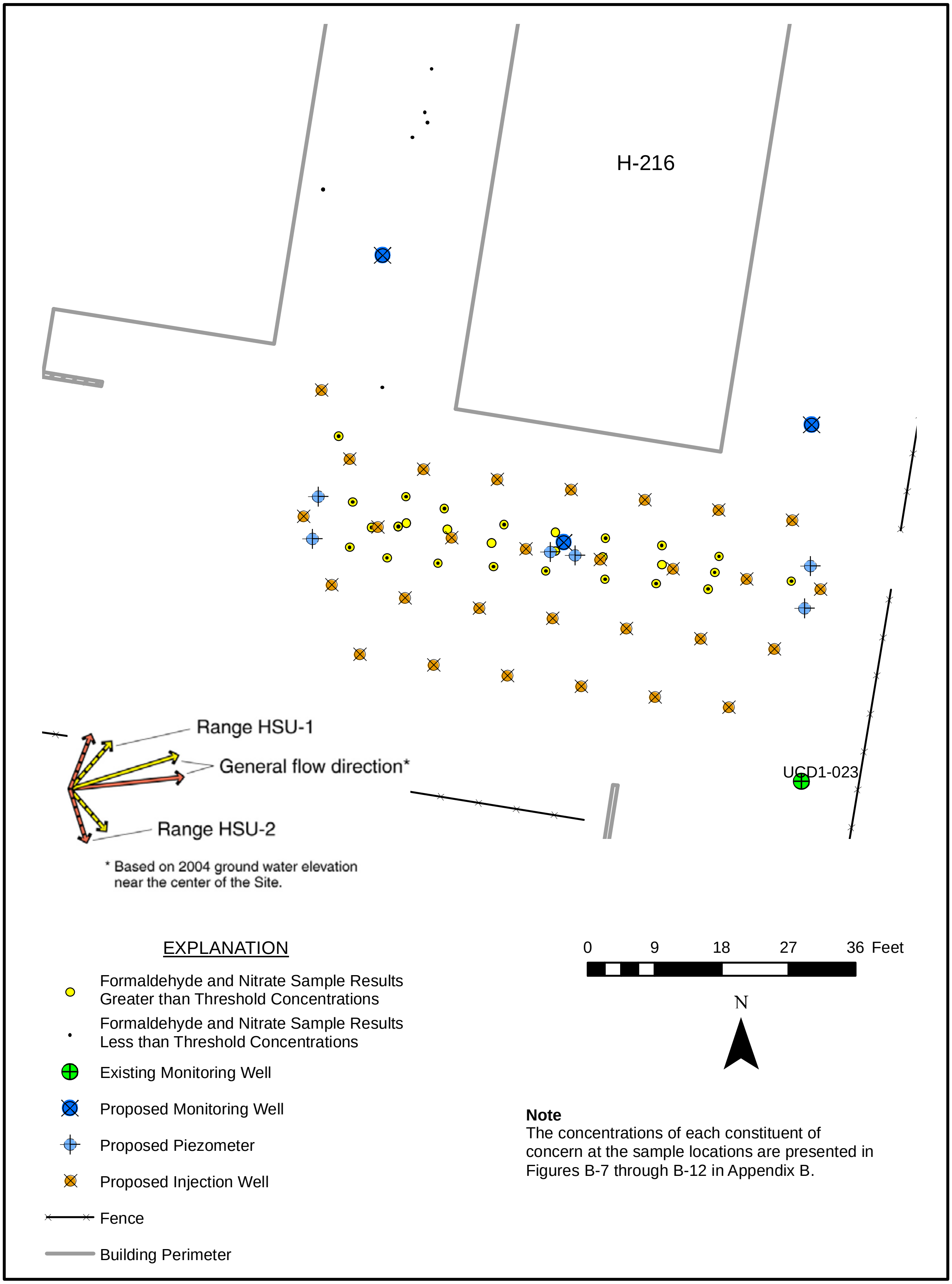

Figure 4-12. Alternative 5 at the Domestic Septic System No. 3 Area: Injection and Monitoring Wells

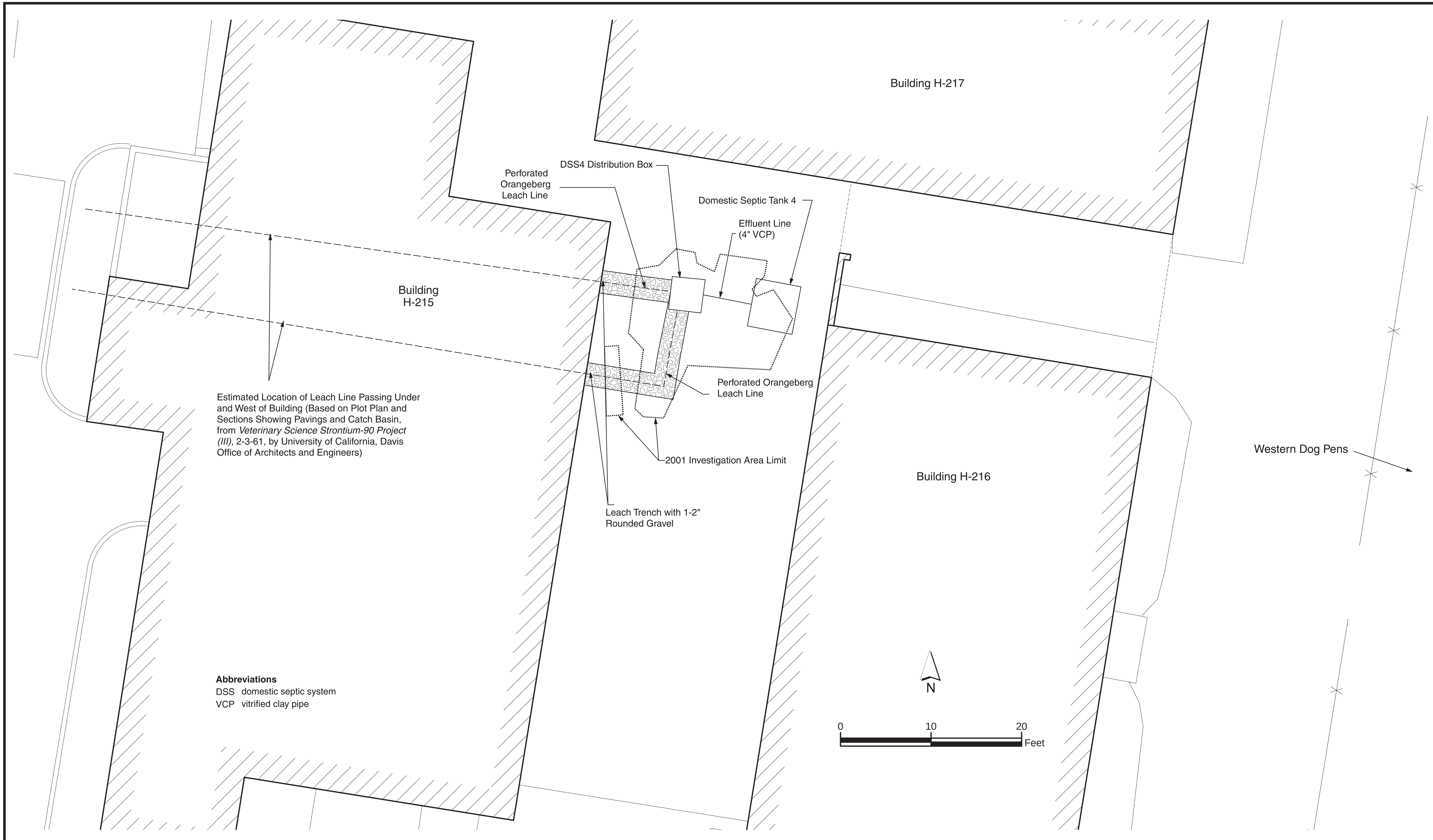

Figure 4-13. Domestic Septic System No. 4 Features

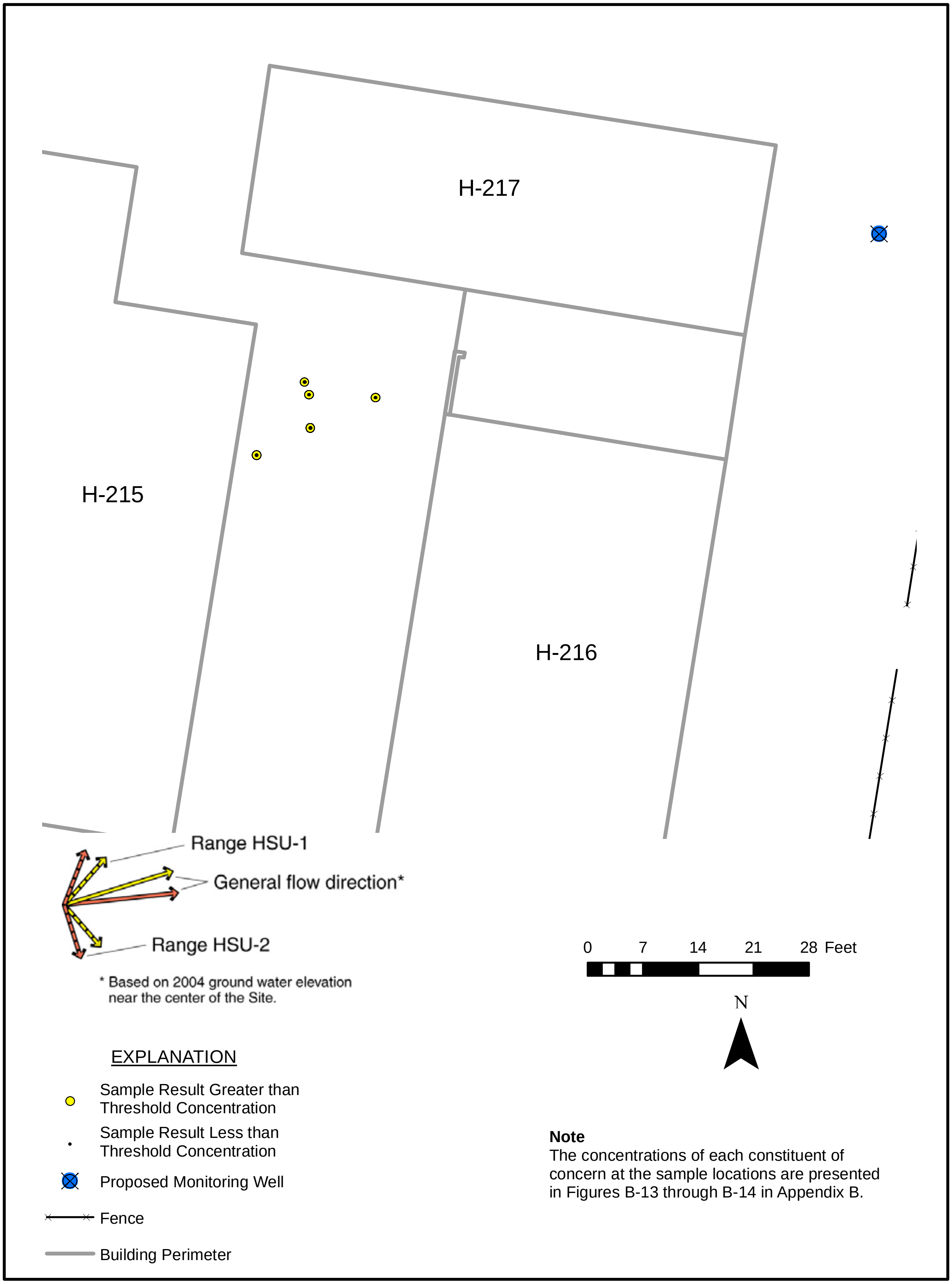

Figure 4-14. Alternative 2 at the Domestic Septic System No. 4 Area: Monitoring Well Location

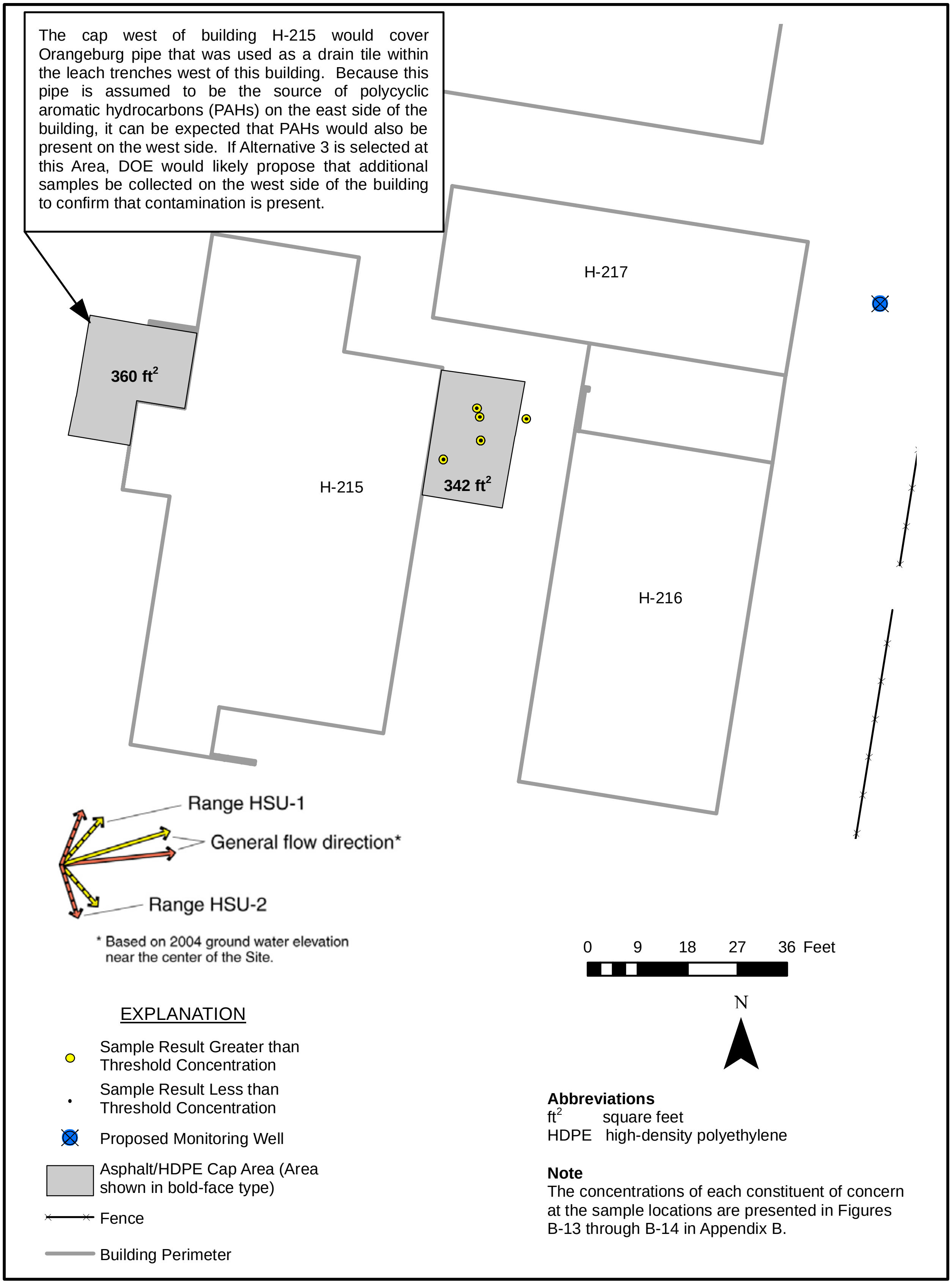

Figure 4-15. Alternative 3 at the Domestic Septic System No. 4 Area: Asphalt/High-Density-Polyethylene Cap Area

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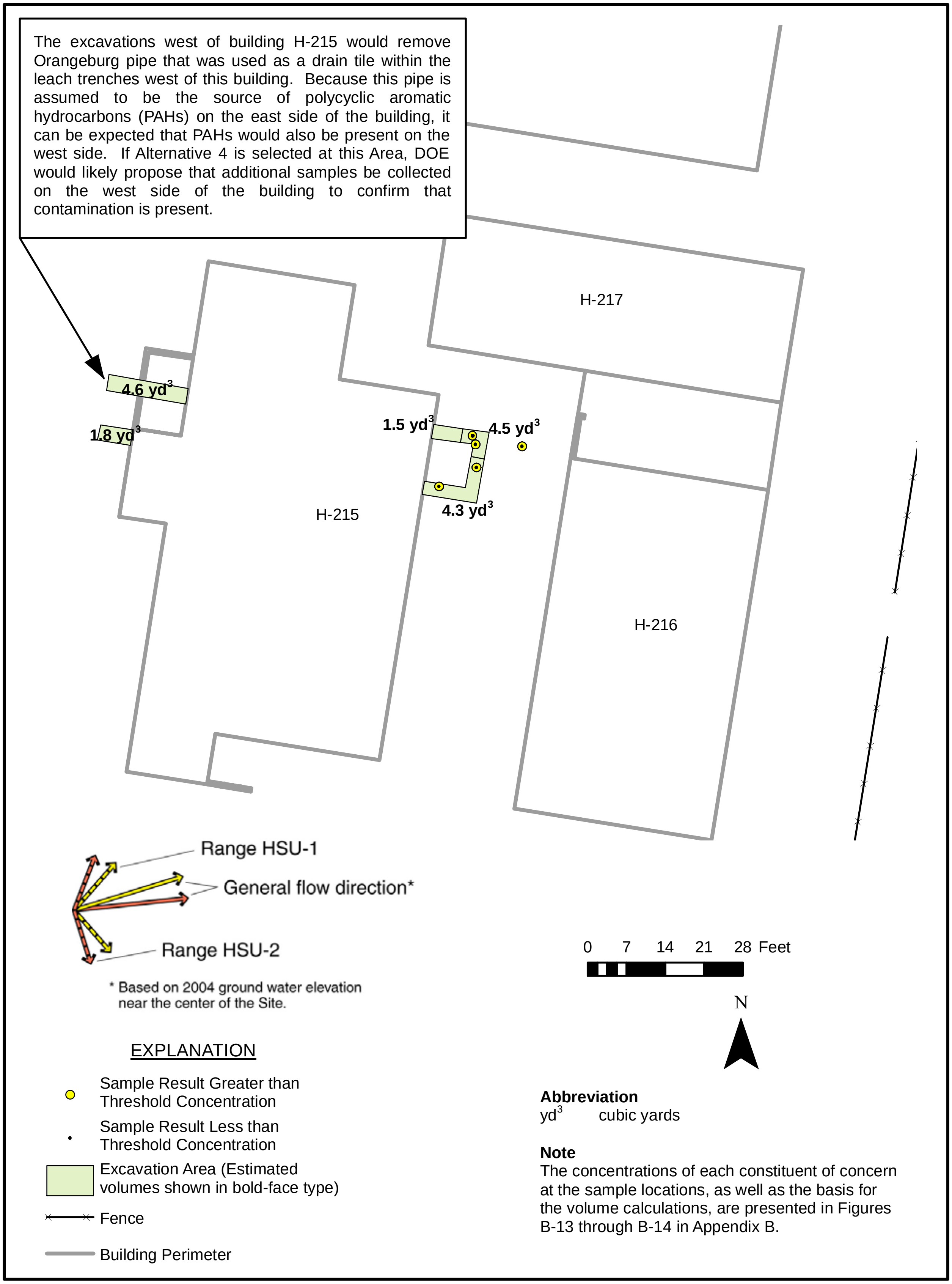

Figure 4-16. Alternative 4 at the Domestic Septic System No. 4 Area: Excavation Area

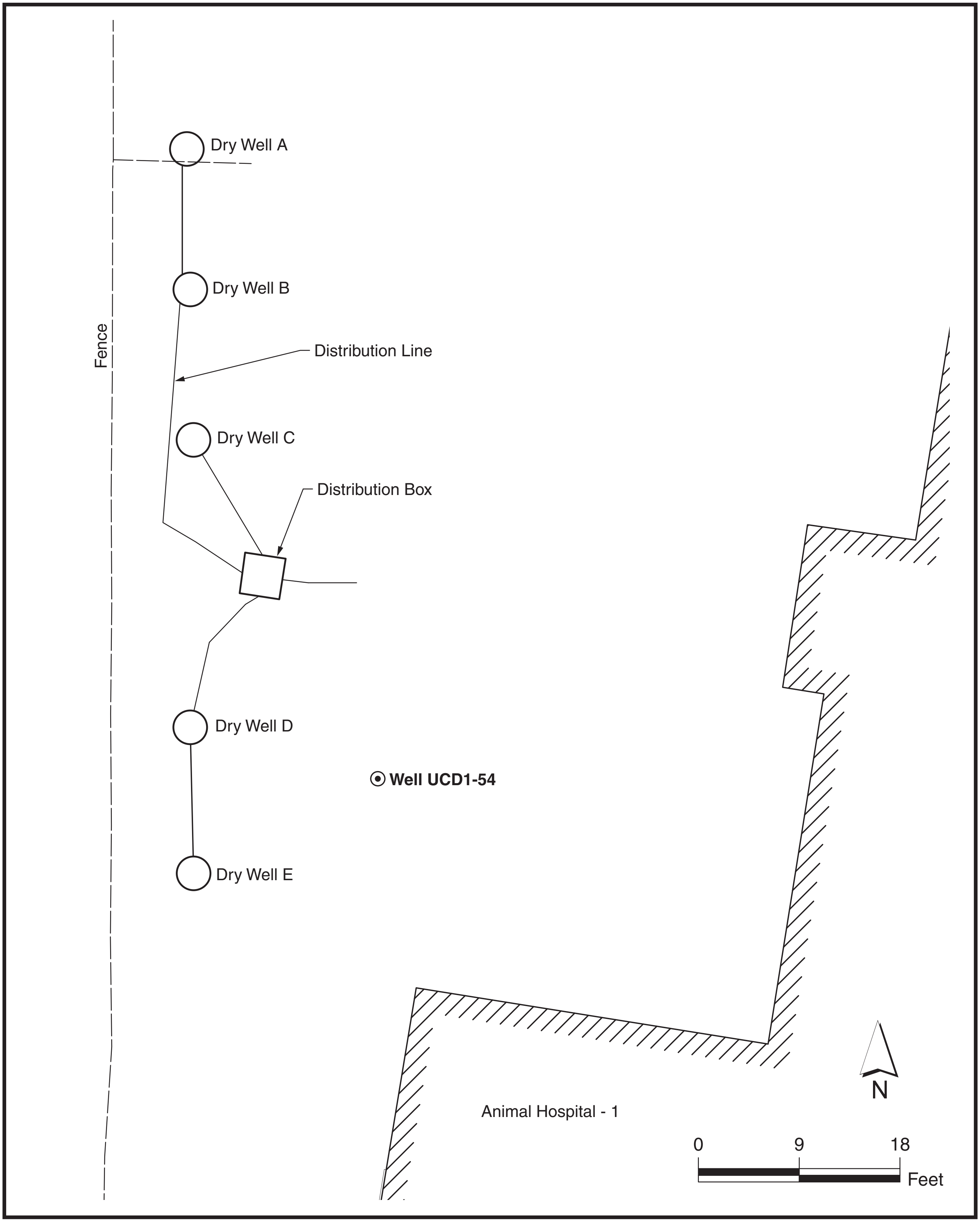

Figure 4-17. Domestic Septic System Dry Wells A-E Area Features

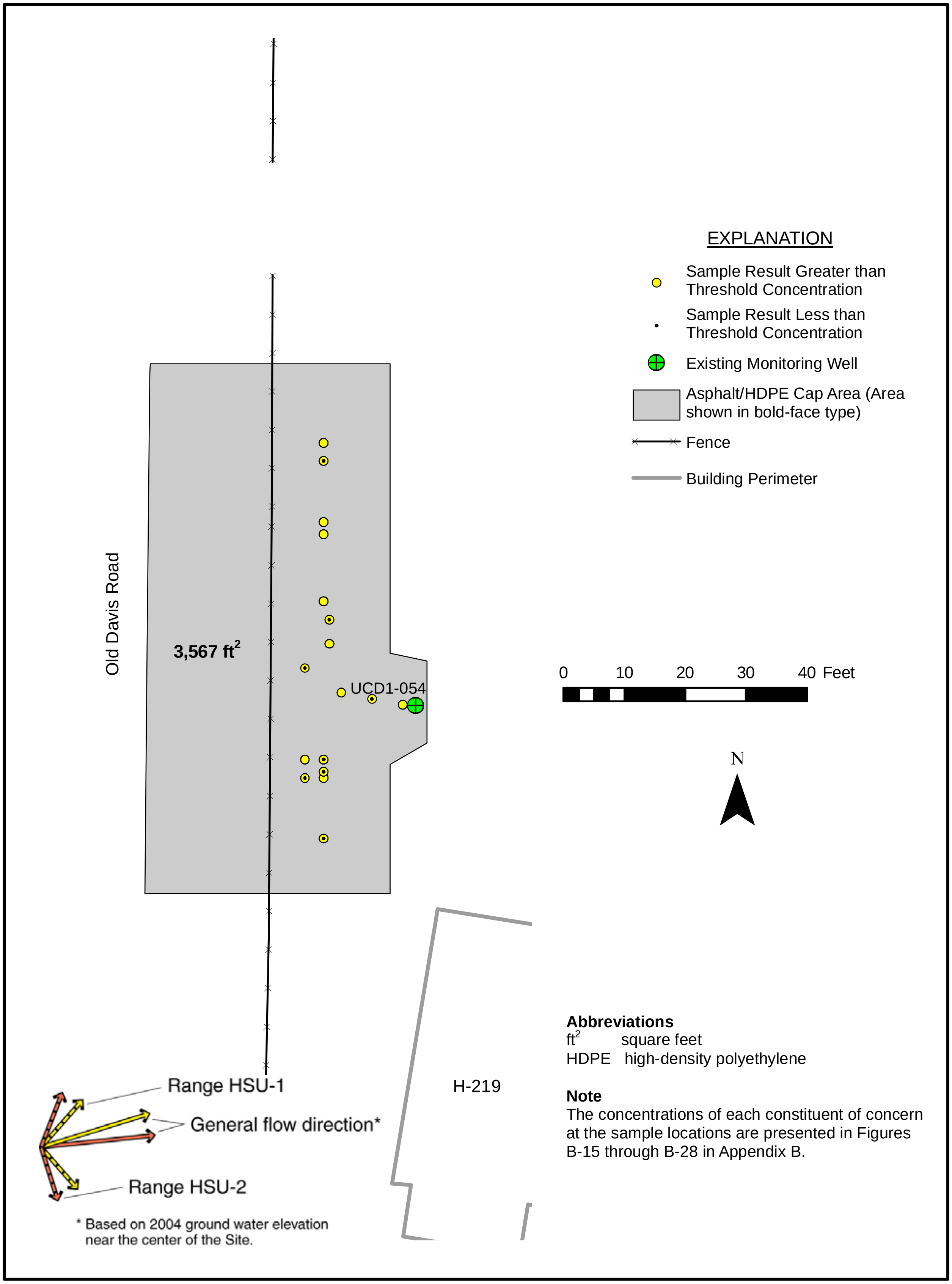

Figure 4-18. Alternative 3 at the Domestic Septic System Dry Wells A-E Area: Asphalt/High-Density-Polyethylene Cap Area

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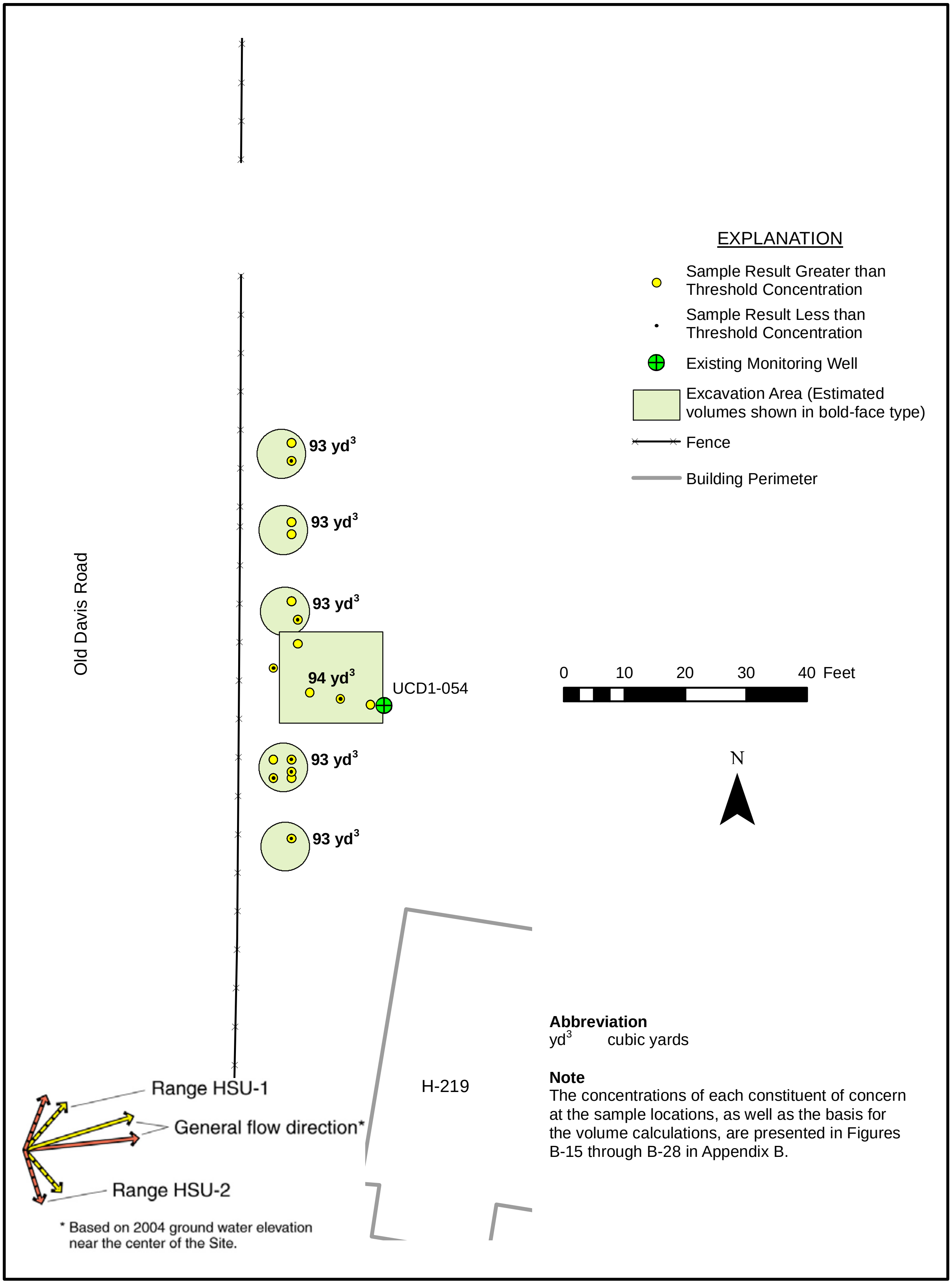

Figure 4-19. Alternative 4a at the Domestic Septic System Dry Wells A-E Area: Excavation Areas

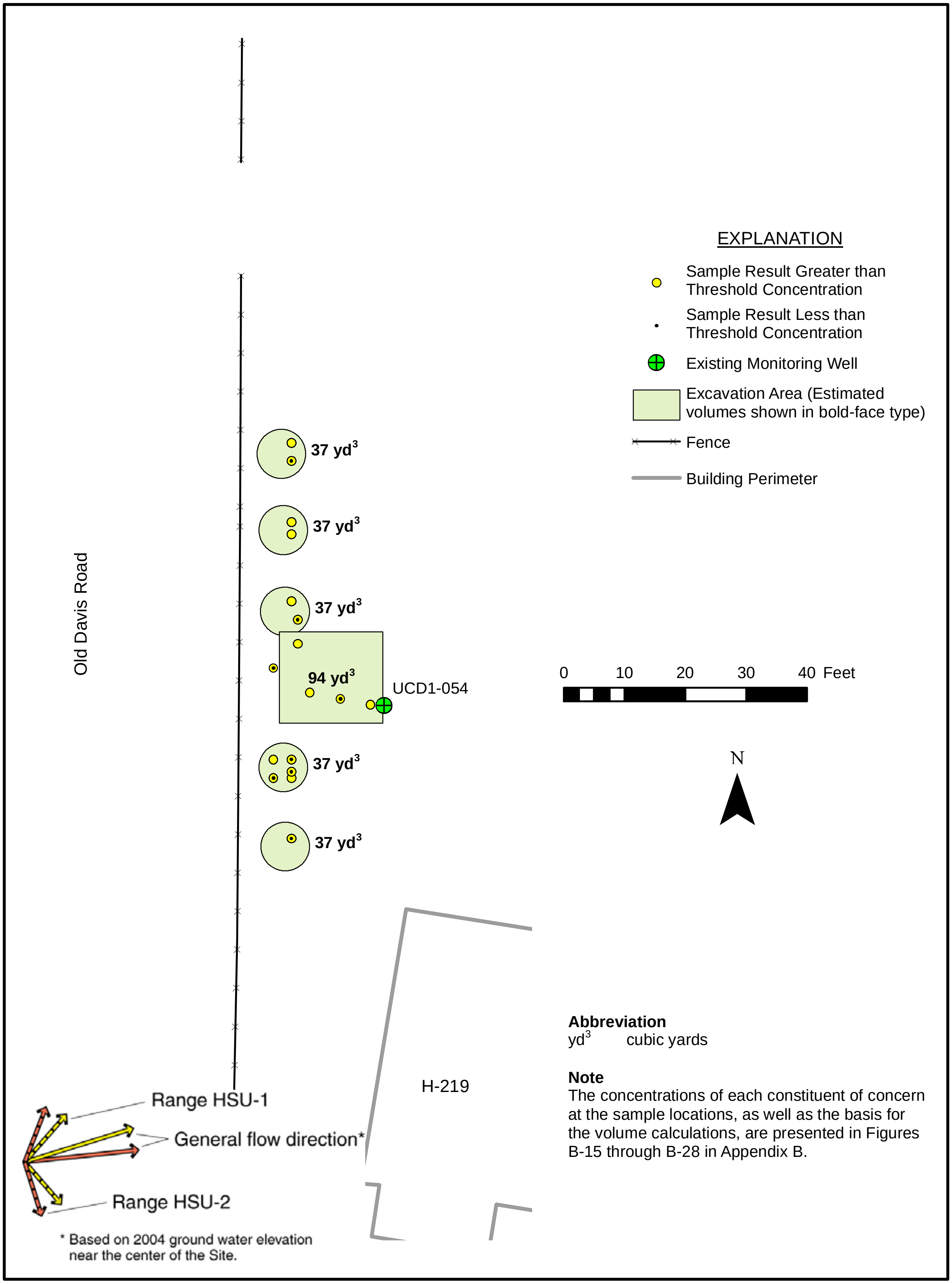

Figure 4-20. Alternative 4b at the Domestic Septic System Dry Wells A-E Area: Excavation Areas

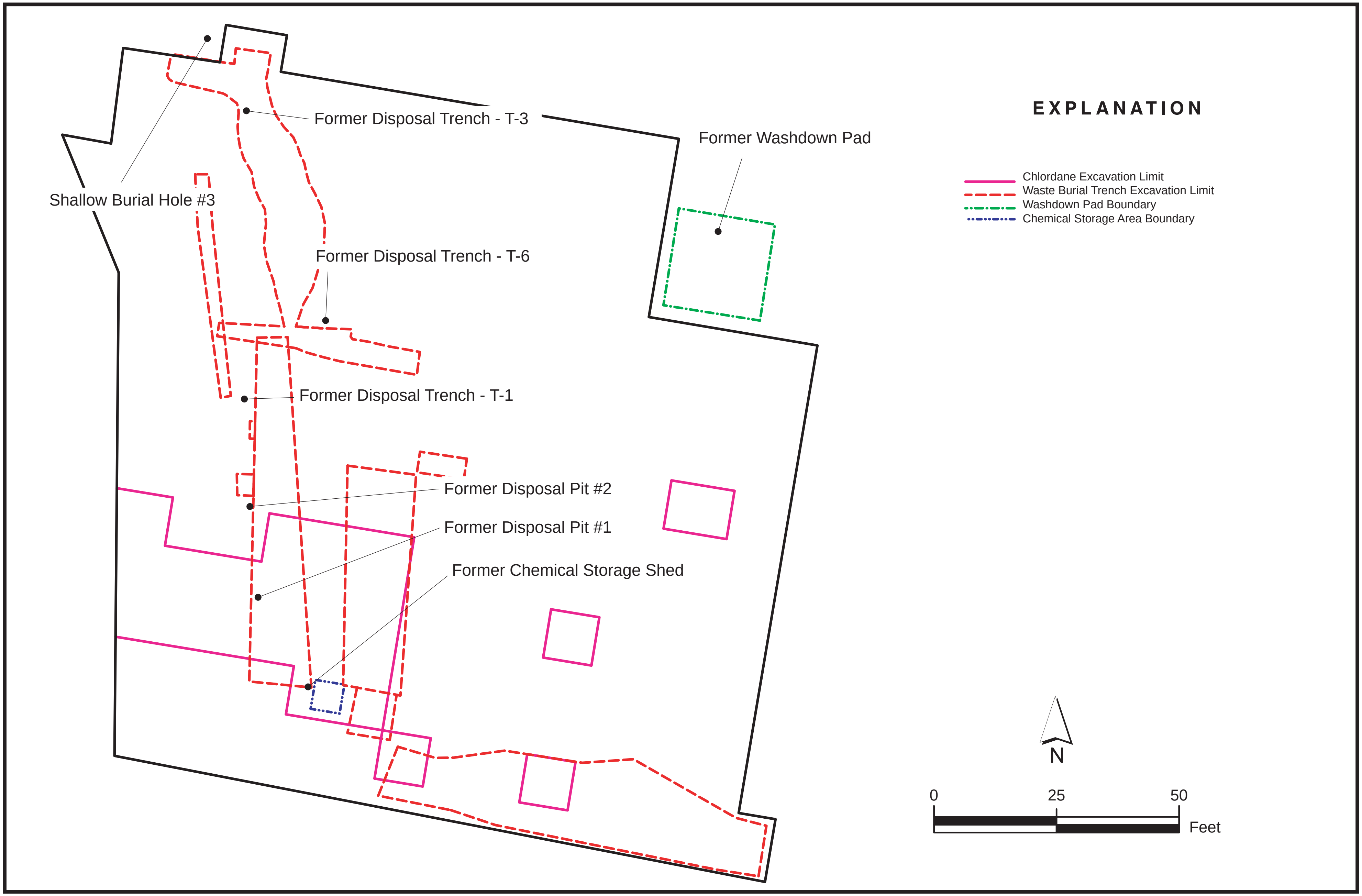

Figure 4-21. Southwest Trenches Area Features

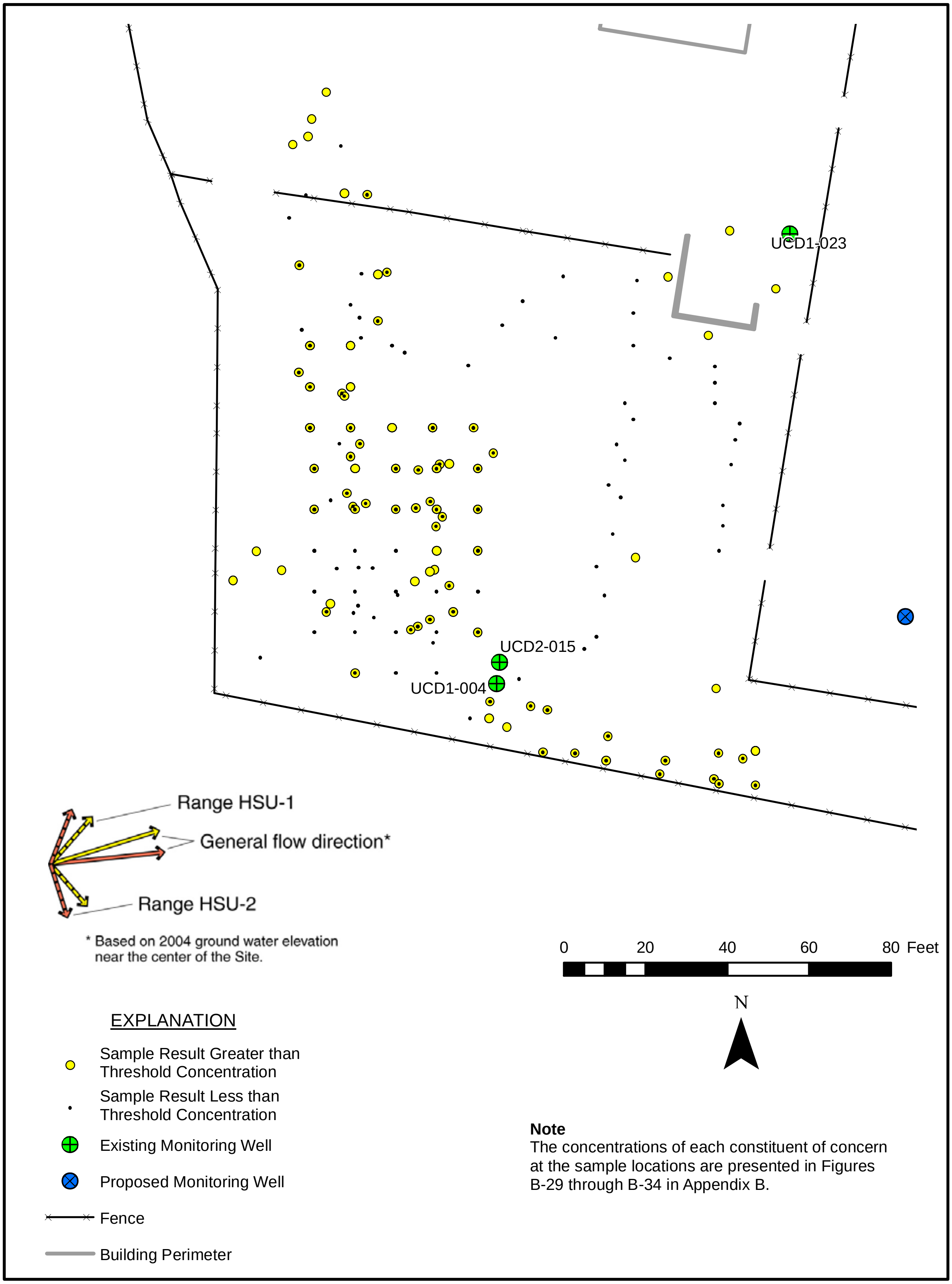

Figure 4-22. Alternative 2a/2b at the Southwest Trenches Area: Monitoring Well Location

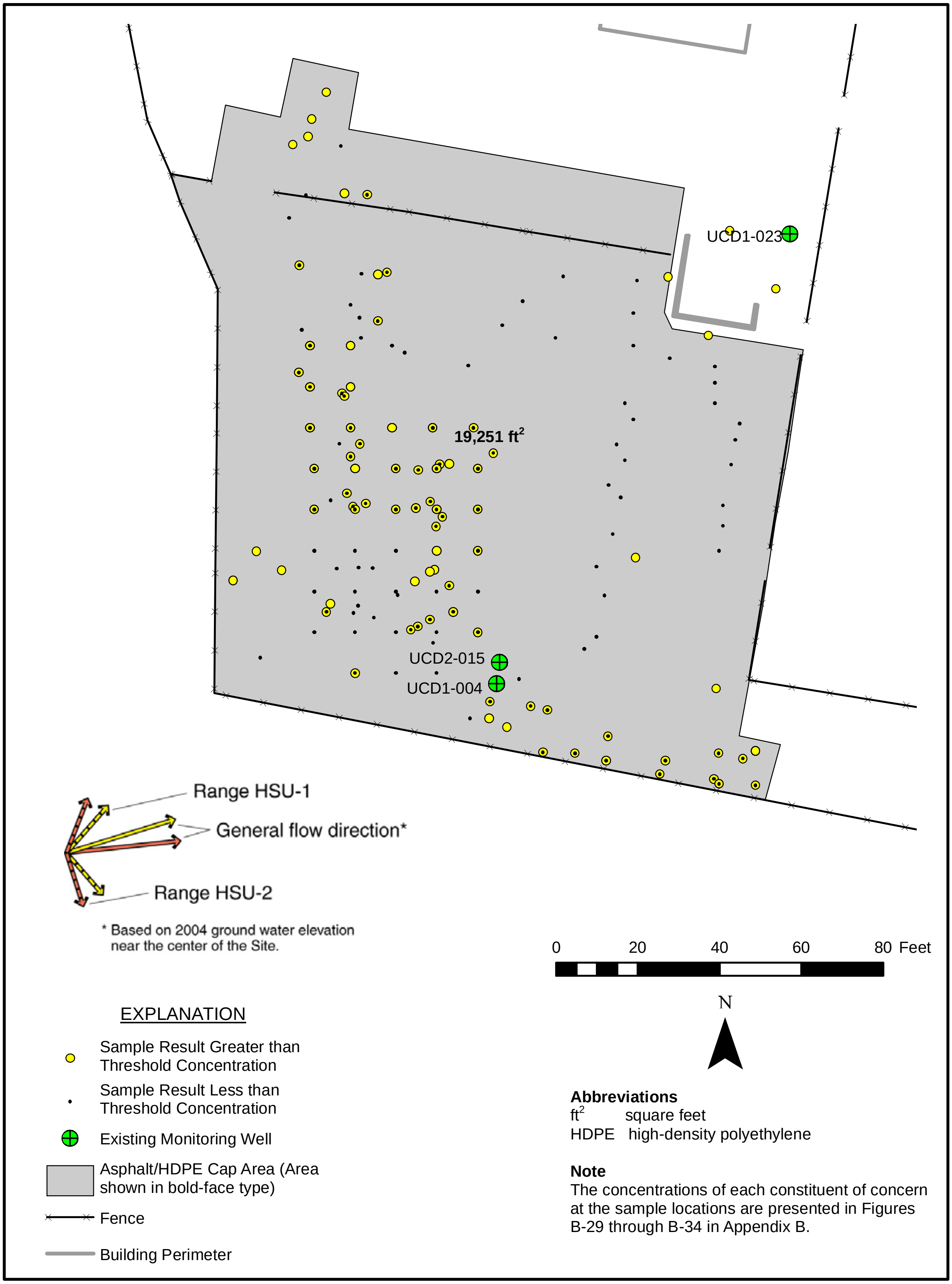

Figure 4-23. Alternative 3 at the Southwest Trenches Area: Asphalt/High-Density-Polyethylene Cap Area

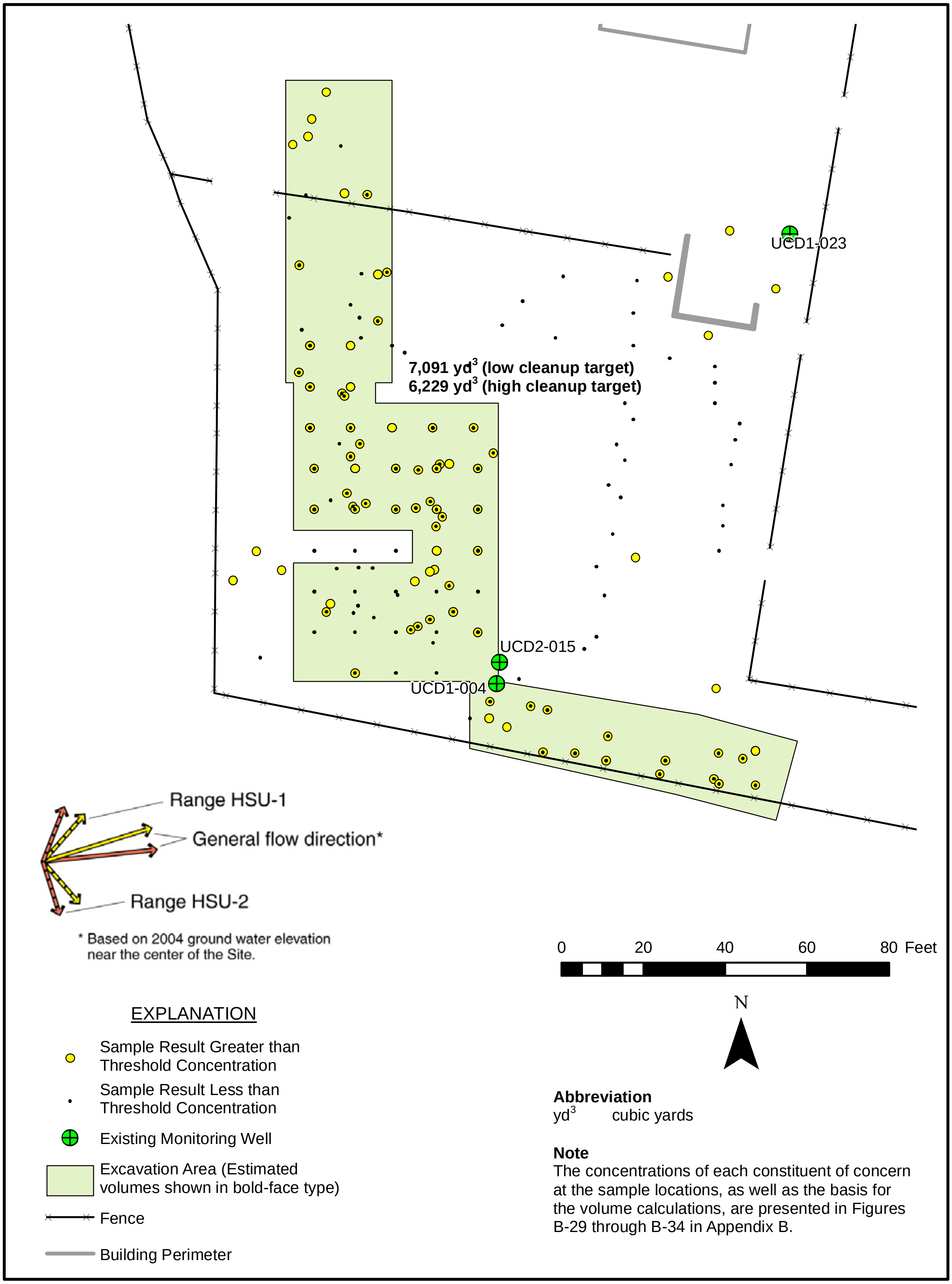

Figure 4-24. Alternative 4a/4b at the Southwest Trenches Area: Excavation Area

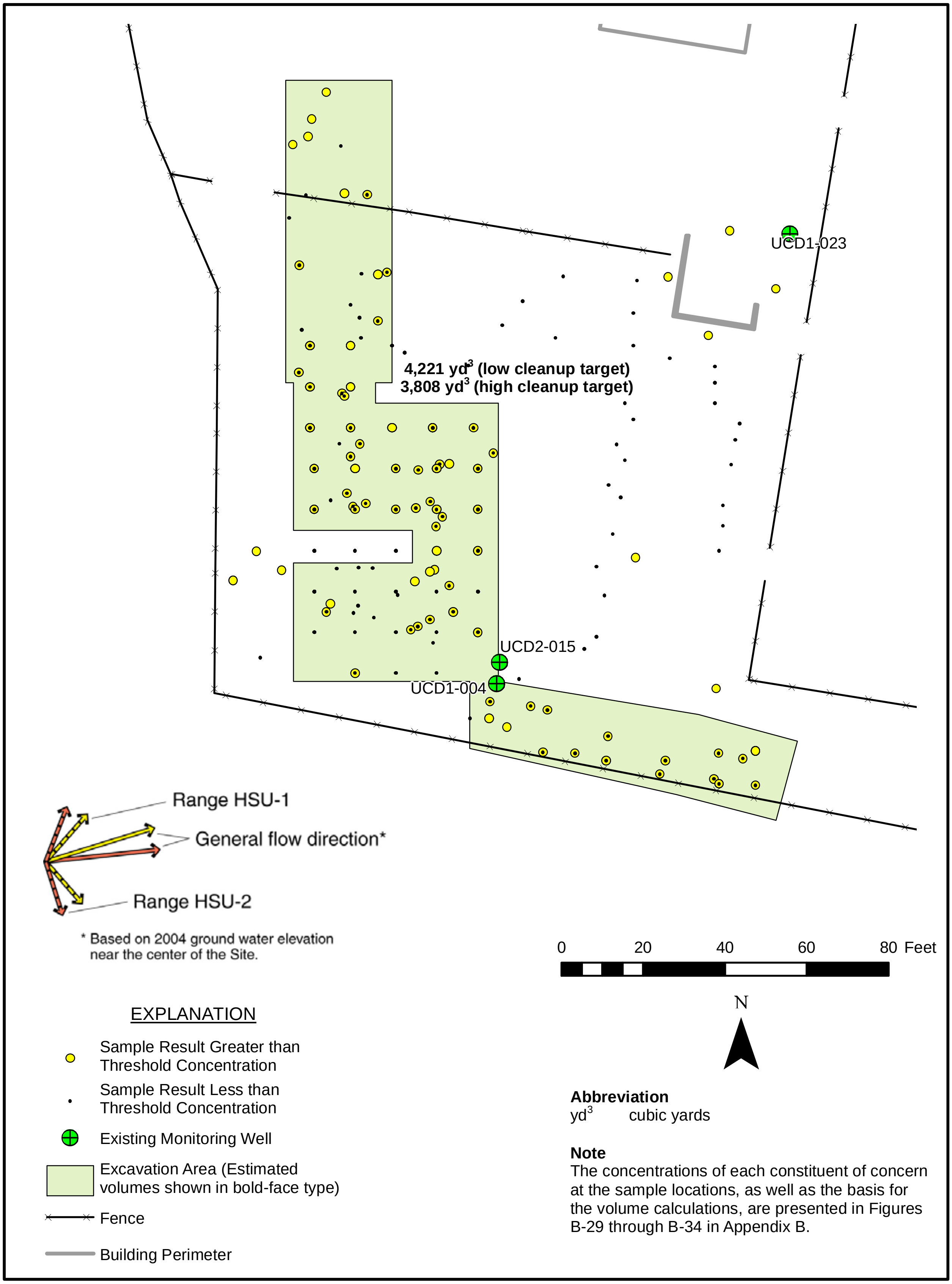

Figure 4-25. Alternative 4c at the Southwest Trenches Area: Excavation Area

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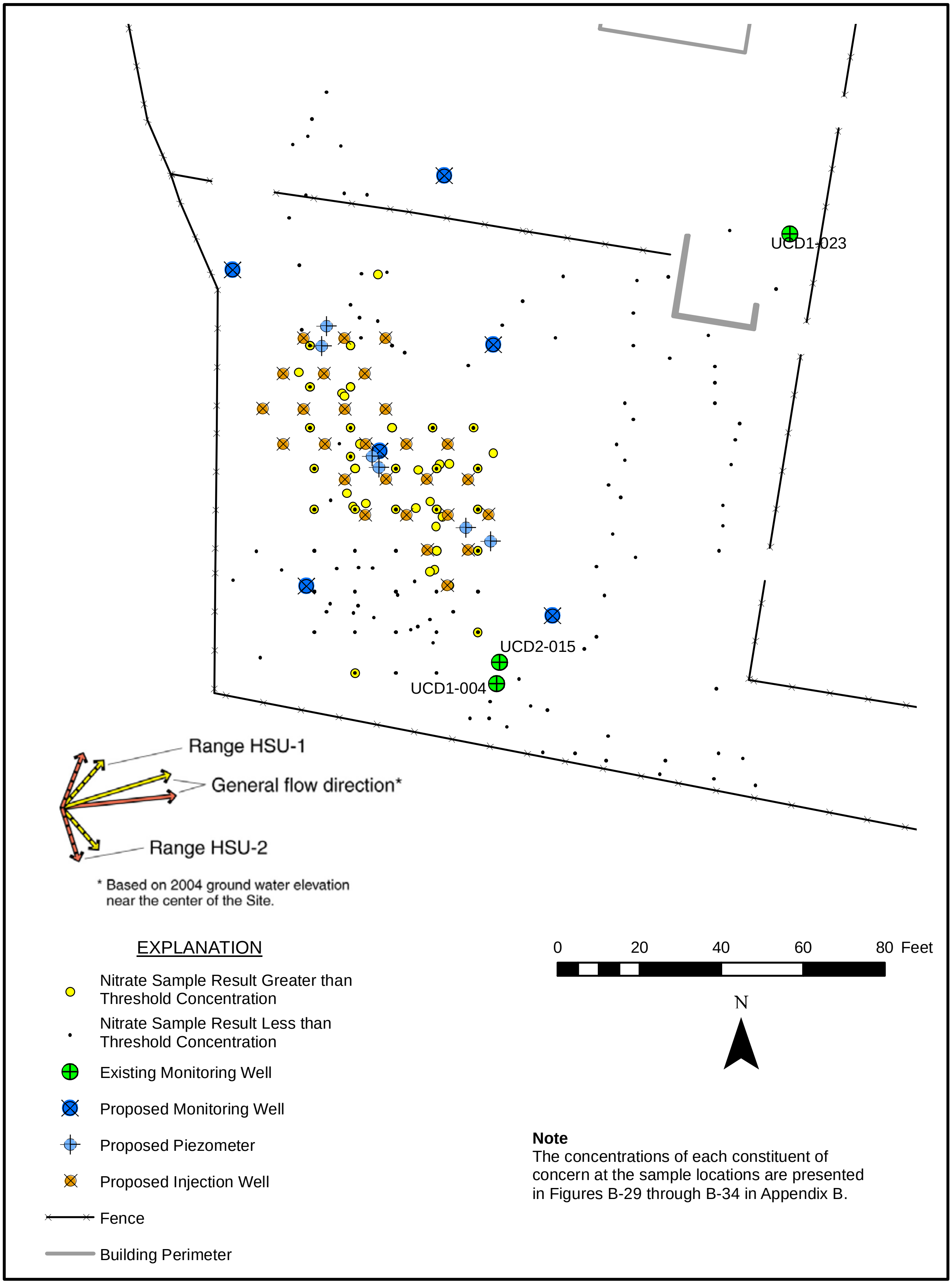

Figure 4-26. Alternative 5 at the Southwest Trenches Area: Injection and Monitoring Wells

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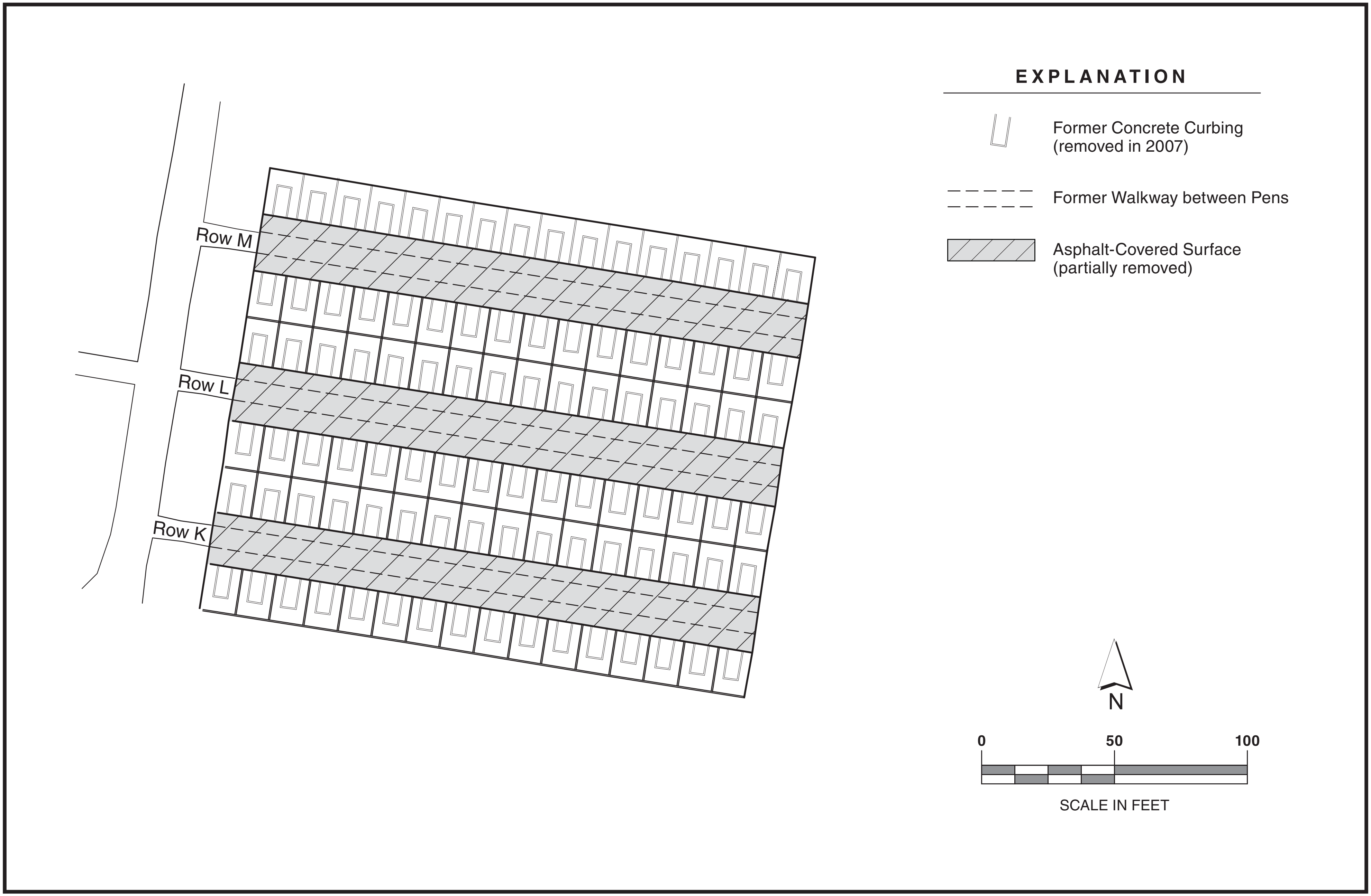

Figure 4-27. Former Eastern Dog Pens Features

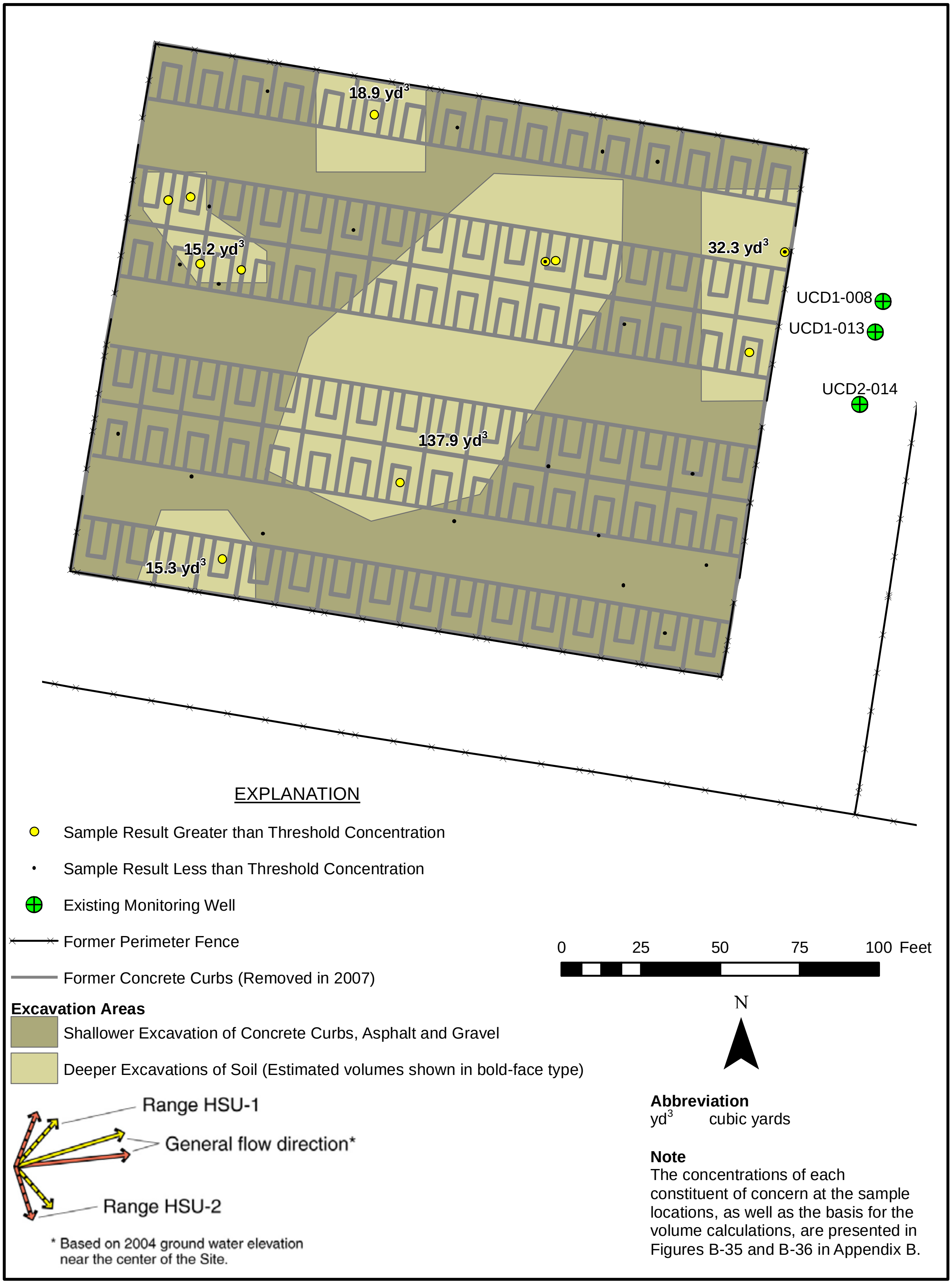

Figure 4-28. Alternative 3 at the Eastern Dog Pens Area: Excavation Areas

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5. ASSESSMENT OF ENVIRONMENTAL IMPACTS

5.1 Integration of the National Environmental Policy Act Process with the Feasibility Study

This section discusses existing environmental conditions and potential impacts that may result from implementing any of the remedial alternatives. This section reviews environmental impacts in a manner consistent with NEPA (*Public Law 91-190*), Regulations for Implementing the Procedural Provisions of the NEPA (Council on Environmental Quality 40 CFR 1500-1508), and DOE environmental compliance regulations in 10 CFR 1021, NEPA Implementing Procedures.

Evaluating environmental impacts of the alternatives concurrently with the FS allows these considerations to be integrated with the CERCLA process, thereby eliminating the need for a separate NEPA analysis, and is consistent with DOE policy and guidance (DOE, 2002a).

5.2 California Environmental Quality Act Compliance

This environmental analysis will satisfy the substantive requirements of the CEQA (California Public Resources Code, Section 12000 *et seq.*), and the CEQA guidance codified in Title 14, Chapter 3 of the CCR, to conduct an evaluation of projects which involve one or more state or local agency. In order to ensure compliance with CEQA, a discussion of mitigation measures and growth-inducing impacts is included in this evaluation.

5.3 Publication of Documents

In addition to meeting federal public notice and circulation requirements, an Environmental Impact Statement (EIS) or Finding of No Significant Impact (FONSI) resulting from this evaluation will be circulated for public review as broadly as required by the CEQA guidance codified in Title 14 CCR, Chapter 3 to ensure compliance with the substantive requirements of state law. A notice meeting the standards of Title 14 CCR, Section 15072(a) or 15087(a) will be provided to allow the use of a federal document (EIS or FONSI) to be reviewed by the public in the place of the state-equivalent Environmental Impact Report (EIR) or Negative Declaration so that the federal document does not have to be recirculated. The notice will be given in the same manner as a notice of the public availability of a draft EIR under Title 14 CCR, Section 15087.

Notice of availability of the FS, including the environmental evaluation, will be provided via publication in a newspaper of general circulation. The document will be provided to the State Clearinghouse for distribution to responsible agencies and will be placed at the Davis branch of the Yolo County Library in Davis. The document will also be provided to all RPMs. Comments on the FS will be reviewed and responses provided in the Record of Decision.

5.4 Purpose and Need for Action

The purpose of the proposed alternatives is to reduce the potential exposure to contaminants potentially remaining in DOE areas to acceptable exposure levels that protect human health and the environment. The actions would meet the objectives discussed in Section 4. The proposed alternatives fulfill a requirement of the FFA under CERCLA Section 120, entered into by DOE and regulatory agencies, to take appropriate response action, as necessary, to protect human health, welfare or the environment (FFA, Docket No. 99-17, Section 1.1a).

5.5 Proposed Actions and Alternatives

No action is proposed for DSSs 1, 5, 6 and 7, and the WDPs. Proposed alternatives for the remaining DOE areas are listed in Table 5-1. Detailed descriptions of each alternative are provided in Section 4.

5.6 Alternatives Not Carried Forward for Analysis

A number of technological alternatives were considered for application in various DOE areas and discarded as not viable. A discussion of remedial technologies considered, but not analyzed, is provided in Section 3.4.

5.7 Affected Environment

The existing site environmental setting is discussed in this section. Descriptions of the Site and facility structures are provided in Sections 1.2.1 and 1.2.5, respectively, and are not repeated in this section.

5.7.1 Site Setting

The Site is situated on relatively flat land, with an average elevation of approximately 50 ft above mean sea level. The land surface slopes to the east/northeast at approximately 0.001 ft/ft (5 ft per mile). Relief across the Site is about 2 ft.

The land within a one-mile radius of the Site is owned both privately and by the Regents of the University of California, and is used for animal research, agriculture and recreation. Immediately east, north and west of the Site are UC Davis-owned research facilities. Privately owned lands within one mile to the south and east of the Site include permanent residences and fields that support agricultural crops. Approximately 75 percent of the surrounding land in the general vicinity of the Site is used for agriculture. Major crops include fruits, nuts and grains. Approximately 40 percent of the agricultural land in the LEHR vicinity is irrigated and some of the nearby lands are used for cattle grazing (DOE, 1988). Recreational uses in this area primarily involve fishing and swimming along nearby Putah Creek.

5.7.2 Aesthetics and Scenic Values

The Site is primarily covered with buildings, pavement, former dog pens and about three acres of open or grassy areas, with trees and scattered strips of landscaping alongside buildings. Site boundaries are demarcated by chain link fences. Mature pine trees are located along portions of the south and north boundaries of the Site. Although aesthetics and scenic values are subjective, the present appearance of the Site is not found to have high scenic value.

Surrounding farmlands contain open space and contrast with the Site's synthetic structures and anthropogenic modifications. Visually, these farmlands generally provide a sense of wide expanse and greenery, which lends scenic and visual value to the area.

Putah Creek, south of the Site, is another area of scenic and visual value because of its flowing water. The diversity of vegetation and wildlife alongside the creek add to the scenic appeal of Putah Creek.

5.7.3 Air Quality

The Site is located within the Yolo/Solano Air Quality Management District and is part of the Sacramento Valley Air Basin. The Site is located in a state and federal non-attainment area for particulate matter with less than 10 microns aerodynamic diameter (PM_{10}) and ozone.

The prevailing wind direction at the Site is from the south, reflecting frequent incursions of marine air through the Carquinez Strait into the Sacramento Valley. Changes in wind direction are common, with winds from the northwest occurring diurnally. During the summer months (May through September), the predominant wind direction is from the south. The average wind speed recorded at the Site meteorological station in 1999 was approximately 1.14 meters per second (2.49 miles per hour).

Within the Site and surrounding areas, the most notable sources of air pollution are from moving automobiles (primarily from Old Davis Road, the Site, adjacent roads and freeways). Fugitive dust (i.e., particulate matter) is associated with moving vehicles, construction equipment (when construction or earth-moving activities occur) and agricultural equipment (when work such as harvesting, planting and clearing is involved). Fugitive dust is also generated when high winds blow over dry, barren or open fields.

5.7.4 Biological Resources

The biological resources discussed herein are plant communities and wildlife. Detailed information on the plant communities and wildlife is presented in the Final SWERA (UC Davis, 2006b). The subsections below summarize the information regarding existing site plants and wildlife.

5.7.4.1 Plant Communities

Areas of the Site not covered by buildings, structures and pavement support ruderal vegetation (e.g., weeds), non-native grassland, landscaped vegetation, bare ground and Aleppo pine (WA, 1997; MWH, 2004). Weedy vegetation that has recolonized disturbed areas, non-native annual grasses, weedy annual and perennial forbs and scattered native herbaceous species are dominant plants in these habitats. Landscaped vegetation, such as horticultural trees and shrubs, has been planted in a few locations along roadways and fence lines (UC Davis, 2006b).

Plant species present in the surrounding area were identified in biological surveys performed in the vicinity (Jones and Stokes Associates, 1996). Approximately 70 different plant species including a number of willows, types of wild grass, non-native grasses, thistles, filarees and oak trees were identified (UC Davis, 2006b).

Special-status species are those species of plants and animals defined under the Endangered Species Act (50 CFR 17.12), California Endangered Species Act (14 CCR 670.5) and those considered sufficiently rare by the scientific community to qualify for such a listing. The Scoping Assessment (WA, 1997b) identified 32 special-status plant species with potential to occur in the vicinity. Of these 32 plants, none have been recorded at the Site. No special-status plant species were detected or have been recorded in the surrounding region (within approximately a one-mile radius from the Site).

5.7.4.2 Wildlife

A variety of animal species have been observed on the Site and the adjacent areas. Although many of these animal species are not likely to live within the Site, they may forage there. Resident burrowing mammals observed at the Site include the California ground squirrel, California vole, Botta's pocket gopher and various mice species. Common predatory mammals and reptiles likely to forage on the Site include the coyote, gray fox, red fox, house cat, gopher snake and garter snake. Common predatory birds likely to forage on the Site include the red-tailed hawk, red-shouldered hawk, American kestrel, great-horned owl and barn owl. Common fish expected in the nearby Putah Creek include largemouth bass, green sunfish, carp and catfish. Fish-eating animals likely to occur in the South Fork of Putah Creek include the river otter, beaver and muskrat.

A total of 26 special-status wildlife species have been recorded in the vicinity of the Site or are considered to have a moderate to high potential for occurrence in the area. The Scoping Assessment (WA, 1997b) identified 14 special-status wildlife species with potential to occur in the vicinity. A total of seven special-status wildlife species are considered to have a moderate to high potential to inhabit or forage on the Site. The following avian species were observed at the Site: California horned lark, northern harrier, white-tailed kite, and Cooper's hawk. The California horned lark (also referred to as the horned lark in this SWERA), Cooper's hawk and northern harrier are California species of special concern. The white-tailed kite is a California Department of Fish and Game fully protected species and a federal species of concern. Evidence of the presence of Swainson's hawks was also noted in the vicinity of the Site. Nests were found in the riparian areas of Putah Creek. The Swainson's hawk (*Buteo Swainsoni*) is listed as threatened by the State of California and is a federal species of concern (UC Davis, 2006b).

The burrowing owl (*Athene cunicularia*), a special-status species, was previously identified at the Site, but it has not been observed on the Site since the abandonment of the UC Davis Raptor Center breeding program (UC Davis, 2006b).

A potential habitat for the Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*) was identified in both the WDPs and EDPs. The habitat consists of elderberry trees and shrubs (WA, 2001a: Figure 8-1). The beetle has not been identified at the Site in any of a number of surveys.

5.7.5 Flood Plains

As shown on federal flood maps, the 100-year flood plain is confined within the Putah Creek levees at the southern boundary of the Site. The Site lies in the Federal Emergency Management Administration (FEMA) Zone C. The area is expected to experience minimal flooding.

5.7.6 Geology/Soils

The Site and vicinity are in the Putah Plain of the Sacramento Valley (DWR, 1978), which consists of alluvial fan deposits associated with Putah Creek. These alluvial sediments consist primarily of silt and clay with localized, interfingered, coarse-grained sediments and are approximately 180-ft thick (DWR, 1978). Beneath the Site, the sediments are nearly flat-lying and conformably overlie the Tehama Formation, the principal water-bearing geologic unit on the west side of the Sacramento Valley.

The depths and types of major sedimentary units encountered in boreholes beneath the Site are described below from youngest to oldest. Some of the units contain gradational sequences or more than one lithology.

- 0 to 80 ft—Interbedded silt, clay and sand with some sand and gravel channel deposits. The surface soils are underlain by interbedded clay, silty clay, silt and sand. This fine-grained interval is fairly continuous across the Site and contains some coarse sand and gravel. The ground water table is in this stratigraphic unit and varies in depth from approximately 15 to 65 ft bgs, depending on the season and total rainfall.

- 80 to 135 ft—Cobbles and gravel. Well-rounded cobbles and gravel are encountered at approximately 80 ft bgs and appear to be laterally continuous beneath most of the Site. Where present, this unit is approximately 35 to 52 ft thick.
- 135 to 143 ft—Clay and some silt. Clay and silt underlie the cobbles and gravel. The top of this clayey unit is encountered at depths ranging from 120 to 137 ft bgs (D&M, 1993).

5.7.6.1 Surface Soil

The surface soils at the Site have been mapped as Reiff fine sandy loam in the Soil Survey of Solano County, California (USDA, 1977). These soils are relatively young and weakly developed. The "A" horizons are relatively thick and organic-rich, and therefore ideal for agriculture (USDA, 1977). Surface soils have been disturbed in some areas of the Site as a result of subsurface disposal and construction activities.

5.7.7 Hydrogeology

Unconsolidated Pliocene and Pleistocene deposits are the major ground water sources for public and private water supplies in the Sacramento Valley (DWR, 1978). Both unconfined and confined fresh-water aquifers are present in these sedimentary deposits in the uppermost 3,000 ft of the valley subsurface. Ground water generally flows from the valley sides towards the valley axis. In the vicinity of the Site, regional ground water generally flows east from the Coast Ranges toward the Sacramento River (D&M, 1993).

At various depths beneath the valley floor, fresh water gives way to saline water as a result of entrapment during the deposition of sediments in a marine environment. The depth to the base of fresh water in the Sacramento Valley varies from 400 ft to over 3,000 ft, and is 2,600 to 3,100 ft bgs in the Davis area (DOG, 1982).

The results of previous investigations identified five HSUs beneath the Site (D&M, 1999). The HSUs identified beneath the Site include the vadose zone, HSU-1, HSU-2, HSU-3 and HSU-4. The vadose zone extends from the ground surface to the top of ground water, which has historically ranged from 15 to 65 ft bgs. The vadose zone consists primarily of unsaturated clay and silt with lesser amounts of interbedded sand and gravel. HSU-1 extends from the bottom of the vadose zone to a depth of approximately 76 to 88 ft bgs. This unit is lithologically similar to the vadose zone and consists primarily of silt and clay, with lesser amounts of sand and gravel. HSU-2 extends from the bottom of HSU-1 to a depth of approximately 114 to 130 ft bgs. This unit is composed primarily of sand in the upper portion of the unit and gravel in the middle to lower portions of the unit. HSU-3, investigated in off-site areas, extends from the bottom of HSU-2 to a depth of about 250 ft bgs and is approximately 120 ft thick. The unit consists primarily of relatively fine-grained sediments varying from very fine-grained sandy silt to clayey silt and silty clay. HSU-4, investigated in off-site areas, extends from the bottom of HSU-3 to a depth of about 282 ft bgs and is approximately 32 ft thick. This unit consists of coarse sand and gravel. Beneath HSU-4, a sharp contact with a bluish, dark gray silt was encountered at 282 ft bgs in wells UCD4-041 and UCD4-043. The bottom of this unit was not penetrated in any of the site borings (D&M, 1999).

The uppermost distinct aquifer beneath the Site has been divided into two HSUs (HSU-1 and HSU-2), based on the stratigraphy of the sediments at the Site, and the associated ground water flow and contaminant migration characteristics (D&M, 1994). Well drillers' logs indicate that a 90-ft-thick clay unit separates HSU-2 from a second aquifer below (D&M, 1994).

Irrigation water, rainfall and Putah Creek recharge ground water in the vicinity of the Site (D&M, 1997). The main component of ground water recharge, however, has been identified as irrigation water infiltration (WA, 1998). Ground water pumping associated with agricultural demands is largely responsible for ground water withdrawal. In addition, UC Davis extracts ground water from HSU-2 as part of its interim remedial actions.

Generally, there is a 20- to 30-ft seasonal fluctuation in the depth-to-ground water beneath the Site, caused predominantly by the lack of surface recharge and agricultural pumping in the summer. Vertical gradients vary both temporally and spatially. The magnitude of the vertical gradient is greatest when ground water elevations are rising or falling sharply. Short-term activities, such as local agricultural pumping, can produce downward vertical gradients during periods of an otherwise rising water table.

The HSU-1 lateral gradient across the Site typically ranges from 0.01 to 0.04 ft/ft, and the direction of ground water flow is predominantly northeast. Representative values of HSU-1 horizontal hydraulic conductivity are between 10^{-4} and 10^{-7} cm/sec (D&M, 1999). The lateral gradient across the Site within HSU-2 typically ranges from 0.005 ft/ft to 0.015 ft/ft. The direction of flow appears to be predominantly northeast, although it can occasionally be east-southeast. Based on pumping tests, hydraulic conductivity in HSU-2 ranges from 0.26 to 0.43 cm/sec (D&M, 1997).

Ground water in HSU-1, HSU-2 and HSU-4 has been impacted by site activities. Based on investigations to date (WA, 1997c; WA, 1999), significant ground water impact appears to be associated only with the UC Davis disposal areas.

5.7.8 Land Use

Land in the vicinity of the Site is either part of the UC Davis campus or is in agricultural use. Immediately adjacent to the Site are the UC Davis Raptor Center and animal research facilities. The Raptor Center houses raptors that have been injured or orphaned. An unrestricted outdoor area containing a burrowing owl project is located about 1,500 ft east of the Site. UC Davis animal research facilities house horses, cows, goats and other domesticated farm animals in outdoor corrals and pens. Agricultural land lies south of Putah Creek, and east and west of property owned by UC Davis. Wheat, tomatoes, corn, barley and oats are the main crops grown on this agricultural land. The main UC Davis campus and the City of Davis (downtown area) are located 1.2 and 1.9 miles north of the Site, respectively.

The Site is designated as "Urban and Built-up Land" by the State of California Department of Conservation on Yolo and Solano Counties Important Farmlands Maps (UC Davis, 2002). Specific land uses on the Site and the immediate adjacent areas are under the control of UC Davis and are defined by the UC Davis LRDP (UC Davis, 2003). The LRDP designations for the LEHR site are "Academic/Administrative Low Density" and "Support Services" (UC Davis, 2003).

Future land-use plans for areas surrounding UC Davis identify a 225-acre University neighborhood that will be located west of State Route 113 and south of Russell Boulevard. The neighborhood would include housing for about 3,000 students and about 500 faculty and staff. The neighborhood would also include recreation areas, open space, a mixed-use retail center, a Community Education Center, and an elementary school. A research park is also planned for 38 acres located west of the former LEHR facility, west of Old Davis Road to the north and south of I-80. The plan anticipates about 480,000 square ft of building space with capacity for approximately 1,400 employees (UC Davis, 2003).

5.7.9 Noise Quality

No significant or loud noises appear to affect the Site, although several sources of noise exist, including vehicular traffic, sounds from air conditioning units and other operating equipment, moving railroad trains (located about 0.25 miles from the Site) and small aircraft. Ambient noise level surveys were not conducted as a part of this analysis.

5.7.10 Socioeconomic Conditions

The Site is located on the South Campus of UC Davis in a rural area in northeast Solano County, just outside the City of Davis (Yolo County), The Site is considered part of the Davis/UC Davis community. UC Davis comprises a 3,600-acre campus and research area, with a student population of approximately 30,065 (UC, 2004) and 17,000 staff employed (City of Davis, 2005).

The current population of Davis is over 62,200 residents (City of Davis, 2005). Most of the residents work in professional, technical, and governmental (managerial and administrative) occupations due mainly to the city's close relationship with the UC Davis campus, and the professional and technical environment the university creates. Outside of the university, there are approximately 3,000 jobs in the City of Davis. The city has approximately 23,249 housing units (City of Davis, 2005).

The current population of Yolo County is 168,660 (USCB, 2000). In recent years, the total employment in Yolo County was approximately 92,000 jobs (CSU, 2003). The more densely populated and metropolitan Sacramento area is approximately 13 miles east of the Site. Approximately 407,018 people live in the City of Sacramento, and about 1,223,499 people live in Sacramento County (USCB, 2000).

5.7.11 Water Resources

This section describes the water resources at the Site and, where appropriate, the adjacent area. Water resources include ground water, and surface and recreational waters (i.e., rivers and wetlands). Hydrogeologic characteristics of the Site are described in Section 5.7.7.

5.7.11.1 Ground Water

The occurrence and characteristics of ground water beneath the Site have been summarized in numerous reports (WA, 1997d; D&M, 1999; PNNL, 1996). Ground water quality is summarized herein based on detailed information reported in the Final Tiered Initial Study, Laboratory for Energy-Related Health Research and South Campus Disposal Site Interim Remedial Actions Project (UC Davis, 1997).

There are a total of 52 monitoring wells on and around the Site that monitor HSU-1, HSU-2 and/or HSU-4 ground water wells. Ground water samples from these wells and Hydropunch locations provide information on ground water characteristics. Ground water wells are also present in the surrounding areas and are used to provide water for agricultural and domestic purposes. Site ground water is not currently provided for drinking water or other direct human use, nor is it expected to be used for such in the future. Drinking water is supplied by the campus water system, which draws water from five deep wells, the nearest of which is about 400 ft north of the Site.

Regional water quality has been impacted by the presence of nitrates from agricultural sources, and Cr-VI, probably from natural sources (D&M, 1997). Ground water in HSUs 1 and 2 has been impacted by past site activities, particularly the release of chloroform from Landfill No. 2, a former campus municipal landfill.

As indicated in Section 1, DOE and UC Davis have signed a MOA to divide responsibility for areas of contamination at the Site according to historical information regarding Site operations. UC Davis has assumed responsibility for ground water remediation activities. The primary COCs in ground water are chloroform and other VOCs, C-14, tritium, chromium (primarily as Cr-VI) and nitrate. UC Davis is currently operating an interim remedial action system to extract and treat chloroform in HSU-2 and gather data that will aid in the assessment of ground water treatment effectiveness and the need for further ground water remedial actions.

5.7.11.2 Storm Water

Storm water runoff at the Site is collected in surface and sub-surface drainage systems. Storm water from the paved area in the western part of the Site is collected in catch basins and discharged to an unlined ditch along Old Davis Road. Drainage around the southern buildings in the western area and from the paved portion of the Site, including the eastern side of the AH buildings and the area near the WDPs, is collected in a main storm water drainage system, routed to a lift station and subsequently pumped to an outfall along the east side of Old Davis Road, where it is discharged to an unlined ditch. Storm water flows to the west side of Old Davis Road in a culvert pipe and then flows south to Putah Creek in an unlined ditch. Storm water that falls along the eastern and unpaved southern portions of the Site, including most of the SWT, the EDPs and WDPs, infiltrates into the soil or evaporates. Drainage for a section of the former Co-60 Field, where dog pens were once located, is connected to the sanitary sewer. During heavy rains, water ponds in some areas on the Site.

5.7.11.3 Surface and Recreational Waters

No natural or man-made surface or recreational waters are present at the Site. The east-flowing South Fork of Putah Creek is about 125 ft south of the Site within a man-made channel constructed to divert floodwaters from the City of Davis and the UC Davis main campus. The channel borders the southern portion of the Site and is separated from the Site by the north levee of the creek, which supports a two-lane paved roadway.

Flow in the South Fork of Putah Creek is regulated by releases from Monticello Dam at Lake Berryessa and from the Putah Diversion Dam, located about 18 and 14 miles west of the Site, respectively. In 1948, the United States Army Corps of Engineers (USACE) modified the South Fork and dammed the North Fork so that all water in Putah Creek now flows in the South Fork. Putah Creek is a "losing" stream (water flows from the streambed toward the ground water table) in the LEHR vicinity; therefore, Putah Creek water may impact shallow ground water beneath the Site, but not vice-versa. In the past, drought conditions during the dry summer months have resulted in the lower portions of the creek going dry and in significant fish and invertebrate animal kills (Marchetti and Moyle, 1995).

Based on data from 1980 through 1991, flows several miles upstream from the Site typically range from 0.1 cubic ft per second (cfs) to about 3 cfs, although flows as high as 15,500 cfs (in March 1983) have been reported (D&M, 1994). In the reach bordering the Site, flow in the South Fork of Putah Creek is supplemented by discharge from the UC Davis Waste Water Treatment Plant. Based on data from a gauge near Old Davis Road, flow rates for the reach bordering the Site ranged from 0.17 to 148 cfs from 1989 to 1993. Flows have not changed substantially since 1993 (WA, 1997d).

Putah Creek is typically bordered by dense vegetation and small trees within and adjacent to the channel, which provide habitat for birds and small wildlife. The South Fork of Putah Creek in the vicinity of the Site is used for recreational activities, such as fishing, swimming, rafting and other related water activities.

5.7.12 Wetlands

The area of the South Fork of Putah Creek is identified as a wetland by USACE. Wetlands perform vital ecological functions providing communities with a variety of resident and migratory animal species habitat, breeding, spawning and forage areas. Wetlands also provide for the movement of water and sediments, ground water recharge, water purification, storage of storm water runoff and recreation. There are no wetlands located directly at the Site.

5.8 Environmental Considerations Not Affected by Any of the Alternatives

There are several existing environmental conditions that will not be affected by any of the alternatives. These include:

- Aesthetics and scenic values;
- Flood plains;
- Historical and Cultural Resources;
- Population and Housing;
- Socioeconomic conditions;
- Surface recreational waters; and
- Wetlands.

Each of these is discussed below.

5.8.1 Aesthetics and Scenic Values

The proposed alternatives will not affect the aesthetics and scenic values of the area. The present site appearance does not have high scenic value.

Under some of the alternatives, the appearance of the Site may change during excavation, cap installation or phytoremediation activities. These visual changes are within small localized areas that are normally out of view from the public and public thoroughfares, and are expected to be unnoticed, except by individuals working on or visiting the Site. Under the removal alternatives, the affected areas will be backfilled and graded, as appropriate, and restored to their current condition. All areas where an asphalt cap may be installed, except the SWTs, are currently paved; therefore, the asphalt cap would not modify the aesthetic value of the current condition. In the SWT area, installation of an asphalt cap would convert the existing dirt field currently covered with polyethylene material to an asphalt surface. Such a change would not significantly change the aesthetic value of the location, although it may be considered an improvement over the current condition of the area.

Under the phytoremediation alternative (Alternative 4b, Sections 4.4.2.5, 4.6.2.5, and 4.12.2.6), the WDPs would be covered with an HDPE liner on which grass would be grown during the summer season for three years. The grass would be covered with an HDPE liner during the rainy season. This temporary site modification would not be visible to the public. It would modify the site aesthetics locally for the research staff at the Site. The change would not be permanent and is not very different from the activities undertaken in the area in the past ten years or during the use of the area for dog kennels. The aesthetic is consistent with the research operation conducted at the Site.

Under the *in situ* bioremediation alternative (Alternative 5, Sections 4.4.2.7, 4.6.2.7 and 4.12.2.8) a 1,000-gallon storage tank would be installed in a fenced-in area at the Site. This tank would remain in operation for two years and would be removed after the completion of the bioremediation remedial action. The tank would not be visible to the public and would not be inconsistent with the current equipment and facilities present at the Site.

There will be no long-term impacts to aesthetics and scenic values under any of the alternatives.

5.8.2 Agricultural Resources

The Site is designated as "Urban and Built-up Land" by the State of California Department of Conservation for Yolo and Solano Counties Important Farmlands Maps (UC Davis, 2002). There are no farmlands at the Site and no conversion of farmland would directly result from any of the alternatives. Surrounding agricultural use has co-existed with the research operations at the Site for decades. The proposed alternatives are not anticipated to change the use of the Site, and therefore, the alternatives are not expected to lead to changes in the use of surrounding parcels.

5.8.3 Flood Plains

As shown on federal flood maps, the 100-year floodplain is confined within the Putah Creek levees at the southern boundary of the Site. The Site lies in FEMA Zone C, defined as an area of moderate or minimal hazard from the principal source of flooding in the area. Hazards associated with flooding are not expected to result from any of the alternatives. None of the alternatives will create any long- or short-term adverse effects associated with occupancy of the floodplain.

5.8.4 Historical and Cultural Resources

Historically, the Site was used for agriculture. In the 1970s, the South Fork of Putah Creek was constructed south of the Site. The State Historic Preservation Officer has indicated that there are no known historical or cultural resources identified within or adjacent to the Site (UC Davis, 1996). No historical or cultural resources have been found at the Site, and because of previous disturbances to the subsurface Site, no historical or cultural resources are expected to be uncovered. No impact on historical or cultural resources is expected under any of the alternatives.

5.8.5 Mineral Resources

The proposed alternatives would have no impact on mineral resources, since no such resources are known to exist at the Site.

5.8.6 Public Services

None of the proposed alternatives will have a significant impact on the current level of public services in the area. Police and fire services are provided by UC Davis and are expected to remain unchanged with the implementation of any of the proposed alternatives. No increase in demand for school services, parks, or other recreation or public facilities will occur as a result of any of the alternatives.

5.8.7 Socioeconomic Conditions (including Population and Housing) and Growth Inducement

None of the alternatives will significantly affect the socioeconomic conditions of the area. The alternatives that require short-term construction-type activities may increase the level of staff at the Site during the duration of these activities. The effect of these activities on the local area, such as the number of jobs created, the amount of money spent in the area, the effect on sensitive populations (i.e., minorities, low-income) and land values will be minimal. The alternatives will result in the creation of no more than 12 full-time jobs lasting no more than 12 months, which is less than 0.03 percent of the economy of the City of Davis. Similarly, implementation of long-term monitoring alternatives will result in creation of only a handful of full-time jobs that will not impact the socioeconomic condition of the local area.

The alternatives are not expected to generate a need for new housing. Alternatives that include construction-type activities (asphalt/HDPE cap installation and removal and off-site disposal) would create short-term increases in the number of workers at the Site. The increase would be temporary in nature, and would not involve construction of new housing or infrastructure that could directly or indirectly induce substantial growth in population or housing. Project employees would be temporary, and are expected to live within commute distance from the project site or to use local hotels for short-term stays. The project will not increase the number of immigrants to the area attracted by new job opportunities and will not affect population growth.

None of the proposed alternatives are likely to induce growth in the area. No land-use changes are planned for the Site after the completion of any of the actions and/or the alternatives. The area will remain designated as “Academic/Administrative Low Density” and “Support Services” until 2015, in accordance with the UC Davis 2003 LRDP (UC Davis, 2003). It is possible for the site use to change over time in ways that may encourage growth; however, such land-use changes will not result from the proposed alternatives and will require separate environmental evaluation.

5.8.8 Surface Recreational Waters

No existing surface recreational waters will be affected by any of the alternatives. No surface or recreational waters are found on the Site. The South Fork of Putah Creek provides recreational opportunities, such as fishing, swimming, boating and other related water activities. This area is about 125 ft south of the Site and is separated from the Site by a levee and a two-lane paved roadway. Site activities are separated from recreational areas by sufficient distance to prevent impact to the recreational uses of the creek.

5.8.9 Utilities and Service Systems

No additional utilities or services, such as waste water treatment, waste supply systems or storm drain infrastructure would be required to implement any of the proposed alternatives.

5.8.10 Wetlands

A wetland, as defined in 10 CFR 1022.4 (v), is an area that is inundated by surface or ground water with a frequency sufficient to support, and under normal circumstances does or would support, a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. The Site contains no areas that meet this or other wetland definitions. No impacts are expected to any wetlands located off site (e.g., South Fork of Putah Creek).

5.9 Potential Environmental Impacts

This section describes the potential environmental impact of each alternative. Actions associated with each alternative are provided in Table 5-2. Potential impacts of each alternative are summarized in Tables 5-3 through 5-10. Potential impacts include:

- Short-term, construction-related impacts;
- Long-term impacts associated with the implementation of each alternative; and
- Cumulative impacts.

Construction activities may create short-term impacts on:

- Air quality;
- Biological resources;
- Noise;
- Occupational and public health;

- Transportation of wastes; and
- Water resources (from storm water runoff).

Long-term impacts of the alternatives potentially include effects on:

- Biological resources;
- Occupational and public health;
- Soils; and
- Water resources (storm water runoff and ground water).

All of the potential impacts are discussed below. Cumulative impacts are discussed in Section 5.9.11.

5.9.1 Air Quality Impact

5.9.1.1 Short-Term Impacts

Alternatives that involve earth moving/altering activities have the potential to create dust. These activities include installation of an HDPE cap (Alternative 3) and soil removal activities (Alternative 4). The Site is within a non-attainment area for PM_{10}. Standard dust suppression measures would be taken during construction activities, primarily by wetting down the disturbed areas. Any stockpiled soil or materials subject to being made airborne by blowing wind would be covered or placed in containers. Ground cover would be provided at the completion of the RAs as a permanent measure to control dust. Air monitoring would be performed during dust-generating activities to ensure that no significant adverse impact to air quality is occurring. No significant or adverse long-term impact to the ambient air quality is foreseen.

5.9.1.2 Long-Term Impacts

Inhalation of soil dust containing residual contaminants is a potential long-term hazard associated with alternatives that contaminants in place: no action, long-term ground water monitoring and land-use restrictions. The risks associated with inhalation of contaminants remaining in site soil are evaluated in the SWRA (UC Davis, 2005). Cancer and non-cancer risks associated with inhalation of contaminants under the current condition (no action alternatives) are well below 1×10^{-6} for all DOE areas. The risk of exposure to all COCs at the Site is usually below 1×10^{-8}. These risk estimates are based on residential use of the Site, a conservative assumption that is unlikely to be true in the foreseeable future, since the UC Davis LRDP calls for site use to be administrative and university support.

The risk estimates in the SWRA are corroborated by air emissions estimates conducted for National Emission Standards for Hazardous Air Pollutants (NESHAPs) compliance using air emission data collected at the Site. For calendar year 2005, maximum effective dose equivalent (MEDE) for radiation was calculated for non-point sources of radiation defined as wind-blown fugitive dust. The MEDE was 5.9 x 10^{-4} millirem per year (mrem/year), which corresponds to about 0.006% of the 10 mrem/year standard. The location of the maximally-exposed individual in the scenario was at the Specimen Storage Building (Building H-216), 48 meters west of the WDPs (WA, 2006).

Air impacts may also result from alternatives that call for ground water sampling; however, these impacts are not expected to be significant. Some sampling will be conducted using submersible pumps driven by gasoline-powered generators. The Site is within severe non-attainment area for ozone, a product of fuel combustion. Although generators are regulated as air pollution sources by the Yolo-Solano Air Quality Management District, generators under 50 horse power (hp) are exempt from regulation, due to their small size and limited impact. The generators used for sampling activities would be one order of magnitude less powerful than those exempt by the air district, at about 5 hp. The pumps would be used for a duration of less than 24 hours per year if all of the alternatives involving ground water monitoring were selected. The air emissions associated with these generators are not expected to produce a significant impact on the local air quality.

5.9.2 Biological Resources

5.9.2.1 Short-Term Impacts

Construction activities may impact biological resources by generating noise, airborne dust and airborne contamination, filling borrows, and removing or disturbing vegetation and habitat. Prior to any activities that would involve excavation, earthmoving, grading, cap construction or installation of any treatment system, the area of disturbance and any potentially affected off-site areas will be inspected for presence of special-status species and, if appropriate, mitigation measures will be developed to prevent adversely affecting species. If potential to cause adverse effects is identified, DOE will consult with the United States Fish and Wildlife Service and National Oceanic and Atmospheric Administration National Marine Fisheries Service on mitigation measures and will implement measures to reduce potentially significant impacts to non-significant levels.

5.9.2.2 Long-Term Impacts

The Final SWERA provides an evaluation of long-term effects of residual contamination present at the Site on biological resources (UC Davis, 2006b). The SWERA identifies constituents of potential ecological concern (COPECs) at the Site and compares the COPEC site concentrations in soil to conservative ecological screening benchmarks and toxicity reference values. The risk to assessment endpoints, which reflect "an explicit expression of the environmental value that is to be protected" (US EPA 1997) are evaluated for each area of the Site. Site soil concentrations are evaluated to depths of 10 ft bgs. Surface water contamination, fate and transport of contaminants to Putah Creek and burrow air contamination are included in the evaluation. Exposure estimates based on food web exposure, species-specific exposure parameters (e.g., ingestion rates, home range), and bioaccumulation factors are considered.

For each DOE area, the potential risk to all assessment endpoints exposed to residual contamination (No Action Alternatives) is concluded in the SWERA to be acceptable. The alternatives that would remove or treat residual contamination from the Site are likely to reduce potential risks to ecological receptors. Alternatives that include monitoring would ensure that any potential effects of contaminant migration and/or increase in concentration of residual contamination are evaluated and that any potential increase in risk is appropriately mitigated.

5.9.3 Geology

No significant impacts are associated with any of the alternatives due to seismic activity. The Site is not traversed by any identified active faults. The probability of earthquakes with a magnitude equal to or greater than 5 in the next 30 years is between approximately 0.6 and 0.7 (USGS, 2005). Ground shaking may impact activities at the Site if it were to occur during soil excavation, installation of the asphalt/HDPE cap or ground water monitoring. Ground shaking may also impact the carbon solution storage tank associated with Alternative 5, *in situ* bioremediation. The tank will be seismically braced in accordance with the applicable building codes and City of Davis and UC Davis construction requirements.

Workers will be instructed in earthquake response procedures. Site-specific emergency procedures will be developed and implemented. Emergency equipment, such as fire extinguishers, water, and first aid supplies will be available on site. Site evacuation routes will be posted in conspicuous locations. Personnel will be properly trained in emergency procedures applicable to all equipment used in soil excavation, installation of the asphalt/HDPE cap or ground water monitoring.

5.9.4 Land Use

Under all of the alternatives, the Site will remain under the control of UC Davis and will continue to be used for UC Davis educational and research operations, consistent with the UC Davis LRDP (UC Davis, 2003). Land-use restrictions are contemplated for areas with residual contamination. The land-use restrictions would vary by area and may prohibit residential use of the Site, require that any soil excavated be profiled and disposed in accordance with applicable requirements at the time of disposal, prohibit use of contaminated ground water, prohibit activities that damage installed cap and liner material, and require maintenance of the cap area as long as contaminants are present. Under California statute, land-use restrictions would be drafted by DTSC and recorded with Solano County. DTSC is responsible for ensuring that the responsible party meets its land-use control obligations.

Land-use restrictions would have some impact on the use of the Site by preventing unrestricted use of the affected areas. The impact is not expected to be significant, however, since the land-use restrictions would not interfere with the land uses contemplated for the Site in the UC Davis LRDP (UC Davis, 2003).

Alternative 4b would prevent the use of the phytoremediation location for three years and storage tank installation footprint associated with Alternative 5 for two years, but these areas would be available to the University for use consistent with the UC Davis LRDP after completion of the remediation activities. No significant long-term impacts on land use are anticipated as a result of these alternatives.

5.9.5 Noise Impact

5.9.5.1 Short-Term Impacts

Alternatives involving earthwork and construction, including the HDPE cap installation, irrigation system installation, well installation, construction of the bioremediation system and soil removal would create short-term construction noise. Sensitive receptors to this noise may include the raptors in the UC Davis Raptor Center located in small buildings east of the Site. Some of the raptors may be sensitive to noise and experience stress associated with it. The Raptor Center administrators will be notified about any construction activities that may affect the raptors and mitigation measures will be taken, as appropriate. Other species occupying the Site may also experience noise-related stress and temporarily leave the Site. However, considering the small area (three acres) and the limited duration of these activities, any impacts associated with noise exposure will be short term and are not anticipated to cause any significant adverse impact on species occupying the Site.

The noise associated with the construction activities may also create a short-term nuisance for the students and faculty who work at the UC Davis facilities. The noise is not expected to exceed regulatory thresholds except in the immediate area of the machinery, and hence will not create any health impacts for persons other than the operators or workers in the immediate area. Dosimetry equipment will be used to monitor the noise levels and ensure that regulatory thresholds are not exceeded for personnel outside of the construction zone(s). The noise exposure to the workers will be mitigated by the use of personal protective equipment.

Noise is not expected to impact any surrounding residences. The closest residences are located south of Putah Creek, about 0.5 miles away from the Site. Any noise generated at the Site would be attenuated by the levee at Putah Creek.

5.9.5.2 Long-Term Impacts

None of the other alternatives are expected to generate any significant noise impacts over the long term. Some noise may be associated with sampling activities and maintenance of the bioremediation system; however, the noise will be of very limited duration and will be relatively low in intensity. The noise associated with sampling activities would be produced by gasoline-powered generators used to drive submersible sampling pumps. The noise would be localized at the sampling locations (within an approximately 25-ft radius) and would occur on one day during any calendar year. The noise in and near the sampling locations (about 25 ft) is expected to be on the order of a 58- to 82-decibels (dB) A scale (based on specifications for typical gasoline power generators such as the Honda EU 3000 6.5 HP and Honda Power Arc 5500 7.5 HP). Workers collecting samples would be equipped with appropriate hearing protection to ensure that they are not exposed to noise above the Occupational Safety and Health Administration (OSHA) threshold level of 85 dB. Researchers and UC Davis staff would not be impacted by noise levels above OSHA thresholds at or above 85 dB averaged over 8 working hours. Many of the samples collected during the annual sample collection event would be collected in unoccupied areas of the Site away from research and support facilities. Same samples would be collected in locations near the UC Davis facilities; however, these samples would be only a subset of the total number of samples collected at various locations. The UC Davis staff would not be present within the immediate radius of the sampling location for an eight-hour duration. Any potential noise inside the University facilities would be attenuated by the buildings and would not exceed the 85 dB threshold.

Any noise associated with the bioremediation system pumps is anticipated to be negligible. The pumps are anticipated to be similar in their noise profile to other equipment currently present at the Site. They will be installed in a manner to minimize any noise amplification or projection that would affect the site occupants.

5.9.6 Occupational and Public Health Considerations

The no action alternative does not provide for replacement of fencing or other controls over time. Under this alternative, the present contamination will remain at the Site in some cases and may present public health impacts, especially if the site controls degrade and land use changes. The public health impacts are summarized in the SWRA (WA, 2005). Elevated cancer risk to a potential resident currently exists in the DSS 4 and possibly in the SWT areas as shown in Table 2-1. These risks would remain under the no action alternatives for DSS 4 and the SWT areas. Occupational health impacts to construction workers from the residual contamination would remain if this alternative is selected.

Alternatives that include long-term ground water monitoring would also leave contaminants in place, but monitoring would ensure that significant impacts to ground water do not arise. Although monitoring cannot by itself prevent impacts to ground water, monitoring can provide timely information that triggers a response in the event of significant impacts.

Removal and off-site disposal alternatives would require worker contact with low-level radioactive and hazardous materials. Worker protection would be provided in accordance with site- and activity-specific health and safety plans that would be compliant with OSHA and DOE regulations concerning the handling of low-level radioactive materials and hazardous materials. Only personnel trained in hazardous waste operations and emergency response would be allowed to conduct remediation field activities. Protective clothing would be used when working with radioactive materials. These precautions would ensure that worker health is protected. Similar precautions would be taken during well installation activities associated with the *in situ* bioremediation alternatives (Alternative 5) and with soil handling activities associated with the phytoremediation alternative (Alternative 4b).

Some activities associated with the installation of the asphalt/HDPE cap, and soil removal and off-site disposal in the Ra/Sr Treatment Systems, WDPs and DSS areas would be conducted in close proximity to UC Davis buildings occupied by university staff. Engineering controls would be evaluated and implemented, as necessary, to prevent contaminants from entering any of the UC Davis facilities. Air monitoring would be conducted to ensure that there is no impact to the building occupants from airborne contaminants generated by the remediation activities.

Because they are geographically confined to the Site, remediation activities are not expected to produce off-site public health consequences (except for possible transportation impacts, discussed below). Access to the areas in which these activities would occur would be controlled, eliminating any potential health impact to members of the public.

Formaldehyde vapor emissions will be generated during excavation activities at DSS 3 (Alternatives 4a, 4b and 4c). Outdoor workers in the vicinity of excavated soil will have the greatest exposure to formaldehyde vapors. Outdoor researchers are a receptor group that may be exposed to vapors from a DSS 3 soil stockpile. Vapor emissions were evaluated for the soil stockpiles under Alternatives 4a and 4c and the phytoremediation cell under Alternative 4b.

Formaldehyde concentrations in air were estimated using the volatilization factor approach presented in the Users' Guide and Background Technical Document for US EPA Region 9's Preliminary Remediation Goals (US EPA, 2004). The estimated air concentrations were determined from formaldehyde concentrations in soil, chemical-specific parameters and site-specific soil parameters. The calculations are presented in Appendix D and the estimated air concentrations are shown in Table 5-15. The US EPA Region 9 PRG for formaldehyde in ambient air is also shown in Table 5-15. As shown, Alternatives 4a and 4b estimated air concentration are below the PRG and the estimated air concentration for Alternative 4c is slightly above the PRG.

Daily intake of formaldehyde was estimated for outdoor workers conducting excavation activities at DSS 3. The estimated air concentration and a standard EPA default inhalation rate were used to estimate daily intake. The estimated intakes are shown in Table 5-15 with comparison to the California Proposition 65 Safe Harbor Level. As shown, all of the estimated intakes are below the Safe Harbor Level. The intake calculations are shown in Appendix D.

5.9.7 Soils

The site has minimal elevation variations. Landslides are not expected to result from any of the proposed alternatives. Soil erosion is not expected under any of the alternatives where asphalt is installed. Soil erosion and topsoil loss may occur during construction activities when heavy equipment is used in areas of bare soil. Soil loss will be prevented by use of water spray to minimize soil erosion.

5.9.8 Transportation

Shipments of low-level radioactive waste and non-hazardous waste are anticipated in all asphalt/HDPE cap and removal and off-site disposal alternatives. Waste material will be transported off site by truck. Waste will be packaged in proper containers in compliance with appropriate Department of Transportation regulations and DOE waste packaging requirements. Potential impacts associated with these shipments are discussed below.

5.9.8.1 Short-Term Impacts

5.9.8.1.1 Radiological Impacts

Radiation dose calculations were performed to estimate the radiological impacts to drivers and the public from transportation of low-level radioactive waste from LEHR to disposal facilities. The maximum detected activity of each radionuclide within a DOE area was used to represent a conservative upper bound of radiation dose associated with the DOE area waste. LEHR soil background values were used to represent waste soil containing no added radiological activity. Doses from background were subtracted from doses from DOE areas soil to determine the net dose associated with contaminated soil.

Table 5-11 provides the estimated number of trucks trips to the low-level radioactive waste disposal site, Envirocare of Utah via Interstate 80 generated by each of the alternatives. Table 5-11 also shows the estimated number of drivers that will be needed per alternative. The total distance for each one-way truck shipment is approximately 725 miles. Assuming an average speed of 50 miles per hour, the duration of exposure to radiologically impacted soil by a driver is calculated to be 23 hours per trip, comprising 15 hours of driving time and eight hours of rest. Each driver is estimated to complete one round trip in three days, and it is assumed that each driver will make no more than 83 roundtrips per year. Under each of the alternatives, all waste would be shipped off site within one year, which would necessitate the use of multiple drivers for all alternatives, except Alternatives 4a and 4b for the Dry Wells A-E area, Alternative 4b for the Ra/Sr Treatment Systems area and Alternative 4 for the EDPs area.

The exposure assumptions discussed above were input into a radiation exposure model, TSD-Dose, Version 2.22 to calculate the driver's radiation dose using the Transport-to-Off-Site-Landfill feature. RISKIND 1.11 was used to determine the public radiation dose from routine transportation of low-level waste. The results are shown in Table 5-12 and represent the net doses that drivers and the public would receive from the additional radiological activity associated with shipping of low-level radioactive waste from the Site.

The highest exposure to each driver was calculated as 0.68 mrem/year (Table 5-12). This dose is associated with Alternative 3 in the EDPs area. This estimated dose is conservative, since it is based on the maximum radiological activities found in the LEHR soils. The actual exposure to a driver is likely to be at least one order of magnitude below this dose. Even in the worst case, the estimated dose is well below the 100 millirem (0.1 rem) per year dose limit for individual members of the public established by the Nuclear Regulatory Commission (NRC) (10 CFR 20.1301).

The population dose associated with transportation of low-level radioactive waste from the Site for disposal is much lower than the driver dose, as shown in Table 5-12. The highest estimated collective dose based on the national average population density of 27.2 people per square kilometer (RISKIND 1.11) is estimated to be 2.57×10^{-3} person-rem per year. Using a general population dose-to-risk conversion factor of 6×10^{-4} cancer fatalities per person-rem (DOE, 2002b), this dose corresponds to 1.54×10^{-6} latent cancer fatalities. Based on the cancer fatality risk in the United States about 2×10^{-3} per year, the cancer risk from transporting radioactive waste from LEHR translates to 0.08 percent of the total cancer fatality risk per year.

5.9.8.1.2 Accidents

The number of accidents associated with the transportation of low-level radioactive waste from the Site to a disposal facility in Utah (Envirocare of Utah) is estimated at less than 1 for each DOE area. This estimate assumes that the route traveled is 10 percent on urban interstates and 90 percent on rural interstates. According to a Federal Highway Administration study (Miaou, 1991), accident rates are 1.86 for urban interstates and 0.88 for rural interstates per million truck miles. These accidents were moderately severe, resulting in a vehicle being towed from the accident site. The highest accident risk is associated with Alternative 4a in the SWT, which has the highest estimated number of truck trips (485 truck trips to Envirocare and 420 trips to Forward). The estimated number of accidents associated with this alternative is 0.75.

The highest individual public radiation dose associated with a transportation accident is estimated at 0.016 mrem/year (Table 5-13), which is almost four orders of magnitude below the 100 mrem/year NRC standard. The highest estimated collective public radiation dose from a transportation accident is 1.23×10^{-3} person-rem per year based on the national average population density of 27.2 persons per square kilometer (RISKIND 1.11). The accident scenario assumes ten percent of the single shipment of low-level waste is dispersed in air. All other truckloads are assumed to arrive at the disposal site without incidents. Using a general population dose-to-risk conversion factor of 6×10^{-4} cancer fatalities per person-rem (DOE, 2002b), this collective dose to the public corresponds to 7.38×10^{-7} latent cancer fatalities. Since the cancer fatality risk in the U.S. is about 2×10^{-3} per year, the risk of a catastrophic transportation accident involving radioactive waste from LEHR translates to 0.04 percent of the total cancer fatality risk per year.

5.9.8.1.3 Non-Radiological Impacts

Non-radiological impacts of transportation of waste from the Site include motor vehicle-related fatalities and air quality impacts associated with exhaust and road dust. These impacts would be associated with both low-level radioactive waste and non-hazardous waste shipments. Estimated numbers of truck shipments of low-level radioactive waste and non-hazardous waste for each alternative are shown in Table 5-11. The maximum distance is 1,450 miles round trip for low-level waste shipments and 145 miles round trip for non-hazardous waste shipments. The non-hazardous waste disposal site is assumed to be the Forward, Inc. Landfill in Manteca, California.

The risk of an accident resulting in a fatal injury has been computed using data from the United States Department of Transportation National Highway Traffic Safety Administration (US DOT, 1998) and is shown in Table 5-14. The fatality rate for large trucks is 2.82 per 100 million miles traveled. Based on this rate, the highest risk of a fatality is 2.15 x 10^{-2} under Alternative 4a for the SWT.

The risk of latent fatalities from exposure to diesel exhaust and entrained road dust for residents along the highway in urban areas has been estimated to be 6.21 x 10^{-8} fatalities per mile (Rao et al., 1982). Assuming as much as 10 percent travel though urban areas, the highest risk of fatality from exposure to exhaust and road dust for people in urban areas would be 4.75 x 10^{-3} under Alternative 4a for the SWT (Table 5-14).

Transport operations will expose the public to formaldehyde vapors if excavation alternatives 4a, 4b or 4c are selected at DSS 3. Worst-case formaldehyde concentrations in air and maximum daily formaldehyde intakes were calculated as described in Appendix D. The estimated air concentrations were 0.077 micrograms per cubic meter (µg/m3), 0.044 µg/m3 and 0.154 µg/m3 for DSS 3 Alternatives 4a, 4b and 4c, respectively. The estimated air concentration for DSS 3 Alternative 4c was slightly above the US EPA Region 9 PRG of 0.15 µg/m3. Air concentrations for Alternatives 4a and 4b were below the PRG.

Daily intakes for DSS 3 Alternatives 4a, 4b and 4c were 1.5 micrograms per day (µg/day), 0.88 µg/day and 3.1 µg/day, respectively. All of the estimated daily intakes were below the California Proposition 65 Safe Harbor - No Significant Risk Level of 40 µg/day.

5.9.8.2 Long-Term Impacts

No significant long-term impacts are expected from any of the alternatives. The only long-term transportation activity anticipated at the Site is the transfer of samples collected from the Site to an off-site analytical laboratory, under the long-term ground water monitoring alternatives. The transportation of samples would occur approximately four times per year, which is insignificant compared to the current transportation of materials to and from the Site on a daily basis.

5.9.9 Traffic

5.9.9.1 Short-Term Impacts

Under the asphalt/HDPE cap and removal and off-site disposal alternatives, truck traffic would increase near the Site for a short period of time due to transportation of waste from the Site to a disposal facility, and as a result of an increase in personnel at the Site during remediation activities. The traffic increase due to transportation of waste is greatest under Alternative 4a in the SWT. Under this alternative, 905 additional trucks will enter and leave the Site. The increased traffic during transportation of waste from the Site would affect the local area for a short period of time. The Site is located less than one mile from a major highway (I-80) and therefore, street traffic would be limited to a small portion of Old Davis Road. Strategic scheduling of waste transportation activities would be used to minimize potential traffic effects. The impact would also be mitigated by the use of traffic controls, such as barriers, flags and trained traffic control personnel.

The impact of increased traffic due to additional personnel at the Site would be minimal. As discussed in Section 5.8.7, the personnel increase resulting from any of the proposed alternatives would be negligible (less than 0.03 percent of the City of Davis work force). Separate parking facilities would be provided for site personnel to mitigate any impact to UC Davis staff.

5.9.9.2 Long-Term Impacts

No significant long-term impact on traffic is expected from any of the alternatives. The no action and removal and off-site disposal alternatives will result in no impact to traffic, since they do not anticipate any long-term activities that would necessitate trips to the Site. The long-term monitoring alternatives will generate approximately four truck trips per year (one sampling event per quarter), which is an insignificant number of additional trips in the area. The asphalt/HDPE cap alternative will require trips to the Site to conduct inspection and maintenance of the cap and perform long-term monitoring. The inspection will require one round-trip per year and monitoring is expected to require four round-trips annually. Maintenance of the cap, when required, may necessitate an additional dozen trips to the Site annually. The on-site treatment and *in situ* bioremediation will require a similar number of trips as the long-term ground water monitoring alternatives. These additional trips would be a small fraction of the daily traffic to the Site and would not be significant.

5.9.10 Water Resources

5.9.10.1 Ground Water

Under the no action alternative, residual COCs will remain at the Site and may impact ground water resources at DSS 3, DSS 4, Dry Wells A-E, Ra/Sr Treatment Systems and the SWT areas. Under the land-use restrictions alternatives where ground water impacts may be a concern (DSS 3, DSS 4, Dry Wells A-E, Ra/Sr Treatment Systems and the SWT areas), long-term ground water monitoring would be implemented. Consequently, potential ground water impacts would be detected and appropriate action would be undertaken. However, localized ground water impacts may occur prior to the detection of contaminants in monitoring wells and the implementation of mitigation measures.

Under the *in situ* bioremediation alternatives, contaminant migration into the ground water may be induced. Long-term ground water monitoring would be used to monitor any adverse effects of the bioremediation and measures to mitigate any noted effects would be taken.

Under all removal alternatives, remaining contaminants would be removed and shipped off site. Under these alternatives, no significant long-term ground water impact is anticipated.

5.9.10.2 Storm Water

No short-term impact from increased sediment in site run-off would result from implementation of the no action alternatives, because no disturbance of any area causing additional sedimentation to enter storm water runoff would occur. However, long-term impacts may be higher for these alternatives than the removal or asphalt/HDPE cap alternatives, since contamination would remain in place and may enter storm water runoff during the rainy season, especially from areas where water ponds at the Site or runs off directly into Putah Creek. Little runoff would occur in the WDPs and EDPs, since storm water generally percolates into the soil with little or no runoff.

Although disturbance of the Site would occur under the removal or asphalt/HDPE cap alternatives, no significant impact to existing water resources is expected. The actions proposed under these alternatives would be conducted during the dry season and runoff from the Site is unlikely. However, if rainfall occurs during any earth moving/construction activities, storm water from the disturbed areas can be affected by the potential presence of contaminants and sediment in the runoff.

Under the phytoremediation alternative (Alternative 4b), rain water or irrigation water could accumulate on the HDPE liner and generate runoff that is potentially contaminated by any constituents present in the vegetation used for phytoremediation. This potential impact will be mitigated by the construction of a berm around the phytoremediation area and placement of a cover over this area during the rainy season. The integrity of the berm and the cover will be inspected on a periodic basis to ensure its effectiveness. The irrigation system will be set up in a manner that prevents over-watering of the area.

Under any of the other alternatives, potential impact from contaminants in the storm water runoff will be mitigated by the implementation of best management practices (e.g., berms, drainage control) in accordance with the Clean Water Act. The best management practices are described in the *Final Revised Field Sampling Plan* (D&M, 1998).

5.9.11 Cumulative Impact

Cumulative impacts for the alternatives are categorized into potential short-term cumulative impacts related to construction activities or potential long-term cumulative impacts associated with the release of COPCs into the environment.

During the implementation of any of the alternatives, UC Davis will be conducting remedial action(s) associated with their landfill areas on contiguous portions of the Site. These activities would increase construction-related impacts at the Site and adjacent areas. DOE would coordinate all remediation activities with UC Davis to mitigate any cumulative impacts. There are no other known projects at the Site or in the vicinity which would require consideration in evaluating cumulative impacts of the proposed actions and the alternatives.

No long-term cumulative impacts are expected as a consequence of any of the alternatives. Implementation of these alternatives would be coordinated with UC Davis to ensure that there are no conflicts with UC Davis activities or impacts to research operations.

5.10 Mandatory Finding of Significance

The proposed actions will not result in significant impacts to known plant and animal habitats. The Site does not provide important examples of the major periods of California history or prehistory. No additional impacts are expected to result from the proposed project that will combine with other projects to create a significant impact. As long as the required mitigation identified for all proposed projects is implemented, the cumulative impacts of the proposed project and past and future projects at the Site will not create a significant impact.

5.11 Mitigation Measures

Mitigation measures will be implemented, as necessary, to ensure no environmental impacts occur. Mitigation measures to be implemented are summarized in Table 5-16.

5.12 List of Agencies and Persons Consulted

The local agencies and persons consulted for this environmental assessment are identified in Table 5-17.

5.13 List of Preparers

Agata A. Sulczynski, JD, REA, Senior Project Manager, Weiss Associates

Tim Utterback, Senior Environmental Scientist, Weiss Associates

5.14 Summary of Environmental Impacts

Evaluation of the likely environmental impacts associated with all of the alternatives discussed in this FS, except for no action alternatives, indicates that there would be either no impact or minimal impact to the environment should any of the proposed alternatives be selected. The following values would not be impacted:

- Aesthetics and scenic values;
- Agricultural resources;
- Flood plains;
- Historical and cultural resources;
- Mineral resources;
- Public services;

- Socioeconomic conditions (including population and housing);
- Surface recreational water;
- Utilities and service systems; and
- Wetlands.

Short-term, minimal impacts would occur in the following areas:

- Air quality;
- Biological resources;
- Noise (occupational and public health considerations);
- Transportation of low-level radioactive waste;
- Traffic; and
- Water resources.

These impacts are expected to be fully mitigated by compliance with existing regulations. Most impacts (i.e., dust and noise) would be limited to the Site and immediate surroundings, and are expected to have no long-lasting consequences.

Significant long-term impacts to public health and water quality may occur under the no action alternative in areas where remaining contamination presents a threat to public health or ground water values.

Table 5-1. Proposed Actions and Alternatives for the Department of Energy Areas

DOE Area	Alternatives
Domestic Septic System No. 1	Alternative 1—No action
Domestic Septic System No. 3	Alternative 1—No action Alternative 2—Long-term ground water monitoring and contingent remediation Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions Alternative 4a—Removal and off-site disposal Alternative 4b—Removal and on-site treatment Alternative 4c—Limited removal, off-site disposal and long-term ground watering monitoring Alternative 5—*In situ* bioremediation and long-term ground water monitoring
Domestic Septic System No. 4	Alternative 1—No action Alternative 2—Long-term ground water monitoring, contingent remediation and land-use restrictions Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions Alternative 4—Removal, off-site disposal and land-use restrictions
Dry Wells A-E Area	Alternative 1—No action Alternative 2—Long-term ground water monitoring and contingent remediation Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions Alternative 4a—Removal and off-site disposal Alternative 4b—Limited removal, off-site disposal and long-term ground watering monitoring
Domestic Septic System No. 5	Alternative 1—No action
Domestic Septic System No. 6	Alternative 1—No action
Domestic Septic System No. 7	Alternative 1—No action
Radium/Strontium Treatment Systems	Alternative 1—No action Alternative 2—Long-term ground water monitoring and contingent remediation Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions Alternative 4a—Removal and off-site disposal Alternative 4b—Removal and on-site treatment Alternative 4c—Limited removal, off-site disposal and long-term ground watering monitoring Alternative 5—*In situ* bioremediation and long-term ground water monitoring
Southwest Trenches	Alternative 1—No action Alternative 2a—Long-term ground water monitoring and contingent remediation Alternative 2b—Long-term ground water monitoring, contingent remediation and land-use restriction Alternative 3—Asphalt/HDPE cap, long-term ground water monitoring and land-use restrictions Alternative 4a—Removal and off-site disposal Alternative 4b—Removal and on-site treatment

Table 5-1. Proposed Actions and Alternatives for the Department of Energy Areas (continued)

DOE Area	Alternatives
	Alternative 4c—Limited removal, off-site disposal and long-term ground watering monitoring Alternative 5—*In situ* bioremediation, long-term ground water monitoring, and land-use restrictions
Western Dog Pens	Alternative 1—No action
Eastern Dog Pens	Alternative 1— No action Alternative 2—Land-use restrictions Alternative 3—Removal and off-site disposal

Abbreviations

DOE United States Department of Energy
HDPE high-density polyethylene
No. number

Table 5-2. Actions Associated with Alternatives

Long-Term Ground Water Monitoring	Land-Use Restrictions	Asphalt/HDPE Cap	Removal and Off-Site Disposal	Removal and On-Site Treatment	Limited Removal and Off-Site Disposal	*In Situ* Bioremediation (Microbial Denitrification)[1]
Well installation.[2]	Negotiation of land-use controls with UC Davis and drafting of appropriate documents limiting site use.	Removal of soil and road base asphalt from the Site.	Removal of soil and road base asphalt from the Site.	Removal of soil and road base asphalt from the site.	Removal road base and asphalt, and/or clean fill soil.	Installation of injection wells and manifold to connect to a carbon solution storage tank.
Characterization and disposal of drill cuttings.	Recording of a deed restriction(s) with Solano County and/or UC Davis.	Off-site disposal of removed soil and road base asphalt as non-hazardous waste.	Off-site disposal of removed soil and road base asphalt as non-hazardous waste.	Segregation of radiologically contaminated soils from non-radiologically contaminated soil.	Segregation and storage of clean fill for reuse as backfill material.	Installation of a 1,000-gallon above grade holding tank, carbon, metering pump/systems, manifold valves, filtration system and electrical control panel on a concrete slab within a fenced compound.
Collection of ground water samples from downgradient wells.	Installation of warning signage with contact information for construction workers.	Removal of imported fill soil.	Removal of clean fill and storage for reuse as backfill material.	Off-site disposal of radiologically contaminated soil as low-level waste at the Envirocare site in Utah.	Off-site disposal of removed non-hazardous road base and asphalt as non- hazardous waste.	Operation and maintenance of carbon injection system for two years.
Disposal of purge water.	Annual inspections of the signage and records.	Placement of native soil into the excavation and compaction.	Removal of contaminated soil and stockpiling separately from clean fill.	Grading to prevent pond formation.	Removal of site soil to 20 ft bgs or less using conventional excavation equipment.	Decommissioning of system, including cementing of wells and removal of tank and pumps.
		Construction of cap with asphalt surface, gravel base and a HDPE liner.	Segregation of non-hazardous waste from low-level radioactive waste.	Installation of a timed sprinkler system.	Segregation of contaminated soil.	
		Visual inspection on an annual basis.	Sampling of contaminated soil for characterization.	Installation of a single welded sheet of HDPE liner under nitrate-contaminated soil to prevent contact with clean soil.	Sampling of contaminated soil for characterization.	
		Minor maintenance (i.e., asphalt overlay) every 10 years.	Packaging of low-level radioactive waste.	Placement of nitrate-contaminated soil evenly throughout the lined area. Mixing of nitrate contaminated soil with amendments to facilitate optimal crop growth.	Packaging of low-level radioactive waste.	
		Long-term ground water monitoring (see first column of this table).	Shipment of low-level radioactive waste to Envirocare of Utah for disposal.	Planting of warm season grass in a treatment cell to remove excess nitrate.	Shipment of low-level radioactive waste to Envirocare of Utah for disposal.	
			Collection of confirmation samples from the excavation floor and sidewalls.	Regular trimming of grass. Drying and storage for disposal upon decommissioning.	Collection of confirmation samples from the excavation floor and sidewalls.	

Table 5-2. Actions Associated with Alternatives (continued)

Long-Term Ground Water Monitoring	Land-Use Restrictions	Asphalt/HDPE Cap	Removal and Off-Site Disposal	Removal and On-Site Treatment	Limited Removal and Off-Site Disposal	*In Situ* Bioremediation (Microbial Denitrification)[1]
			Filling of excavation with low-strength concrete in locations that require oversize auger excavation or clean soil backfill in areas excavated using conventional equipment.	Regular inspection of the irrigation system and liner.	Filling of excavation with reused and imported soil.	
			Compaction to specification.	Covering of the cell with plastic sheets during the rainy season to prevent storm water contamination.	Compaction to specification.	
			Site restoration and pavement, as appropriate.	Soil and grass sample collection and evaluation. Collection from the treatment cell at the end of each growing season.	Site restoration and pavement, as appropriate.	
				Sampling and disposal of accumulated grass cuttings. Removal and disposal of the liner, sprinkler system, and cuttings at a Class II landfill.		
				Compaction of area to specification.		
				Site restoration and pavement, as appropriate.		

Notes
[1]Long-term ground water monitoring is included in this alternative
[2]Well installation is applicable to Domestic Septic System Numbers 3 and 4 and the Southwest Trenches only.

Abbreviation
HDPE high-density polyethylene

Table 5-3. Potential Environmental Impacts from Alternative 1—No Action

Value	Domestic Septic System No. 1	Domestic Septic System No. 3	Domestic Septic System No. 4	Dry Wells A-E Area	Domestic Septic System No. 6	Domestic Septic System No. 7	Radium/ Strontium Treatment Systems	Southwest Trenches	Western Dog Pens	Eastern Dog Pens	DOE Box
Aesthetics and Scenic Values	○	○	○	○	○	○	○	○	○	○	○
Agricultural Resources	○	○	○	○	○	○	○	○	○	○	○
Air Quality	○	○	○	○	○	○	○	○	○	○	○
Biological Resources	○	○	○	○	○	○	○	○	○	○	○
Flood Plains	○	○	○	○	○	○	○	○	○	○	○
Geology	○	○	○	○	○	○	○	○	○	○	○
Historical and Cultural Resources	○	○	○	○	○	○	○	○	○	○	○
Land Use	○	○	○	○	○	○	○	○	○	○	○
Mineral Resources	○	○	○	○	○	○	○	○	○	○	○
Noise	○	○	○	○	○	○	○	○	○	○	○
Occupational and Public Health	○	○	●	○	○	○	○	○	○	○	○
Public Services	○	○	○	○	○	○	○	○	○	○	○
Socioeconomic Conditions (Population & Housing)	○	○	○	○	○	○	○	○	○	○	○
Soils	○	○	○	○	○	○	○	○	○	○	○
Surface Recreational Waters	○	○	○	○	○	○	○	○	○	○	○
Traffic	○	○	○	○	○	○	○	○	○	○	○
Transportation	○	○	○	○	○	○	○	○	○	○	○
Utilities and Service Systems	○	○	○	○	○	○	○	○	○	○	○
Water Resources	○	●	●	●	○	○	●	●	○	○	○
Wetlands	○	○	○	○	○	○	○	○	○	○	○
Cumulative Impacts	○	○	○	○	○	○	○	○	○	○	○

Abbreviations

○	No foreseeable impact.
⊙	Short-term negligible (construction-type) impacts; mitigation measures will be implemented to minimize adverse impacts.
●	Potential significant and/or adverse impacts; may not meet remedial action objectives or National Contingency Plan criteria.
DOE	United States Department of Energy
No.	number

Table 5-4. Potential Environmental Impacts from Long-Term Ground Water Monitoring and Contingent Remedial Action

Value	Domestic Septic System No. 3	Domestic Septic System 1 and 5 Leach Field - Dry Wells A-E Area	Radium/Strontium Treatment Systems	Southwest Trenches
Aesthetics and Scenic Values	○	○	○	○
Agricultural Resources	○	○	○	○
Air Quality	○	○	○	○
Biological Resources	○	○	○	○
Flood Plains	○	○	○	○
Geology	○	○	○	○
Historical and Cultural Resources	○	○	○	○
Land Use	○	○	○	○
Mineral Resources	○	○	○	○
Noise	○	○	○	○
Occupational and Public Health	○	○	○	○
Public Services	○	○	○	○
Socioeconomic Conditions (including Population and Housing)	○	○	○	○
Soils	○	○	○	○
Surface Recreational Waters	○	○	○	○
Traffic	○	○	○	○
Transportation	○	○	○	○
Utilities and Service Systems	○	○	○	○
Water Resources	●	●	●	●
Wetlands	○	○	○	○
Cumulative Impacts	○	○	○	○

Abbreviations

○	No foreseeable impact.
⊙	Short-term negligible (construction-type) impacts; mitigation measures will be implemented to minimize adverse impacts.
●	Potential significant and/or adverse impacts; may not meet remedial action objectives or National Contingency Plan criteria.
No.	number

Table 5-5. Potential Environmental Impacts from Long-Term Ground Water Monitoring, Land-Use Restrictions and Contingent Remedial Action

Value	Domestic Septic System No. 4	Southwest Trenches	Eastern Dog Pens[1]
Aesthetics and Scenic Values	○	○	○
Agricultural Resources	○	○	○
Air Quality	○	○	○
Biological Resources	○	○	○
Flood Plains	○	○	○
Geology	○	○	○
Historical and Cultural Resources	○	○	○
Land Use	○	○	○
Mineral Resources	○	○	○
Noise	○	○	○
Occupational and Public Health	○	○	○
Public Services	○	○	○
Socioeconomic Conditions (incl. Population & Housing)	○	○	○
Soils	○	○	○
Surface Recreational Waters	○	○	○
Traffic	○	○	○
Transportation	○	○	○
Utilities and Service Systems	○	○	○
Water Resources	○[2]	●	○
Wetlands	○	○	○
Cumulative Impacts	○	○	○

Note
[1]Land-use restrictions only.
[2]The estimated mass of selenium in DSS 4 unsaturated soil is only 0.027 kg and the worst-case ground water impact is estimated as an area of 0.018 acres. Future ground water impacts at DSS 4 will likely be insignificant.

Abbreviations

○	No foreseeable impact.
⊙	Short-term negligible (construction-type) impacts; mitigation measures will be implemented to minimize adverse impacts.
●	Potential significant and/or adverse impacts; may not meet remedial action objectives or National Contingency Plan criteria.
No.	number

Table 5-6. Potential Environmental Impacts from Asphalt/HDPE Cap, Long-Term Ground Water Monitoring and Land-Use Controls

Value	Domestic Septic System No. 3	Domestic Septic System No. 4	Domestic Septic System 1 and 5 Leach Field - Dry Wells A-E Area	Radium/Strontium Treatment Systems	Southwest Trenches[1]
Aesthetics and Scenic Values	⦿	⦿	⦿	⦿	⦿
Agricultural Resources	○	○	○	○	○
Air Quality	⦿	⦿	⦿	⦿	⦿
Biological Resources	⦿	⦿	⦿	⦿	⦿
Flood Plains	○	○	○	○	○
Geology	○	○	○	○	○
Historical and Cultural Resources	○	○	○	○	○
Land Use	⦿	⦿	⦿	⦿	⦿
Mineral Resources	○	○	⦿	⦿	⦿
Noise	⦿	⦿	⦿	⦿	⦿
Occupational and Public Health	⦿	⦿	⦿	⦿	⦿
Public Services	○	○	⦿	⦿	⦿
Socioeconomic Conditions (including Population and Housing)	○	○	○	○	○
Soils	⦿	⦿	⦿	⦿	⦿
Surface Recreational Waters	⦿	⦿	⦿	⦿	⦿
Traffic	⦿	⦿	⦿	⦿	⦿
Transportation	⦿	⦿	⦿	⦿	⦿
Utilities and Service Systems	○	○	○	○	○
Water Resources	⦿	⦿	⦿	⦿	⦿
Wetlands	○	○	○	○	○
Cumulative Impacts	○	○	○	○	○

Note
[1]Alternative includes land-use controls.

Table 5-6. Potential Environmental Impacts from Asphalt/HDPE Cap, Long-Term Ground Water Monitoring and Land-Use Controls (continued)

Abbreviations

○	No foreseeable impact.
⊙	Short-term negligible (construction-type) impacts; mitigation measures will be implemented to minimize adverse impacts.
●	Potential significant and/or adverse impacts – may not meet remedial action objectives or National Contingency Plan criteria.
No.	number

Table 5-7. Potential Environmental Impacts from Removal and Off-Site Disposal

Value	Domestic Septic System No. 3	Domestic Septic System No. 4	Dry Wells A-E Area	Radium/ Strontium Treatment Systems	Southwest Trenches	Eastern Dog Pens
Aesthetics and Scenic Values	⦿	⦿	⦿	⦿	⦿	⦿
Agricultural Resources	○	○	○	○	○	○
Air Quality	⦿	⦿	⦿	⦿	⦿	⦿
Biological Resources	⦿	⦿	⦿	⦿	⦿	⦿
Flood Plains	○	○	○	○	○	○
Geology	○	○	○	○	○	○
Historical and Cultural Resources	○	○	○	○	○	○
Land Use	⦿	⦿	⦿	⦿	⦿	⦿
Mineral Resources	○	○	○	○	○	○
Noise	⦿	⦿	⦿	⦿	⦿	⦿
Occupational and Public Health	⦿	⦿	⦿	⦿	⦿	⦿
Public Services	○	○	○	○	○	○
Socioeconomic Conditions (including Population and Housing)	○	○	○	○	○	○
Soils	⦿	⦿	⦿	⦿	⦿	⦿
Surface Recreational Waters	⦿	⦿	⦿	⦿	⦿	⦿
Traffic	⦿	⦿	⦿	⦿	⦿	⦿
Transportation	⦿	⦿	⦿	⦿	⦿	⦿
Utilities and Service Systems	○	○	○	⦿	○	○
Water Resources	⦿	⦿	⦿	⦿	⦿	⦿
Wetlands	○	○	○	○	○	○
Cumulative Impacts	○	○	○	○	○	○

Abbreviations

○ No foreseeable impact.
⦿ Short-term negligible (construction-type) impacts; mitigation measures will be implemented to minimize adverse impacts.
● Potential significant and/or adverse impacts; may not meet remedial action objectives or National Contingency Plan criteria.
No. number

Table 5-8. Potential Environmental Impacts from Removal and On-Site Treatment

Value	Domestic Septic System No. 3	Radium/ Strontium Treatment Systems	Southwest Trenches[2]
Aesthetics and Scenic Values	⊙	⊙	⊙
Agricultural Resources	○	○	○
Air Quality	⊙	⊙	⊙
Biological Resources	⊙	⊙	⊙
Flood Plains	○	○	○
Geology	○	○	○
Historical and Cultural Resources	○	○	○
Land Use	⊙	⊙	⊙
Mineral Resources	○	○	○
Noise	⊙	⊙	⊙
Occupational and Public Health	⊙	⊙	⊙
Public Services	○	○	○
Socioeconomic Conditions (including Population and Housing)	○	○	○
Soils	⊙	⊙	⊙
Surface Recreational Waters	⊙	⊙	⊙
Traffic	⊙	⊙	⊙
Transportation	⊙	⊙	⊙
Utilities and Service Systems	○	○	○
Water Resources	⊙	⊙	⊙
Wetlands	○	○	○
Cumulative Impacts	○	○	○

Abbreviations

○ No foreseeable impact.

⊙ Short-term negligible (construction-type) impacts; mitigation measures will be implemented to minimize adverse impacts.

● Potential significant and/or adverse impacts – may not meet remedial action objectives or National Contingency Plan criteria.

No. number

Table 5-9. Potential Environmental Impacts from Limited Removal and Off-Site Disposal

Value	Domestic Septic System No. 3	Dry Wells A-E Area	Radium/ Strontium Treatment Systems	Southwest Trenches[2]
Aesthetics and Scenic Values	⊙	⊙	⊙	⊙
Agricultural Resources	○	○	○	○
Air Quality	⊙	⊙	⊙	⊙
Biological Resources	⊙	⊙	⊙	⊙
Flood Plains	○	○	○	○
Geology	○	○	○	○
Historical and Cultural Resources	○	○	○	○
Land Use	⊙	⊙	⊙	⊙
Mineral Resources	○	○	○	○
Noise	⊙	⊙	⊙	⊙
Occupational and Public Health	⊙	⊙	⊙	⊙
Public Services	○	○	○	○
Socioeconomic Conditions (including Population and Housing)	○	○	○	○
Soils	⊙	⊙	⊙	⊙
Surface Recreational Waters	⊙	⊙	⊙	⊙
Traffic	⊙	⊙	⊙	⊙
Transportation	⊙	⊙	⊙	⊙
Utilities and Service Systems	○	○	○	○
Water Resources	●	●	●	●
Wetlands	○	○	○	○
Cumulative Impacts	○	○	○	○

Abbreviations

○	No foreseeable impact.
⊙	Short-term negligible (construction-type) impacts; mitigation measures will be implemented to minimize adverse impacts.
●	Potential significant and/or adverse impacts – may not meet remedial action objectives or National Contingency Plan criteria
No.	number.

Table 5-10. Potential Environmental Impacts from *In Situ* Bioremediation and Long-Term Ground Water Monitoring

Value	Domestic Septic System No. 3	Radium/Strontium Treatment Systems	Southwest Trenches[1]
Aesthetics and Scenic Values	⦿	⦿	⦿
Agricultural Resources	○	○	○
Air Quality	⦿	⦿	⦿
Biological Resources	○	○	○
Flood Plains	○	○	○
Geology	○	○	○
Historical and Cultural Resources	○	○	○
Land Use	○	○	○
Mineral Resources	○	○	○
Noise	⦿	⦿	⦿
Occupational and Public Health	⦿	⦿	⦿
Public Services	○	○	○
Socioeconomic Conditions (including Population &Housing)	○	○	○
Soils	⦿	⦿	⦿
Surface Recreational Waters	⦿	⦿	⦿
Traffic	⦿	⦿	⦿
Transportation	⦿	⦿	⦿
Utilities and Service Systems	○	○	○
Water Resources	⦿	⦿	⦿
Wetlands	○	○	○
Cumulative Impacts	○	○	○

Notes
[1]Includes groundwater monitoring

Abbreviations

○ No foreseeable impact.
⦿ Short-term negligible (construction-type) impacts; mitigation measures will be implemented to minimize adverse impacts.
● Potential significant and/or adverse impacts; may not meet remedial action objectives or National Contingency Plan criteria.
No. number

Table 5-11. Estimated Number of Truck Trips and Drivers per Alternative

	Truck Trips		Drivers	
	Low-Level Radioactive Waste	Solid Waste	Low-Level Radioactive Waste	Solid Waste
Domestic Septic System No. 3				
Alternative 4a	213	432	3	1
Alternative 4b	213	0	3	0
Alternative 4c	148	0	2	0
Domestic Septic System No. 4				
Alternative 4	0	2	0	1
Dry Wells A-E				
Alternative 4a	63	0	1	0
Alternative 4b	27	0	1	0
Radium/ Strontium Treatment Systems				
Alternative 4a	242	441	3	1
Alternative 4b	46	0	1	0
Alternative 4c	193	0	3	0
Southwest Trenches				
Alternative 4a	485	420	6	1
Alternative 4b	359	0	5	0
Alternative 4c	464	0	6	0
Eastern Dog Pens				
Alternative 3	144	0	2	0

Notes
Estimates are based on 10-cubic yard capacity per truck.
Estimates are based on the assumption that all waste will be disposed in one year.
Trucks carrying low-level radioactive waste are assumed to deliver it to Envirocare of Utah.
Trucks carrying solid waste are assumed to deliver to the Forward, Inc. Landfill facility in Manteca, California (145-mile round trip).
Abbreviation
No. number

Table 5-12. Potential Radiation Dose to Truck Driver and Public per Alternative

Net Dose	Individual Driver (mrem/year)	Individual Member of the Public (mrem/year)	Collective (person-rem/year)
Domestic Septic System No. 3			
Alternative 4a	0.21	3.20E-06	5.43E-04
Alternative 4b	0.21	3.20E-06	5.43E-04
Alternative 4c	0.21	2.22E-06	3.77E-04
Dry Wells			
Alternative 4a	0.057	3.78E-07	5.80E-05
Alternative 4b	0.024	1.62E-07	2.49E-05
Radium/ Strontium Treatment Systems			
Alternative 4a	0.43	8.47E-06	1.29E-03
Alternative 4b	0.24	1.61E-06	2.45E-04
Alternative 4c	0.43	6.76E-06	1.03E-03
Southwest Trenches			
Alternative 4a	0.43	1.46E-05	2.57E-03
Alternative 4b	0.43	1.08E-05	1.90E-03
Alternative 4c	0.43	1.39E-05	2.46E-03
Eastern Dog Pens			
Alternative 3	0.68	4.03E-06	1.19E-03

Abbreviations

mrem	millirem
No.	number
rem	Roentgen-equivalent man

Table 5-13. Potential Radiation Dose from a Transportation Accident to Truck Driver and Public per Alternative

	Net Dose	
	Individual – Public/Driver (mrem/year)	Collective (person-rem/year)
Domestic Septic System No. 3		
Alternatives 4a, 4b and 4c	0.0008	8.73E-05
Dry Wells		
Alternatives 4a and 4b	0.0042	3.06E-04
Ra/Sr Treatment Systems		
Alternatives 4a, 4b and 4c	0.0079	6.30E-04
Southwest Trenches		
Alternatives 4a, 4b and 4c	0.016	1.23E-03
Eastern Dog Pens		
Alternative 3	0.014	1.05E-03

Abbreviations

Ra/Sr	Radium/Strontium
mrem	millirem
No.	number
rem	Roentgen-equivalent man

Table 5-14. Statistical Highway Fatality Rate per Alternative

	Miles Traveled[1]	Risk of Traffic Fatality [2]	Risk of Fatality due to Road Dust and Diesel Exhaust [3]
Domestic Septic System No. 3			
Alternative 4a	371,490	1.05E-02	2.31E-03
Alternative 4b	308,850	8.71E-03	1.92E-03
Alternative 4c	214,600	6.05E-03	1.33E-03
Domestic Septic System No. 4			
Alternative 3	290	8.18E-06	1.80E-06
Dry Wells A-E			
Alternative 4a	91,350	2.58E-03	5.67E-04
Alternative 4b	39,150	1.10E-03	2.43E-04
Radium/ Strontium Treatment Systems			
Alternative 4a	414,845	1.17E-02	2.58E-03
Alternative 4b	66,700	1.88E-03	4.14E-04
Alternative 4c	279,850	7.89E-03	1.74E-03
Southwest Trenches			
Alternative 4a	764,150	2.15E-02	4.75E-03
Alternative 4b	520,550	1.47E-02	3.23E-03
Alternative 4c	672,800	1.90E-02	4.18E-03
Eastern Dog Pens			
Alternative 3	208,800	5.89E-03	1.30E-03

Notes
[1]Based on 145 miles round trip to Forward Inc. Landfill and 1,450 miles round trip to Envirocare of Utah.
[2]Based on 2.82 fatalities per 100 million miles traveled for large trucks (U.S. Department of Transportation, 1998 Traffic Safety Facts).
[3]Based on 6.21 x 10-8 fatalities per mile (Rao et al., 1982) and 10% travel through urban areas.

Abbreviations
N/A not applicable
No. number

Table 5-15. Domestic Septic System No. 3 Risk Associated with Formaldehyde Exposure

	Alternative 4a	**Alternative 4b**	**Alternative 4c**	**Toxicity Reference**
Air Concentration (μg/m^3)	0.077	0.044	0.154	0.15 [1]
Daily Intake (μg/day)	1.5	0.88	3.1	40 [2]

Notes
[1] United States Environmental Protection Agency, Region 9 Preliminary Remediation Goal for ambient air.
[2] California Proposition 65 Safe Harbor Level – No Significant Risk Level.

Abbreviations

No.	number
μg/day	micrograms per day
μg/m^3	micrograms per cubic meter

Table 5-16. Mitigation Measures for Potential Environmental Impacts

Impact Areas	**Mitigation Measures**
Air Quality	Dust suppression during construction activity using water or other approved liquids. Covering or containment of loose soil piles/areas when there is no work activity. Air monitoring to ensure public protection.
Biological Resources	Activities will be halted and appropriate measures will be implemented if a biological resource will be impacted.
Geology	Workers will be instructed in earthquake safety. All installations will be completed in accordance with seismic requirements of the City of Davis and UC Davis.
Historical and Cultural Resources	Activities will be halted if any cultural resources are uncovered, so that appropriate actions can be implemented.
Land Use	Under California statute land-use restrictions would be drafted by DTSC and recorded with Solano County. DTSC is responsible for ensuring the responsible party meets its land-use control obligations.
Noise Impact	The Raptor Center will be advised of construction activities that may generate noise. Worker and university personnel noise exposure will be monitored and appropriate action will be taken in case the noise levels exceed OSHA thresholds. Workers exposed to noise will be provided personal protective equipment, as necessary. When possible, equipment that would produce less noise will be used.
Occupational and Public Human Health	All field, transportation, packaging and disposal activities related to waste handling will be conducted according to a site-specific health and safety plan and procedures. This includes using the appropriate personal protective equipment required for the activity. Air quality will be monitored, as necessary, for buildings in close proximity to soil-disturbing activities that can generate airborne contaminants. Decontamination facilities and procedures will be used, as appropriate, to prevent the spread of contamination. Staff will be trained on procedures for emergencies and accidents. Land-use controls will be developed and recorded with Solano County and UCOP and will include requirements for occupational and public health controls to be implemented for any earth-disturbing activities.

Table 5-16. Mitigation Measures for Potential Environmental Impacts (continued)

Impact Areas	Mitigation Measures
Soils	Light water spray on truck and equipment routes will be used to prevent topsoil loss. Soil piles will be covered.
Transportation/Traffic- Local	If traffic from the removal actions would result in increased ingress/egress from the Site, then traffic control on Old Davis Road would be provided.
Transportation of Low-level Radioactive Waste	Drivers will adhere to applicable DOT regulations (49 CFR 173) relating to the packaging, handling, labeling, disposal, routing, and transporting of low-level radioactive waste. Drivers will be appropriately trained in these regulations.
Water Resources	Potential impact from contaminants in the stormwater runoff will be mitigated by the implementation of best management practices (e.g., berms, drainage control) in accordance with the Clean Water Act. The best management practices are described in the Final Revised Field Sampling Plan (D&M, 1998). Ground water will be monitored and appropriate actions will be taken based on the monitoring results.
Cumulative Impacts	Monitoring of other Site activities will be conducted during site activities and work will be halted as required to implement mitigation measures. All work will be coordinated with UC Davis to avoid any potential cumulative impacts.

Abbreviations

CFR Code of Federal Regulations
DOT Department of Transportation
OSHA Occupational Health and Safety Administration
UCOP University of California Office of the President

Table 5-17. Local Agencies Contacted

Agency/Person/Title	Date	Subject
UC Davis Environmental Health & Safety, Brian Oatman, Project Manager	August 2005	Planned projects in the area
California Office of Historic Preservation, Northwest Information Center, Lee Jordan, Coordinator	June 26, 1998 and April 12, 2000	Historical and Cultural Resources

Abbreviation
UC University of California

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