LMS/LEH/S04803

# Proposed Plan for the Department of Energy Areas at the Former Laboratory for Energy-Related Health Research, at the University of California, Davis

U.S. DEPARTMENT OF ENERGY | Office of Legacy Management

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## 1. Introduction

This Proposed Plan presents the U.S. Department of Energy's (DOE) cleanup plan for the former Laboratory for Energy-Related Health Research (LEHR or Site) located at the University of California, Davis (UC Davis) (Figure 1). LEHR is designated by the U.S. Environmental Protection Agency (EPA) as a **Superfund*** Site due to the historic releases of contaminants to the soil and **groundwater**. The public is encouraged to review and comment on DOE's proposed cleanup plan (see "How to Participate"). Based on new information and/or public comment, the remedy may be modified or another **response action** selected. The public is encouraged to review and comment on all of the alternatives presented in this Proposed Plan.

After reviewing and considering all information submitted during the comment period, DOE will select a final remedy in consultation with the EPA, the California Regional Water Quality Control Board (RWQCB), the California Department of Public Health (CDPH), and the California Department of Toxic Substances Control (DTSC). A response to all public comments, as well as the selected remedy, will be documented in the Record of Decision (Figure 2, page 3).

Since some cleanup options could potentially impact long-term land use at the Site, UC Davis and The Regents of the University of California, as the land owners, are developing an agreement with DOE that will ensure that the cleanup plan is implementable. This agreement will be established prior to finalizing the Record of Decision.

This Proposed Plan is issued by DOE, as the lead federal agency for the Site cleanup, to summarize key information contained in the Remedial Investigation, Site-Wide Risk Assessment, and Feasibility Study reports.

### HOW TO PARTICIPATE

The U.S. Department of Energy will accept written comments on the Proposed Plan between **October 15, 2008 and November 17, 2008**.

Mail written comments to:

U.S. Department of Energy, Office of Legacy Management
Attn: LEHR Proposed Plan Comments
11025 Dover St., Suite 1000
Westminster, CO 80021-5573

E-mail comments to:
LEHRPPcomments@lm.doe.gov

If you have questions or need more information, contact us at:

Phone: (720) 377-9672, or
E-mail: LEHRPPcomments@lm.doe.gov

**PUBLIC MEETING:**
On October 23, 2008, DOE will hold a public meeting to discuss the Proposed Plan. Oral and written comments will also be accepted at the meeting. The meeting will be held at: the Veterans Memorial Center, Club Room, 203 E. 14th Street (corner of E. 14th and B Streets), Davis, CA, at 7 p.m.

**ADDITIONAL SOURCES OF INFORMATION:**
The Administrative Record is available at:

Yolo County Library, Davis Branch
315 E. 14th Street
Davis, California 95616
(530) 757-5593

Or at:

http://www.lm.doe.gov/land/sites/ca/lehr/lehr.htm

The Administrative Record, which contains these reports and many more Site documents, is available to the public at the Yolo County Library in Davis and on the internet (see "How to Participate").

This Proposed Plan evaluates **remedial alternatives** developed by DOE to address soil contaminants present in six DOE areas: Radium/Strontium (Ra/Sr) Treatment Systems, Domestic Septic System (DSS) 3, DSS 4, Dry Wells A-E, the Southwest Trenches, and the Eastern Dog Pens (Figure 1). This Proposed Plan only addresses the cleanup options for soil contamination. A separate Proposed Plan for groundwater and the UC Davis disposal units will be issued by UC Davis in the future.

*__Bold__ text indicates that a definition is provided in the glossary at the end of this document.


**Figure 1. Map of the LEHR Site, UC Davis, California**

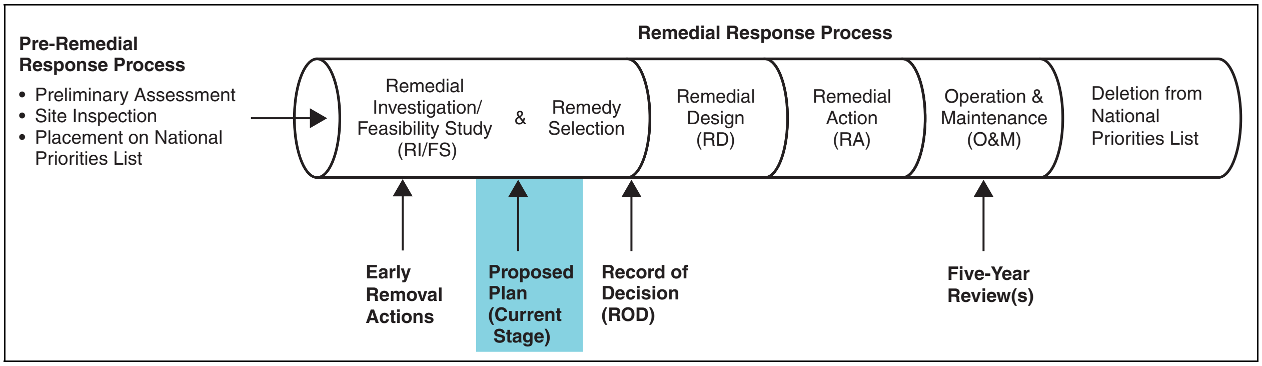


**Figure 2. The Superfund Remedial Response Process**

## 2. Site History

In the late 1950s, the Atomic Energy Commission, now DOE, began conducting radiological studies on laboratory animals at the Site. Beginning in 1958 and continuing through the mid-1980s, DOE-funded research activities focused on the health effects from chronic exposure to **radionuclides**, primarily strontium-90 (Sr-90) and radium-226 (Ra-226). DOE research activities at the Site ended in 1988. During research activities, beagle dogs involved in the Ra-226 and Sr-90 experiments were housed in Animal Hospitals 1 and 2 (Figure 1, page 2). Wastewater from these buildings was treated at the Ra/Sr Treatment Systems prior to discharge in subsurface leach trenches and dry wells. Dogs used for research were also housed in outdoor facilities known as the Western and Eastern Dog Pens (Figure 1, page 2).

Some solid wastes were disposed in the Southwest Trenches and DOE Disposal Box areas (Figure 1, page 2). Between 1958 and 1971, Site sewage was treated by the Site's septic-type wastewater treatment systems, known as the Domestic Septic Systems (DSSs). Treated DSS waste was discharged to subsurface leach trenches and dry wells.

Between 1988 and 1995, DOE conducted site investigations at the Southwest Trenches and Ra/Sr Treatment Systems areas. A comprehensive soil investigation was conducted in July and August of 1996 in the Southwest Trenches, Ra/Sr Treatment Systems, DSS 1 and DSS 7 areas (Figure 1, page 2). In 1997 and 2001, additional soil investigations focusing on DSS 1, DSS 3, DSS 4, DSS 5 and DSS 6 were conducted. In 1999, the Dry Wells A-E Area was investigated. In October 1997 and February through March of 1998, extensive sampling was conducted in the Western Dog Pens to characterize dog pen gravel and underlying soil. In March 1999, a soil investigation of the Eastern Dog Pens was conducted. In September and October of 1996 and 2002, the DOE Disposal Box Area was investigated.

DOE removed significant quantities of contaminated soil and debris from the DOE Disposal Box Area in 1996; Southwest Trenches Area in 1998; Ra/Sr Treatment Systems Area in 1999 and 2000; Dry Wells A-E in 1999; Western Dog Pens in 2001; DSS 3 in 2002; and DSS 6 in 2002. In addition, concrete curbs were removed from the Eastern Dog Pens in 2007. Over 8,500 cubic yards of contaminated soil and debris have been removed from the Site and properly disposed at off-site facilities. Post-**removal action** confirmation sampling results indicate that the majority of contaminants have been successfully removed.

## 3. Site Characteristics

The LEHR Site is a flat 15-acre parcel located on Old Davis Road in the South Campus Area of UC Davis (Figure 1, page 2). The east-flowing South Fork of Putah Creek bounds the Site to the south. The Site is currently used for academic research.

The Site is underlain by river- and creek-deposited sediments called **alluvium**. Two layers of alluvium are important to DOE areas of the Site. The first unit of alluvium extends from ground surface to approximately 80 feet below ground surface, and consists of sandy/silty clay with occasional sand layers. The second unit of alluvium consists of sand and gravel located approximately 80 to 135 feet below ground surface.

Groundwater encountered within the first unit of alluvium is not used due to low yield and poor natural water quality (high dissolved solids). Some Site contamination has impacted groundwater in this unit. However, this impact is limited and predicted to remain on-site.

The second alluvial unit is a high-yield aquifer that is used for local agricultural and domestic water supplies. Most of the focus in this Proposed Plan involves protecting the second alluvial unit from future impacts due to the migration of contaminants remaining in soil at the Site.

Between 2003 and 2007, DOE conducted a remedial investigation. The remedial investigation identified the quantity and location of contaminants remaining in soil after the removal actions. The remedial investigation results indicated that residual contamination remained at Ra/Sr Treatment Systems, DSS 3, DSS 4, DSS 6, Dry Wells A–E, Southwest Trenches, Western Dog Pens, Eastern Dog Pens and DOE Disposal Box areas. No significant contamination was identified at DSS 1, DSS 5 or DSS 7.

## 4. Summary of Site Risks

In 2005, DOE, in coordination with UC Davis, the EPA and the State of California, completed a baseline **risk** assessment to estimate the potential effects of site contaminants on humans and wildlife. Under Superfund requirements, risk assessment provides the basis for determining if remedial action is necessary. **Carcinogenic risks** and **non-cancer risks** resulting from exposure to site contamination were estimated for research workers, construction workers, hypothetical on-site residents, trespassers, and off-site residents. Ecological risks were estimated for invertebrates and various bird and mammal species representative of wildlife that could inhabit the area. Existing and potential groundwater impacts were also evaluated during this phase of the project.

The EPA requires further evaluation and possible cleanup for estimated excess cancer risk greater than 1 in 1,000,000. The results of the baseline risk assessment indicated that risks were below this threshold and no further action was necessary at DSS 1, DSS 5, DSS 6, DSS 7, Western Dog Pens, and DOE Disposal Box areas. The remainder of this document will focus on the DSS 3, DSS 4, Southwest Trenches, Ra/Sr Treatment System, Dry Wells A-E, and Eastern Dog Pen areas, where potential excess risks from direct or indirect exposure to soil exceed 1 in 1,000,000 or the potential for future groundwater impacts exists, as discussed below.

### 4.1. Human Health Risks

The risk assessment indicates that a hypothetical on-site resident might be affected by the presence of some carcinogenic contaminants at DSS 4, Southwest Trenches Area and Eastern Dog Pens (Table 1). The highest risk in this scenario is 4 in 10,000 from benzo(k)fluoranthene at DSS 4, primarily due to ingestion of home-grown produce. Sr-90 risks at the Southwest Trenches (3 in 1,000,000) and Eastern Dog Pens (2 in 1,000,000) were also related primarily to the ingestion of home-grown produce.

As shown in Table 1, all of the human health risks above 1 in 1,000,000 are due to hypothetical on-site resident exposure. The estimated risk to on-site construction workers from benzo(a)pyrene in subsurface soil at DSS 4 is 1 in 1,000,000. The risk assessment indicated that the potential risk to on-site construction workers from contamination in the other DOE areas is less than 1 in 1,000,000.

Table 1. Human Health Constituents of Concern for Areas Exceeding Risk Levels of 1 in 1,000,000

| Receptor / Constituent of Concern | Soil Concentration[a] | Excess Risk[b] |
|---|---|---|
| **Domestic Septic System 4** | | |
| *Hypothetical On-Site Resident* | | |
| Benzo(a)anthracene | 3.8 mg/kg | 2 in 100,000 |
| Benzo(a)pyrene | 2.4 mg/kg | 7 in 100,000 |
| Benzo(b)fluoranthene | 2.7 mg/kg | 7 in 1,000,000 |
| Benzo(k)fluoranthene | 1.5 mg/kg | 4 in 10,000 |
| Dibenzo(a,h)anthracene | 1.1 mg/kg | 1 in 100,000 |
| Indeno(1,2,3-cd)pyrene | 0.86 mg/kg | 4 in 1,000,000 |
| | **Total** | **5 in 10,000** |
| *On-Site Construction Worker* | | |
| Benzo(a)pyrene | 2.4 mg/kg | 1 in 1,000,000 |
| **Southwest Trenches** | | |
| *Hypothetical On-Site Resident* | | |
| Strontium-90+Daughter | 0.94 pCi/g | 3 in 1,000,000 |
| **Eastern Dog Pens** | | |
| *Hypothetical On-Site Resident* | | |
| Dieldrin | 0.019 mg/kg | 3 in 1,000,000 |
| Strontium-90+Daughter | 0.33 pCi/g | 1 in 1,000,000 |
| | **Total** | **4 in 1,000,000** |

**Notes**
[a]Maximum detected **concentration** or 95% upper confidence limit on the mean (if sufficient data were available).
[b]Estimated probability an individual will acquire cancer. An excess cancer risk of 2 in 100,000 is a 2 in 100,000 probability of an individual developing cancer.
Risks below 1 in 1,000,000 are rarely considered significant.

**Abbreviations**
mg/kg milligrams per kilogram
pCi/g picoCuries per gram

The risks from contaminants at Ra/Sr Treatment Systems Area, DSS 3 and Dry Wells A-E were below 1 in 1,000,000. The risk assessment did not identify any non-cancer risks in any of the DOE areas.

The risk assessment indicated that the risks from contaminants to off-site residents, indoor and outdoor research workers, and trespassers were less than 1 in 1,000,000 in all DOE areas.

## 4.2. Ecological Risks

The risk assessment concluded that residual contamination in Site soil presents no significant risks to ecological receptors.

## 4.3. Groundwater Resource Protection

Groundwater near the Site is used for both domestic and agricultural purposes. The site has developed a system to classify water-bearing strata based on its depth and geologic characteristics. The shallowest unit, identified as Hydrostratigraphic Unit 1 (HSU-1), extends from ground surface to approximately 80 feet below ground surface, and is not used for water supply. Hydrostratigraphic Unit 2 (HSU-2), which is located between 80 and 135 feet below ground surface, serves as a water supply aquifer. The water table at the Site varies seasonally from approximately 20 to 60 feet below ground surface. Additional deeper water-bearing units of alluvial deposits are present, but have not been affected by DOE activities.

Groundwater in the vicinity of the Site generally flows to the northeast. A number of nearby domestic and irrigation wells draw water from HSU-2. UC Davis monitored these wells, and determined that they are not impacted by Site contaminants. Additionally, UC Davis maintains a network of monitoring wells on and around the Site to monitor water quality.

Contaminants that have or could impact HSU-1 groundwater are listed in Table 2. Based on very conservative estimates, DOE determined that these contaminants were a potential concern to groundwater due to estimates of future migration. Based on additional evaluation, DOE concluded that residual contamination has extremely limited potential to migrate off-site in groundwater.

## 4.4. Surface Water Resource Protection

Stormwater at DOE areas either **infiltrates** or is discharged to a drainage ditch on Old Davis Road which flows to the South Fork of Putah Creek. Since October 1996, DOE areas stormwater has been sampled during storm events in the fall and winter. Stormwater samples collected at the lift station have not shown toxicity in aquatic test organisms, but mercury in the samples has exceeded the California Toxic Rule levels. Mercury at the Site appears to originate from shallow soil, but does not appear to be an artifact of DOE or UC Davis activities or releases. DOE and UC Davis are implementing best management practices to reduce mercury in stormwater by controlling erosion and runoff at the Site.

The baseline risk assessment concluded that Site activities have not resulted in significant risk to human or ecological receptors in Putah Creek.

Table 2. DOE Areas Soil Constituents That May Impact Groundwater Quality

| |
|---|
| **Radium/Strontium Treatment Systems** |
| Nitrate[a] |
| Carbon-14 |
| Radium-226[b] |
| **Domestic Septic System Number 3** |
| Formaldehyde |
| Molybdenum |
| Nitrate[a] |
| **Domestic Septic System Number 4** |
| Selenium[b] |
| **Dry Wells A-E Area** |
| Chromium |
| Hexavalent Chromium |
| Mercury |
| Molybdenum |
| Silver |
| Cesium-137 |
| Strontium-90 |
| **Southwest Trenches** |
| Nitrate[a] |
| Carbon-14[a] |

**Notes**
[a]Elevated concentration detected in Site monitoring wells.
[b]Inconsistent or only slightly elevated concentrations detected in Site monitoring wells.

## 5. Remedial Action Objectives

As determined by DOE and the regulatory agencies, the Remedial Action Objectives for the Site are to:

- Prevent human contact with contamination in soil that poses an excess cumulative cancer risk greater than an upper bound range of 1 in 10,000 to 1 in 1,000,000. Any risk greater than 1 in 1,000,000, requires investigation to determine if remedial action is necessary.
- Mitigate potential future impacts to groundwater.
- 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 Acts.
- Comply with all **applicable or relevant and appropriate requirements** (**ARAR**s).
- Minimize impact to UC Davis research activities at the Site as specified in the Memorandum of Agreement between DOE and UC Davis.

Based on these Remedial Action Objectives, numerical cleanup goals were established in the Feasibility Study Report in Tables 2-1 and 2-2, available on the internet at http://www.lm.doe.gov/documents/sites/ca/lehr/FinalFeasibilityStudy.pdf.

## 6. Scope and Role of Cleanup Response Action

The previous removal actions conducted at the Site resulted in most of the contamination being removed from the DOE areas. DOE now plans to mitigate any significant risk or future groundwater threats posed by the residual contamination by conducting appropriate remedial actions. In the Feasibility Study, DOE evaluated various technologies and remedial alternatives that could achieve this objective. Contaminants of concern for the Site are summarized in Table 1 and Table 2. DOE areas that require evaluation of alternatives are shown in Figure 1, page 2.

The remedial alternatives discussed below, excluding the no action alternative, are intended to either remove or treat contamination to exposure levels below cleanup goals or prevent exposure through engineering or administrative measures.

# 7. Summary of Cleanup Technologies and Alternatives

Cleanup technologies and alternatives have been developed to address contaminants remaining in the DOE areas. A remedial alternative consists of one or more cleanup technologies assembled together to address specific conditions in a release area. Eight cleanup technologies were identified to address the forms of contamination at the Site. The cleanup technologies are presented in Sections 7.2 through 7.8. The assembly of cleanup technologies into alternatives is presented in Section 7.9. The complete development of cleanup technologies and alternatives is presented in the Feasibility Study Report.

## 7.1. No Further Action and No Action

As required by EPA guidance, “No Further Action” and “No Action” alternatives were developed to determine the potential effects associated with leaving residual contamination in place without monitoring or controls. No further action applies to the areas that have undergone removal actions: Ra/Sr Treatment Systems, DSS 3, Dry Wells A-E and Southwest Trenches. No action applies to the areas that have not undergone remedial action: DSS 4 and Eastern Dog Pens. Under this alternative, nothing further would be done.

## 7.2. Long-Term Groundwater Monitoring and Contingent Remedial Action

Under this option, some contaminant concentrations may remain in soil. The contaminants may move downward from soil into groundwater. However, the soil concentrations are not likely to be high enough to raise contaminant levels in groundwater above the groundwater cleanup goals (background or regulatory mandated levels).

The purpose of long-term groundwater monitoring is to ensure that if contaminants begin to impact groundwater, contingent remediation can be implemented. DOE believes that the likelihood of needing contingent remediation is low, since the previous removal actions removed most of the contaminants.

Groundwater monitoring would consist of sampling groundwater from wells located in HSU-1 and close to the contaminated area. HSU-1 groundwater is not used due to inadequate yield and poor natural quality. HSU-2 is a higher yield aquifer located directly below HSU-1, and is used for domestic and agricultural supply. Groundwater monitoring of HSU-1 near the DOE areas would detect any future releases in advance of reaching groundwater resources used by the public (e.g., HSU-2). Thus, the probability of public exposure to contaminated groundwater under this option is extremely low.

New monitoring wells may be installed under this option. DOE would evaluate the locations of these wells and sampling requirements during the Remedial Action/Remedial Design phase. Results from monitoring new and existing wells would be presented and evaluated in annual water monitoring reports and in Superfund-mandated Five-Year Reviews.

If contaminants of concern increase above background levels or display an increasing trend, confirmation sampling would be conducted within 60 days of the report of analysis, and more frequent sampling (e.g., quarterly sampling) would occur at the specific source area for at least one year. Four consecutive groundwater sample results that exceed background levels and show an increasing concentration trend would trigger a new evaluation of remedial cleanup technologies and identification of a contingent remedy, if necessary.

If implementation is required, the selected contingent remedial alternative would address only new contamination in groundwater attributable to residual soil in the DOE areas. Current groundwater contamination will be addressed by the remedial alternative(s) to be implemented by UC Davis.

The proposed trigger level for formaldehyde is the CDPH Drinking Water Notification Level of 100 micrograms per liter. Complete details of the monitoring program decision process would be presented in the Record of Decision. The monitoring program would be detailed in the Remedial Design document which follows the Record of Decision.

### 7.3. Land-Use Restrictions

Land-use restrictions are physical, administrative and/or legal mechanisms used to limit exposure to residual contamination. Land-use restrictions could include deed restrictions, covenants, easements, zoning ordinances and groundwater use restrictions. Land-use restrictions could be used in coordination with other technologies; for instance, with asphalt caps to ensure the integrity of the cap area and prohibit site development activities that might affect cap performance.

Due to the potential elevated risk of a hypothetical resident in the DSS 4 Area, DOE would establish a land-use covenant prohibiting residential land use in this area. For alternatives requiring capping, a land-use restriction would be used to prevent development that would disturb or adversely affect performance of the cap.

As a conservative measure to reduce long-term risks to the public and site occupants, DOE would require a Soil Management Plan for all of the DOE areas, except areas where no action/no further action was identified. The Soil Management Plan would be maintained and updated during Superfund five-year reviews, and would provide strict management requirements for reuse and disposal of soil in DOE areas. The general requirements for this plan would be documented in land-use covenants discussed below.

Land-use covenants would be drafted by DTSC, with input from EPA; signed by the University of California and DTSC, listing EPA as a third-party beneficiary; and recorded by Solano County after the Record of Decision is finalized. Land-use restrictions would be implemented by the University of California.

### 7.4. Asphalt Cap

Generally, residual contaminants in DOE areas are located in soil above the water table. Surface water **infiltration** is the primary mechanism to move these contaminants to groundwater. An asphalt cap would divert surface water from the contaminated soil area and prevent infiltration.

An asphalt cap would consist of a thick plastic liner overlain by eight inches of compacted gravel and four inches of asphalt pavement. The liner and pavement would be sloped to direct stormwater runoff away from the area. The asphalt cap would be inspected periodically and repaired as necessary.

### 7.5. Removal and Off-Site Disposal

This option would consist of excavating all contaminated soil, regardless of depth, and disposing it in an appropriately permitted off-site facility. All soil containing concentrations above cleanup goals would be removed and disposed.

Confirmation samples would be collected from excavation floors and sidewalls prior to filling the excavation with clean soil or low-strength concrete.

Excavated soil classified as low-level radioactive waste would be transported by truck and disposed at a permitted facility outside of California. Other soil would be disposed at a Class II industrial waste landfill located within 50 miles of the Site.

### 7.6. Removal and On-Site Treatment by Phytoremediation

This option would involve removing soil to achieve the cleanup goals and treating a portion of the contaminated soil on-site. Phytoremediation would treat nitrate in contaminated soil by planting crops that remove nitrate through root uptake and convert it to nitrogen gas.

On-site phytoremediation would be accomplished by spreading contaminated soil over the former Western Dog Pens and planting annual crops of warm-season grass.

A plastic liner would be installed under the contaminated soil to prevent contact with surface soil in the treatment area. The grass crop would be seeded in spring and regularly trimmed through early fall. The trimmings would be properly disposed off-site.

When monitoring data indicates that remediation is complete, confirmation samples would be collected to verify that concentrations are below the cleanup goals.

### 7.7. Limited Removal and Off-Site Disposal

This option would involve removing soil that is accessible with conventional excavation equipment and disposing the soil in an appropriately permitted off-site facility. The lateral excavation limits would include soil with concentrations above the cleanup goals, but excavation would be terminated approximately 20 feet below ground surface regardless of the presence of deeper contamination.

### 7.8. *In Situ* Bioremediation

This option would treat nitrate in place using a process called anaerobic microbial denitrification.

To initiate this process, a benign nutrient solution (e.g., molasses) would be injected into the subsurface until complete soil saturation is achieved in the vicinity of the nitrate contamination. Over time, naturally-occurring microorganisms would reduce the nitrate to nitrogen gas.

The treatment system would consist of several injection wells connected to a solution tank and metered delivery pump. Clustered **piezometers** and monitoring wells would be used to measure the level of soil saturation, nutrient concentration**,** and nitrate **concentration** at various distances away from the injection wells.

When monitoring data indicates that remediation is complete, confirmation samples would be collected to verify that concentrations are below the cleanup goals.

### 7.9. Assembly of Alternatives

Alternatives consist of one or more cleanup options assembled to meet all Remedial Action Objectives and ARARs for a particular area. The full assembly of cleanup technologies into alternatives for each Site area is shown in Table 3, page 19, following the Evaluation of Alternatives. The ARARs for each alternative are identified in the Feasibility Study Report.

## 8. Evaluation of Alternatives

Remedial alternatives consisting of one or more cleanup technologies were evaluated against seven EPA evaluation criteria to select the preferred alternative (Figure 3). This section profiles the estimated performance of each alternative against the seven criteria. A detailed analysis of the alternatives can be found in the Feasibility Study Report.

As shown in Figure 3, there are three types of evaluation criteria: threshold, balancing, and modifying. Viable alternatives must meet the threshold criteria of 1) overall protection of human health and the environment, and 2) compliance with ARARs. The balancing criteria are used to evaluate trade-offs among the alternatives.

The balancing criteria include long-term effectiveness; reduction in toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. State and community acceptance are modifying criteria used to evaluate trade-offs

*Each alternative was assessed against the first seven EPA evaluation criteria described below. Using results of this assessment, DOE compared the alternatives and selected a preferred alternative for each DOE area. State and community acceptance will be addressed after public comments have been received.*

***Threshold Criteria***

**1. Overall Protection of Human Health and the Environment:** Address whether a remedy provides adequate protection.

**2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs):** Address whether a remedy will meet federal and state environmental statues, regulations and requirements.

***Balancing Criteria***


**3. Long-term Effectiveness and Permanence:** Evaluates whether an alternative will be successful and able to maintain reliable protection once cleanup goals have been met.

**4. Reduction of Toxicity, Mobility, or Volume Through Treatment:** Refers to the anticipated ability of a remedy to reduce the toxicity, mobility, or volume of the contamination present through treatment.

**5. Short-term Effectiveness:** Addresses the period of time needed to achieve short-term protection, and any adverse impact on human health. and the environment that may be posed during the construction and implementation period.

**6. Implementability:** Refers to the technical and administrative feasibility of a remedy, including the availability of materials and services needed to carry out a particular option.

**7. Cost:** Evaluates the estimated capital, and operation and maintenance costs of each alternative.

***Modifying Criteria***

**8. State Acceptance:** Indicates whether, based on its review of the information, the state concurs with, opposes, or has no comment on the preferred alternatives.

**9. Community Acceptance:** Indicates whether community concerns are addressed by the remedy and whether the community has a preference for a remedy. Although public comment is an important part of the final decision, DOE is required by law to balance community concerns with all of the previously mentioned criteria.

**Figure 3. EPA Evaluation Criteria for Remedial Alternatives**

between alternatives; acceptance will be evaluated upon receipt of comments from the public.

Evaluation of the alternatives and the preferred alternative for the Ra/Sr Treatment Systems, DSS 3, DSS 4, Dry Wells A-E, Southwest Trenches and Eastern Dog Pens is summarized below.

## 8.1. Evaluation of Alternatives for the Radium/Strontium Treatment Systems Area

The Ra/Sr Treatment Systems Area (Figure 1, page 2) was used to treat and discharge wastewater generated by LEHR research operations. The area consisted of two treatment systems and two leach fields.

In 1999 and 2000, DOE removed and disposed the subsurface treatment systems, leach fields and surrounding contaminated soil. The post-excavation sample results indicated that nearly all of the contaminants were removed.

The Site-Wide Risk Assessment found no significant human health or ecological risk. However, nitrate, Ra-226 and carbon-14 (C-14) were identified as having some potential to impact a small area of on-site groundwater in HSU-1.

Remedial alternatives were developed in the Feasibility Study (Table 3, page 19) as potential response actions for the residual nitrate, Ra-226 and C-14. The Ra/Sr Treatment Systems Area alternatives are:

- Alternative 1—No Further Action
- Alternative 2—Long-Term Groundwater Monitoring /Contingency Remediation/Land-Use Restrictions

- Alternative 3—Capping/Long-Term Groundwater Monitoring /Land-Use Restrictions
- Alternative 4a—Removal and Off-Site Disposal
- Alternative 4b—Removal and On-Site Treatment/Land-Use Restrictions
- Alternative 4c—Limited Removal and Off-Site Disposal/Long-Term Groundwater Monitoring /Land-Use Restrictions
- Alternative 5—*In Situ* Bioremediation/Long-Term Groundwater Monitoring /Land-Use Restrictions

Each alternative was evaluated against the seven EPA criteria (Figure 3, page 10). A comparison of alternatives based on the EPA criteria follows.

**Overall Protection of Human Health and the Environment**—The human health risk in the Ra/Sr Treatment Systems Area is less than 1 in 1,000,000. Further removal or treatment will not significantly improve protectiveness. Alternative 2 would protect groundwater resources in HSU-2 by monitoring groundwater in HSU-1 near the Ra/Sr Treatment Systems Area contamination. Contingent remediation could then be implemented before contaminants reach HSU-2. A soil management plan will prevent improper disposal or exposure to residual contaminants. The reduced uncertainty of the future fate and transport of residual contaminants provided by Alternatives 4a, 4b and 4c is offset by construction and waste shipment risks, transfer of risk to disposal site workers, and high costs. All of the alternatives, except Alternative 1, provide approximately the same level of protectiveness to human health and the environment. Alternative 1 is not protective, because it does not monitor shallow groundwater.

**Compliance with ARARs**—All of the alternatives except Alternative 1 comply with all ARARs. Alternative 1 is not in compliance with ARARs because it does not provide assurance of compliance with California's water protection requirements. The ARARs evaluation was identical for all areas except the Eastern Dog Pens. ARARs compliance is discussed further in Section 8.6, entitled Evaluation of Alternatives for the Eastern Dog Pens.

**Long-Term Effectiveness**—The removal actions in 1999 and 2000 permanently removed most of the Ra/Sr Treatment Systems Area contaminants. All of the alternatives are likely effective in mitigating long-term risk, given the limited mass of residual contamination. Alternative 1 may be effective, but there is no way of verifying it.

**Reduction in Toxicity, Mobility or Volume through Treatment**—Alternatives 2, 3, 4a and 4c do not include treatment, so this criterion is not satisfied, but they reduce or manage contamination through other means. Only alternatives 4b and 5 treat contamination. These technologies treat nitrate without treating C-14 or Ra-226. Alternatives 4b and 5 have some drawbacks. Alternative 4b will leave limited amounts of C-14 and Ra-226 contamination in the Western Dog Pens and Alternative 5 has the potential to mobilize and spread residual contamination due to the injection of the nutrient solution.

**Short-Term Effectiveness**—Short-term effectiveness will be attained under alternatives 4a and 4b through removal of all residual contamination. Alternatives 2, 3, 4c and 5 will be effective because of nearby monitoring that will protect HSU-2, and land-use restriction that will ensure proper management of residual contamination. Alternatives 2, 3, 4a and 4c are predicted to protect human health and the environment in approximately one year. Alternatives 4b and 5 are predicted to achieve protectiveness in four and three years, respectively. The protectiveness of alternatives 4a, 4b and 4c is offset by waste shipment risks and construction/heavy equipment risks. Alternatives 2, 3 and 5 pose only small risks from construction/heavy equipment.

**Implementability—**Alternative 2 is readily implementable because it only involves installing a monitoring well and modifying the existing monitoring program. Alternatives 3 and 5 will involve more implementation work because of cap construction and *in situ* treatment system installation, respectively. Alternatives 4a, 4b and 4c are implementable, but will be challenging due to safety and environmental impacts associated with large-scale earth-moving operations.

**Cost—**Alternative 1 has zero cost. The present worth cost for Alternative 2 is $0.3 million (M). Contingent remediation costs associated with Alternative 2 are currently unknown. The estimated cost of Alternative 3 is $0.7 M. Alternatives 4a, 4b and 4c are markedly more expensive, with estimated cost ranging from $2.1 M to $5.1 M. The estimated cost for Alternative 5 is $1.2 M.

#### *8.1.1. Preferred Remedial Alternative for the Radium/Strontium Treatment Systems Area*

Alternative 2 is the preferred remedial alternative, because the Ra/Sr Treatment Systems Area removal actions were successful and the residual contamination can be monitored and managed at a reasonable cost. Alternative 2 is protective of human health and the environment, is easy to implement, does not involve waste shipment risks and is about one-tenth the cost of alternatives 4a, 4b and 4c. In the event that monitoring shows the need for a contingent remedy, DOE would be responsible for the future costs to implement an alternative remedy. Alternative 3 could reduce the potential for groundwater impact, but at more than twice the cost. Alternative 5 has a significantly higher cost and might increase the area and likelihood of potential groundwater impact. Alternative 1 does not monitor groundwater for possible future impacts, and therefore is unacceptable.

### 8.2. Evaluation of Alternatives for the Domestic Septic System 3 Area

In 1958, DSS 3 was installed to treat domestic sewage from LEHR facilities. DSS 3 was taken out of service in 1971 when LEHR was connected to the UC Davis wastewater treatment plant.

In 2002, DOE excavated the DSS 3 distribution box, piping, leach field and surrounding contaminated soil and disposed the excavated waste off-site. Samples were collected from the excavation floors and sidewalls and the excavations were backfilled with clean soil.

The Site-Wide Risk Assessment identified no significant human health or ecological risk at DSS 3 after the removal action. The indoor air risk calculation for formaldehyde showed a residential exposure risk of less than 1 in 1,000,000. Nitrate, formaldehyde and molybdenum are predicted to impact a small area of on-site groundwater in HSU-1.

The remedial situation at DSS 3 is nearly identical to the Ra/Sr Treatment Systems Area. DSS 3 has no human health or ecological contaminants of concern and only three potential groundwater contaminants. Nearly all of the contamination was excavated from the area, and only very small quantities of residual contamination remain in subsurface soil. Surface soil is not contaminated.

The DSS 3 remedial alternatives (Table 3, page 19) and their comparisons based on the EPA criteria (Figure 3, page 10) were identical to the Ra/Sr Treatment Systems Area.

#### *8.2.1. Preferred Remedial Alternative for the Domestic Septic System 3 Area*

Alternative 2 is the preferred remedial alternative at DSS 3 for the same reasons identified in Section 8.1.1.

### 8.3. Evaluation of Alternatives for the Domestic Septic System 4 Area

The remedial situation at DSS 4 differs from DSS 3 and the Ra/Sr Treatment Systems Area in that a removal action has not been performed, and the risk for a hypothetical on-site resident is greater than 1 in 10,000 due to **polycyclic aromatic hydrocarbons** (**PAHs**) in subsurface soil (Table 1). Contamination in the DSS 4 Area poses no significant ecological risk.

Selenium is the only groundwater contaminant of concern at DSS 4. Groundwater monitoring in this area indicated minor impact from selenium.

As shown on Figure 1, page 2, the septic tank, distribution box and piping remain at DSS 4, and the leach field extends below Building H-215. The PAHs that pose human health risk at DSS 4 are believed to originate from a tar-composite pipe used in the leach system (Figure 1, page 2).

Tar, which contains PAHs, was a common component of leach and drain pipes at the time DSS 4 was installed. The quantity of PAHs that can be released from pipe material is small. PAHs adhere strongly to the surface of soil particles and do not tend to migrate.

The PAH concentrations are based on samples collected from subsurface soil located very close to the composite pipe. PAHs are not present in soil at the ground surface or within a few feet of the pipe. Thus, PAHs at DSS 4 are limited to a small volume of subsurface soil.

Selenium was slightly above background levels in a few soil samples collected at DSS 4. The selenium was located approximately 4 feet below ground surface.

Remedial alternatives developed for PAHs and selenium at DSS 4 are:

- Alternative 1—No Further Action
- Alternative 2—Long-Term Groundwater Monitoring /Contingency Remediation/Land-Use Restrictions
- Alternative 3—Capping/Long-Term Groundwater Monitoring/Land-Use Restrictions
- Alternative 4—Limited Removal and Off-Site Disposal (does not remove contaminated soil located below Building H-215)/Land-Use Restrictions

The comparison of alternatives based on EPA criteria follows.

**Overall Protection of Human Health and the Environment**—Alternatives 2, 3, and 4 are protective of human health and the environment; Alternative 1 is not. The land-use restrictions in Alternatives 2, 3 and 4 protect human health by managing access to contaminated subsurface soil and prohibiting residential development. PAHs exhibit a very low vapor pressure and are not a concern for workers occupying Building H-215. Selenium is managed under Alternatives 2 and 3 through long-term groundwater monitoring. Accessible PAHs and selenium are removed under Alternative 4.

**Long-Term Effectiveness**—Alternative 1 is not effective because it does not address the human health risk. Alternatives 2, 3 and 4 are effective because human health risk is addressed through land-use restrictions (i.e., no residential development). In Alternative 3, cap effectiveness could eventually diminish if the cap is neglected. Alternative 4 offers good long-term effectiveness by permanently removing most of the selenium and all of the accessible PAHs, but it leaves inaccessible PAHs below Building H-215.

**Reduction in Toxicity, Mobility or Volume through Treatment**—The alternatives do not meet EPA's definition of treatment.

**Short-Term Effectiveness**—Alternatives 2, 3 and 4 are predicted to protect human health and groundwater within one year. Basic protection will be achieved through land use restrictions and groundwater monitoring. Capping and excavation provide some additional short-term effectiveness.

Alternative 1 is not effective due to unaddressed human health risk.

**Implementability—**Alternative 2, 3 and 4 are readily implementable.

**Cost—**Alternative 1 has zero cost. Alternative 2 is slightly lower in cost than Alternatives 3 and 4.

#### *8.3.1. Preferred Remedial Alternative for the Domestic Septic System 4 Area*

Alternative 2 is the preferred remedial alternative because it is protective of human health and slightly less costly than Alternatives 3 and 4.

### 8.4. Evaluation of Alternatives for the Dry Wells A-E Area

In 1999, Dry Wells A through E were partly removed by DOE. At the location shown in Figure 1, page 2, the dry wells consisted of buried concrete surface casings and open boreholes filled with gravel and cobbles.

A distribution box was connected to the dry wells, but no septic tank connections were found. Based on existing site maps, it is believed that the dry wells were connected to domestic septic tanks one and five.

In 1999, DOE excavated the dry wells, distribution box, and interconnected piping. The excavation extended to 8 feet below ground surface at Dry Wells A, B, C and E and 20 feet below ground surface at Dry Well D. Gravel was still present in the excavation floor at Dry Well D.

In 2001, soil samples were collected at each dry well to determine if the removal action was successful and to characterize the nature and extent of contamination in deeper soil. Sample depths ranged from 10 to 40 feet below ground surface. The soil sample results indicated elevated levels of chromium, hexavalent chromium, mercury, molybdenum, silver, Cs-137 and Sr-90.

After the removal action, the Site-Wide Risk Assessment found no significant human health or ecological risk. Chromium, hexavalent chromium, mercury, molybdenum, silver, Cs-137 and Sr-90 were identified as potential groundwater contaminants.

In 2004, HSU-1 well UCD1-054 was installed immediately down-gradient of the former dry wells area to determine if contaminants were impacting groundwater. Subsequent groundwater sampling has shown that Dry Wells A through E Area contaminants have not impacted groundwater.

Remedial alternatives developed for the Dry Wells A through E Area are:

- Alternative 1—No Further Action
- Alternative 2—Long-Term Groundwater Monitoring/Contingency Remediation/Land-Use Restrictions
- Alternative 3—Capping/Long-Term Groundwater Monitoring/Land-Use Restrictions
- Alternative 4a—Removal and Off-Site Disposal
- Alternative 4b—Limited Removal and Off-Site Disposal/Long-Term Groundwater Monitoring/Land-Use Restrictions

The comparison of alternatives based on EPA criteria follows.

**Overall Protection of Human Health and the Environment—**Alternatives 2, 3, 4a and 4b are protective of human health and the environment. The human health risk is less than 1 in 1,000,000 and groundwater monitoring data indicates that the released contaminants are not impacting groundwater. Alternative 1 cannot be considered protective because it does not monitor groundwater.

**Long-Term Effectiveness—**Long-term effectiveness should be easily achievable under Alternatives 2, 3, 4a or 4b. Thirty-three years after the dry wells were abandoned, none of the released contaminants are currently impacting groundwater.

**Reduction in Toxicity, Mobility or Volume through Treatment—**The alternatives do not meet EPA's definition of treatment.

**Short-Term Effectiveness**—Alternatives 2, 3, 4a and 4b are predicted to protect groundwater within one year. Alternatives 2, 3, 4a and 4b are equally effective because the contaminants are not moving into groundwater at a significant rate. In Alternative 4a, the excavation safety issues and waste shipment risks far outweigh its groundwater protection benefit. Alternative 1 is not effective because it does not monitor groundwater.

**Implementability**—Alternative 2 is easy to implement because it only involves modifying the existing monitoring program. Alternatives 3 and 4b involve more effort because they include cap construction and excavation, respectively. Alternative 4a is difficult to implement because of excavation safety issues and the need for large equipment to remove contaminants below a depth of 20 feet.

**Cost—**Alternative 1 has zero cost. The Alternative 2 cost is $0.2 M and the Alternative 3 cost is $0.4 M. Alternatives 4a and 4b are more expensive, with estimated cost ranging from $0.8 M to $1.2 M.

#### *8.4.1. Preferred Remedial Alternative for the Dry Wells A-E Area*

Alternative 2 is the preferred remedial alternative because the human health risk is less than 1 in 1,000,000 and the residual contaminants are not significantly impacting groundwater. Alternatives 3, 4a and 4b offer no significant improvements over and are more costly than Alternative 2.

### 8.5. Evaluation of Alternatives for the Southwest Trenches Area

Between the late 1950s and early 1970s, low-level radioactive waste, animal waste and laboratory wastes from LEHR research activities were disposed in shallow pits and trenches in the Southwest Trenches Area. Part of the Southwest Trenches Area was also used for chemical storage and treating dogs for fleas.

In 1998, DOE excavated the trenches, pits and surrounding contaminated soil. DOE also excavated shallow chlordane-impacted soil in the former chemical storage area. Samples were collected from the excavation floors and sidewalls, and the excavations were backfilled with uncontaminated soil.

After the excavation, the Site-Wide Risk Assessment results indicated Sr-90 was a potential concern (3 in 1,000,000) for a hypothetical on-site resident (Table 1). Risks below 1 in 1,000,000 are rarely considered significant. The risks from Sr-90 are at the low end of the risk spectrum and may never be realized. The Site is not used for residential housing, and UC Davis plans to use the Site for academic research for the foreseeable future. No significant risks were identified for on-site researchers, off-site residents, or the public.

There were no significant risks to ecological receptors. Nitrate and C-14 are predicted to impact a small area of on-site groundwater in HSU-1.

Remedial alternatives developed for the Southwest Trenches Area are:

- Alternative 1—No Further Action
- Alternative 2—Long-Term Groundwater Monitoring/Contingency Remediation/Land-Use Restrictions
- Alternative 3—Capping/Long-Term Groundwater Monitoring /Land-Use Restrictions
- Alternative 4a—Removal and Off-Site Disposal
- Alternative 4b—Removal and On-Site Treatment/Land-Use Restrictions
- Alternative 4c—Limited Removal and Off-Site Disposal/Long-Term Groundwater Monitoring /Land-Use Restrictions
- Alternative 5—*In Situ* Bioremediation/Long-Term Groundwater Monitoring/Land-Use Restrictions

A comparison of the remedial alternatives follows.

**Overall Protection of Human Health and the Environment—**Alternatives 2, 3, 4a, 4b, 4c and 5 are protective of human health and the environment. Alternative 1 is not. Alternative 2 would protect groundwater resources, and contingent remediation could be implemented long before contaminants reach HSU-2. A soil management plan will prevent improper disposal or exposure to residual contaminants. Alternatives 4a, 4b and 4c would slightly improve protectiveness by removing Sr-90 human health risk and some potential ground water impact risk, but the risk improvement may be offset by waste shipment risks and the transfer of risk to disposal site workers. Alternatives 3 and 5 do not treat Sr-90 contamination and Alternative 5 may spread C-14 and Sr-90 contamination.

**Long-Term Effectiveness—**All of the alternatives have inherited good long-term effectiveness because the removal action in 1998 was successful at permanently removing most of the contaminants. It is possible that Alternatives 4a and 4b could marginally improve long-term effectiveness if they successfully remove all of the residual contamination.

**Reduction in Toxicity, Mobility or Volume through Treatment—**Alternatives 2, 3, 4a and 4c do not include treatment, so this criterion is not satisfied, but they reduce or manage contamination through other means. Alternatives 4b and 5 only treat nitrate. Alternative 4b will leave C-14 contamination in the Western Dog Pens. Alternative 5 could spread C-14 and Sr-90.

**Short-Term Effectiveness—**Alternatives 2, 3, 4a and 4c could be effective in approximately one year, and Alternatives 4b and 5 are predicted to achieve effectiveness in four and three years, respectively. Alternatives 4a, 4b and 4c will achieve effectiveness via excavation, but with some excavation safety issues and waste shipment risks. Alternative 2 will be effective because of land-use restrictions and monitoring. Alternatives 3 and 5 may offer slight improvements because of capping and treatment, respectively. However, Alternative 5 may spread contamination.

**Implementability—**Alternative 2 is easy to implement because it only involves installing a well and modifying the existing monitoring program. Alternatives 3, 4a, 4b, 4c and 5 are more difficult to implement because they add construction and maintenance issues.

**Cost—**Alternative 1 has zero cost and Alternative 2 has a cost of $0.4 M. Alternatives 3 and 5 are more expensive, with estimated costs of $0.7 M to $1.3 M, respectively. Alternatives 4a, 4b and 4c are markedly more expensive, with estimated costs ranging from $4.6 M to $8.8 M.

#### *8.5.1. Preferred Remedial Alternative for the Southwest Trenches Area*

Alternative 2 is the preferred remedial alternative for the Southwest Trenches Area, because it protects human health and the environment, is relatively quick and easy to implement and is significantly less expensive than the other alternatives. Alternative 2 is sufficient because very little contamination remains in the Southwest Trenches Area after the 1998 removal action. Under the current land use, risk is less than 1 in 1,000,000. More aggressive remediation will increase costs without significantly improving protection of human health and the environment.

### 8.6. Evaluation of Alternatives for the Eastern Dog Pens

Between 1968 and 1970, the Eastern Dog Pens were constructed and used to house dogs that were involved in LEHR experiments. The area consisted of 96 individual pens arranged in six rows separated by three asphalt-covered aisles.

The Eastern Dog Pens were constructed above an inactive UC Davis land disposal unit

(Figure 1, page 2). UC Davis will issue a separate Proposed Plan addressing the underlying land disposal unit.

Low levels of radioactive constituents were released to the pens in the dogs' excreta. Chlordane was released to the pens to control fleas on the dogs.

The pens were used until research ceased in 1988. In 1996, above-ground features of the individual pens were removed and disposed off-site. Concrete curbs and the perimeter fence were removed and disposed off-site in 2007. The asphalt aisles and gravel that formerly covered the dog pen floors remains.

The Site-Wide Risk Assessment results indicate dieldrin and Sr-90 in shallow soil posed small risks to hypothetical future on-site residents. No significant risks to ecological receptors or groundwater were identified.

The risks from dieldrin and Sr-90 are low on the risk spectrum and may never be realized. The Site is not used for residential housing, and UC Davis plans to use the Site for academic research for the foreseeable future.

Remedial alternatives developed for the Eastern Dog Pens are:

- Alternative 1—No Further Action
- Alternative 2—Land-Use Restrictions
- Alternative 3—Removal and Off-Site Disposal

The comparison of alternatives based on EPA criteria follows.

**Overall Protection of Human Health and the Environment—**Alternatives 2 and 3 are protective of human health and the environment. Alternative 1 is not. The human health risk is low and easily addressed by land-use restrictions (Alternative 2). A soil management plan will prevent improper disposal or exposure to residual contaminants. The risk can also be removed by excavation and off-site disposal under Alternative 3.

**Compliance with ARARs—**All of the alternatives comply with the ARARs.

**Long-Term Effectiveness—**Land-use restrictions that prevent residential development (Alternative 2) are consistent with UC Davis long-range plans. The university intends to continue using the Site for academic research into the foreseeable future. Excavation and off-site disposal (Alternative 3) could permanently remove the contaminants.

**Reduction in Toxicity, Mobility or Volume through Treatment—**The alternatives do not meet EPA's definition of treatment.

**Short-Term Effectiveness—**Alternatives 2 and 3 are effective in the short term and are predicted to protect human health within one year. Alternative 1 will be effective in the short term if research facility land use remains unchanged. The risk to on-site workers is less than 1 in 1,000,000.

**Implementability—**Alternative 2 involves negotiations between DOE and UC Davis and implementation of the decided-upon restrictions. Alternative 3 involves shallow excavation and off-site disposal. Alternative 1 has no implementation work.

**Cost—**Alternative 1 has zero cost. Alternative 2 has a cost of only \$0.05 M. Alternative 3 is significantly more expensive, with an estimated cost of \$1.6 M.

#### *8.6.1. Preferred Remedial Alternative for the Eastern Dog Pens*

Alternative 2 is the preferred remedial alternative for the Eastern Dog Pens, because the small risks to hypothetical on-site residents can be managed by maintaining the existing land use. The UC Davis long-range plan is to continue using the Site as an academic research facility for the foreseeable future.

## 9. Conclusion

DOE has evaluated the remedial alternatives according to the first seven EPA Evaluation Criteria as summarized in Table 4, page 20, and has presented its rationale for the selection of preferred remedial alternatives which address environmental impacts at the Site. Public input on the selection of the alternatives for the Site is requested. Prior to issuing the Record of Decision, DOE will establish a formal agreement with UC Davis on remedial action implementation. DOE will select the final remedy for the Site, after balancing public input and the other EPA Evaluation Criteria, in coordination with EPA, DTSC, RWQCB and CDPH. After the final remedial actions are implemented, DOE will monitor the performance of the selected alternatives over time and remain responsible for the long-term surveillance and maintenance of the cleanup.

## 10. Glossary

Terms appearing in bold type in the text of this document are defined in this glossary.

**Alluvium—**Unconsolidated clay, silt, sand, gravel, and/or larger rocks deposited by streams.

**Applicable or Relevant and Appropriate Requirement (ARAR)—**Applicable or Relevant and Appropriate Requirements are generally state and federal laws and regulations or local ordinances.

**Carcinogen (carcinogenic compound)—**An agent capable of inducing cancer.

**Concentration—**The relative amount of a substance mixed with another substance. For example, 5 milligrams per liter of iron in water means that 5 milligrams (five one-thousandths of a gram) of iron is present in one liter (1,000 grams) of water.

**Groundwater—**Water that flows in soil or rock, supplying springs and wells.

**Infiltration—**Flow of water from the land surface into the subsurface.

**Non-Cancer Risk—**Adverse effects, other than cancer, resulting from exposure to an environmental agent.

**Piezometer—**A non-pumping well, generally of small diameter, for measuring water levels.

**Polycyclic aromatic hydrocarbons (PAHs)—**a group of organic chemicals that includes several petroleum products and their derivatives.

**Radionuclide—**A chemical element that radioactively decays, resulting in the emission of radiation.

**Remedial Alternative—**A cleanup solution developed by assembling a combination of technologies.

**Removal Action—**An expedited response to address releases of hazardous substances.

**Response Action—**An authorized action to address environmental release of hazardous substances involving either a short-term removal action or a long-term removal response.

**Risk—**The probability of adverse effects resulting from exposure to an environmental agent or mixture of agents.

**Superfund—**Federal authority, established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980, to respond directly to releases or threatened releases of hazardous substances that may endanger health or the environment.

Table 3. Cleanup Technologies, Alternatives and Estimated Costs

| Cleanup Technology | Ra/Sr Treatment Systems | | | | | | | DSS 3 | | | | | | | DSS 4 | | | | Dry Wells A-E | | | | | Southwest Trenches | | | | | | | Eastern Dog Pens | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Alternatives | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4a | 4b | 4c | 5 | 1 | 2 | 3 | 4a | 4b | 4c | 5 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4a | 4b | 1 | 2 | 3 | 4a | 4b | 4c | 5 | 1 | 2 | 3 |
| **No Further Action / No Action** | ✓ | | | | | | | ✓ | | | | | | | ✓ | | | | ✓ | | | | | ✓ | | | | | | | ✓ | | |
| **Long-Term Groundwater Monitoring** | | | ✓ | | | | | | | ✓ | | | | | | | ✓ | | | | ✓ | | | | | ✓ | | | | | | | |
| **Long-Term Groundwater Monitoring/Contingency Remediation** | | ✓ | | | | ✓ | ✓ | | ✓ | | | | ✓ | ✓ | | ✓ | | | | ✓ | | | ✓ | | ✓ | | | | ✓ | ✓ | | | |
| **Land-Use Restrictions:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| • Soil Management Plan | | ✓ | | | ✓ | ✓ | ✓ | | ✓ | | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | | ✓ | | ✓ | | | ✓ | ✓ | ✓ | | ✓ | |
| • Limit Development (cap protection) | | | ✓ | | | | | | | ✓ | | | | | | | ✓ | | | | ✓ | | | | | ✓ | | | | | | | |
| • No Residential Use | | | | | | | | | | | | | | | | ✓ | ✓ | ✓ | | | | | | | | | | | | | | | |
| **Capping** | | | ✓ | | | | | | | ✓ | | | | | | | ✓ | | | | ✓ | | | | | ✓ | | | | | | | |
| **Removal and Off-Site Disposal** | | | | ✓ | | | | | | | ✓ | | | | | | | | | | | ✓ | | | | | ✓ | | | | | | ✓ |
| **Removal and On-Site Treatment** | | | | | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | ✓ | | | | | |
| **Limited Removal and Off-Site Disposal** | | | | | | ✓ | | | | | | | ✓ | | | | | ✓ | | | | | ✓ | | | | | | ✓ | | | | |
| ***In Situ* Bioremediation** | | | | | | | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | ✓ | | | |

**Notes**

Alternatives were numbered based on the primary approach they represent. Variations of an approach were lettered. Alternative numbers are sequential for each area, and are not necessarily the same from area to area.

Blue highlighting denotes DOE's preferred alternative.

**Abbreviations**

DSS Domestic Septic System

Ra/Sr radium/strontium

Table 4. Evaluation of Remedial Alternatives

**Ra/Sr Treatment Systems**

| Criterion | 1) No Further Action | 2) Monitor / Contingency / Restrict | 3) Capping / Monitor / Restrict | 4a) Removal and Off-Site Disposal | 4b) Removal and On-Site Treatment | 4c) Lim Remove / Monitor / Restrict | 5) Bio / Monitor / Restrict |
|---|---|---|---|---|---|---|---|
| Overall Protection of Human Health and the Environment | Unacceptable | Good | Good | Good | Good | Good | Good |
| Compliance with ARARs | Unacceptable | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent |
| Long-term Effectiveness | Poor | Good | Good | Excellent | Excellent | Good | Good |
| Reduction in Toxicity, Mobility, or Volume through Treatment | Unacceptable | Unacceptable | Unacceptable | Unacceptable | Fair | Unacceptable | Fair |
| Short-term Effectiveness | Unacceptable | Good | Good | Fair | Fair | Fair | Good |
| Implementability | Excellent | Good | Fair | Poor | Poor | Poor | Fair |
| Cost | Excellent | Good | Fair | Poor | Poor | Poor | Fair |
| *Estimated Present Worth Cost[1] (millions of dollars)* | $ 0 | $ 0.3 | $ 0.7 | $ 3.3-$ 5.1 | $ 2.4-$ 3.2 | $ 2.1-$ 2.5 | $ 1.2 |

**Domestic Septic System 3**

| Criterion | 1) No Further Action | 2) Monitor / Contingency / Restrict | 3) Capping / Monitor / Restrict | 4a) Removal and Off-Site Disposal | 4b) Removal and On-Site Treatment | 4c) Lim Remove / Monitor / Restrict | 5) Bio / Monitor / Restrict |
|---|---|---|---|---|---|---|---|
| Overall Protection of Human Health and the Environment | Unacceptable | Good | Good | Good | Good | Good | Good |
| Compliance with ARARs | Unacceptable | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent |
| Long-term Effectiveness | Poor | Good | Good | Excellent | Excellent | Good | Good |
| Reduction in Toxicity, Mobility, or Volume through Treatment | Unacceptable | Unacceptable | Unacceptable | Unacceptable | Fair | Unacceptable | Fair |
| Short-term Effectiveness | Unacceptable | Good | Good | Fair | Fair | Fair | Good |
| Implementability | Excellent | Good | Fair | Poor | Poor | Poor | Fair |
| Cost | Excellent | Good | Fair | Poor | Poor | Poor | Fair |
| *Estimated Present Worth Cost[1] (millions of dollars)* | $ 0 | $ 0.2 | $ 0.5 | $ 4.6 | $ 4.5 | $ 2.2 | $ 1.3 |

**Domestic Septic System 4**

| Criterion | 1) No Action | 2) Monitor / Contingency / Restrict | 3) Capping / Monitor / Restrict | 4c) Lim Remove / Restrict |
|---|---|---|---|---|
| Overall Protection of Human Health and the Environment | Unacceptable | Good | Good | Good |
| Compliance with ARARs | Unacceptable | Excellent | Excellent | Excellent |
| Long-term Effectiveness | Unacceptable | Good | Good | Good |
| Reduction in Toxicity, Mobility, or Volume through Treatment | Unacceptable | Unacceptable | Unacceptable | Unacceptable |
| Short-term Effectiveness | Unacceptable | Good | Excellent | Excellent |
| Implementability | Excellent | Good | Fair | Fair |
| Cost | Excellent | Good | Good | Good |
| *Estimated Present Worth Cost[1] (millions of dollars)* | $ 0 | $ 0.3 | $ 0.4 | $ 0.5 |

**Dry Wells A-E Area**

| Criterion | 1) No Further Action | 2) Monitor / Contingency | 3) Capping / Monitor / Restrict | 4a) Removal and Off-Site Disposal | 4b) Lim Remove / Monitor |
|---|---|---|---|---|---|
| Overall Protection of Human Health and the Environment | Unacceptable | Good | Good | Good | Good |
| Compliance with ARARs | Unacceptable | Excellent | Excellent | Excellent | Excellent |
| Long-term Effectiveness | Poor | Excellent | Excellent | Excellent | Excellent |
| Reduction in Toxicity, Mobility, or Volume through Treatment | Unacceptable | Unacceptable | Unacceptable | Unacceptable | Unacceptable |
| Short-term Effectiveness | Unacceptable | Good | Good | Fair | Fair |
| Implementability | Excellent | Good | Fair | Poor | Fair |
| Cost | Excellent | Good | Good | Fair | Fair |
| *Estimated Present Worth Cost[1] (millions of dollars)* | $ 0 | $ 0.2 | $ 0.4 | $ 1.2 | $ 0.8 |

**Southwest Trenches**

| Criterion | 1) No Further Action | 2) Monitor / Contingency / Restrict | 3) Capping / Monitor / Restrict | 4a) Removal and Off-Site Disposal | 4b) Removal and On-Site Treatment | 4c) Lim Remove Disp / Mon / Restrict | 5) Bio / Monitor / Restrict |
|---|---|---|---|---|---|---|---|
| Overall Protection of Human Health and the Environment | Unacceptable | Good | Good | Good | Good | Good | Good |
| Compliance with ARARs | Unacceptable | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent |
| Long-term Effectiveness | Poor | Good | Good | Excellent | Excellent | Good | Good |
| Reduction in Toxicity, Mobility, or Volume through Treatment | Unacceptable | Unacceptable | Unacceptable | Unacceptable | Fair | Unacceptable | Fair |
| Short-term Effectiveness | Unacceptable | Good | Good | Fair | Fair | Fair | Good |
| Implementability | Excellent | Good | Good | Poor | Poor | Poor | Fair |
| Cost | Excellent | Good | Fair | Poor | Poor | Poor | Fair |
| *Estimated Present Worth Cost[1] (millions of dollars)* | $ 0 | $ 0.4 | $ 0.7 | $ 7.3-$ 8.8 | $ 6.4-$ 8.0 | $ 4.6-$ 5.2 | $ 1.3 |

**Eastern Dog Pens**

| Criterion | 1) No Action | 2) Restrict | 3) Removal and Off-Site Disposal |
|---|---|---|---|
| Overall Protection of Human Health and the Environment | Unacceptable | Good | Excellent |
| Compliance with ARARs | Excellent | Excellent | Excellent |
| Long-term Effectiveness | Poor | Good | Excellent |
| Reduction in Toxicity, Mobility, or Volume through Treatment | Unacceptable | Unacceptable | Unacceptable |
| Short-term Effectiveness | Unacceptable | Good | Good |
| Implementability | Excellent | Good | Fair |
| Cost | Excellent | Good | Poor |
| *Estimated Present Worth Cost[1] (millions of dollars)* | $ 0 | $ 0.05 | $ 1.6 |

[1]Present worth cost is the sum of the present worth of all direct expenditures over the life of the project.

**Key**

- Excellent
- Good
- Fair
- Poor
- Unacceptable

**Abbreviations**

| | |
|---|---|
| Bio | *In Situ* Bioremediation |
| Contingency | Contingency Remediation |
| Lim Remove | Limited Removal and Off-Site Disposal |
| Monitor | Long-Term Groundwater Monitoring |
| Ra/Sr | Radium/Strontium |
| Restrict | Land-Use Restrictions |