

6. Description of Remedial Alternatives

In this chapter we present remedial alternatives to address COCs in the Site 300 OUs. Each of the remedial alternatives is developed from the retained technologies described in Chapter 3 and modules presented in Chapter 4.

To develop these remedial alternatives, we incorporated retained technologies and modules based on applicability, implementability, effectiveness, cost, site- and OU-specific requirements, and best professional judgment. Therefore, not all retained technologies from Chapter 3 are presented as components of the alternatives. Specific innovative technologies are not discussed as integral components of the presented alternatives. However, as discussed in Chapter 3, innovative technologies will continue to be considered for application, after appropriate regulatory reviews, to the site throughout the process of remediation. These technologies may be introduced into the process if site conditions change or technology development and testing indicate a potential for cost-effective and expedited remediation.

Two or more alternatives are presented for each OU. In OU 5 (Building 850/Pits 3 & 5) and OU 8 (Buildings 801, 833, 845, and 851), where multiple release sites are present, alternatives are presented by release site subarea.

In order to expedite the FS process, presumptive remedies and/or technologies were incorporated where appropriate. Presumptive remedies are preferred technologies for common categories of sites, based on historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data on technology implementation. The objective of EPA's presumptive remedy program is to "use the program's past experience to streamline site investigation and speed up selection of cleanup actions." As stated in EPA Guidance, "the use of presumptive remedies simplifies and streamlines the remedy selection process by:

1. Reducing the large number and diverse assortment of technologies to relatively few technology types.
2. Eliminating the need to perform the technology screening portion of the FS.
3. Allowing, in some cases, further consideration and selection among the presumptive technologies to be deferred from the Feasibility Study (FS) and ROD to the Remedial Design (RD), which prevents duplication of effort and allows selection to be based on additional data collected during the RD (EPA, 1996)."

In some cases, it may be appropriate to specify a general remedial strategy for a release site in the FS but defer selection of specific technologies until the RD (EPA, 1996). Remediation-specific details, such as the number and location of extraction wells used for a pump-and-treat alternative, are presented in this SWFS for purposes of costing and strategy presentation. The actual site- and technology-specific details will be based on additional data and design criteria presented in the RDs.

The remedial alternatives consist of a combination of selected modules, as described above. The remedial alternatives for all OUs are summarized in Table 6-1, along with their total estimated cost. The detailed cost estimates for these modules are presented in Appendix D. Consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP),

DOE/LLNL will reevaluate remediation performance, effectiveness, feasibility, and protectiveness every five years. Based on the outcome of these evaluations, the required level of cleanup, remedial actions, and project life may be redefined.

6.1. Remedial Alternatives for Building 834 (OU 2)

Three remedial alternatives were assembled to address COCs in environmental media in the Building 834 OU. Past spills at release sites at the core of the Building 834 complex have resulted in the contamination of subsurface soil/bedrock and ground water. The COCs in subsurface soil/bedrock are primarily VOCs, predominantly TCE. COCs in ground water include VOCs, TBOS/TKEBS, and nitrate (as NO₃). Ground water contaminants are present in a shallow perched aquifer (Qt-Tpsg).

Dense non-aqueous-phase liquids (DNAPLs) and light non-aqueous-phase liquids (LNAPLs) may be present in ground water. In general, if a ground water VOC concentration is 1 to 10% of the solubility of that VOC in ground water, a DNAPL may be present. Because the aqueous solubility of TCE is 1,100,000 µg/L or greater may indicate DNAPL. TCE concentrations in the range of 11,000 to 110,000 µg/L or greater may indicate DNAPL.

Ground water and soil vapor extraction and treatment have been ongoing since 1995 under an Interim ROD for this OU. Remediation has reduced TCE concentrations from an historical maximum of 800,000 µg/L to 120,000 µg/L in 1998, and TBOS/TKEBS concentrations from 7,300,000 µg/L to 62,000 µg/L in 1998. Nitrate concentrations have decreased from an historical maximum of 480 mg/L to 280 mg/L. No new subsurface soil data are available to determine recent VOC concentrations in soil/bedrock, although soil vapor extraction (SVE) has reduced soil/bedrock mass and concentrations by removing approximately 21.6 kilograms of VOCs from the vadose zone since 1995. Other remedial activities performed at Building 834 include the excavation of VOC-contaminated soil in 1983 and installation of a surface water drainage diversion system in 1998 to prevent rainwater infiltration in the source area.

6.1.1. Alternative 1—No Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all remedial and monitoring activities in the Building 834 complex would cease. There are no costs associated with the no-action alternative.

6.1.2. Alternative 2—Monitoring, Exposure Control, Ground Water and Soil Vapor Extraction and Treatment

The primary components of Alternative 2 are: (1) the monitoring of soil vapor and ground water, (2) risk and hazard management to prevent exposure of humans to COCs and impacts to ecological receptors, and (3) extraction and treatment of ground water and soil vapor at the Building 834 Complex source area to mitigate risk and hazards posed by VOCs in subsurface soil, and to protect and restore beneficial uses of ground water. These components are described in Sections 6.1.2.1 through 6.1.2.3 below.

The present-worth cost of Alternative 2 for the Building 834 OU is \$12,095,000 based on 30 years of monitoring, exposure control, and remediation.

6.1.2.1. Monitoring

Sampling and analysis of soil vapor and ground water from monitor wells in the area would continue in order to monitor COCs in the subsurface. No additional monitor wells would be installed. Monitoring would be conducted to:

1. Track changes in ground water plume concentration and size, and vadose zone concentrations as remediation progresses.
2. Evaluate the effectiveness of the remedial action.
3. Determine when cleanup actions should cease by comparing site data against RAOs, ARARs, and cleanup goals.
4. Indicate and analyze deviations from expected performance.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for the monitoring component of Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the Building 834 OU quarterly for 30 years.

The well-specific ground water monitoring program for the Building 834 OU will be presented in the Site 300 Site-Wide Compliance Monitoring Plan (CMP). Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

6.1.2.2. Exposure Control

As part of Alternative 2, institutional and/or administrative controls and a risk and hazard management program will be implemented to:

1. Ensure RAOs are achieved.
2. Manage risk and/or hazard by preventing exposure to contaminated media.

These controls would provide a degree of protection to human health by restricting access to or activities in areas of contamination, thereby preventing exposure to contaminants.

An inhalation risk of 1×10^{-3} and HI of 36 to adult onsite workers was identified for TCE and PCE volatilizing from subsurface soil to air inside Building 834D, based on conditions before 1991. An inhalation risk of 4.5×10^{-5} and HI of 3.2 for adult onsite workers was identified for TCE and PCE volatilizing from subsurface soil to outside air in the vicinity of Building 834D. SVE has been conducted since 1995 and is included as a component of Alternative 2 to mitigate inhalation risk by reducing VOC concentrations in subsurface soil. In

addition, the risk and hazard management program would include: (1) implementing restrictions for building access and/or construction in the area, (2) analyzing indoor air at Building 834D annually for a minimum of two years, and if air concentrations indicate that the inhalation risk exceeds 10^{-6} or the HI exceeds 1, instituting restrictions for building use or, if building use is again anticipated, installing a building ventilation system and operating it whenever the building is occupied, (3) periodically collecting soil vapor samples, (4) reviewing exposure pathway-related conditions, such as building occupancy and land use, (5) refining risk and hazard models using current data, and (6) reporting the results to the stakeholders.

The combined baseline HI for both the inhalation pathway and the combined oral and inhalation pathways for individual and juvenile ground squirrels and kit foxes exceeded 1 for TCE, PCE, and total VOCs, and for individual adult ground squirrels and kit fox and individual juvenile and adult deer for cadmium. However there is no unacceptable risk to the ground squirrel and deer populations (Webster-Scholten, 1994, and Sections 1.5.3.1 and 1.5.3.2, respectively). As part of the hazard management program to mitigate impacts to the kit fox, biologists will monitor the Building 834 area. Should the kit fox or other fossorial vertebrate species of special concern to wildlife agencies be found in the Building 834 area, DOE will consult with the California Department of Fish and Game to develop response actions, such as animal relocation.

The Site 300 Contingency Plan (CP) will include actions to be implemented in the event the active remedy described below does not achieve RAOs or comply with ARARs. The Site 300 CP will also address situations where the existing access restrictions are removed or relaxed.

6.1.2.3. Ground Water and Soil Vapor Extraction and Treatment

Ground water and soil vapor remediation would be implemented to: (1) reduce soil VOC concentrations in the vadose zone to acceptable risk- and hazard-based concentrations, (2) reduce soil vapor VOC concentrations in the vadose zone to levels protective of ground water, (3) reduce COC concentrations in ground water to meet RAOs and ARARs by reducing contaminant concentration and mass, and to achieve mass removal and plume migration control.

COCs in ground water at the source area include VOCs, TBOS/TKEBS, and nitrate (as NO_3). The primary VOC mass removal mechanism would be by SVE. SVE is an *in situ* process that physically removes contaminants from the vadose zone by inducing air flow through the soil/bedrock. The flowing air strips VOCs from the soil/bedrock and carries them to the extraction wells, and eventually to a treatment system. SVE and treatment would also address residual DNAPLs. SVE has been identified as a technology that can effectively remediate volatile DNAPLs in the unsaturated zone and prevent uncontrolled migration of VOCs in soil gas (U.S. EPA, 1992; 1993).

Ground water extraction wells will be used primarily to dewater the perched water-bearing zone, thereby enhancing remediation by SVE. Soil vapor and ground water would be simultaneously extracted (dual phase extraction) from approximately 25 wells completed in the shallow, perched water-bearing zone (Tps).

This dual-phase extraction is considered a presumptive remedy by EPA for remediation of VOCs and other contaminants in subsurface formations (EPA, 1997a). Dual-phase extraction will be implemented at approximately seventeen wells located in the Building 834 Complex core

area for source area mass removal. Ground water and soil vapor will be extracted from eight additional wells located from 300 to 700 feet downgradient of the Building 834D source area to control plume migration.

All extracted ground water and soil vapor would be treated using the existing treatment systems. VOCs in ground water would be treated using an air stripping unit with aqueous-phase GAC polish. The final component of the treatment train would consist of phytoremediation or other appropriate technology demonstrated to be effective in removing nitrate. Air stripping and GAC are listed by EPA as presumptive technologies for the treatment of dissolved organic contaminants such as VOCs (EPA, 1996). Vapor from the ground water treatment system would be treated using vapor-phase GAC. An oil-water gravity separator would be used to separate TBOS/TKEBS from ground water prior to entering the air sparging system. Treated ground water effluent would be pumped to an effluent storage tank and later discharged on site through an air misting system to a sloped, undeveloped grassy area east of the Building 834 Complex. Air misting would be conducted in a manner to maximize evaporation. The low discharge rate does not create surface flow or attract wildlife. The treated effluent would be discharged in accordance with Substantive Requirements issued by the RWQCB.

Extracted soil vapor would be treated using vapor-phase GAC and discharged to the atmosphere in accordance with the permit requirements issued by the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD).

The spent GAC from the soil vapor and ground water treatment systems would be disposed or regenerated at an offsite treatment facility.

6.1.3. Alternative 3—Monitoring, Exposure Control and Ground Water and Soil Vapor Extraction and Treatment, and Plume Migration Control by Enhanced *In Situ* Bioremediation

Alternative 3 combines the monitoring, exposure control, and ground water and soil vapor remediation described in Alternative 2 with downgradient plume control and mass removal by enhanced *in situ* bioremediation of VOCs. The enhanced *in situ* bioremediation component would consist of injecting a carbon source into approximately 12 injection wells located downgradient of Building 834. Indigenous microorganisms use the carbon as an electron donor and consume available oxygen as an electron acceptor. When dissolved oxygen concentrations decrease to below 2 mg/L, the indigenous denitrifying bacteria begin to use nitrate as an electron acceptor, converting nitrate (NO_3^-) to nitrite (NO_2^-). With a continued supply of an electron donor, the bacteria will further reduce the NO_2^- to innocuous nitrogen gas. Once the available dissolved oxygen and nitrate supplies are exhausted, indigenous bacteria begin the reductive dechlorination of TCE.

As part of Alternative 3, eight of the downgradient wells located 300 to 700 feet downgradient of the Building 834D source area, would be used for both ground water/soil vapor extraction, as well as enhanced *in situ* bioremediation. A suitable carbon source would also be injected in four wells, located at the distal portion of the TCE plume approximately 800 to 1,200 ft from Building 834D, for additional plume migration control.

The present-worth cost of Alternative 3 for the Building 834 OU is \$14,504,000 based on 30 years of monitoring, exposure control and remediation.

6.2. Remedial Alternatives for the Pit 6 Landfill (OU 3)

Three remedial alternatives were assembled to address COCs in environmental media in the Pit 6 Landfill OU. From 1964 to 1973, approximately 1,900 cubic yards of waste was buried in nine unlined debris trenches and animal pits at the landfill resulting in the contamination of surface water and ground water. The material buried included laboratory and shop debris, and biomedical waste. The COCs in surface water include VOCs, primarily TCE. COCs in ground water include VOCs (primarily TCE), tritium, and perchlorate. Contaminants in ground water are restricted to the uppermost section (Qt and Tnbs₁) of the Qt-Tmss hydrogeologic unit. No contaminants have been detected in ground water samples from the Qal-Tts hydrogeologic unit south of the Holocene fault strand located approximately 150 ft south of the landfill.

VOC concentrations in ground water have naturally attenuated by almost two orders of magnitude over the past several years, and are close to or below MCLs in all wells. VOC concentrations in ground water have declined from an historical maximum TCE at 250 µg/L in 1988 to 15 µg/L in 1998. TCE concentrations in ground water samples collected in 1999 have all been below 10 µg/L. Concentration plots of TCE versus 1,2-DCE concentrations indicate that TCE is degrading naturally.

Activities of tritium are above background in ground water samples from four wells indicating a localized release from shipment cell 55. This release may be the result of rainwater infiltration through areas of subsidence in the landfill prior to installation of the pit cap. The maximum tritium activity detected in ground water (2,460 pCi/L) is an order of magnitude below the State MCL of 20,000 pCi/L. No evidence of anthropogenic releases of other radioactive contaminants has been detected in soil or ground water samples collected during environmental investigations. Perchlorate has been detected in ground water at 47.2 µg/L in one well. Nitrate (as NO₃) has also recently been detected in ground water at a concentration of 228 mg/L.

In 1988, shallow subsurface water samples collected from the Spring 7 area contained TCE at 110 µg/L, but by 1998 had dropped to 0.77 µg/L. All other VOCs were below the analytical method detection limit in 1998. No contaminants other than VOCs have been detected at Spring 7.

A landfill cap was installed as a CERCLA removal action in 1997 to prevent infiltrating precipitation from further leaching contaminants from the buried waste. Other remedial activities performed at the Pit 6 landfill include removal of waste contaminated with uranium-238 in 1971.

6.2.1. Alternative 1—No Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, no remedial activities in the Pit 6 Landfill OU would occur. There are no costs associated with the no-action alternative.

6.2.2. Alternative 2—Monitoring, Exposure Control, and Monitored Natural Attenuation

The primary components of Alternative 2 are (1) monitoring of ground water and surface water, (2) risk and hazard management to prevent exposure of humans to COCs and impacts to ecological receptors, and (3) monitored natural attenuation of VOCs and tritium in ground water. These components are described in Sections 6.2.2.1 through 6.2.2.3 below.

The present-worth cost of Alternative 2 for the Pit 6 Landfill OU is \$2,377,000 based on 30 years of monitoring, exposure control and monitored natural attenuation.

6.2.2.1. Monitoring

Sampling and analysis of ground water from monitor wells in the area would continue in order to monitor COCs in the subsurface. No additional monitor wells would be installed. Monitoring would be conducted to:

1. Track changes in plume concentration and size to ensure there is no impact to downgradient receptors.
 2. Identify any potentially toxic transformation products resulting from biodegradation.
3. Evaluate the effectiveness of the natural attenuation of contaminants in ground water to meet RAOs, ARARs and cleanup goals.
 4. Verify attainment of cleanup goals.
 5. Indicate and analyze deviations from expected rates of natural attenuation of contaminants.
 6. Monitor perchlorate and nitrate (as NO₃) to understand their sources, determine their extent, time concentration trends, and potential future risks, and recommend future actions.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for the monitoring component of Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the Pit 6 Landfill OU quarterly for 30 years.

The well-specific ground water monitoring program for the Pit 6 Landfill OU will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

In addition, a Detection Monitoring Program is currently in place as part of the Post-Closure Monitoring Plan for the Pit 6 Landfill. This program is designed to detect any new releases from the Pit 6 Landfill. The data collected as part of the Detection Monitoring Program would be

evaluated to determine potential impacts to the effectiveness of the natural attenuation remedy should new releases be detected, and to evaluate the need for additional remedial measures.

As ground water monitoring data for perchlorate and nitrate are limited and they have been detected in only one well each to date, DOE/LLNL would continue to monitor perchlorate and nitrate in ground water to determine if and when an active remedy for these COCs might be necessary.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

6.2.2.2. Exposure Control

As part of Alternative 2, institutional and/or administrative controls and a risk and hazard management program would be implemented to:

1. Ensure RAOs are achieved.
2. Manage risk and/or hazard by preventing exposure to contaminated media.

These controls provide a degree of protection to human health by restricting access to or activities in areas of contamination, thereby preventing exposure to contaminants.

In the baseline risk assessment, an inhalation risk of 4×10^{-5} and HI of 1.5 to adult onsite workers was identified for VOCs volatilizing from surface water at Spring 7 to ambient air. These risk and hazard levels were based on an exposure to maximum historical concentrations of VOCs detected at Spring 7 (e.g., TCE at 110 $\mu\text{g/L}$). However, in 1998, only TCE was detected at Spring 7, at 0.77 $\mu\text{g/L}$. As a result, risk and hazard management measures are not necessary at this time to prevent inhalation exposure to contaminants from Spring 7. Monitoring of shallow subsurface water would continue to monitor VOC concentrations at Spring 7. Risk and hazard management measures would be implemented if exposure risk or hazard becomes a problem in the future.

Similarly, in the baseline risk assessment, an inhalation risk of 3×10^{-6} (with a HI less than 1) to commercial users, was identified for VOCs volatilizing from surface water at the SVRA residence pond. This risk level was based on an exposure to predicted future maximum concentrations of VOCs migrating to the well that could be used to fill the pond (CARNRW2), from the area upgradient, where TCE had been reported at 110 $\mu\text{g/L}$. However, no VOCs have been detected in the well (or the pond). Furthermore, the upgradient concentrations have diminished by over a factor of 10, reducing the potential for future migration of VOCs to the well or pond. As a result, risk and hazard management measures are not necessary at this time to prevent inhalation exposure to contaminants from the SVRA residence pond. Monitoring of shallow sub-surface water would continue to monitor well CARNRW2 for VOCs. Risk and hazard management measures would be implemented if exposure risk or hazard becomes a problem in the future.

The baseline risk assessment also identified an inhalation risk of 5×10^{-5} for adult onsite workers for VOCs volatilizing from subsurface soil to outside air in the vicinity of Pit 6 Landfill.

The landfill cap installed in 1997 prevents exposure to VOCs that may volatilize from the materials buried in the landfill.

The risk and hazard management program will include: (1) implementing restrictions for construction in the area, (2) reviewing exposure pathway-related conditions, such as facility and land use, (3) refining risk and hazard models using current data, and (4) reporting the results to the stakeholders.

The combined baseline HI for inhalation and combined oral and inhalation pathways for individual juvenile ground squirrels and kit foxes exceeded 1 for TCE, PCE, and total VOCs, and for individual adult ground squirrels and kit fox for total VOCs. However there is no unacceptable risk to the ground squirrel population (Webster-Scholten, 1994, and Section 1.5.3.1). An engineered layer installed as part of the landfill cap was designed to prevent animals from burrowing through the landfill cap, thus preventing exposure of ground squirrels and kit foxes to contaminants in the pit. In addition, as part of the hazard management program to mitigate impacts to the kit fox, biologists will monitor the Pit 6 Land area. Should the kit fox or other fossorial vertebrate species of special concern to wildlife agencies be found in the Pit 6 Landfill area, DOE will consult with the California Department of Fish and Game to develop response actions, such as animal relocation.

The Site 300 CP will include actions to be implemented in the event that monitored natural attenuation described below does not achieve RAOs or comply with ARARs. The Site 300 CP will also address situations where the existing access restrictions are removed or relaxed.

6.2.2.3. Monitored Natural Attenuation of VOCs and Tritium in Ground Water

Alternative 2 includes utilizing natural attenuation to reduce VOC concentrations and tritium activities in ground water to meet RAOs and ARARs. EPA defines natural attenuation as “the naturally occurring process in soil and groundwaters that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media.” Contaminant concentrations may naturally attenuate *in situ* through the processes of degradation or decay, dispersion, dilution, sorption, precipitation, volatilization, and/or chemical and biochemical stabilization of contaminants (EPA, 1997b). Natural attenuation may be demonstrated through a variety of lines of evidence, including static or retreating plume concentration contours, the presence of contaminant breakdown products, or the formation or depletion of geochemical indicator compounds.

Ground water data from monitor wells in the Pit 6 OU indicate that TCE and other VOCs are naturally attenuating as demonstrated by the steady decline in VOC concentrations over time. Analytic data also indicate that TCE is degrading to 1,2-DCE in ground water in the Pit 6 area.

Tritium has a known decay half-life of 12.3 years. Tritium activities are fluctuating in ground water monitor wells in the Pit 6 area. There is not enough data to determine if this is a long-term decreasing trend. Monitoring of tritium in ground water will continue to determine long-term activity trends. The maximum activity of tritium detected in ground water to date in the Pit 6 Landfill area is 2,460 pCi/L; well below the State MCL for tritium (20,000 pCi/L).

Perchlorate and nitrate (as NO₃) have recently been detected in the Pit 6 Landfill area. However, data are not yet sufficient to understand the extent, source, or concentration trends of

these contaminants. Increased monitoring and analyses for these constituents have been instituted. As part of the contingency plan, criteria will be established and contingent remedies will be described.

In the EPA's Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17 (1997b), the EPA suggests that:

1. Source control actions should use engineering controls, such as containment, for source waste that pose a relatively low, long-term threat or where treatment is impracticable.
2. Contaminated ground waters should be returned to their beneficial uses where practicable, within a time frame that is reasonable given the particular circumstances of the site.

Source control measures have been implemented at the Pit 6 Landfill through the installation of the landfill cap in 1997. VOC concentrations have continued to decrease and are near or below MCLs in ground water in all wells in the Pit 6 area. The presence of cis-1,2-DCE, a breakdown product of TCE (Howard et al., 1987; Buchanan, 1996), further indicates that biodegradation is occurring. The observed decreases in TCE concentrations suggest that the beneficial uses of ground water should be restored through the natural attenuation of TCE in a reasonable timeframe.

Similarly, given that tritium activities in ground water in the vicinity of the Pit 6 Landfill appear to be generally decreasing, relatively low activities are detected, and the 12.3 year tritium half-life, natural attenuation of tritium appears to be an effective mechanism to restore beneficial ground water use in a reasonable timeframe.

The following activities would be conducted to monitor the effectiveness of monitored natural attenuation:

1. Measure ground water levels.
2. Perform ground water and surface sampling and analysis.
3. Manage, analyze, and present data.
4. Perform fate and transport modeling to predict the spatial distribution of contaminants of concern over time and demonstrate the efficacy of monitored natural attenuation in meeting RAOs and ARARs. If modeling does not support MNA, alternate remedies will be proposed.
5. Install additional monitoring wells, if required.

6.2.3. Alternative 3—Monitoring, Exposure Control, Monitored Natural Attenuation of Tritium in Ground Water, and Extraction and Treatment of VOCs and Perchlorate in Ground Water

Alternative 3 combines the ground water monitoring, exposure control, and monitored natural attenuation of tritium in ground water described in Alternative 2 and adds the extraction and treatment of VOCs and perchlorate in ground water.

The ground water extraction and treatment component of this alternative includes extracting ground water from wells located downgradient (east-southeast) of the Pit 6 Landfill. TCE and

perchlorate in extracted ground water would be treated using aqueous-phase GAC. A fixed-film bioreactor will be added to the treatment system if necessary to reduce perchlorate concentrations to meet discharge requirements. As there is currently no viable technology available for the treatment of tritiated ground water, the treated water containing only tritium would be re-injected. Safety precautions would need to be implemented to prevent exposure to tritium during the extraction and re-injection process. The location of injection wells would be discussed with the regulatory agencies when the remedial design for the relevant OU is prepared.

The efficacy of this remedial strategy would depend on the volume and tritium activities in the water to be re-injected. Modeling would need to be conducted prior to implementation of this type of remedial action to ensure that re-injection would not result in further mobilization of the tritium plume. If the modeling results indicate that the re-injection of even limited volumes of water could potentially result in the further spread of the tritium plume, the implementability of this remedial strategy may be limited.

Treated ground water effluent would be discharged onsite under Waste Discharge Requirements issued by the RWQCB. The spent GAC will be disposed or regenerated at an offsite treatment facility.

The present-worth cost of Alternative 3 for the Pit 6 Landfill OU is \$5,939,000 based on 30 years of monitoring, exposure control, monitored natural attenuation, and ground water extraction and treatment.

6.3. Remedial Alternatives for the HE Process Area (OU 4)

Surface spills at the drum storage and dispensing area for the former Building 815 steam plant resulted in the release of TCE and other VOCs to the vadose zone and ground water. Other COCs in ground water include HE compounds, nitrate (as NO_3), and perchlorate. The presence of these contaminants is likely the result of wastewater discharges to former unlined rinsewater lagoons. HE compounds have also been detected in surface soil and the vadose zone. In addition, VOCs, nitrate (as NO_3), and perchlorate have been detected in ground water in the vicinity of the former HE Burn Pits.

Contaminants in ground water in the vicinity of Building 815 have been detected in the clays and silts of the Tps unit and in shallow Tnbs_2 and Tnsc_1 bedrock. VOC concentrations in ground water in the Building 815 area have decreased over time, with TCE decreasing from an historical maximum of 450 $\mu\text{g/L}$ to 330 $\mu\text{g/L}$ in 1998. Other VOCs have shown a similar decrease with most VOC concentrations below the analytical method detection limit, and are all below their MCL and (Water Quality Objective) WQO. Plume migration control measures were implemented at the site boundary as a CERCLA Removal Action in June 1999 to prevent offsite migration of the TCE plume emanating from Building 815.

Ground water contamination in the vicinity of the HE rinsewater lagoons has been detected in the Tps and shallow Tnbs_2 bedrock. In the HE lagoon area, RDX, 4-amino-2,6-dinitrotoluene, and nitrate have shown steady decreasing concentration trends in ground water. HMX concentrations in ground water fluctuate but show a generally decreasing trend. Excavation and capping of these lagoons, completed in 1989, should prevent further releases of VOCs, HE compounds and associated constituents (nitrate and perchlorate).

TCE and cis-1,2-DCE, nitrate, and perchlorate have been detected in ground water in the Tnsc₁ bedrock in the vicinity of the HE Burn Pit. The HE Burn Pit area is isolated from other contaminated areas in the HE Process Area, and the affected water-bearing zone may daylight without providing a pathway outside the immediate area. Soil analytic data indicate that low levels of HE compounds are present in the upper 10 ft in the vicinity of the burn pits, and trace concentrations of VOCs are present. The HE Burn Pits were capped and closed under RCRA in 1998.

In 1987, samples collected from well W-817-03A, screened 5 to 10 ft below ground surface adjacent to Spring 5, contained TCE at 150 µg/L. A 1998 analysis indicated a TCE concentration of 120 µg/L. No contaminants other than VOCs have been detected in well W-817-03A. The VOCs are believed to have migrated downgradient in the Tps water-bearing unit from Building 815, and discharged at well W-817-03A/Spring 5. The well and spring are located approximately 800 ft south of Building 815.

6.3.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all remedial and monitoring activities in the HE Process Area OU would cease. There are no costs with the no-action alternative.

6.3.2. Alternative 2—No Further Action for VOCs and HE Compounds in Soil and Rock, Monitoring, Exposure Control, Ground Water Extraction and Treatment

The primary components of Alternative 2 are:

1. No further action for VOCs in subsurface soil/rock at the HE rinsewater lagoon release sites, and VOCs and HMX/RDX in subsurface soil/rock at the HE burn pit release sites.
2. Monitoring of ground water and surface water for COCs.
3. Risk and hazard management to prevent exposure of humans and impacts to ecological receptors to COCs.
4. Contaminant migration control by ground water extraction and treatment of VOCs and nitrate at the leading edge of the Building 815 TCE plume.
5. Plume migration control through ground water extraction and treatment of VOCs, HE compounds, nitrate, and perchlorate released from Building 815 and the HE rinsewater lagoons.
6. Plume migration control through ground water extraction and treatment of VOCs, nitrate, and perchlorate released from the HE Burn Pits.

These components are described in Sections 6.3.2.1 through 6.3.2.6 below.

Ground water extraction and treatment of contaminated ground water is proposed in this alternative to control the migration of contaminant plumes originating from source areas in the HE Process Area OU. Ground water extraction has proven to be an effective method for plume migration control in a Removal Action for this OU and at several other OU source areas at

Site 300, such as the GSA and Building 834 OUs. In these areas, ground water is being extracted from the same or similar hydrogeologic units in which contaminants are present at and downgradient from the Building 815, HE rinsewater lagoons, and HE Burn Pit source areas. Presumptive technologies are proposed for the treatment of VOC-contaminated ground water extracted from these source areas as described in Sections 6.3.2.4, 6.3.2.5, and 6.3.2.6 below. Due to the demonstrated success of pump-and-treat remedial measures at this and other OUs at Site 300, ground water extraction and treatment may be the most effective method of remediating contaminated ground water in the HE Process Area OU at this time. DOE/LLNL will continue to evaluate innovative technologies that may allow faster and more cost-effective cleanup.

The present-worth cost of Alternative 2 for the HE Process Area OU is \$27,621,000 based on 30 years of monitoring, exposure control, and ground water remediation.

6.3.2.1. No Further Action for VOCs in Subsurface Soil/rock at the HE Rinsewater Lagoon Release Sites, and VOCs and HMX/RDX in Subsurface Soil/rock at the HE Burn Pit Release Sites

TCE has been detected at relatively low concentrations (historical maximum of 7 mg/kg at 15 ft in 1986) in subsurface soil/bedrock in the vicinity of the HE rinsewater lagoons. However, the HE rinsewater lagoons were excavated and capped in 1989, which should prevent further releases of VOCs to ground water by preventing the infiltration of precipitation into the former lagoons. There is no risk to human health or ecological receptors associated with VOCs in subsurface soil/bedrock at the HE rinsewater lagoons. VOCs in ground water underlying the rinsewater lagoons are addressed through ground water extraction as described in Section 6.3.2.5.

TCE, HMX, and RDX have been detected in subsurface soil/bedrock in the vicinity of the HE Burn Pits at historical maximum concentrations of 0.028, 3.12, and 0.9 mg/kg, respectively. HMX and RDX have also been detected in surface soil at concentrations of 4.0 and 0.18 mg/kg, respectively. The HE Burn Pits were capped and closed under RCRA in 1998 which should prevent further releases of contaminants to ground water by preventing the infiltration of precipitation into the burn pits. There is no risk to human health or ecological receptors associated with VOCs in subsurface soil/bedrock or HMX and RDX in surface or subsurface soil/bedrock at the HE Burn Pits. HMX and RDX have not been identified as COCs in ground water underlying the Burn Pits.

We performed one-dimensional transport modeling to determine the potential impact of HMX in the vadose zone on ground water. The highest concentrations of HMX in soil (28 mg/kg) were detected in the vicinity of the HE Burn Pits. The HE Burn Pit area also has the shallowest depth to ground water and the most conductive soil profile in the HE Process area. The modeling results indicated that HMX could reach ground water at a maximum concentration of 580 µg/L in about 500 years. The PRG for HMX in ground water is 1,800 µg/L. These modeling results are conservative as the results are heavily influenced by one data point (28 mg/kg HMX in borehole 829-15). Soil samples from other boreholes contained much lower HMX concentrations of about 1 mg/kg or less.

No further action is proposed for these COCs in surface soil and subsurface soil/bedrock because: (1) source control measures have already been implemented to prevent further impact to ground water, (2) there is no risk or hazard to human health or ecological receptors posed by these contaminants, and (3) ground water COC contamination is addressed through ground water extraction and treatment actions described in Sections 6.3.2.5 and 6.2.3.6.

6.3.2.2. Monitoring

Sampling and analysis of ground water from monitor wells in the area would continue in order to monitor COCs in the subsurface. No additional monitor wells would be installed. Monitoring would be conducted to:

1. Track changes in plume concentration and size as remediation progresses.
2. Evaluate the effectiveness of the remedial action.
3. Determine when cleanup actions should cease by comparing site data to RAOs, ARARs and cleanup goals.
4. Indicate and analyze deviations from expected performance.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the HE Process Area OU quarterly for 30 years.

The well-specific ground water monitoring program for the HE Process Area OU will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

In addition, surface water monitoring will be conducted to determine contaminant concentrations and trends in Spring 5 through sampling of well W-817-03A.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

6.3.2.3. Exposure Control

As part of Alternative 2, institutional and/or administrative controls and a risk and hazard management program will be implemented to:

1. Ensure RAOs are achieved.
2. Manage risk and/or hazard by preventing exposure to contaminated media.

These controls provide a degree of protection to human health by restricting access to, or activities in, areas of contamination, thereby preventing exposure to contaminants.

In the baseline risk assessment, an inhalation risk of 1×10^{-5} to adult onsite workers was identified for VOCs volatilizing from surface water at Spring 5 to ambient air. The risk level was calculated from maximum historical concentrations of VOCs detected in well W-817-03A, which is located adjacent to Spring 5 (i.e., TCE at 150 $\mu\text{g/L}$). The actual flow in Spring 5 is too low to measure and the "spring" consists of moist soil with wetland vegetation. The assumption was made for risk assessment purposes that the same water-bearing unit (Tps) in which well W-817-03A is completed, also feeds Spring 5, and that Spring 5 contained similar concentrations of TCE as well W-817-03A. Since no actual standing surface water exists at Spring 5, the calculated risk levels are extremely conservative. As a result, risk and hazard management measures are not necessary at this time to prevent inhalation exposure to contaminants in Spring 5. Well W-817-03A will continue to be sampled to monitor VOC concentrations, and Spring 5 will be surveyed periodically for standing water. Risk and hazard management measures will be implemented if exposure risk or hazard becomes a problem in the future.

An inhalation risk of 1.4×10^{-5} for adult onsite workers was calculated for VOCs volatilizing from subsurface soil to outside air in the vicinity of Building 815. The maximum historical concentration of VOCs detected in subsurface soil is 33 mg/kg in 1987. VOCs were detected in five boreholes in this area at concentrations ranging from 0.0003 mg/kg to 33 mg/kg. No VOCs were detected in soil samples from the other seven boreholes drilled in the area. An active remedy, such as SVE and treatment, generally is not warranted or very effective when VOC concentrations are very low.

The risk and hazard management program will include (1) implementing restrictions for construction in the Building 815 area, (2) reviewing exposure pathway-related conditions, such as building and land use, (3) refining risk and hazard models using current data, and (4) reporting the results to the stakeholders.

The HI for combined oral and inhalation for individual adult ground squirrels, and for individual adult and juvenile deer exceeds 1 for cadmium, and for the sum of all metals. However, there is no unacceptable risk to the ground squirrel and deer populations (Webster-Scholten, 1994, and Sections 1.5.3.1 and 1.5.3.2, respectively).

The Site 300 CP will include actions to be implemented in the event that active remediation described below does not achieve RAOs or comply with ARARs. The Site 300 CP will also address situations where the existing access restrictions are removed or relaxed.

6.3.2.4. Ground Water Extraction and Treatment of VOCs and Nitrate at the Leading Edge of the Building 815 TCE Plume

Ground water extraction and treatment was implemented at the leading edge of the Building 815 TCE plume in June 1999 as part of the Building 815 Removal Action. The objective of this removal action was to prevent ground water in the Tnbs₂ aquifer containing VOCs from migrating offsite. This will be accomplished by pumping and treating ground water from well W-35C-04 located near the Site 300 boundary. The ground water treatment system consists of aqueous-phase GAC contained in a Solar-powered Water Activated Carbon Treatment (SWAT) unit. GAC is considered to be a presumptive technology for the treatment of VOCs in ground water (EPA, 1996). Ground water pumped from this well currently contains only low concentrations (2 to 5 $\mu\text{g/L}$) of TCE. Samples are also analyzed for nitrate (as NO_3). If nitrate is detected above background concentrations in extracted ground water in the future, additional

treatment may be necessary. Treated ground water effluent is discharged onsite under Waste Discharge Requirements issued by the RWQCB. The spent GAC will be disposed or regenerated at an offsite treatment facility.

As part of Alternative 2, ground water extraction at the leading edge of the Building 815 TCE plume would continue, and a second ground water extraction well near in this area would be employed. The purpose of this extraction well would be to ensure capture of any potential off-site flow of contaminants.

6.3.2.5. Ground Water Extraction and Treatment of VOCs, HE Compounds, Nitrate, and Perchlorate Released from Building 815 and the HE Rinsewater Lagoons

Ground water remediation would be implemented at the Building 815 and HE rinsewater lagoons source areas to reduce COC concentrations in ground water to meet RAOs and ARARs by reducing contaminant concentrations and mass, and to achieve source control. A ground water extraction and treatment system in the Building 815 source area is scheduled for installation by September 29, 2000. The purpose of this unit would be to reduce the mass of contaminants near the source.

COCs in ground water at the Building 815 source area include VOCs, RDX, perchlorate, nitrate (as NO_3), and carbon disulfide. Ground water would be extracted from wells completed in the Tnbs₂ and Tps hydrogeologic units in the vicinity of Building 815. Extracted ground water would be treated using aqueous-phase GAC contained in a SWAT unit. GAC is considered to be a presumptive technology for the treatment of VOCs in ground water (EPA, 1996). Carbon disulfide concentrations in ground water in this area are currently (1998) below method detection limits.

COCs in ground water at the HE rinsewater lagoon source areas include HE compounds, nitrate (as NO_3), and perchlorate. Ground water would be extracted from wells completed in the Tnbs₂ and Tps hydrogeologic units in the vicinity of the HE rinsewater lagoon source areas. Extracted ground water would be treated using aqueous-phase GAC contained in a SWAT unit. A treatability test conducted on well W-817-03A in the HE Process area indicated that GAC effectively removes HE compounds and perchlorate from ground water to levels below method detection limits. Nitrate in ground water would be treated through phytoremediation, by a fixed-film bioreactor, or through the use of other technologies demonstrated to effectively remove nitrate. Treated ground water effluent would be discharged onsite under Waste Discharge Requirements issued by the RWQCB. The spent GAC would be disposed or regenerated at an offsite treatment facility.

6.3.2.6. Ground Water Extraction and Treatment of VOCs, Nitrate, and Perchlorate Released from the HE Burn Pits

Ground water remediation would be implemented at the HE Burn Pit source area to reduce COC concentrations in ground water to meet RAOs and ARARs by reducing contaminant concentrations and mass to achieve source control.

COCs in ground water at the HE Burn Pit source area include VOCs, nitrate (as NO_3), and perchlorate. Ground water would be extracted from wells completed in the Tnsc₁ hydrogeologic

unit in the vicinity of HE Burn Pit source area. Extracted ground water would be treated by aqueous-phase GAC and a fixed film bioreactor contained in a SWAT unit. GAC is considered to be a presumptive technology for the treatment of VOCs in ground water (EPA, 1996). Treatability tests indicate that GAC effectively removes perchlorate from ground water to levels below method detection limits. Nitrate in ground water would be treated by a fixed-film bioreactor, or through the use of other technologies demonstrated to effectively remove nitrate. Treated ground water effluent would be discharged onsite under Waste Discharge Requirements issued by the RWQCB. The spent GAC will be disposed or regenerated at an offsite treatment facility.

6.4. Remedial Alternatives for Building 850/Pits 3 & 5 (OU 5)

Because of the spatial separation of release sites within the Building 850/Pits 3 & 5 OU, it has been divided into three subareas. These subareas are:

1. The Pit 7 Complex, including the Pits 3, 4, 5, and 7 Landfills.
2. Building 850.
3. The Pit 2 Landfill.

Separate sets of alternatives assembled to address release sites and associated subsurface contaminants in each of these subareas are presented below.

6.4.1. Remedial Alternatives for the Pit 7 Complex Subarea, Including the Pits 3, 4, 5, and 7 Landfills

Three remedial alternatives were assembled to address COCs in surface soil, subsurface soil/rock and ground water in the Pit 7 Complex subarea.

The Pit 7 Complex consists of a group of four landfills, Pits 3, 4, 5, and 7, which were used in the past to dispose firing table debris and gravel. LLNL constructed the pits by excavating topsoil and alluvial material to an average depth of 10 to 12 ft (Taffet et al., 1989). LLNL used these landfills to dispose of firing table debris and gravel between 1958 and 1988. The majority of the waste material in the pits came from the firing tables at Buildings 850 and 851, and included wood; plastic; material and debris from tent structures; pea gravel; exploded test assemblies; remnants of capacitor banks; generators; and other testing material (Taffet et al., 1989; Simmons, 1992). About 99% of the tritium shipped to Site 300 was used at Buildings 850 (95%) and 851 (4%), so the debris placed in these pits contains the majority of tritium residue at Site 300 (Buddemeier, 1985).

The Pit 3 Landfill was used from 1958 until 1967 and contains approximately 26,220 yd³ of material contained in a 6,200 yd² area (Lindeken and Hieb, 1988). The Pit 4 Landfill contains approximately 2,800 yd³ of waste material in a 855 yd² area and was used from 1968 until 1979. The Pit 5 Landfill was used from 1968 until 1979 and contains approximately 29,910 yd³ of waste material in a 9,100 yd² area. The "panhandle" in the southern part of Pit 5 was originally planned to be part of the pit, but interviews with Site 300 employees suggest that this section of the pit was never actually excavated (Simmons, 1992). LLNL opened the Pit 7 Landfill in 1978 and ceased depositing waste in it in 1988. The area and volume of pit 7 are approximately

6,250 yd² and 31,100 yd³, respectively. The Pit 4 and 7 Landfills were capped and closed in 1992 in compliance with RCRA requirements. The cap design is intended to prevent erosion, shallow subsurface interflows, precipitation infiltration, and mobilization of contaminants in Pits 4 and 7. Ground water contamination associated with previous releases from Pit 7 is addressed in the remedial alternatives.

Leaching from these unlined landfills resulted in the release of contaminants to the subsurface. Contaminants in ground water in the vicinity of and downgradient from the pits have been detected in the shallow alluvium (Qal) and underlying bedrock (Tnbs₁). TCE and 1,1-DCE have been detected in ground water downgradient of the Pit 5 Landfill. VOC concentrations in the vicinity of Pit 5 have shown a declining trend, with TCE decreasing from an historical maximum of 15 µg/L to 3.5 µg/L in 1998. Uranium-238 has been identified in ground water downgradient of Pits 3 and 7. The maximum activities of tritium in ground water near Pits 3 and 5 were detected in 1998 indicating continued releases of tritium from these pits. Although elevated tritium activity was detected in shallow soil between Pit 3 and Pit 4, tritium has not been detected at elevated levels in ground water from wells directly downgradient of Pit 4. Nitrate (as NO₃) and perchlorate have also been detected in ground water downgradient of the Pit 7 Complex.

Tritium and uranium-238 have also been identified as COCs in surface soil and subsurface soil/bedrock in the vicinity of the Pit 7 Complex.

6.4.1.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all monitoring activities in the Pit 7 Complex subarea would cease. There are no costs associated with the no-action alternative.

6.4.1.2. Alternative 2—No Further Action for Tritium and Uranium-238 in Surface Soil outside of Pits 3 and 5, Monitoring, Exposure Control, Monitored Natural Attenuation of Tritium and Uranium in Ground Water, Waste Characterization with Contingent Monitoring, Capping, and/or Excavation, and Optional Plume Migration Control

Two options are presented within this Alternative; 2a and 2b. The primary components of Alternative 2a include:

1. No further action for tritium and uranium-238 in surface soil at Pits 3 and 5
2. Monitoring of ground water for COCs.
3. Risk and hazard management to prevent exposure of humans and ecological receptors to COCs.
4. Monitored natural attenuation of tritium and uranium-238 in ground water.
5. Characterization of waste in Pits 3 and 5 with contingent monitoring, capping and/or excavation.

The second option, Alternative 2b, includes all of the components of 2a. In addition, plume migration control is added by installing a subsurface reactive barrier to remove uranium from ground water.

These components are described in Sections 6.4.1.2.1 through 6.4.1.2.6 below.

The present-worth cost of Alternative 2a for the Pit 7 Complex subarea ranges from \$3,186,000 to \$50,282,000 depending on the amount of excavation at Pits 3 and 5, based on 30 years of monitoring, exposure control, monitored natural attenuation. The present-worth cost of Alternative 2b ranges from \$7,530,000 to \$54,623,000.

6.4.1.2.1. No Further Action for Tritium and Uranium-238 in Surface Soil Outside Pits 3 and 5. Tritium has been identified in surface soil in the vicinity of Pits 3 and 5 at a maximum activity of 18,100 pCi/Lsm. Uranium-238 was also detected in surface soil in this area at a maximum historical activity of 24 pCi/g. However, the samples in which these values were detected were collected from the edge of the pits. This area of surface soil contamination would be addressed in the waste characterization with contingent excavation module described in Section 6.4.1.2.5. Outside of the immediate pit areas, activities of tritium (up to 310 pCi/Lsm) and uranium (up to 0.9 +/-0.2 pCi/g) have been detected in surface soil at or near background levels.

No human health risk greater than 10^{-6} , HI greater than 1 or ecological HI greater than 1 has been identified for these contaminants in surface soil.

No further action is proposed for tritium and uranium-238 in surface soil outside of Pits 3 and 5 because:

1. There is no risk or hazard to human or ecological receptors posed by these contaminants in surface soil,
2. Surface soil with elevated tritium and uranium-238 activities are located on the pit edge and would be addressed in the waste characterization with contingent capping or excavation module,
3. The activities of tritium and uranium that have been detected in surface soil outside the immediate pit area are within background levels,
4. Tritium and uranium contamination in ground water is addressed through other remedial measures, and
5. Data indicate that the primary release mechanism for tritium and uranium-238 to ground water is through inundation of the pit waste.

6.4.1.2.2. Monitoring. Sampling and analysis of ground water from monitor wells in the area would continue in order to monitor COCs in the subsurface. Additional monitor wells would be installed, if necessary, to monitor the effectiveness of the remedial action in meeting RAOs and ARARs.

Monitoring would be conducted to:

1. Track changes in plume concentration and size that results from remediation and to ensure there is no impact to downgradient receptors.
2. Evaluate the effectiveness of the remedial action.

Evaluate the effectiveness of source control measures and the natural attenuation of contaminants in ground water to meet ARARs and cleanup goals.

Verify the attainment of cleanup goals.

Indicate and analyze deviations from expected rates of natural attenuation of contaminants.

The maximum TCE concentrations in ground water in the Pits 3 and 5 area are declining, from an historical maximum of 15 µg/L to 3.5 µg/L (below the MCL) in 1998. Nitrate (as NO₃) has also been found at greater than the MCL, while perchlorate has been detected at a maximum concentration of 8.7 µg/L (below the State Action Limit). Monitoring would be conducted for VOCs, nitrate (as NO₃), and perchlorate in ground water to assess potential migration, changes in concentrations, and assess human or ecological impacts while source control measures prevent further releases.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the Pit 7 Complex subarea quarterly for 30 years.

In addition to the ground water COC monitoring to be conducted in the Pit 7 Complex subarea, ground water in the vicinity of the Pit 1 Landfill will also be monitored for perchlorate. Although this pit is not technically or geographically part of the Pit 7 Complex, perchlorate was recently (1998) detected in ground water in the vicinity of Pit 1 at a concentration of 6.4 µg/L. As the data are currently limited and the concentrations are well below Action Levels for perchlorate, monitoring for perchlorate in ground water in the vicinity of the Pit 1 Landfill would be conducted to determine if this contaminant has significantly impacted ground water.

Only one well near Pits 3 and 5 Complex registered a nitrate concentration above the MCL in 1998. This well, K7-01, had a 1998 maximum of 49 mg/L, down from a historic maximum of 195 mg/L. Two other wells nominally assigned to the Pit 7 Complex, NC7-47 and NC7-50, have nitrate above the MCL, but these wells are located far to the northeast, are unaffected by releases from the Pits, and nitrate may be natural.

The well-specific ground water monitoring program for the Pit 7 Complex subarea will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be reviewed regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

6.4.1.2.3. Exposure Control. As part of Alternative 2, institutional and/or administrative controls and a risk and hazard management program will be implemented to:

1. Ensure RAOs are achieved.

2. Manage risk and/or hazard by preventing exposure to contaminated media.

These controls provide a degree of protection to human health by restricting access to or activities in areas of contamination, thereby preventing exposure to contaminants.

In the baseline risk assessment, an inhalation risk of 4×10^{-6} to adult onsite workers was identified for tritium evaporating from subsurface soil to the ambient air in the vicinity of the Pit 3 Landfill. There are currently no active facilities located in the vicinity and the landfill was closed to use in 1967. Since there are no manned facilities in this area, there is no exposure pathway for tritium volatilizing from subsurface soil into air to affect workers. In addition, in 1992, a landfill cover was installed on Pit 7 which is adjacent to Pit 3. Approximately 40% of the Pit 3 landfill was covered during the capping of Pit 7. Exposure control measures would be implemented in the area to prevent inhalation risk in the event that land usage changes occur in the vicinity of Pit 3 that would result in exposure to onsite workers.

The risk and hazard management program will include: (1) implementing restrictions for construction in the Pit 7 complex area, (2) sampling outdoor air annually (or until two successive years indicate no risk) for tritium near Pit 3, (3) reviewing exposure pathway-related conditions, such as facility and land use, (4) refining risk and hazard models using current data, and (5) reporting the results to the stakeholders.

There is no unacceptable risk of exposure to contaminants in any media in the vicinity of the Pit 7 complex to individual adult or juvenile ground squirrels, deer, or kit fox.

The Site 300 CP will include actions to be implemented in the event that actions described below does not achieve RAOs or comply with ARARs. The Site 300 CP will also address situations where the existing access restriction are removed or relaxed.

6.4.1.2.4. Monitored Natural Attenuation of Tritium and Uranium in Ground Water.

Alternative 2 includes monitored natural attenuation to reduce tritium and uranium activities in ground water to meet RAOs and ARARs.

EPA's OSWER Directive 9200.4-17 (1997b) states that monitored natural attenuation may be appropriate as a remedial approach where it can be demonstrated capable of achieving a site's remedial objectives within a time frame that is reasonable compared to that offered by other methods and given the particular circumstances of the site. According to this directive, the elements that are important to establish an MNA remedy are: (1) the contamination is not currently posing an unacceptable risk, (2) source control measures have been implemented or the data show that the source is no longer releasing contaminants to the environment, and (3) static or retreating plume contours. Natural attenuation may be demonstrated through a variety of lines of evidence, including static or retreating plume concentration contours, the presence of contaminant breakdown products, or the formation or depletion of geochemical indicator compounds.

The maximum activities of tritium in ground water near Pits 3 and 5 were detected in 1998 indicating continued releases of tritium from these pits. Tritium was detected in ground water from well NC7-63 at 2,660,000 pCi/L in the 4th quarter of 1998. Historical tritium data indicate that periodic spikes of tritium activities in ground water occur during time periods associated with elevated rainfall such as during the occurrence of El Nino in the winter of 1998. During these periods of increased precipitation, water levels rise and inundate the bottom of the Pits 3

and 5, releasing tritium to ground water. Previous releases of tritium from Pit 7 to ground water occurred prior to the installation of the pit cap.

A time series plot of tritium activities in ground water in the vicinity of Pits 3 and 5 from 1986 through 1998 is presented in Figure 6-1. Although the plots indicate periodic releases of tritium from Pits 3 and 5, the data also indicate that the portion of the tritium plume with activities exceeding the 20,000 pCi/L MCL has increased very little over the 13-year period. This may be the result of the natural attenuation of tritium in the downgradient portion of the plume. Modeling of tritium fate and transport in ground water from the Pits 3 and 5 area predicted that, without further releases from the pit, tritium activities will decrease to the drinking water standard of 20,000 pCi/L after 46 years without impacting ground water offsite above background activities (Webster-Scholten, 1994). Additional modeling, to be conducted as part of the monitored natural attenuation component of this remedy, could predict when background levels for tritium would be achieved onsite.

Given the short half-life of tritium (12.3 years), it may be that once the tritium source has been quantified and controlled, monitored natural attenuation would reduce tritium activities in ground water to meet remedial objectives within a reasonable time frame. Monitored natural attenuation for tritium will also prevent incurring risk associated with extracting tritiated ground water and bringing it to the surface for disposal. As discussed in Chapter 3, there are currently no effective or reasonable technologies available to remediate tritiated ground water.

Uranium-238 has also been detected in ground water in the vicinity of Pits 3 and 5 at a historical maximum activity of 187 pCi/L in 1998. Data indicate that the extent of uranium-238 in ground water is limited to the area immediately adjacent to the pits. Although the uranium-238 activities in ground water exceed the State and Federal drinking water MCL for total uranium (20 pCi/L), uranium-238 is less toxic than natural uranium, which contains the more radioactive uranium-235 isotope. The modeling of uranium transport from the Pit 7 Complex to the Site 300 boundary to the southeast predicted that the maximum potential uranium exposure-point activities would be significantly less than the State and Federal MCL of 20 pCi/L (Taffet et al., 1996). The maximum calculated uranium potential exposure-point activity in ground water at the Site 300 boundary is 1.77 pCi/L. The modeling results were based on health conservative assumptions, such as assuming that no retardation due to sorption occurs, and that uranium was a non-decaying species.

If further releases of uranium are prevented through source control measures, natural attenuation would eventually reduce uranium-238 activities in ground water to meet ARARs. Although uranium has an extremely long half-life, which may require a long period of time before ARARs are achieved, there is currently no risk associated with uranium in ground water as there are no existing exposure pathways. This may be an effective trade-off with the increases in exposure risk posed by bringing uranium-contaminated ground water (which might also be tritiated) to the surface, thereby increasing the number of exposure pathways.

Recent modeling used the maximum 1998 uranium-238 activity, realistic sorption and dispersion factors, and assumes that the source is removed to prevent future releases. The results indicate that the uranium 20 pCi/L (MCL) contour should not extend more than about 600 feet beyond its current extent at its maximum, and activities will decline everywhere to less than 20 pCi/L in about 60 years. The monitoring and continued modeling of uranium fate and

transport in ground water would determine any changes in uranium activities or plume size that could impact human health and warrant more active remedial measures.

There are significant geologic and hydrogeologic constraints to the movement of tritium- and uranium-contaminated ground water in bedrock underlying and to the northeast of Pits 3 and 5. A thick low-permeability claystone aquitard underlies the Tnbs₁ aquifer in the vicinity of Pits 3 and 5 and the northern part of Site 300. As a result, the underlying Cierbo Formation is unsaturated and the movement of tritium and uranium into deeper water-bearing zones is prevented. Ground water in the Tnbs₁ sandstone flows to the northeast of the pit area at a low velocity. The Tnbs₁ sandstone is unsaturated to the east and northeast of the Site 300 boundary. The Tnbs₁ sandstone and Cierbo Formation are eroded to the east of Site 300 and are not hydraulically connected to the aquifer currently used for water-supply for the City of Tracy. In addition, significant water level changes (drops) occur across the Elk Ravine Fault, located to the east-northeast of the pits. The water level drops across the fault indicate that the fault significantly retards the flow of ground water in the east-northeast direction. This geologic and hydrogeologic data indicate that there is not a complete pathway to existing water-supply wells to the east of the site.

Ground water in the alluvium flows to the southeast. Although ground water transport in the alluvium occurs at a higher velocity than in the Tnbs₁ bedrock, the flow pathway distance for alluvial ground water to hypothetical receptors at the southeast site boundary is much greater than in bedrock (over 15,000 ft). As discussed above, the modeling of tritium and uranium in ground water indicates that, without further releases from the pit, tritium and uranium will decay to background activities without impacting ground water offsite above background activities.

The following activities would be conducted to monitor the effectiveness of monitored natural attenuation and to detect any changes in activities or plume size that could result in impacts to human or ecological receptors :

- Measure ground water levels

- Perform ground water sampling and analysis.

- Manage, analyze, and present data.

- Perform fate and transport modeling to predict the spatial distribution of tritium over time and demonstrate the efficacy of monitored natural attenuation in meeting RAOs and ARARs.

- Conduct risk assessment, as necessary, to re-evaluate risk and hazard posed to human and ecological receptors based on newer data and modeling results.

- Install additional monitoring wells, if required.

The Site 300 CP will include actions to be implemented in the event that monitored natural attenuation of tritium and uranium-238 in ground water does not achieve RAOs or comply with ARARs.

6.4.1.2.5. Waste Characterization with Contingent Monitoring, Capping, and/or Excavation of Pits 3 and 5. As part of Alternative 2, the waste in the Pits 3 and 5 Landfills would be characterized with contingent monitoring, capping, and/or excavation of the pit (partial or total), depending on the waste characterization results.

Characterization of soil, rock, and ground water in the vicinity of the Pits 3 and 5 Landfills was conducted as part of the SWRI. A total of 146 soil and rock samples were collected from pilot boreholes in the vicinity of Pits 3 and 5. Sample analysis included VOCs, aromatic and fuel hydrocarbons, HE compounds, beryllium, tritium and uranium. Tritium and uranium-238 have been identified as COCs in surface soil and subsurface soil and bedrock in the vicinity of the pits. Uranium-238 has been detected at activities of up to 24 pCi/g in surface soil and 2.4 pCi/g in subsurface soil/rock. Tritium has been detected at activities of up to 18,100 pCi/L_{sm} in surface soil and 8,090,000 pCi/L_{sm} (in 1984) in subsurface soil/rock.

Uranium-238 has been identified in ground water downgradient of Pits 3 and 7 at a maximum historical activity of 187 pCi/L. Tritium has also been consistently detected in ground water samples with a historical maximum activity of 2,660,000 pCi/L in 1998. A comparison of high tritium activities detected in ground water in the vicinity of Pits 3 and 5 with periods of increased precipitation and elevated water levels in this area found that during years of significant rainfall, such as the winters of 1997-98 (El Nino) and 1998-1999 (La Nina), the water table rises significantly, inundating the bottom of Pits 3 and 5. Elevated tritium activities in ground water correspond to these water levels rises, indicating continued releases of tritium from these pits as a result of inundation. Therefore, capping may not be a useful tool to prevent future releases.

TCE and 1,1-DCE have been detected in ground water downgradient of the Pit 5 Landfill. VOC concentrations in the vicinity of Pit 5 show a declining trend with TCE decreasing from an historical maximum of 15 µg/L to 3.5 µg/L in 1998. The concentration reductions are likely attributable to natural attenuation. Nitrate and perchlorate have also been detected in ground water downgradient of the Pit 7 complex.

This component of Alternative 2 for the Pits 3 and 5 Landfills is designed to address the potential for continued releases of contaminants from the pits. This process would begin with a detailed characterization of the contents of the Pits 3 and 5 Landfills, followed by modeling to estimate potential impacts of ground water and risk assessment to evaluate impacts to human health and the environment. The results of these activities will be used to support remedial action decisions. The overall decision process is shown graphically in Figure 4-1. Documentation of the work planned and data collected will be provided throughout the landfill characterization and remediation process (Table 6-2).

DOE has preliminarily identified five possible remedial approaches to address actual or potential releases of contaminants from the Pits 3 and 5 Landfills including:

Monitoring only.

Capping.

Source control through partial excavation of waste with elevated contaminant concentrations or activities, with capping.

Source control through partial excavation of waste with elevated contaminant concentrations or activities, without capping.

Source control through total excavation of waste.

General decision criteria were developed to use the characterization data to evaluate the most appropriate remedial pathway for the landfills. These criteria are presented in Table 6-3 and will

be addressed in the Focused Feasibility Study discussed in Section 4.1.2.9.1.3. Capping of Pits 3 and 5 is unlikely to be effective, because the prime mechanism for release is through inundation from rising ground water levels, rather than infiltration from above.

If waste excavation is selected as the best remedial option for these landfills, two options are available for the disposition of excavated waste, as discussed in Chapter 3 (Section 3.2.7) and Appendix C (Section C-2.7).

The disposal options retained for consideration include:

1. Transportation to an off-site permitted facility for treatment, destruction, and/or disposal.
2. Placement of excavated waste in an on-site engineered containment unit either at the location of an existing landfill or outside the areas of existing contamination within a Corrective Action Management Unit (CAMU).

Because the ground water level in the Pits 3 and 5 area can periodically rise into the landfill, re-consolidation in place is not considered to be a suitable option for waste in Pits 3 and 5. It may, however, be feasible to consolidate excavated waste within the footprint of another existing landfill on site.

Figure 4-1 presents the disposal options and how they fit into the remedial action selection process. The primary decision criteria that will be used to select a disposal option for excavated material include: (1) the time, resources, and cost necessary to implement the disposal option, (2) engineering feasibility, (3) regulatory agency approval, and (4) public acceptance.

6.4.1.2.6. (For Alternative 2b only) Plume Migration Control Through *In Situ* Treatment of Uranium. This component of Alternative 2b consists of providing additional plume migration control for uranium-238 in ground water by installing an *in situ* permeable reactive barrier downgradient of the Pit 5 Landfill. For the purposes of costing, we assumed the *in situ* reactive barrier would be approximately 250 ft long and 10 ft wide, excavated to a depth of 30 ft and filled with a suitable reactive material (e.g., iron filings or resins) capable of removing uranium from ground water from a depth of 10 to 30 ft bgs. The reactive barrier would be designed to reduce the uranium-238 to concentrations below detection limits. Tritium would be unaffected by the barrier. The reactive material would be encased in resistant netting so it can be removed every 10 years for replacement and to remove the precipitated uranium. The spent reactive material, assumed to be mixed low-level radioactive waste, would be transported and disposed at an offsite disposal facility permitted to accept mixed waste.

6.4.1.3. Alternative 3—No Further Action for Tritium and Uranium-238 in Surface Soils at Pits 3 and 5, Monitoring, Exposure Prevention, Monitored Natural Attenuation of Tritium in Ground Water, Plume Migration Control, and Waste Characterization with Contingent Monitoring, Capping, and/or Excavation

Alternative 3 includes the following elements of Alternative 2 as described in Sections 6.4.1.2.1, 6.4.1.2.2, 6.4.1.2.3, 6.4.1.2.4 (for tritium only), 6.4.1.2.5, and 6.4.1.2.6:

- No further action for tritium and uranium-238 in surface soil at Pits 3 and 5,

- Monitoring of ground water for COCs,
- Risk and hazard management to prevent exposure of humans and ecological receptors to COCs, and
- Monitored natural attenuation of tritium in ground water.
- Characterization of waste in Pits 3 and 5 with contingent monitoring, capping and/or excavation.
- Uranium ground water plume migration control using *in situ* permeable barrier(s).

Alternative 3 includes an additional component of ground water extraction and treatment of VOCs, uranium, and nitrate described below.

The present-worth cost of Alternative 3 for the Pit 7 Complex subarea ranges from \$16,655,000 to \$63,748,000, depending on the amount of excavation that takes place, based on 30 years of monitoring, exposure control, monitored natural attenuation, and ground water remediation.

6.4.1.3.1. Ground Water Extraction and Treatment of VOCs, Uranium, and Nitrate.

TCE and 1,1-DCE have been detected in ground water downgradient of the Pit 5 Landfill. VOC concentrations in the vicinity of Pit 5 show a declining trend with TCE decreasing from an historical maximum of 15 µg/L to 3.5 µg/L in 1998. These concentration reductions may be attributable to natural attenuation. Nitrate and perchlorate have also been detected in ground water downgradient of the Pit 7 complex. Nitrate above MCLs has only been detected in one well near Pits 3 and 5, where it has decreased from an historical maximum concentration of 195 mg/L in 1993 to 49 mg/L in 1998. Two other wells nominally assigned to the Pit 7 Complex, NC7-47 and NC7-50, have nitrate above the MCL, but these wells are located far to the northeast, where the nitrate may be natural. Perchlorate was first detected in 1998 at a maximum concentration 6.4 µg/L. Uranium-238 has been identified in ground water downgradient of Pits 3 and 7 at a maximum historical activity of 187 pCi/L in 1998.

This component of Alternative 3 consists of providing plume migration control for VOCs, nitrate, and uranium-238 in ground water. VOC concentrations and mass would be reduced by extracting ground water from three wells (NC7-51, K7-03, and NC7-67) in which the highest VOC concentrations have been detected. Extracted ground water would be treated using aqueous-phase GAC to remove VOCs followed by an ion exchange system or other treatment technology demonstrated to be effective in removing nitrate. The spent GAC would be disposed or regenerated at an offsite treatment facility.

Ground water would be extracted from approximately eleven wells located near the center of mass of uranium-238 in ground water near Pits 3 and 5. Ground water would also be extracted from 3 wells located downgradient of the pits to control plume migration. Extracted ground water would be treated using an ion exchange treatment unit to remove uranium followed by a fixed-film bioreactor or other technology demonstrated to be effective in removing nitrate.

Treated ground water effluent from the treatment systems that does not contain tritium would be discharged onsite under Waste Discharge Requirements issued by the RWQCB.

As there is currently no viable technology available for the treatment of tritiated ground water, the treated water containing only tritium would be re-injected. Safety precautions would

need to be implemented to prevent exposure to tritium during the extraction and re-injection process. The specific location of injection wells would be discussed with the regulatory agencies when the remedial design for the relevant OU is prepared.

The efficacy of this remedial strategy would depend on the volume and tritium activities in the water to be re-injected, as well as the re-injection location. The re-injection of tritiated water in the Pits 3 and 5 area, where ground water is present at shallow depths, could exacerbate the inundation of this source area during periods of high rainfall and result in further contaminant releases. Modeling would need to be conducted prior to implementation of this type of remedial action to ensure that re-injection would not result in increased inundation of Pits 3 and 5 and further mobilization of the tritium plume. If the modeling results indicate that the re-injection of even limited volumes of water could potentially result in further releases and/or the spread of the tritium plume, the implementability of this remedial strategy may be limited.

6.4.2. Remedial Alternatives for Building 850 (OU 5)

Four remedial alternatives were assembled to address COCs in surface soil, subsurface soil/bedrock, surface water, and ground water in the Building 850 subarea. High-explosives experiments have been conducted at the Building 850 firing table since 1960. Tritium was used in hydrodynamic experiments at the firing table, primarily between 1963 and 1978. In addition, the experimental test assemblies sometimes contained uranium-238 and metals. Leaching of contaminants from firing table debris has resulted in tritium and uranium contamination of subsurface soil and ground water. Nitrate (as NO_3) has also been identified as a COC in ground water in this area. As a result of the dispersion of contaminated shrapnel during explosives testing, surface soil was contaminated with various metals, PCBs, HMX, and uranium. Dioxins and furans have also been identified as COCs in surface soil in the vicinity of the firing table. Gravel was removed from the firing table in 1988 and disposed at Pit 7. Since 1988, firing table gravel has been periodically removed and taken to the Building 804 gravel washing area. Sludge from the washing activities is drummed and sent to the Nevada Test Site for disposal and the cleaned gravel is reused.

From 1962 to 1972, a large volume of sand was stockpiled near the Building 850 firing table and was periodically used and reused during large experiments, gradually becoming contaminated with tritium. Leaching from this sandpile resulted in the release of tritium to the vadose zone and the ground water.

Ground water contaminants have been detected in shallow alluvial deposits (Qal) and sandstone (Tnbs₁) and claystone (Tmss) bedrock. The tritium plume emanating from the Building 850 source area extends east of the building and commingles with the Pits 3 and 5 tritium plume. As shown in the time series plot in Figure 6-2, tritium activities in ground water in the Building 850 source area have significantly decreased from 1985 to 1998, and the portion of the tritium plume with activities exceeding the 20,000 pCi/L MCL has decreased in size over the 13-year period.

6.4.2.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk

assessment. Under a no-action response, all monitoring activities in the Building 850 subarea would cease. There are no costs associated with the no-action alternative.

6.4.2.2. Alternative 2—Monitoring, Exposure Control, Monitored Natural Attenuation of Tritium in Ground Water and Surface Water, and Sandpile/Soil Removal

The primary components of Alternative 2 include:

1. Monitoring of ground water and surface water for COCs.
2. Risk and hazard management to prevent exposure of humans and ecological receptors to COCs.
3. Monitored natural attenuation of tritium in ground water and surface water.
4. Source control through the removal and disposal of contaminated sandpile and soil in the vicinity of Building 850.

These components are described in Sections 6.4.2.2.1 through 6.4.2.2.4 below.

The present-worth cost of Alternative 2 for the Building 850 subarea is \$4,029,000 based on 30 years of monitoring, exposure control, monitored natural attenuation, and sandpile/soil removal.

6.4.2.2.1. Monitoring. Sampling and analysis of ground water from monitor wells in the Building 850 subarea would continue in order to monitor COCs in the subsurface. Additional monitor wells would be installed, if necessary, to monitor the effectiveness of the remedial action in meeting RAOs and ARARs. Monitoring would be conducted to:

1. Track changes in plume concentration and size that result from source control measures and natural attenuation and to ensure there is no impact to downgradient receptors.
2. Evaluate the effectiveness of source control measures and the natural attenuation of contaminants in ground water to meet ARARs and cleanup goals.
3. Verify the attainment of cleanup goals.
4. Indicate and analyze deviations from expected rates of natural attenuation of contaminants.

Uranium-238 activities in ground water have decreased from a maximum historical activity of 18.4 pCi/L to 3.96 pCi/L in 1998, which is below the MCL (20 pCi/L) and background activity (9.28 pCi/L) for total uranium. Uranium activities in ground water would continue to be monitored to detect any changes in activities that could impact human health or the environment.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for ground water COCs and water levels will be measured in all monitor wells in the Building 850 subarea quarterly for 30 years.

The well-specific ground water monitoring program for the Building 850 subarea will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the

total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

In addition, surface water monitoring will be conducted to determine contaminant concentrations and trends in Well 8 Spring.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

6.4.2.2.2. Exposure Control. As part of Alternative 2, institutional and/or administrative controls and a risk and hazard management program would be implemented to:

1. Ensure RAOs are achieved.
2. Manage risk and/or hazard by preventing exposure to contaminated media.

These controls provide a degree of protection to human health by restricting access to or activities in areas of contamination, thereby preventing exposure to contaminants.

The baseline risk assessment identified a risk of 5.3×10^{-3} associated with potential inhalation of resuspended particulates, and incidental ingestion and direct dermal contact with surface soil contaminated with PCBs at the Building 850 firing table area. In addition, a risk of 9.5×10^{-5} was identified for potential inhalation of resuspended particulates, and incidental ingestion and direct dermal contact with surface soil contaminated with chlorinated dibenzo-p-dioxins (CDDs) and dibenzofurans (CDFs). Exposure control measures may be implemented, if necessary, to prevent exposure to CDDs and CDFs in surface soil until soil removal occurs as described in Section 6.4.2.2.4.

The risk and hazard management program will include: (1) implementing restrictions for construction in the Building 850 area, (2) reviewing exposure pathway-related conditions, such as building and land use, (3) refining risk and hazard models using current data, and (4) reporting the results to the stakeholders.

In the baseline ecological risk assessment a HI exceeding 1 was identified for combined oral and inhalation risk for individual adult squirrels, and for individual adult and juvenile deer for cadmium, and for the sum of VOCs, metals, and HE. However, there is no unacceptable risk to the ground squirrel and deer populations (Webster-Scholten, 1994, and Sections 1.5.3.1 and 1.5.3.2, respectively). The Toxicity Quotient (TQ) at Spring 6 exceeds 1 for copper when using the Federal Ambient Water Quality Criteria (AWQC), and exceeds 1 for copper and zinc when using the conservative California Applied Action Levels (AALs). New data indicate that there is no unacceptable risk from Spring 6 (Section 1.5.3.1).

The Site 300 CP will include actions to be implemented in the event that actions described below do not achieve RAOs or comply with ARARs. The Site 300 CP will also address situations where the existing access restrictions are removed or relaxed.

6.4.2.2.3. Monitored Natural Attenuation of Tritium in Ground Water and Surface Water. Alternative 2 includes natural attenuation to reduce tritium activities in ground water to meet RAOs and ARARs.

EPA's OSWER Directive 9200.4-17 (1997b) states that monitored natural attenuation may be appropriate as a remedial approach where it can be demonstrated to be capable of achieving a site's remedial objectives within a time frame that is reasonable compared to that offered by other methods and given the particular circumstances of the site. According to this directive, the elements that are important to establish an MNA remedy are: (1) the contamination is not currently posing an unacceptable risk, (2) source control measures have been implemented or the data show that the source is no longer releasing contaminants to the environment, and (3) static or retreating plume contours. Natural attenuation may be demonstrated through a variety of lines of evidence, including static or retreating plume concentration contours, the presence of contaminant breakdown products, or the formation or depletion of geochemical indicator compounds.

The historical maximum tritium activity in ground water near Building 850 was 471,000 pCi/L in 1984. Tritium activities in ground water monitor wells have shown a steadily decreasing trend over time with a maximum activity in 1998 of 206,000 pCi/L. Tritium in Well 8 Spring, which has analytical data dating back to 1971, has declined by more than an order of magnitude over the past 27 years.

Extreme storm events have occurred intermittently since tritium was first detected in Well 8 Spring in the early 1970s. Elevated tritium activities have never been detected in alluvium anywhere along the surface water flow path along Elk Ravine. This is presumably due to the extreme dilution that would occur, the fact that there is no baseflow within the alluvium, and the fact that this water quickly infiltrates the ground upon cessation of the storm.

A time series plot of tritium activities in ground water in the vicinity of Building 850 from 1985 through 1998 is presented in Figure 6-2. This plot shows that tritium activities in the Building 850 source areas are decreasing over time, indicating that an ongoing source is not present at Building 850. Figure 6-2 also indicates that the portion of the tritium plume with activities exceeding the 20,000 pCi/L MCL has steadily decreased over the 13-year period, indicating the natural attenuation of tritium in the downgradient portion of the plume. Modeling of tritium fate and transport in ground water from Building 850 predicted that tritium activities will decrease to the drinking water standard of 20,000 pCi/L after 45 years without impacting ground water offsite above the MCL (Webster-Scholten, 1994). The modeling results were based on health conservative assumptions as it assumed a continuous tritium point source located beneath the Building 850 firing table. The decreases in tritium activities over time in the vicinity of the Building 850 firing table indicate that the source is diminishing.

Given the short half-life of tritium (12.3 years) and the indications that an ongoing source is not present at Building 850, natural attenuation may reduce tritium activities in ground water and surface water to meet remedial objectives within a reasonable time frame. As discussed in Chapter 3, there are currently no effective or reasonable technologies available to remediate tritiated ground water.

The following activities would be conducted to monitor the effectiveness of monitored natural attenuation:

1. Measure ground water levels.
2. Perform ground water and surface water sampling and analysis.
3. Manage, analyze and present data.
4. Perform fate and transport modeling to predict the spatial distribution of tritium over time and demonstrate the efficacy of monitored natural attenuation in meeting RAOs and ARARs.
5. Install additional monitoring wells, if required.

The Site 300 CP will include actions to be implemented in the event that monitored natural attenuation of tritium in ground water does not achieve RAOs or comply with ARARs.

6.4.2.2.4. Removal of Contaminated Sandpile and Surface Soil. From 1962 to 1972, a large volume of sand was stockpiled near the Building 850 firing table and was periodically used and reused during large experiments, gradually becoming contaminated with tritium. Leaching from this sandpile resulted in the release of tritium to the vadose zone and ground water. Tritium was detected at activities of up to 204,000 pCi/L_{sm} in the sandpile in 1990.

As part of Alternative 2, approximately 460 yd³ of sand would be removed from the area adjacent to Building 850. The material would be transported and disposed at an offsite disposal facility permitted to accept mixed waste.

In addition, surface soil in the vicinity of the Building 850 firing table contaminated with various metals, PCBs, dioxins, furans, metals, HMX, and uranium would be removed. The estimated removal area is 43,700 ft² and 0.5 ft deep. To estimate costs, we assumed the total estimated volume of material to be removed is 800 yd³. This surface soil would be removed to mitigate the risks associated with potential inhalation of resuspended particulates, and incidental ingestion and direct dermal contact with surface soil contaminated with PCBs, and chlorinated dibenzo-p-dioxins and dibenzofurans at the Building 850 firing table area. The material removed is assumed to be mixed low-level radioactive and hazardous waste and would be transported and disposed at an offsite disposal facility permitted to accept mixed waste.

6.4.2.3. Alternative 3—Monitoring, Exposure Control, Water, Sandpile/Soil Removal, and Soil/Rock Excavation

Alternative 3 includes the following elements of Alternative 2 described above:

- Monitoring of ground water and surface water for COCs,
- Risk and hazard management to prevent exposure of humans and ecological receptors to COCs,
- Monitored natural attenuation of tritium in ground water, and
- Source control through the removal of contaminated sandpile and surface soil.

Alternative 3 adds excavation of contaminated soil and bedrock under the Building 850 firing table. The leaching of contaminants from firing table debris has resulted in tritium and uranium contamination of subsurface soil. Tritium was detected at a maximum activity of 11,000,000 pCi/L_{sm} in 1988, in subsurface soil at 5 ft bgs in a shallow borehole drilled beneath the firing table gravel. Tritium activities up to 2,790,000 pCi/L_{sm} were detected in subsurface

bedrock in boreholes directly adjacent to the firing table at depths of up to 20 ft bgs. Uranium has also been detected in subsurface soil at a maximum activity of 28.2 pCi/g.

As part of Alternative 3, approximately 5,000 yd³ of subsurface soil and bedrock underlying and in the vicinity of the Building 850 firing table would be excavated. For purposes of costing, we assumed that soil and bedrock would be excavated over an area of approximately 6,750 ft² to a depth of 20 ft.

It is assumed that the subsurface soil and bedrock removed from the area adjacent to the firing table would be classified as mixed low-level radioactive and hazardous waste. This material would be transported and disposed at an offsite disposal facility permitted to accept mixed waste.

The present-worth cost of Alternative 3 for the Building 850 subarea is \$8,246,000 based on 30 years of monitoring, exposure control, monitored natural attenuation, sandpile/soil removal, and excavation of bedrock underlying the firing table and soil adjacent to the firing table.

6.4.2.4. Alternative 4—Monitoring, Exposure Control, Monitored Natural Attenuation of Tritium in Ground Water and Surface Water, Ground Water Extraction and Treatment, Uranium Plume Migration Control, Sandpile/Soil Removal, and Soil/Rock Excavation

Alternative 4 combines all the elements of Alternative 3 with extraction and treatment of uranium- and nitrate-contaminated ground water and uranium plume migration control using an *in situ* reactive permeable barrier. These additional components of Alternative 4 are discussed in Sections 6.4.2.4.1 and 6.4.2.4.2.

The present-worth cost of Alternative 4 for the Building 850 subarea is \$16,097,000 based on 30 years of monitoring, exposure control, monitored natural attenuation, sandpile/soil removal, excavation of bedrock underlying the firing table and soil adjacent to the firing table, and ground water remediation.

6.4.2.4.1. Extraction and Treatment of Uranium and Nitrate in Ground Water. Uranium-238 has been identified in ground water in the vicinity of Building 850 at a maximum historical activity of 18.4 pCi/L in 1996. Uranium-238 activities in ground water have decreased to a maximum of 3.96 pCi/L in 1998. Nitrate concentrations in ground water have similarly decreased from an historical maximum of 140 mg/L in 1995 to 97 mg/L in 1998.

This component of Alternative 4 consists of providing source and plume migration control for uranium-238, and nitrate in ground water.

Uranium and nitrate concentrations and mass would be reduced by extracting ground water from approximately 4 wells near the center of mass of uranium-238 in ground water in the vicinity of Building 850. Ground water would also be extracted from 3 wells located downgradient of Building 850 to control plume migration. Extracted ground water would be treated using an ion exchange treatment unit to remove uranium followed by a fixed-film bioreactor or other technology demonstrated to be effective in removing nitrate.

Treated ground water effluent from the treatment systems that does not contain tritium would be discharged onsite under Waste Discharge Requirements issued by the RWQCB.

As there is currently no viable technology available for the treatment of tritiated ground water, the treated water containing only tritium would be re-injected into five injection wells located downgradient of Building 850. Safety precautions would need to be implemented to prevent exposure to tritium during the extraction and re-injection process. The specific location of injection wells would be discussed with the regulatory agencies when the remedial design for the relevant OU is prepared.

The efficacy of this remedial strategy would depend on the volume and tritium activities in the water to be re-injected. Modeling would need to be conducted prior to implementation of this type of remedial action to ensure that re-injection would not result in further mobilization of the tritium plume. If the modeling results indicate that the re-injection of even limited volumes of water could potentially result in the further spread of the tritium plume, the implementability of this remedial strategy may be limited.

6.4.2.4.2. Uranium Plume Migration Control Using an *In Situ* Reactive Permeable Barrier. This component of Alternative 4 consists of providing additional plume migration control for uranium-238 in ground water through installation of an *in situ* permeable reactive barrier. The barrier would be installed downgradient of Building 850 in the saturated alluvial fill of Doall Ravine to prevent migration of the uranium plume in the alluvium (Qal). For the purposes of costing, we assumed the *in situ* reactive barrier would be approximately 150 ft long and 10 ft wide, excavated to a depth of 30 ft and filled with a suitable reactive material (i.e., iron filings or resins) capable of removing uranium from ground water from a depth of 10 to 30 ft bgs. The reactive barrier would be designed to reduce the concentrations of uranium-238 to below detection limits. Tritium would be unaffected by the barrier. The reactive material would be encased in resistant netting so it can be removed every 10 years for replacement and to remove the precipitated uranium.

It is assumed that the spent reactive material will be a mixed low-level radioactive waste which would be transported and disposed at an offsite disposal facility permitted to accept mixed waste.

6.4.3. Remedial Alternatives for the Pit 2 Landfill (OU 5)

The Pit 2 Landfill was used for disposal of firing table debris and gravel from Buildings 801 and 802. Pit 2 encloses an area of 6,000 yd² and contains about 25,412 yd³ of firing table waste (Lindeken and Hieb, 1985). The total pit depth is estimated to be 12 to 14 ft with 2 ft of overburden (Buddemeier, 1985). Material was buried to depths of 6 to 8 ft and then covered with local soil (Raber et al., 1982).

VOCs were detected in ground water in 1989 but have not been detected since that time. Although tritium has been detected in subsurface soil/rock, the depth of maximum tritium detection indicates that the tritium has probably migrated in ground water from the Building 850 area. No risk or hazard to human health or ecological receptor has been associated with the Pit 2 Landfill. There are no COCs identified in any media in the vicinity of the landfill.

6.4.3.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk

assessment. Under a no-action response, all monitoring activities in the Pit 2 Landfill subarea would cease. There are no costs associated with the no-action alternative.

6.4.3.2. Alternative 2—Monitoring

Alternative 2 consists of the sampling and analysis of ground water from monitor wells in the area to monitor potential COCs for future releases of contaminants from the Pit 2 Landfill. The landfill surface would also be inspected annually to ensure that no damage threatens a release from the waste. Additional monitor wells may be installed, if necessary, for complete detection monitoring.

No COCs have been identified in surface soil, subsurface soil/bedrock, ground water or surface water associated with the Pit 2 Landfill. Characterization of soil, rock, and ground water in the vicinity of the Pit 2 Landfill was conducted as part of the SWRI. A series of shallow (2 to 6 ft) subsurface soil samples were collected from the Pit 2 Landfill area. In addition, soil and rock samples were collected and analyzed from 6 pilot boreholes for wells located in the vicinity of the Pit 2 Landfill. Ground water has been routinely monitored for possible contamination in these wells. Although tritium has been detected in saturated subsurface rock and ground water in the vicinity of Pit 2, data indicate that tritium detected beneath Pit 2 has migrated in ground water from the Building 850 area. Although, data indicate a rise in ground water elevation in the vicinity of Pit 2 Landfill during the wet winters of 1997 and 1998, the water table is still in excess of 65 ft below the pit and there is no risk of inundation.

As currently, there are no COCs in any environmental media emanating from the Pit 2 Landfill, monitoring would be conducted to:

1. Detect future releases from the landfill that might impact ground water.
2. Verify continued compliance with ARARs.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for possible contaminants that could leach from the landfill and that water levels will be measured in all monitor wells in the Pit 2 Landfill subarea on a quarterly basis for 30 years.

The well-specific ground water monitoring program for the Pit 2 Landfill subarea will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

The present-worth cost of Alternative 2 for the Pit 2 Landfill subarea is \$515,000 based on 30 years of monitoring.

6.4.3.3. Alternative 3—Monitoring, and Waste Characterization with Contingent Monitoring, Capping, and/or Excavation

Alternative 3 combines the monitoring described in Alternative 2 with characterization of waste in the Pit 2 Landfill, with contingent monitoring, capping, and/or excavation of the pit, depending on the waste characterization results.

As described in Alternative 2, characterization of soil, rock, and ground water in the vicinity of the Pit 2 Landfill was conducted as part of the SWRI. Data collected during the SWRI indicate there are no COCs in surface soil, subsurface soil/bedrock, ground water, or surface water associated with the Pit 2 Landfill.

Some of the waste buried in the landfill may have contained uranium-238, beryllium, thorium, and tritium (LLNL, 1982). VOCs and heavy metals may also have been buried in this landfill (LLNL, 1982). Several contaminants including uranium-238 and metals were detected in the gravel from the Building 845 firing table. As potentially contaminated firing table gravel from this firing table was disposed in Pit 2, this alternative includes evaluation of the potential for contamination of the subsurface beneath the pit as a result of future releases from the landfill waste, as described in Section 4.1.2.9.1.3.

As discussed in Chapter 4, a strategy has been developed for addressing potential releases of contaminants from landfills. The process begins with a detailed characterization of the contents of the landfill, followed by modeling to estimate potential impacts of ground water and risk assessment to evaluate impacts to human health and the environment. The results of these activities will be used to support decisions on remedial actions. The overall decision process is shown in Figure 4-1. Documentation of the work planned and data collected will be provided throughout the landfill characterization and remediation process (Table 6-2).

DOE has preliminarily identified five possible remedial approaches to address actual or potential releases of contaminants from the Pit 2 Landfill including:

1. Monitoring only.
2. Capping.
3. Partial excavation with capping.
4. Partial excavation without capping.
5. Total excavation.

General decision criteria were developed to use the characterization data to evaluate the most appropriate remedial pathway for the landfill. These criteria are presented in Table 6-3 and will be addressed in the Focused Feasibility Study discussed in Section 4.1.2.9.1.3.

As the depth to ground water is 65 feet or more beneath the Pit 2 Landfill, there is no risk of inundation of the pit that could result in releases. Therefore, the excavation of the waste may provide no significant increase in protection to human health or the environment over that provided by capping.

If waste excavation is selected as the best remedial option for this landfill, two options are available for the disposition of excavated waste, as discussed in Chapter 3 (Section 3.2.7) and Appendix C (Section C-2.7),

The disposal options retained for consideration include:

1. Transportation to an off-site permitted facility for treatment, destruction, and/or disposal.
2. Placement of excavated waste in an on-site engineered containment unit either at the location of an existing landfill or outside the areas of existing contamination within a Corrective Action Management Unit (CAMU).

Because the Pit 2 Landfill is located in a low-lying area through which surface water runoff tends to flow, a surface water flow management system would need to be installed as part of a containment unit for this landfill. In addition, the available, relatively flat-lying area in which the Pit 2 Landfill is contained is small (250 ft × 400 ft), therefore the consolidation of waste from other landfills into a containment unit in this area may not be feasible.

Figure 4-1 presents the disposal options and how they fit into the remedial action selection process. The primary decision criteria that will be used to select a disposal option for excavated material include: (1) the time, resources, and cost necessary to implement the disposal option, (2) engineering feasibility, (3) DOE and regulatory agency approval, and (4) public acceptance considerations.

The present-worth cost of Alternative 3 for the Pit 2 Landfill subarea is \$22,250,000 based on 30 years of monitoring and waste characterization with total excavation of Landfill Pit 2.

6.5. Remedial Alternatives for Building 854 (OU 6)

A presumptive remedy has been identified for this OU. Therefore, only two alternatives, a no action alternative required by EPA guidance and the presumptive remedy, are presented.

TCE was released to subsurface soil and ground water through leaks and discharges of TCE-based heat exchange fluid from a TCE brine system that was removed in 1989. TCE concentrations in ground water have decreased from a historical maximum of 2,900 µg/L to 410 µg/L in 1998. Other COCs in ground water include tritium, uranium-238, nitrate, and perchlorate. The maximum historical activity of tritium detected in ground water (410 pCi/L) slightly exceeds the background activity of tritium in ground water (300 pCi/L). Uranium-238 has been detected in one well in the Building 854 area at a historical maximum of 2.58 pCi/L. Ground water contamination exists in a 10- to 20- ft thick, shallow water-bearing zone comprised of the lower Tnbs₁ sandstone and upper Cierbo Formation. This zone appears to be perched as there is unsaturated permeable material below the low permeability siltstone/claystone confining layer located at the base of the shallow water-bearing zone. No contamination has been detected in the deeper water-bearing zone located at least 50 ft below the first water-bearing zone.

TCE has also been identified as a COC in the vadose zone at concentrations up to 1,000 mg/kg in subsurface bedrock. This sample was collected in the vicinity of the Building 854H drain outfall from which contaminated soil was excavated and removed in 1983. COCs in surface soil include lead, zinc, HMX, tritium, and PCBs. Contaminated surface soil was removed at the northeast corner of Building 854F in 1983.

6.5.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all monitoring activities in the Building 854 OU would cease. There are no costs associated with the no-action alternative.

6.5.2. Alternative 2—No Further Action for Metals, HMX, PCBs, and Tritium in Surface Soils, Monitoring, Exposure Control, Ground Water and Soil Vapor Extraction and Treatment

The primary components of Alternative 2 include:

1. No further action for metals, HMX, PCBs, and tritium in surface soil.
2. Monitoring of ground water and surface water for COCs.
3. Risk and hazard management to prevent exposure of humans and ecological receptors to COCs.
4. Source mass removal and mitigation of TCE inhalation risk at Buildings 845F and 854F through extraction and treatment of TCE in ground water and soil vapor and nitrate in ground water.

These components are described below in Sections 6.5.2.1 through 6.5.2.4.

The present-worth cost of Alternative 2 for the Building 854 OU is \$9,150,000 based on 30 years of monitoring, exposure control, and ground water and vadose zone remediation.

6.5.2.1. No Further Action for Metals, HMX, PCBs, and Tritium in Surface Soil

Lead, zinc, HMX, tritium, and PCBs have been identified as COCs in surface soil in the Building 854 OU. Lead, zinc, and HMX have been detected at concentrations of 98 mg/kg, 1,400 mg/kg, and 150 mg/kg, respectively. Tritium was detected at concentrations of 317 pCi/L, slightly above background concentrations of 300 pCi/L. No risk or hazard to human health or ecological receptors have been identified in this area associated with lead, zinc, HMX, or tritium. Modeling indicates that lead and zinc in surface soil will not impact ground water above MCLs. Modeling of HMX indicates that HMX could reach ground water at concentrations of 1.79 mg/L (MCL: 1.7 mg/L) in 500 years. No further action is proposed for these COCs in surface soil because (1) there is no risk or hazard to human health or ecological receptors posed by these contaminants, and (2) there is no significant impact to ground water indicated by modeling.

PCB 1242 and 1248 were detected in surface soil at concentrations of 34 mg/kg and 52 mg/kg, respectively. A baseline human health risk of 6.6×10^{-5} was identified that results from incidental ingestion and direct dermal contact with PCB-contaminated soil. The risk calculation was based on an onsite worker exposure scenario of 8-hr/day, 5 days/wk for 30 years. This facility is no longer used so the exposure scenario used to calculate risk is no longer valid. No further action is proposed for PCBs in surface soil because (1) there are no workers at this facility, and therefore no risk to humans, and (2) there is no impact to ground water indicated by modeling.

Monitoring for these COCs in ground water would be conducted to ensure the contaminants do not impact ground water as indicated by modeling. Detections of these COCs in ground water, as well as changes to building use that could affect exposure scenarios, will be addressed in the Site-Wide CP. In addition, exposure control methods are presented below in Section 6.5.2.3.

6.5.2.2. Monitoring

Sampling and analysis of ground water from monitor wells in the area would continue to monitor COCs in the subsurface. No additional monitor wells would be installed. Monitoring would be conducted to:

- Track changes in plume concentration and size as remediation progresses.
- Evaluate the effectiveness of the remedial action.
- Determine when cleanup actions should cease by comparing site data against RAOs, ARARs and cleanup goals.
- Indicate and analyze deviations from expected performance.
- Validate results of modeling of COCs in surface soil to ground water.

In addition, monitoring for tritium and uranium-238 in ground water will be conducted to determine any changes in activities that could result in impacts to human health or the environment. Uranium-238 has been detected in one well in the Building 854 OU at an historical maximum activity of 2.6 pCi/L. Tritium has been detected in ground water at an historical maximum concentration of 410 pCi/L, slightly above background concentrations of 300 pCi/L.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the Building 854 OU quarterly for 30 years.

The well-specific ground water monitoring program for the Building 854 OU will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be reevaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

Although no contaminants have been detected in Spring 10, located downgradient of the Building 854 Complex, surface (spring) water will be monitored for any future impact.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

6.5.2.3. Exposure Control

As part of Alternative 2, institutional and/or administrative controls and a risk and hazard management program will be implemented to:

1. Ensure RAOs are achieved.
2. Manage risk and/or hazard by preventing exposure to contaminated media.

These controls provide a degree of protection to human health by restricting access to or activities in areas of contamination, thereby preventing exposure to contaminants.

Baseline inhalation risks of 8.7×10^{-6} and 5.1×10^{-6} for adult onsite workers were identified for TCE volatilizing from subsurface soil to air inside Buildings 854F and 854A, respectively. The maximum historical concentration of TCE detected in subsurface soil was 30.7 mg/kg, in 1983. Of the almost 200 soil samples from the Building 854 area analyzed since 1983, no TCE result has exceeded 0.06 mg/kg. Neither Building 854F nor 854A are currently used for daily operations. Since these facilities are not manned, there is currently no exposure pathway for TCE volatilizing from subsurface soil into the buildings to affect humans.

The risk and hazard management program will include: (1) analyzing indoor air at Buildings 854A and 854F annually for a minimum of two years, and if air concentrations indicate that the inhalation risk exceeds 10^{-6} or the HI exceeds 1, instituting restrictions for building use or, if building use is again anticipated, installing a building ventilation system and operating it whenever the building is occupied, (2) conducting semi-annual wildlife surveys to evaluate the presence of any species of concern, (3) reviewing exposure pathway-related conditions, such building and land use, (4) refining risk and hazard models using current data, and (5) reporting the results to the stakeholders. These measures will prevent exposure while soil vapor remediation activities described below reduce TCE concentrations in subsurface soil and mitigate this risk.

There are no exposure pathways for ecological receptors as the affected portions of the Building 854 area are paved and thus do not provide sufficient ecological habitat.

The Site 300 CP will include actions to be implemented in the event that active remediation described below does not achieve RAOs or comply with ARARs. The Site 300 CP will also address situations where the existing access restrictions are removed or relaxed.

6.5.2.4. Ground Water and Soil Vapor Extraction and Treatment

Ground water and soil vapor remediation would be implemented at Building 854 to: 1) reduce soil vapor TCE concentrations in the vadose zone to acceptable risk- and hazard-based concentrations, 2) reduce soil vapor TCE concentrations in the vadose zone to levels protective of ground water, and 3) reduce TCE, perchlorate, and nitrate concentrations in ground water to meet RAOs and ARARs by reducing contaminant concentrations and mass to achieve plume migration control.

COCs in ground water at the Building 854 OU include TCE, perchlorate, and nitrate(as NO_3). The primary TCE mass removal mechanism would be by SVE. Ground water extraction wells would be used primarily to dewater the perched water-bearing zone and thereby facilitate SVE of

TCE. Soil vapor and ground water would be simultaneously extracted from approximately six wells, and soil vapor would be extracted from 6 other wells.

Dual-phase extraction is considered by EPA as a presumptive remedy for the remediation of TCE and other contaminants in subsurface formations (EPA, 1997a). Dual-phase extraction would be implemented at approximately six wells located in the Building 854 Complex core area for source mass removal. Ground water will be extracted from an additional three wells located from 200 to 500 feet downgradient of the Building 854 source area to control plume migration.

TCE and perchlorate in ground water would be treated using aqueous-phase GAC followed by a fixed-film bioreactor or other appropriate technology demonstrated to be effective in removing nitrate (B854-TF1). GAC, as well as aerobic biological reactors, are listed by EPA as presumptive technologies for the treatment of dissolved organic contaminants such as TCE (EPA, 1996).

Extracted soil vapor would be treated using vapor-phase GAC and discharged to the atmosphere in accordance with the permit requirements issued by the SJVUAPCD.

A second treatment facility (B854-TF2) would be installed to treat ground water extracted from wells located 600 to 1,300 ft downgradient from the source area. Extracted ground water would be treated using aqueous-phase GAC followed by a fixed-film bioreactor or other appropriate technology demonstrated to be effective in removing nitrate. The second extraction and treatment system would be installed to reduce TCE and nitrate concentrations in downgradient portions of the plume, and provide plume migration control in the Tnbs₁ aquifer.

Treated ground water effluent from both treatment systems (B854-TF1 and TF2) would be discharged on site in accordance with Substantive Requirements issued by the RWQCB. The spent GAC from the soil vapor and ground water treatment systems would be disposed or regenerated at an offsite treatment facility.

6.6. Remedial Alternatives for the Building 832 Canyon (OU 7)

A presumptive remedy has been identified for this OU. Therefore, only two alternatives, a no action alternative required by EPA guidance and the presumptive remedy, are presented.

Contaminants, primarily VOCs, were released from Buildings 830 and 832 through piping leaks and surface spills where TCE was used as a heat exchange fluid as part of testing activities at these buildings. TCE in ground water in the Building 830 area has decreased over time from an historical maximum of 30,000 µg/L to 7,900 µg/L in 1998. TCE has also been detected in ground water at Building 832 at an historical maximum of 1,800 µg/L in 1998. Nitrate (as NO₃) and perchlorate are also present in ground water at both Building 830 and 832. Nitrate contamination in ground water may be the result of a combination of HE-related testing and septic system releases, with a possible contribution from naturally occurring nitrate from local geologic units. Although the source of perchlorate is not known at this time, it may be that perchlorate was a component of HE test assemblies. COCs in ground water at Buildings 830 and

832 are present in the shallow alluvium (Qal) and underlying sandstone (Tnbs₂ and Tnbs₁) and siltstone/claystone (Tnsc₁) bedrock.

TCE has also been detected in subsurface soil/bedrock in the vicinity of Buildings 830 and 832 at concentrations of 6 mg/kg and 0.16 mg/kg, respectively.

Rinsewater containing HE compounds was disposed via floor drains in Building 830 which led to a surface discharge outside the building. As a result, HMX has been detected in surface soil and bedrock. However, no HE compounds have been detected in ground water. Low concentrations of HMX (0.2 mg/kg in 1994) have been detected in Building 832 subsurface soil/bedrock. Nitrate has also been detected in subsurface soil/bedrock at Building 830.

A treatability study began in the fall of 1999 to evaluate dual phase (ground water and soil vapor) extraction at Building 832.

6.6.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all monitoring and remediation activities in the Building 832 Canyon OU would cease. There are no costs associated with the no-action alternative.

6.6.2. Alternative 2—No Further Action for Non-VOC Contaminants in Surface and Subsurface Soil, Monitoring, Exposure Control, Ground Water and Soil Vapor Extraction and Treatment, and Downgradient Plume Migration Control

The primary components of Alternative 2 include:

1. No further action for HMX in surface soil and nitrate in subsurface soil/bedrock at Building 830 and HMX in subsurface soil/bedrock at Building 832.
2. Monitoring ground water and surface water for COCs.
3. Risk and hazard management to prevent exposure of humans and ecological receptors to COCs.
4. Mass removal and mitigation of VOC inhalation risk at Building 830 through extraction and treatment of VOCs in ground water and soil vapor, and nitrate and perchlorate in ground water.
5. Mass removal at Building 832 through extraction and treatment of VOCs in ground water and soil vapor, and nitrate and perchlorate in ground water.
6. Plume migration control through downgradient ground water extraction using a siphon with *ex situ* treatment of VOCs.

These components are described below in Sections 6.6.2.1 through 6.6.2.6.

The present-worth cost of Alternative 2 for the Building 832 Canyon OU is \$26,766,000 based on 30 years of monitoring, exposure control, and ground water and vadose zone remediation.

6.6.2.1. No Further Action for Non-VOC Contaminants in Surface and Subsurface Soil/Rock

HMX has been detected at extremely low concentrations in surface soil at Building 830 and subsurface bedrock at Building 832. HMX was detected at a maximum concentration of 0.2 mg/kg in 1994 in Building 830 surface soil. The HMX concentration in a duplicate of this sample was reported at 0.07 mg/kg. The maximum concentration of HMX detected in subsurface soil/bedrock at Building 832 was 0.2 mg/kg in 1994. No risk or hazard associated with HMX in these areas has been identified. HE compounds are not COCs in ground water at either Building 830 or 832. Vadose zone modeling of HMX at Building 832 indicates that there will be no significant impact to ground water.

No further action is proposed for HMX in surface soil at Building 830 and subsurface bedrock at Building 832 because there is (1) no risk or hazard to human health or ecological receptors posed by these contaminants, and (2) no impact to ground water.

Monitoring for HMX in ground water will be conducted to evaluate whether HMX in surface soil and subsurface soil/bedrock impacts ground water. Responses to future detections of HMX in ground water will be addressed in the Site-Wide CP.

Nitrate (as NO_3) has also been detected at extremely low concentrations in subsurface soil/bedrock at Building 830. The maximum reported concentration was 13.5 mg/kg. No risk or hazard associated with HMX in subsurface soil/bedrock in these areas has been identified. Nitrate (as NO_3) is a ground water COC at both Buildings 830 and 832, however it may be that the levels of nitrate detected in ground water are due, in part, to septic system releases, with a possible contribution of naturally occurring nitrate from local geologic units. Nitrate has been detected in the alluvium (Qal) and bedrock (Tnsc_1) in the Building 832 Canyon area, and nitrate may be naturally high in the Tps hydrogeologic unit.

No further action is proposed for nitrate in subsurface soil/bedrock at Building 830 because: (1) there is no risk or hazard to human health or ecological receptors posed by these contaminants, (2) nitrate in ground water is believed to be, in part, from other than anthropogenic sources, and (3) nitrate in ground water would be addressed through extraction and treatment.

Studies are underway to determine the source(s) of nitrate in ground water in the Building 832 Canyon OU.

6.6.2.2. Monitoring

Sampling and analysis of ground water from monitor wells in the area would continue to monitor COCs in the subsurface. No additional monitor wells would be installed. Monitoring would be conducted to:

1. Track changes in plume concentration and size as remediation progresses.
2. Evaluate the effectiveness of the remedial action.
3. Determine when cleanup actions should cease by comparing site data to RAOs, ARARs and cleanup goals.
4. Indicate and analyze deviations from expected performance.

5. Validate results of modeling of COCs in surface soil to ground water.
6. Determine impacts of HMX in surface soil and the vadose zone on ground water.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the Building 832 Canyon OU quarterly for 30 years.

The well-specific ground water monitoring program for the Building 832 Canyon OU will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

In addition, Spring 3 which is located downgradient of Building 830, will be monitored to evaluate whether the active remediation at Building 830 successfully reduces TCE concentrations in the spring.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

6.6.2.3. Exposure Control

As part of Alternative 2, institutional and/or administrative controls and a risk and hazard management program would be implemented to:

1. Ensure RAOs are achieved.
2. Manage risk and/or hazard by preventing exposure to contaminated media.

These controls provide a degree of protection to human health by restricting access to or activities in areas of contamination, thereby preventing exposure to contaminants.

In the baseline risk assessment, an inhalation risk of 2.8×10^{-6} for adult onsite workers was identified for VOCs volatilizing from subsurface soil to air inside Building 830, based on a maximum TCE concentration measured in 1983. An inhalation risk of 1×10^{-5} for adult onsite workers was similarly identified for VOCs volatilizing from subsurface soil to outdoor air in the vicinity of Building 830. The maximum historical concentration of TCE detected in subsurface soil is 6 mg/kg in 1983 at a 26 ft depth.

The baseline risk assessment also identified an inhalation risk of 6.5×10^{-5} for adult onsite worker for TCE volatilizing from surface water (Spring 3) to ambient air. TCE concentrations in Spring 3 have decreased from a maximum historical concentration of 200 µg/L in 1985 to 27 µg/L in 1998. A corresponding decrease in exposure risk has occurred, as the baseline risk numbers were calculated using the maximum historical concentration detected in the spring. In addition, TCE concentrations would continue to be monitored for changes in concentrations that could impact human health. As Spring 3 is fed by ground water, the ground water remediation

activities discussed in Section 6.6.2.4 below should result in a decrease in TCE concentrations in the spring.

The risk and hazard management program would include: (1) sampling and analyzing outdoor ambient air in the vicinity of Building 830 and Spring 3 for VOCs annually, (2) analyzing indoor air at Building 830 annually for a minimum of two years, and if air concentrations indicate that the inhalation risk exceeds 10^{-6} or the HI exceeds 1, instituting restrictions for building use or, if building use is again anticipated, installing a building ventilation system and operating it whenever the building is occupied, (3) reviewing exposure pathway-related conditions, such building and land use, (4) refining risk and hazard models using current data, and (5) reporting the results to the stakeholders. These measures would prevent exposure while soil vapor remediation activities described below reduce VOC concentrations in subsurface soil and surface water (Spring 3) and mitigate this risk.

In the baseline risk assessment, it was determined that there were no impacts from VOCs to ecological receptors at Buildings 830 and 832.

The Site 300 CP will include actions to be implemented in the event that active remediation described below does not achieve RAOs or comply with ARARs. The Site 300 CP will also address situations where the existing access restrictions are removed or relaxed.

6.6.2.4. Ground Water and Soil Vapor Extraction and Treatment

Ground water and soil vapor remediation would be implemented at both Buildings 830 and 832 to: (1) reduce soil vapor VOC concentrations in the vadose zone to acceptable risk- and hazard-based concentrations, (2) reduce soil vapor VOC concentrations in the vadose zone to levels protective of ground water, and (3) reduce VOC and nitrate concentrations in ground water and surface water to meet RAOs and ARARs by reducing contaminant concentrations and mass to achieve source and plume migration control.

COCs in ground water at Buildings 830 and 832 include VOCs, nitrate (as NO_3), and perchlorate. The primary VOC mass removal mechanism in the Buildings 830 and 832 source areas would be by SVE. Ground water extraction wells would be used primarily to dewater the water-bearing zone thereby facilitating SVE of VOCs.

The dual-phase extraction is considered by EPA to be a presumptive remedy for the remediation of VOCs and other contaminants in subsurface formations (EPA, 1997a). Dual-phase extraction will be implemented at approximately ten wells located in the Building 832 Complex source area for mass removal. VOCs and perchlorate in ground water at the Building 832 source area will be treated using aqueous-phase GAC followed by a fixed-film bioreactor or other appropriate technology demonstrated to be effective in removing nitrate (B832-TF1). GAC, as well as aerobic biological reactors, are listed by EPA as presumptive technologies for the treatment of dissolved organic contaminants such as VOCs (EPA, 1996).

Extracted soil vapor will be treated using vapor-phase GAC and discharged to the atmosphere in accordance with the permit requirements issued by the SJVUAPCD.

A treatability study will be started in the fall of 1999 to evaluate dual phase extraction at Building 832.

One to two treatment facilities (B832-TF2 and -TF3) would be installed to treat ground water extracted from four wells located several hundred feet downgradient from the Building 832 source area. Extracted ground water would be treated using aqueous-phase GAC followed by a fixed-film bioreactor or other appropriate technology demonstrated to be effective in removing nitrate. The additional extraction and treatment system(s) would be installed to reduce VOC and nitrate concentrations in downgradient portions of the Building 832 plume, providing plume migration control.

One treatment facility (B830-TF1) would be installed to treat ground water extracted from about ten wells located in the immediate vicinity of the Building 830 source area. Extracted ground water would be treated using aqueous-phase GAC followed by a fixed-film bioreactor or other appropriate technology demonstrated to be effective in removing nitrate. Additional extraction and treatment systems (B830-TF2 and -TF3) would be installed to reduce VOC and nitrate concentrations in downgradient portions of the Building 830 plume, providing plume migration control.

An iron filings treatment system would be installed to treat ground water extracted from wells located in the downgradient portion of the Building 830 plume to control plume migration and prevent contamination of ground water offsite. Ground water would be extracted using low O&M siphon technology that utilizes gravity to extract and transport ground water to the treatment system. VOCs in extracted ground water would be treated using an *ex situ* iron filings treatment system. The capability of iron filings to reduce nitrate concentrations is being investigated. If the iron filings system does not effectively remove nitrate, a fixed-film bioreactor, or other appropriate technology, would be added to the treatment train for nitrate removal.

In the event the siphon extraction system does not effectively capture the plume, an additional extraction and aqueous-phase GAC treatment system may be installed in the downgradient plume.

Treated ground water effluent from Buildings 832 and 830 treatment systems would be discharged on site in accordance with Substantive Requirements issued by the RWQCB. The spent GAC from the soil vapor and ground water treatment systems would be disposed or regenerated at an offsite treatment facility. Spent iron filing would be disposed offsite.

6.7. Remedial Alternatives for the Building 801 and Pit 8 Landfill (OU 8)

Three remedial alternatives were assembled to address COCs in subsurface soil/bedrock, and ground water at Building 801 and the Pit 8 Landfill. Waste fluid discharges to a dry well located adjacent to Building 801 resulted in the release of VOCs to the subsurface. The dry well was decommissioned and filled with concrete in 1984. TCE concentrations in ground water in the Building 801 area have slightly decreased over time to 4 µg/L in 1998. Nitrate is also present in ground water at concentrations up to 47 mg/L. COCs in ground water at Building 801 are present in the shallow alluvium (Qal) and underlying sandstone bedrock (Tnbs₁). TCE has also been detected in subsurface soil/bedrock in the vicinity of Building 801 at a maximum historical concentration of 0.057 mg/kg.

The Pit 8 Landfill was used to dispose debris from the Building 801 firing table until 1974 when an earthen cover was installed. The total estimated volume of material disposed in Pit 8 is about 24,700 yd³. No COCs have been identified in surface soil, subsurface soil/bedrock, ground water or surface water in the Pit 8 Landfill area.

6.7.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all monitoring activities in the vicinity of Building 801 and the Pit 8 Landfill would cease. There are no costs associated with the no-action alternative.

6.7.2. Alternative 2—No Further Action for VOC Contaminants in Subsurface Soil and Monitoring

The primary components of Alternative 2 include:

1. No further action for VOCs in subsurface soil/bedrock in the Building 801 dry well area.
2. Monitoring ground water for COCs and potential contaminants from the Pit 8 Landfill.

These components are described in Sections 6.7.2.1 and 6.7.2.2.

The present-worth cost of Alternative 2 for the Building 801 dry well and Pit 8 Landfill release sites is \$535,000 based on 30 years of monitoring with increased detection monitoring at Pit 8.

6.7.2.1. No Further Action for VOCs in Subsurface Soil

TCE has been detected in subsurface soil at extremely low concentrations below the Building 801 dry well. The historical maximum concentration of TCE was 0.057 mg/kg reported at a depth of 21 ft in 1989. No risk or hazard associated with TCE in this area was identified in the baseline risk assessment. No viable remedial technology has been identified to address such extremely low concentrations. The dry well source was closed in 1984.

No further action is proposed for TCE in subsurface soil/bedrock at the 801 dry well because: (1) there is no risk or hazard to human health or ecological receptors posed by TCE in this medium, (2) the dry well source has been removed and closed, and (3) VOC concentrations in ground water are near or below MCLs (TCE: 4.1 µg/L in 1998) and are declining, indicating a diminishing source of VOCs in subsurface soil/bedrock.

Monitoring for VOCs in ground water will be conducted to evaluate whether VOCs in subsurface soil/bedrock impact ground water. Responses to increases in VOC concentrations in ground water will be addressed in the Site-Wide CP.

6.7.2.2. Monitoring

Sampling and analysis of ground water from monitor wells in the area would continue to monitor COCs in the subsurface. The landfill surface would also be inspected annually to ensure that no damage threatens a release from the waste. Additional monitor wells may be installed, if necessary for leak detection in the vicinity of the Pit 8 Landfill.

Monitoring would be conducted to:

1. Track changes in plume concentration and size.
2. Determine when cleanup goals are attained.
3. Indicate and analyze deviations from expected contaminant concentration trends.
4. Determine impacts of VOCs in the vadose zone at Building 801 on ground water.
5. Monitor for releases of contaminants from the Pit 8 Landfill.

VOCs, including TCE, 1,2-DCA, and chloroform, have been identified in ground water at Building 801. As mentioned previously, the concentrations of these COCs in ground water are near or below State and Federal MCLs and/or State WQOs. In 1998, the maximum concentration of TCE was 4.1 µg/L (MCL: 5 µg/L), 1,2-DCA was 1.4 µg/L (Federal MCL: 5; State MCL: 0.5 µg/L) and chloroform was below analytical method detection limits. Concentration trends for these VOCs in ground water indicate that concentrations are decreasing over time. Nitrate has been detected in ground water in one well downgradient of Building 801 at 47 mg/L (MCL: 45 mg/L). These data indicate that nitrate has not significantly impacted water quality in this area. The concentrations of these contaminants will be monitored over time to track concentration trends and plume size. Responses to increases in VOC and/or nitrate concentrations in ground water will be addressed in the Site-Wide CP and remediation would be implemented, if necessary.

No COCs have been identified in any environmental media in the vicinity of the Pit 8 Landfill. VOCs in ground water in the vicinity of the landfill are believed to emanate from the Building 801 dry well since the highest VOC concentrations were detected in a well located hydraulically upgradient from Pit 8, and concentrations decrease with distance from this well. Debris and gravel from the Building 801 firing table disposed in Pit 8 may have contained tritium, uranium, lead, thorium, beryllium, copper, cobalt, chromium, molybdenum, LiH, and fluoride salts (Taffet, 1989; SAIC, 1992). However, soil, rock, and ground water data indicate that contaminants have not been released from Pit 8 Landfill. Depth to ground water in this area is about 120 ft below ground surface.

As part of Alternative 2, ground water in wells in the vicinity of this landfill would be monitored for metals, tritium, uranium, and thorium to detect any future releases of contaminants from the landfill. Additional monitor wells may be added, if necessary, to provide a complete release detection monitoring network for the landfill.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the vicinity of Building 801 and Pit 8 Landfill quarterly for 30 years.

The well-specific ground water monitoring program for Building 801 and Pit 8 Landfill will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

The Site 300 CP will include actions to be implemented in the event that contaminants are detected in ground water.

6.7.3. Alternative 3—No Further Action for VOC Contaminants in Subsurface Soil; Monitoring; and Waste Characterization with Contingent Monitoring, Capping, and/or Excavation of Pit 8 Landfill

Alternative 3 combines no further action for subsurface soil and monitoring described in Alternative 2 with characterization of waste in Pit 8 Landfill with contingent monitoring, capping, and/or excavation of the pit, depending on the waste characterization results.

Characterization of soil, rock, and ground water in the vicinity of the Pit 8 Landfill was conducted as part of the SWRI. Soil and rock samples were collected from the pilot boreholes for five wells located in the vicinity of the Pit 8 Landfill. Ground water has been routinely monitored for possible contamination in these wells. No COCs have been identified in surface soil, subsurface soil/bedrock, ground water or surface water associated with the Pit 8 Landfill.

Contaminants including uranium-238 and several metals were detected in the analysis of gravel from the Building 801 firing table. As potentially contaminated firing table gravel from this firing table was disposed in Pit 8, this alternative presents methods for evaluating the potential for contamination of the subsurface beneath the pit as a result of future releases from the landfill waste.

As discussed in Chapter 4, a strategy has been developed for addressing potential releases of contaminants from landfills. The process begins with a detailed characterization of the contents of the landfill, followed by modeling to estimate potential impacts of ground water, and risk assessment to evaluate impacts to human health and the environment. The results of these activities will be used to support remedial action decisions. The overall decision process is shown in Figure 4-1. Documentation of the work planned and data collected would be provided throughout the landfill characterization and remediation process (Table 6-2).

DOE has preliminarily identified five possible remedial approaches to address actual or potential releases of contaminants from the Pit 8 Landfill including:

1. Monitoring only.
2. Capping.
3. Partial excavation with capping.
4. Partial excavation without capping.
5. Total excavation.

General decision criteria were developed to use the characterization data to evaluate the most appropriate remedial pathway for the landfill. These criteria are presented in Table 6-3 and will be addressed in the Focused Feasibility Study discussed in Section 4.1.2.9.1.3.

As the depth to ground water is 120 feet or more beneath the Pit 8 Landfill, there is no risk of inundation of the pit that could result in releases. Therefore, the excavation of the waste may provide no significant increase in protection to human health or the environment over that provided by capping.

If waste excavation is selected as the best remedial option for this landfill, two options are available for the disposition of excavated waste, as discussed in Chapter 3 (Section 3.2.7) and Appendix C (Section C-2.7),

The disposal options retained for consideration include:

1. Transportation to an off-site permitted facility for treatment, destruction, and/or disposal.
2. Placement of excavated waste in an on-site engineered containment unit either at the location of an existing landfill or outside the areas of existing contamination within a Corrective Action Management Unit (CAMU).

Figure 4-1 presents the disposal options and how they fit into the remedial action selection process. The primary decision criteria that will be used to select a disposal option for excavated material include: (1) the time, resources, and cost necessary to implement the disposal option, (2) engineering feasibility, (3) regulatory agency approval, and (4) public acceptance.

The present-worth cost of Alternative 3 for the Building 801 dry well and Pit 8 Landfill release sites is \$21,612,000 based on 30 years of monitoring and waste characterization with total excavation of Landfill Pit 8.

6.8. Remedial Alternatives for the Building 833 (OU 8)

Three remedial alternatives were assembled to address COCs in subsurface soil/bedrock and ground water at Building 833. Each of these alternatives is discussed in detail in Sections 6.8.1, 6.8.2, and 6.8.3.

TCE was used as a heat-exchange fluid in the Building 833 area. Surface discharge of waste fluids containing TCE occurred through spills, building washdown, rinsewater from the test cell and settling basin, and rinsewater disposal in a lagoon adjacent to Building 833. As a result, VOC contamination of the shallow soil/bedrock and perched ground water has occurred. However, analytical data indicate that the deeper regional aquifer has not been impacted.

Three hydrogeologic units have been identified in the Building 833 area. With increasing depth, the three units are Qt-Tnsc₂, Tnbs₂-Tnsc₁, and Tnbs₁. The shallow perched Qt-Tnsc₂ unit is comprised of the ephemerally saturated terrace alluvium (Qt), unconsolidated sediments and poorly lithified siltstone and claystone (Tps), and siltstone and claystone (Tnsc₂). The middle unsaturated Tnbs₂-Tnsc₁ unit is comprised of sandstone (Tnbs₂) and siltstone and claystone (Tnsc₁). The lower Tnbs₁ unit is comprised of sandstone (Tnbs₁) and is referred to as the regional aquifer.

After rainfall events, precipitation and some surface runoff infiltrate the Qt gravel and migrate downward into permeable sand and gravel of the Qt and Tps stratigraphic units. This

unconfined ground water is perched atop the low permeability underlying Tps sediments and poorly consolidated claystone unit. This Tps perching horizon extends north into the Building 834 area where it also acts as a perching horizon (Bryn et al., 1990). Field lithologic data indicate that the Qt-Tnsc₂ hydrogeologic unit appears to be hydraulically separated from the underlying unsaturated Tnbs₂-Tnsc₁ unit by low permeability sediments of the Tps perching horizon. The thickness of these low permeability sediments varies from about 23 to 55 ft. Semiconfined ground water is present in the deep Tnbs₁ regional aquifer. The ephemeral perched ground water present in the Qt-Tnsc₂ hydrologic unit is separated from the deep Tnbs₁ regional aquifer by approximately 250 ft of unsaturated sedimentary rock.

TCE has been identified in the near surface vadose zone at a maximum concentration of 1.5 mg/kg. TCE is generally found in relatively shallow soil at depths less than 12 ft below ground surface (bgs) and is rarely present, if at all, greater than 15 feet below the gravel-silty claystone interface within the Tps. This vertical distribution of TCE suggests that TCE may have migrated downward through sand and gravel lenses but was impeded from further downward vertical migration by the silty claystone deposits of the Tps at about 28 to 60 ft bgs. This silty claystone deposit appears to be a significant barrier to downward vertical migration of TCE (Webster-Scholten et al., 1991).

Ground water rarely occurs in the Qt and Tps water-bearing units. Discontinuous areas of perched ground water have been encountered in only two of the nine wells that monitor the shallow (<35 ft bgs) gravel lenses within these units. The Qt stratigraphic unit is discontinuous and ground water has only been encountered in well W-833-12, which is screened in the Qt gravel. Ground water has also been encountered intermittently in well W-833-03, which is screened in the Tps gravel. Water level data indicate that ground water is present in these wells primarily after periods of rainfall. When ground water is present, the saturated thickness of this perched zone is approximately one to four feet (SWRI, 1995). Ground water TCE concentrations in this perched zone have generally decreased from an historical maximum of approximately 2,000 µg/L in 1992 to approximately 1,000 µg/L, or lower, in 1998.

VOCs have not been detected historically in ground water samples collected from the Tnbs₁ regional aquifer, based on VOC ground water concentration data from 1991 through 1999 from well W-833-30, which is screened in the regional aquifer. These data indicate that the regional aquifer has not been impacted by VOCs. As part of the SWRI, numerical modeling was performed to evaluate the potential future impacts to the regional aquifer. A scenario was modeled whereby TCE partitions into infiltrating rainwater and migrates vertically through the Tps claystone perching horizon, and underlying siltstones and claystones of the Tnsc₁, eventually reaching the Tnbs₁ regional aquifer. The model estimates the maximum TCE ground water concentration reaching the regional aquifer would be 1.5×10^{-11} µg/L after 140 years.

6.8.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all monitoring activities in the vicinity of Building 833 would cease. There are no costs associated with the no-action alternative.

6.8.2. Alternative 2—Monitoring and Exposure Control

The primary components of Alternative 2 include:

1. Monitoring of ground water for VOCs.
2. Risk and hazard management to prevent exposure of humans and ecological receptors to COCs.

These components are described below in Sections 6.8.2.1 and 6.8.2.2.

The present-worth cost of Alternative 2 for the Building 833 release site is \$820,000 based on 30 years of monitoring and exposure prevention.

6.8.2.1. Monitoring

Sampling and analysis of ground water from monitor wells in the area would continue in monitor COCs in the subsurface. No additional monitor wells would be installed. Monitoring would be conducted to:

1. Track changes in plume concentration and size.
2. Determine when cleanup goals are attained.
3. Indicate and analyze deviations from expected contaminant concentration trends.

A monitoring only approach is considered an appropriate remedial alternative based on the following subsurface characteristics of the Building 833 area:

- Soil/Bedrock Characteristics
 - Soil impact: The maximum TCE concentration in soil samples was 1.5 mg/kg (in 1991). TCE has not been found (detection limit 0.0005 mg/kg) below a depth of 61 feet (i.e., the base of the Qt-Tnsc₂ hydrologic unit). The total estimated mass of TCE in the vadose zone (Table 1-7) is 600 grams.
 - Soil concentrations decrease with depth below the shallow perched horizon: Based on soil sample data, VOC concentrations generally decrease with depth. This trend indicates that impacted soil is limited to the shallower depths, and that it may be that TCE has not migrated below the low permeability sediments of the Qt-Tnsc₂ hydrologic unit.
 - Infiltration: Infiltration from rainfall and surface run-off may be small due to the relatively low rain fall and high evaporation that occurs at Site 300. Low infiltration would limit the amount of water available for transporting VOCs to greater depths.
- Perched Ground Water Characteristics

Distribution: The downward movement of the ephemerally perched and sporadically distributed ground water in the Qt and Tps is restricted by the low permeability soil and bedrock of the base of the Qt-Tnsc₂ hydrogeologic unit.

Mass of TCE in ground water: The total mass of TCE estimated to be in the ground water is approximately 400 grams (Table 1-8).

- Regional Aquifer Ground Water Characteristics
 - Thick unsaturated zone between perched ground water and regional aquifer: There is approximately 250 feet of unsaturated bedrock between the base of the perched ground water zone and the top of the regional aquifer. This thick unsaturated zone may limit transport of VOCs from the perched ground water zone to the regional aquifer.
 - Regional aquifer is not impacted: VOCs have never been detected in ground water samples collected from the Tnbs1 regional aquifer (i.e., between 1991 and 1999).
 - Model predictions: The transport modeling that was performed for the Building 833 area indicates that the potential future maximum TCE ground water concentration reaching the regional aquifer would be 1.5×10^{-11} $\mu\text{g/L}$ after 140 years.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the Building 833 area quarterly for 30 years.

The well-specific ground water monitoring program for the Building 833 area will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

The Site 300 CP will include actions to be implemented in the event that contaminants are detected in monitor wells screened in the Tnbs₁ regional aquifer, indicating that contaminants have migrated from the impacted shallow perched ground water zone to the regional aquifer in the Building 833 area.

6.8.2.2. Exposure Control

As part of Alternative 2, institutional and/or administrative controls and a risk and hazard management program would be implemented to:

1. Ensure RAOs are achieved.
2. Manage risk and/or hazard by preventing exposure to contaminated media.

These controls provide a degree of protection to human health by restricting access to or activities in areas of contamination, thereby preventing exposure to contaminants.

An inhalation risk of 1×10^{-6} for adult onsite workers was identified for VOCs volatilizing from subsurface soil to air inside Building 833 in the baseline risk assessment. The maximum

historical concentration of TCE detected in subsurface soil is 1.5 mg/kg. New data would be used to recalculate risk and hazard.

The risk and hazard management program would include: (1) analyzing indoor air at Building 833 annually for a minimum of two years, and if air concentrations indicate that the inhalation risk exceeds 10^{-6} or the HI exceeds 1, instituting restrictions for building use or, if building use is again anticipated, installing a building ventilation system and operating it whenever the building is occupied, (2) reviewing exposure pathway-related conditions, such as building and land use, (3) refining risk and hazard models using current data, and (4) reporting the results to the stakeholders.

In the baseline risk assessment, it was determined that there were no impacts from VOCs to ecological receptors at Building 833.

6.8.3. Alternative 3—Monitoring, Exposure Control, and Ground Water and Soil Vapor Extraction and Treatment

Alternative 3 combines the monitoring and exposure control described in Alternative 2 with VOC mass removal at Building 833 through ground water and/or soil vapor extraction at Building 833.

In Alternative 3, an additional objective of the monitoring component of Alternative 2 would be to evaluate the effectiveness of the remedial action. The Site 300 CP will include actions to be implemented in the event that active remediation described below does not achieve RAOs or comply with ARARs. The Site 300 CP will also address situations where the existing access restrictions are removed or relaxed.

As part of Alternative 3, ground water and/or soil vapor remediation would be implemented at Building 833 to: (1) reduce soil vapor VOC concentrations in the vadose zone to acceptable risk- and hazard-based concentrations, (2) reduce soil vapor VOC concentrations in the vadose zone to levels protective of ground water, and/or (3) reduce VOC concentrations in ground water to meet RAOs and ARARs by reducing contaminant concentrations and mass to achieve source and plume migration control.

COCs in ground water at Building 833 consist of TCE, cis-1,2-DCE, benzene and toluene. Neither benzene nor toluene has been detected in ground water at Building 833 for the past five years. Cis-1,2-DCE was below analytical method detection limits in most recent (1998) ground water samples in this area. The primary VOC mass removal mechanism would be by SVE. Ground water extraction wells would be used primarily to dewater the water-bearing zone to enhance SVE of VOCs.

Dual-phase extraction is considered a presumptive remedy by EPA for remediation of VOCs and other contaminants in subsurface formations (EPA, 1997a). Dual-phase extraction would be implemented at approximately two wells located in the Building 833 area for mass removal. VOCs in ground water would be treated using aqueous-phase GAC. Extracted soil vapor would be treated using vapor-phase GAC and discharged to the atmosphere in accordance with the permit requirements issued by the SJVUAPCD.

Due to the very low maximum VOC concentrations in subsurface soil/rock (1.5 mg/kg), SVE may not efficiently remove VOC mass. If SVE does not appear to be effective in removing

source mass, it may be necessary to extract and treat ground water whenever it is present in wells.

Treated ground water effluent from the Building 833 treatment system would be discharged onsite in accordance with Substantive Requirements issued by the RWQCB. The spent GAC from the soil vapor and/or ground water treatment system would be disposed or regenerated at an offsite treatment facility.

The present-worth cost of Alternative 3 for the Building 833 release site is \$4,256,000 based on 30 years of monitoring, exposure prevention, and ground water remediation.

6.9. Remedial Alternatives for the Building 845 Firing Table and Pit 9 Landfill (OU 8)

Three remedial alternatives were assembled to address (1) COCs in subsurface soil/bedrock at the Building 845 firing table and (2) waste buried in the Pit 9 Landfill. High-explosives experiments were conducted at the Building 845 firing table from 1958 to 1963. Leaching of contaminants from firing table debris has resulted in the contamination of subsurface soil. Uranium-238 and HMX have been detected in shallow silty clay, silt, and gravels (Qls) and shallow Tnbs₁ bedrock at concentrations of 1.2 pCi/g and 0.054 mg/kg, respectively. No contamination has been detected in ground water under the Building 845 firing table. In 1988, a total of 1,942 yd³ of Building 845 firing table gravel and 390 yd³ of soil from the firing table berm were removed and disposed in Pit 1 (Lamarre and Taffet, 1989).

The Pit 9 Landfill was used until 1968 to dispose of approximately 4,400 yd³ of firing table debris generated at the Building 845 firing table. The firing table debris buried in the pit may have contained tritium, uranium, and/or HE compounds. However, soil, rock, and ground water analytical data indicate that contaminants have not been released from the Pit 9 Landfill. Depth to ground water in this area is about 140 ft below ground surface.

No risk or hazard to human health or ecological receptors in the Building 845 firing table or Pit 9 Landfill has been identified.

6.9.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all monitoring activities in the vicinity of the Building 845 firing table and the Pit 9 Landfill would cease. There are no costs associated with the no-action alternative.

6.9.2. Alternative 2—No Further Action for HMX and Uranium in Subsurface Soil/Rock and Monitoring

The primary components of Alternative 2 include:

1. No further action for HMX and uranium-238 in subsurface soil/rock.
2. Monitoring of ground water for future releases of HMX and uranium-238 from subsurface soil/rock and contaminants that may present in the Pit 9 Landfill waste.

These components are described below in Sections 6.9.2.1 and 6.9.2.2.

The present-worth cost of Alternative 2 for the Building 845 firing table and Pit 9 Landfill is \$488,000 based on 30 years of monitoring.

6.9.2.1. No Further Action for HMX and U-238 in Subsurface Soil/Rock

The only COCs identified for the Building 845 firing table area were HMX and uranium-238 in subsurface soil/rock. In 1988, 1,942 yd³ of gravel from the firing table and 390 yd³ of soil from the firing table berm were removed and disposed in Pit 1. In the baseline risk assessment, no risk or hazard to human health or ecological receptors posed by HMX or uranium-238 in subsurface soil/rock was identified. No contamination has been detected in ground water under the Building 845 firing table. Monitoring for HMX or uranium-238 in ground water would indicate if contamination in subsurface soil/rock has impacted ground water and enable assessment of changes in risk or hazard that would affect human health and the environment.

6.9.2.2. Monitoring

Sampling and analysis of ground water from monitor wells in the Building 845 firing table and Pit 9 Landfill area would continue in order to monitor for future potential impacts to ground water from: (1) contaminants in subsurface soil/bedrock at the Building 845 firing table, or (2) waste buried in the Pit 9 Landfill. The landfill surface would also be inspected annually to ensure that no damage threatens a release from the waste.

Ground water in the vicinity of the Building 845 firing table would be monitored to determine if uranium-238 and HMX, detected in subsurface soil and bedrock, migrates to and impacts ground water.

No COCs have been identified in surface soil, subsurface soil/bedrock, ground water or surface water in the vicinity of the Pit 9 Landfill. However, ground water monitoring for tritium, uranium and HE compounds would be conducted to detect any future releases of contaminants from the landfill and resulting impact to ground water. Additional monitor wells may be added, if necessary, to provide a complete release detection monitoring network for the landfill.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the Building 845 firing table and Pit 9 Landfill area quarterly for 30 years.

The well-specific ground water monitoring program for the Building 845 firing table and Pit 9 Landfill area will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

The Site 300 CP will include actions to be implemented in the event that contaminants are detected in ground water indicating that: (1) uranium-238 and HMX subsurface in soil and bedrock at the Building 845 firing table migrate to and impact ground water, and/or (2) contaminants in the Pit 9 Landfill are released to ground water.

6.9.3. Alternative 3—Monitoring, No Further Action for HMX and Uranium in Subsurface Soil/Rock, and Waste Characterization with Contingent Monitoring, Capping, and/or Excavation of the Pit 9 Landfill

Alternative 3 combines monitoring and no further action for HMX and uranium-238 in subsurface soil/rock described in Alternative 2 with characterization of waste in Pit 9 Landfill, with contingent monitoring, capping, and/or excavation of the pit, depending on the waste characterization results.

Characterization of soil, rock, and ground water in the vicinity of the Pit 9 Landfill was conducted as part of the SWRI. Soil and rock samples were collected for the pilot boreholes for four wells located in the vicinity of the Pit 9 Landfill. Ground water has been routinely monitored for possible contamination in these wells. No COCs have been identified in surface soil, subsurface soil/bedrock, ground water or surface water associated with the Pit 9 Landfill.

Several contaminants including uranium-238 and metals were detected in the analysis of gravel from the Building 845 firing table. Because potentially contaminated firing table gravel from this firing table was disposed in Pit 9, this alternative presents methods for evaluating the potential for contamination of the subsurface beneath the pit as a result of releases of contaminants that may be present in the landfill waste.

As discussed in Chapter 4, a strategy has been developed for addressing potential releases of contaminants from landfills. The process begins with a detailed characterization of the contents of the landfill, followed by modeling to estimate potential impacts of ground water, and risk assessment to evaluate impacts to human health and the environment. The results of these activities would be used to support remedial action decisions. The overall decision process is shown in Figure 4-1. Documentation of the work planned and data collected would be provided throughout the landfill characterization and remediation process (Table 6-2).

DOE has preliminarily identified five possible remedial approaches to address actual or potential releases of contaminants from the Pit 9 Landfill including:

1. Monitoring only.
2. Capping.
3. Partial excavation with capping.
4. Partial excavation without capping.
5. Total excavation.

General decision criteria were developed to use the characterization data to evaluate the most appropriate remedial pathway for the landfill. These criteria are presented in Table 6-3 and will be addressed in the Focused Feasibility Study discussed in Section 4.1.2.9.1.3.

Because the depth to ground water is 140 feet or more beneath the Pit 9 Landfill, there is no risk of inundation of the pit that could result in releases. Therefore, the excavation of the waste may provide no significant increase in protection to human health or the environment over that provided by capping.

If waste excavation is selected as the best remedial option for this landfill, two options are available for the disposition of excavated waste, as discussed in Chapter 3 (Section 3.2.7) and Appendix C (Section C-2.7),

The disposal options retained for consideration include:

1. Transportation to an off-site permitted facility for treatment, destruction, and/or disposal.
2. Placement of excavated waste in an on-site engineered containment unit either at the location of an existing landfill or outside the areas of existing contamination within a Corrective Action Management Unit (CAMU).

Figure 4-1 presents the disposal options and how they fit into the remedial action selection process. The primary decision criteria that will be used to select a disposal option for excavated material include: (1) the time, resources, and cost necessary to implement the disposal option, (2) engineering feasibility, (3) regulatory agency approval, and (4) public acceptance.

The present-worth cost of Alternative 3 for the Building 845 firing table and Pit 9 Landfill release sites is \$7,065,000 based on 30 years of monitoring and waste characterization with total excavation of the Pit 9 Landfill.

6.10. Remedial Alternatives for the Building 851 Firing Table (OU 8)

Three remedial alternatives were assembled to address COCs in subsurface soil/bedrock at the Building 851 firing table. The Building 851 firing table has been used to conduct high explosives research. These explosives experiments have resulted in the release of VOCs and uranium-238 to subsurface soil. Analytical data also indicate that cadmium, copper, zinc, RDX, and uranium-238 were released to surface soil surrounding the Building 851 firing table. No risk or hazard associated with these COCs in surface soil and subsurface soil/bedrock was identified in this area in the baseline risk assessment.

VOCs have been detected at low concentrations in ground water, including TCE up to 2.7 µg/L in 1992. No VOCs were detected in ground water in 1998. Depleted uranium has been detected in ground water in four wells in the vicinity of the Building 851 firing table. The maximum historical activity of uranium-238 detected in these wells was 1.3 pCi/L. COCs in ground water at the Building 851 firing table were present in the shallow gravel and sand (Q1s) and shallow bedrock (Tnbs₁). In 1988, the firing table gravel was removed and has been replaced periodically since then.

6.10.1. Alternative 1—No Further Action

A no-action alternative is generally required by EPA guidance to provide a baseline for comparison to other remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all monitoring activities in the vicinity of Building 851 firing table would cease. There are no costs associated with the no-action alternative.

6.10.2. Alternative 2—No Further Action for VOCs and U-238 in Subsurface Soil/Rock and for RDX, Metals and U-238 in Surface Soil, and Monitoring

The primary components of Alternative 2 include:

1. No further action for VOCs and U-238 in subsurface soil/bedrock, and for RDX, cadmium, copper, zinc and U-238 in surface soil.
2. Monitoring of ground water for COCs, and tritium, as a potential COC.

These components are described below in Sections 6.10.2.1 and 6.10.2.2.

The present-worth cost of Alternative 2 for the Building 851 firing table release site is \$530,000 based on 30 years of monitoring.

6.10.2.1. No Further Action for VOCs and U-238 in Subsurface Soil/Rock, and for U-238, Metals, and RDX in Surface Soil

Ground water has not been impacted by the RDX, cadmium, copper, or zinc in surface soil in the vicinity of the Building 851 firing table. Modeling indicates that cadmium and copper may reach ground water in 20,000 years in concentrations of 0.0024 mg/L and 0.054 mg/L, respectively. The MCLs for cadmium and copper are 0.005 mg/L and 1,000 mg/L, respectively with background concentrations of 0.0015 mg/L and 0.05 mg/L, respectively. The model indicated that zinc and RDX in surface soil would result in ground water concentrations of 0.041 mg/L in 10,000 years for zinc and RDX in ground water at 2.5 µg/L in 400 years. The MCL for zinc is 5 mg/L with background concentrations of 0.01 mg/L. While there is no MCL for RDX, the method detection limit is 0.7 µg/L. There is no risk or hazard for human or ecological receptors posed by these contaminants in surface soil.

The maximum concentrations of VOCs detected in subsurface soil were TCE at 0.0003 mg/kg and cis-1,2-DCE at 0.012 mg/kg. Concentrations of TCE and other VOCs in ground water have declined to concentrations below analytical method detection limits, indicating that VOCs in subsurface soil/rock are not a continuing source of contamination in ground water. No risk or hazard for VOCs in subsurface soil has been identified. In addition, there are no viable remedial technologies to address such extremely low concentrations.

Uranium-238 has been detected in surface soil and subsurface soil/rock at maximum activities of 14 pCi/g and 11 pCi/g, respectively. Uranium-238 was detected in ground water at a maximum historical activity of 1.3 pCi/L (1990), slightly above the cancer PRG of 1.1 pCi/L and below the MCL and background activities for total uranium. The water-bearing zone affected by the contamination is not currently a drinking water source. No risk or hazard to human health or ecological receptors was identified for uranium in surface or subsurface soil/rock.

No further action for these COCs in surface soil and subsurface soil/rock should be protective of human health and the environment because: (1) there is no risk or hazard associated with these contaminants in surface soil and subsurface soil/rock, (2) there is no significant impact or threat to ground water, (3) monitoring of uranium-238 would detect any changes in activities and enable the assessment of changes in risk or hazard that could affect human health and the environment, and (4) monitoring for VOCs, metals, and RDX in ground water would determine if these soil and rock contaminants impact human health or the environment in the future. For these reasons, the monitoring of VOCs, metals, RDX, and uranium-238 in ground water should be protective of human health and the environment.

6.10.2.2. Monitoring

Sampling and analysis of ground water from monitor wells in the area would continue in order to monitor COCs and potential COCs in the subsurface. No additional monitor wells would be installed. Monitoring would be conducted to:

1. Track changes in plume concentration and size.
2. Determine when cleanup goals are attained.
3. Indicate and analyze deviations from expected contaminant concentration trends.
4. Detect ground water impacts from COCs in surface soil.

Ground water in the vicinity of the Building 851 firing table would be monitored to determine if cadmium, copper, zinc, and RDX detected in surface soil migrate to and impact ground water. In addition, uranium-238 would be monitored in ground water to track changes in activities that could result in a risk to downgradient receptors. Uranium-238 has been detected in ground water at an historical maximum activity of 1.3 pCi/L, slightly above the cancer PRG for uranium (1.1 pCi/L), and below the background activity for total uranium (9.28 pCi/L). Although VOC concentrations are currently below analytical method detection limits, monitoring would be conducted to detect any future increases in concentrations in ground water.

Monitoring costs include water level measurements, ground water sampling and analysis, well maintenance, QA/QC, database management, and data evaluation. The costs for monitoring in Alternative 2 assume that samples will be collected and analyzed for COCs and water levels will be measured in all monitor wells in the Building 851 firing table area on a quarterly basis for 30 years.

The well-specific ground water monitoring program for the Building 851 firing table area will be presented in the Site 300 Site-Wide CMP. Information presented in the CMP will include the total number of wells sampled, well names and sampling frequency, specific analytes, and the purpose/location of each well.

The ground water data obtained as part of the Alternative 2 monitoring program would be re-evaluated regularly. If data indicate that contaminant concentrations, ground water flow direction, and/or velocity have changed, the monitoring program would be reevaluated.

The current LLNL program of conducting ecological resource surveys for sensitive species prior to the initiation of any ground-disturbing activities would also continue. The need for

detailed ecological resource surveys would be evaluated every five years as part of the contract renewal negotiations between the University of California and DOE.

The Site 300 CP will include actions to be implemented in the event that contaminants are detected in ground water, indicating that COCs in soil and bedrock at the Building 851 firing table have migrated to and impacted ground water.

6.10.3. Alternative 3—No Further Action for VOCs and U-238 in Subsurface Soil/Rock, U-238, Metals and RDX in Surface Soil, Monitoring, and Ground Water Extraction and Treatment of Uranium

Alternative 3 combines the no further action and monitoring described in Alternative 2 with uranium mass removal at Building 851 firing table through ground water extraction and treatment.

In Alternative 3, an additional objective of the monitoring component of Alternative 2 would include monitoring to evaluate the effectiveness of the remedial action. The Site 300 CP will include actions to be implemented in the event that active remediation described below does not achieve RAOs or comply with ARARs.

As part of Alternative 3, ground water remediation would be implemented at the Building 851 firing table to reduce uranium concentrations in ground water to meet RAOs and ARARs and to achieve plume migration control.

Uranium-238 has been detected in ground water from four wells in the Building 851 firing table area at activities up to 1.3 pCi/L (1990), slightly above the cancer PRG for uranium (1.1 pCi/L), but below the general background activity for uranium. Ground water would be extracted from these four wells to achieve uranium source mass removal. Uranium-238 in ground water would be treated using an ion exchange treatment system.

Treated ground water effluent from the Building 851 treatment system would be discharged onsite in accordance with Substantive Requirements issued by the RWQCB. The spent resin from the ground water treatment system would be disposed or regenerated at an offsite treatment facility.

The present-worth cost of Alternative 3 for the Building 851 firing table release site is \$4,198,000 based on 30 years of monitoring and ground water extraction and treatment for uranium.

6.11. References

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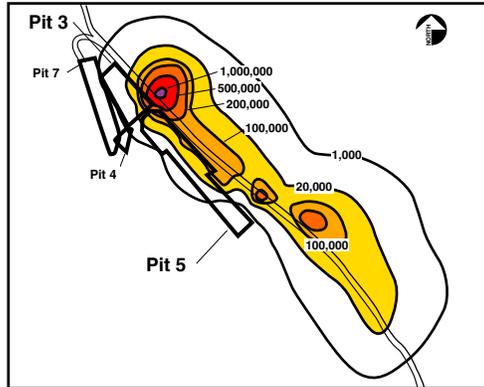
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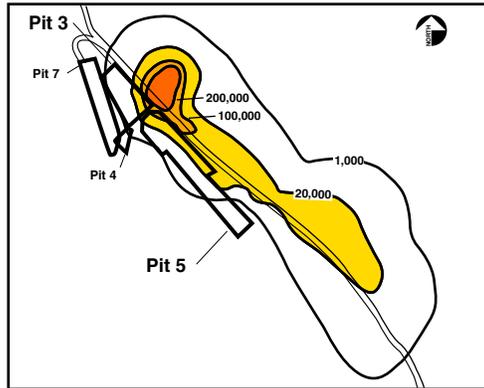
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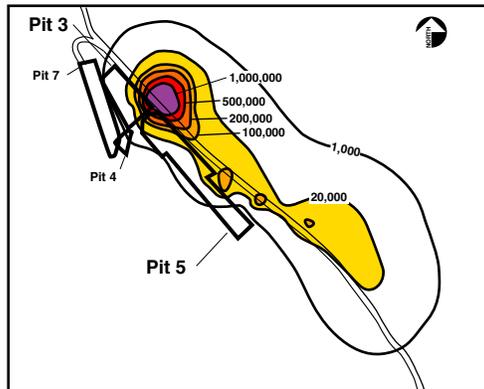
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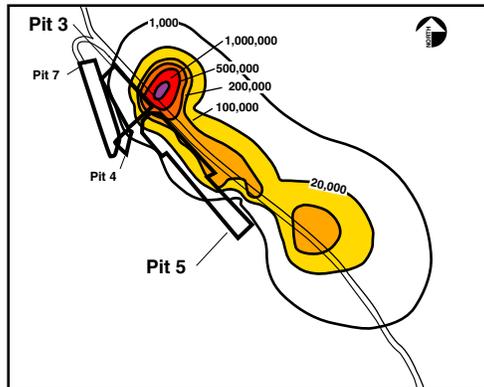
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1993



June
1996



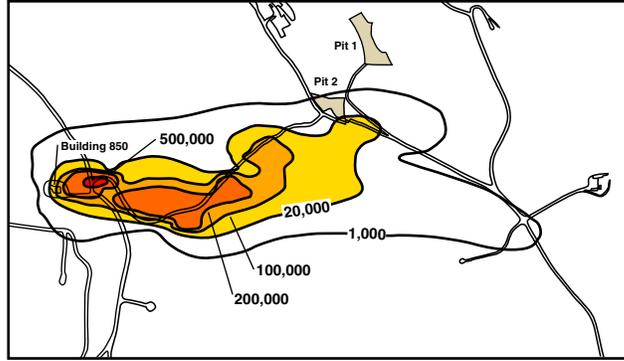
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1998



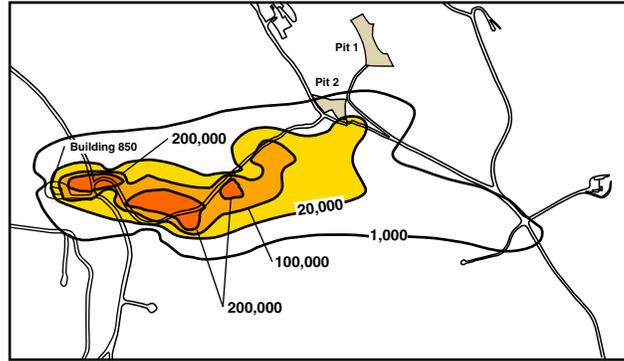
Contour values
in pCi/L
Scale : feet
0 250 500

Figure 6-1. Time series plot of tritium activities in ground water in the vicinity of Pits 3 & 5.

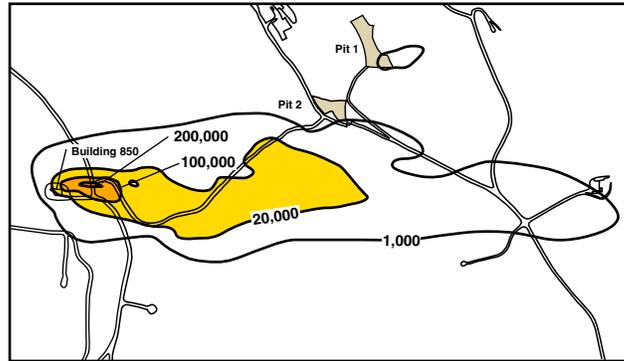
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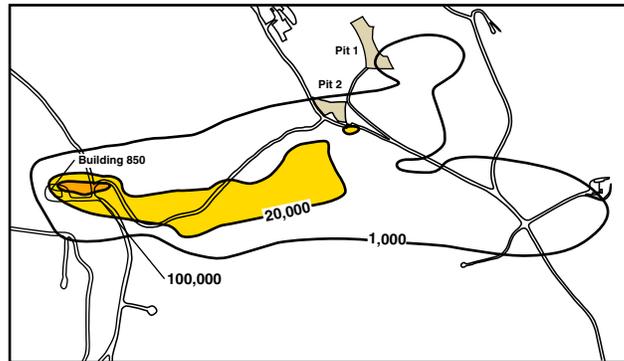
June
1987



June
1995



June
1998



Contour values
in pCi/L
Scale : feet
0 1,000 2,000

ERD-S3R-99-0077

Figure 6-2. Time series plot of tritium activities in ground water in the vicinity of Building 850.

Table 6-1. Remedial Alternatives for the Site 300 Operable Units.

<i>Remedial Alternatives for Building 834 (OU 2)</i>		
Alternative 1	Alternative 2	Alternative 3
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Excavation of VOC contaminated soil (1983). 2) Surface water drainage diversion (1998). 3) Ongoing soil vapor and ground water extraction since 1995. <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Ground water and soil vapor extraction and treatment of VOCs, TBOS/TKEBS, and nitrate (ongoing since 1995).</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Excavation of VOC contaminated soil (1983). 2) Surface water drainage diversion (1998). 3) Ongoing soil vapor and ground water extraction since 1995. <p><u>Total Estimated Cost:</u> \$12,095,000</p>	<p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Ground water and soil vapor extraction and treatment of VOCs, TBOS/TKEBS, and nitrate (ongoing since 1995).</p> <p><u>Module E:</u> Enhanced <i>in situ</i> bioremediation of VOCs.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Excavation of VOC contaminated soil (1983). 2) Surface water drainage diversion (1998). 3) Ongoing soil vapor and ground water extraction since 1995. <p><u>Total Estimated Cost:</u> \$14,504,000</p>

Table 6-1. Remedial Alternatives for the Site 300 Operable Units. (Cont. Page 2 of 9)

Remedial Alternatives for the Pit 6 Landfill (OU 3)		
Alternative 1	Alternative 2	Alternative 3
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Exhumed waste containing uranium-238 (1971). 2) Capped landfill as a CERCLA removal action (1997). <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module B:</u> Monitoring of ground and surface water for COCs. (Monitoring only for perchlorate and nitrate at this time).</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Monitored natural attenuation of VOCs and tritium in ground water.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Exhumed waste containing uranium-238 (1971). 2) Capped landfill as a CERCLA removal action (1997). <p><u>Total Estimated Cost:</u> \$2,377,000</p>	<p><u>Module B:</u> Monitoring of ground and surface water for COCs. (Monitoring only for nitrate at this time).</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Monitored natural attenuation of tritium in ground water</p> <p><u>Module E:</u> Ground water extraction and treatment of VOCs and perchlorate.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Exhumed waste containing uranium-238 (1971). 2) Capped landfill as a CERCLA removal action (1997). <p><u>Total Estimated Cost:</u> \$5,939,000</p>

Table 6-1. Remedial Alternatives for the Site 300 Operable Units. (Cont. Page 3 of 9)

Remedial Alternatives for the HE Process Area (OU 4)	
Alternative 1	Alternative 2
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Closed HE Rinsewater Lagoons under RWQCB (1985-1989). 2) Sealed and abandoned water-supply wells 4 (1990) and 6 (1989). 3) Capped HE Burn Pits under RCRA (1998). <p><u>Total Estimated Costs:</u> \$0</p>	<p><u>Module A:</u> No further action for (1) VOCs in subsurface soil/rock at the HE rinsewater lagoon release sites, and (2) VOCs and HMX/RDX in subsurface soil/rock at the HE burn pit release site.</p> <p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Ground water extraction and treatment of VOCs and nitrate at the leading edge of the B815 TCE plume.</p> <p><u>Module E:</u> Ground water extraction and treatment of VOCs, HE compounds, nitrate, and perchlorate released from B815 and HE rinsewater lagoons.</p> <p><u>Module F:</u> Ground water extraction and treatment of VOCs, nitrate, and perchlorate released from the HE Burn Pit.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Closed HE Rinsewater Lagoons under RWQCB (1985-1989). 2) Sealed and abandoned water-supply wells 4 (1990) and 6 (1989). 3) Capped HE Burn Pits under RCRA (1998). <p><u>Total Estimated Cost:</u> \$27,621,000</p>

Table 6-1. Remedial Alternatives for the Site 300 Operable Units. (Cont. Page 4 of 9)

Remedial Alternatives for the Pit 7 Complex including Pits 3, 4, 5, and 7 (OU 5)			
Alternative 1	Alternative 2a	Alternative 2b	Alternative 3
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u> 1) Capped Pits 4 and 7 under RCRA (1992).</p> <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module A:</u> No further action for tritium and uranium in surface soil at Pits 3 and 5.</p> <p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Monitored natural attenuation of tritium and uranium-238 in ground water. (Modified module D)</p> <p><u>Module H:</u> Waste characterization with contingent monitoring, capping, and/or excavation of Pits 3 and 5.</p> <p><u>Previous interim actions:</u> 1) Capped Pits 4 and 7 under RCRA (1992).</p> <p><u>Total Estimated Cost:</u> \$50,282,000</p>	<p><u>Module A:</u> No further action for tritium and uranium in surface soil at Pits 3 and 5.</p> <p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Monitored natural attenuation of tritium and uranium-238 in ground water. (Modified module D)</p> <p><u>Module G:</u> Control migration of uranium-238 in ground water using <i>in situ</i> reactive permeable barriers.</p> <p><u>Module H:</u> Waste characterization with contingent monitoring, capping, and/or excavation of Pits 3 and 5.</p> <p><u>Previous interim actions:</u> 2) Capped Pits 4 and 7 under RCRA (1992).</p> <p><u>Total Estimated Cost:</u> \$54,623,000</p>	<p><u>Module A:</u> No further action for tritium and uranium in surface soil at Pits 3 and 5.</p> <p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Monitored natural attenuation of tritium in ground water.</p> <p><u>Module E:</u> Ground water extraction and treatment of VOCs.</p> <p><u>Module F:</u> Ground water extraction and treatment of uranium-238 and nitrate.</p> <p><u>Module G:</u> Control migration of uranium-238 in ground water using <i>in situ</i> reactive permeable barriers.</p> <p><u>Module H:</u> Waste characterization with contingent monitoring, capping, and/or excavation of Pits 3 and 5.</p> <p><u>Previous interim actions:</u> 1) Capped Pits 4 and 7 under RCRA (1992).</p> <p><u>Total Estimated Cost:</u> \$63,748,000</p>

Table 6-1. Remedial Alternatives for the Site 300 Operable Units. (Cont. Page 5 of 9)

Remedial Alternatives for Building 850 (OU 5)			
Alternative 1	Alternative 2	Alternative 3	Alternative 4
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Removed PCB-contaminated debris from vicinity of B850 Firing Table (1998). 2) Removed/replaced contaminated gravel from Building 850 Firing Table (1988). <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Monitored natural attenuation of tritium in ground water and surface water.</p> <p><u>Module G:</u> Removal of contaminated sandpile at B850 and removal of contaminated soil adjacent to B850 firing table (partial module G).</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Removed PCB-contaminated debris from vicinity of B850 Firing Table (1998). 2) Removed/replaced contaminated gravel from Building 850 Firing Table (1988). <p><u>Total Estimated Cost:</u> \$4,029,000</p>	<p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Monitored natural attenuation of tritium in ground water and surface water.</p> <p><u>Module G:</u> Excavation of contaminated soil and bedrock under B850 firing table, removal of contaminated sandpile at B850, and removal of contaminated soil adjacent to B850 firing table.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Removed PCB-contaminated debris from vicinity of B850 Firing Table (1998). 2) Removed/replaced contaminated gravel from Building 850 Firing Table (1988). <p><u>Total Estimated Cost:</u> \$8,246,000</p>	<p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Monitored natural attenuation of tritium in ground water and surface water.</p> <p><u>Module E:</u> Ground water extraction and treatment of uranium-238 and nitrate.</p> <p><u>Module F:</u> Control migration of uranium-238 in ground water using an <i>in situ</i> reactive permeable barrier.</p> <p><u>Module G:</u> Excavation of contaminated soil and bedrock under B850 firing table, removal of contaminated sandpile at B850, and removal of contaminated soil adjacent to B850 firing table.</p> <p><u>Previous interim actions:</u></p> <ol style="list-style-type: none"> 1) Removed PCB-contaminated debris from vicinity of B850 Firing Table (1998). 2) Removed/replaced contaminated gravel from Building 850 Firing Table (1988). <p><u>Total Estimated Cost:</u> \$16,097,000</p>

Table 6-1. Remedial Alternatives for the Site 300 Operable Units. (Cont. Page 6 of 9)

Remedial Alternatives for the Landfill Pit 2 (OU 5)		
Alternative 1	Alternative 2	Alternative 3
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u> None.</p> <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Previous interim actions:</u> None.</p> <p><u>Total Estimated Cost:</u> \$515,000</p>	<p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Module C:</u> Waste characterization with contingent monitoring, capping, and/or excavation of Pit 2</p> <p><u>Previous interim actions:</u> None.</p> <p><u>Total Estimated Cost Range:</u> \$767,000 to \$22,250,000, depending on the amount of waste excavated.</p>

Remedial Alternatives for Building 854 (OU 6)	
Alternative 1	Alternative 2
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u> 1) Excavated TCE-contaminated soil at Buildings 854H and 854F (1983).</p> <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module A:</u> No further action for metals, HMX, PCBs, and tritium in surface soil.</p> <p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Ground water and soil vapor extraction and treatment of TCE, perchlorate, and nitrate. (Presumptive remedy)</p> <p><u>Previous interim actions:</u> 1) Excavated TCE-contaminated soil at Buildings 854H and 854F (1983).</p> <p><u>Total Estimated Cost:</u> \$9,150,000</p>

Table 6-1. Remedial Alternatives for the Site 300 Operable Units. (Cont. Page 7 of 9)

Remedial Alternatives for Building 832 Canyon (OU 7)	
Alternative 1	Alternative 2
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u> None.</p> <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module A:</u> No further action for (1) HMX in surface soil and nitrate in subsurface soil/rock at B830 and (2) HMX in subsurface soil/rock at B832.</p> <p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Ground water and soil vapor extraction and treatment of VOCs, perchlorate, and nitrate at Building 832. (Presumptive remedy)</p> <p><u>Module E:</u> Ground water and soil vapor extraction and treatment of VOCs, perchlorate, and nitrate at Building 830. (Presumptive remedy)</p> <p><u>Module F:</u> Downgradient ground water extraction using siphon with <i>ex situ</i> treatment of VOCs by iron filings.</p> <p><u>Previous interim actions:</u> None.</p> <p><u>Total Estimated Cost:</u> \$26,766,000</p>

Table 6-1. Remedial Alternatives for the Site 300 Operable Units. (Cont. Page 8 of 9)

Remedial Alternatives for Building 801 and Landfill Pit 8 (OU 8)		
Alternative 1	Alternative 2	Alternative 3
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988. 2) Closed dry well 801D (1981).</p> <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module A:</u> No further action for VOCs in subsurface soil for the B801 dry well.</p> <p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988. 2) Closed Dry Well 801D (1981).</p> <p><u>Total Estimated Cost:</u> \$535,000</p>	<p><u>Module A:</u> No further action for VOCs in subsurface soil for the B801 dry well.</p> <p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Waste characterization with contingent monitoring, capping, and/or excavation of Pit 8.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988. 2) Closed Dry Well 801D (1981).</p> <p><u>Total Estimated Cost Range:</u> \$742,000 to \$21,612,000, depending on the amount of waste excavated.</p>

Remedial Alternatives for Building 833 (OU 8)		
Alternative 1	Alternative 2	Alternative 3
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u> None.</p> <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Previous interim actions:</u> None.</p> <p><u>Total Estimated Cost:</u> \$820,000</p>	<p><u>Module B:</u> Monitoring of ground water.</p> <p><u>Module C:</u> Exposure control through risk and hazard management.</p> <p><u>Module D:</u> Ground water and soil vapor extraction and treatment of VOCs at Building 833.</p> <p><u>Previous interim actions:</u> None.</p> <p><u>Total Estimated Cost:</u> \$4,256,000</p>

Table 6-1. Remedial Alternatives for the Site 300 Operable Units. (Cont. Page 9 of 9)

Remedial Alternatives for Building 845 Firing Table and Landfill Pit 9 (OU 8)		
Alternative 1	Alternative 2	Alternative 3
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988.</p> <p><u>Total Estimated Cost:</u> \$0</p>	<p><u>Module A:</u> No further action for HMX and uranium-238 in subsurface soil/rock.</p> <p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988.</p> <p><u>Total Estimated Cost:</u> \$488,000</p>	<p><u>Module A:</u> No further action for HMX and uranium-238 in subsurface soil/rock.</p> <p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Module C:</u> Waste characterization with contingent monitoring, capping, and/or excavation of Pit 9.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988.</p> <p><u>Total Estimated Cost Range:</u> \$693,000 to \$7,065,000, depending on the amount of wasted excavated.</p>

Remedial Alternatives for the Building 851 Firing Table (OU 8)		
Alternative 1	Alternative 2	Alternative 3
<p>No further action for all contaminants and media of concern.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988.</p> <p><u>Total Estimated Cost:</u></p>	<p><u>Module A:</u> No further action for VOCs and uranium-238 in subsurface soil/rock and for RDX, metals, and uranium-238 in surface soil.</p> <p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988.</p> <p><u>Total Estimated Cost:</u> \$530,000</p>	<p><u>Module A:</u> No further action for VOCs and uranium-238 in subsurface soil/rock and for RDX, metals, and uranium-238 in surface soil.</p> <p><u>Module B:</u> Monitoring of ground and surface water.</p> <p><u>Module C:</u> Ground water extraction and treatment of uranium.</p> <p><u>Previous interim actions:</u> 1) Removed/replaced firing table gravel periodically since 1988.</p> <p><u>Total Estimated Cost:</u> <u>\$4,198,000</u></p>

Table 6-2. Documentation of landfill pit waste characterization and remediation.

Document	Type of FFA Document	Document Contents
Characterization Workplans	Primary	<p>The workplans will include:</p> <ol style="list-style-type: none"> 1. Sampling methods and the number, location, and depth of samples, 2. Analyses to be performed, 3. Risk assessment procedure, and 4. Description of the methodology to be used to estimate ground water impacts.
Focused Remedial Investigation Report	Primary	<p>These reports will include:</p> <ol style="list-style-type: none"> 1. Descriptions of sample collection, 2. Analytical results, 3. Results of the risk assessment, and 4. Results of modeling.
Focused Feasibility Report	Primary	<p>Data from each landfill will be compared to very specific evaluation criteria to help determine the appropriate remedial action to be implemented. In particular, the following specific questions will be considered in the Focused Feasibility Study documents:</p> <ol style="list-style-type: none"> 1. What are the risks or hazards to human health or the environment posed by the waste? 2. What are the nature, concentration, and distribution of contaminants in the waste? 3. What is the potential for precipitation to infiltrate downward through the waste and mobilize contaminants? 4. What is the potential for ground water to rise into the landfills and inundate the waste, causing mobilization of contaminants? 5. What is the actual or potential (modeled) impact to ground water posed by the waste? 6. What transport mechanisms are present that may cause contaminants to be released from the waste? What is the relative importance of each mechanism? 7. Which remedial actions would best address the concerns above-listed concerns?

**Table 6-2. Documentation of landfill pit waste characterization and remediation
(Cont. Page 2 of 2)**

Document	Type of FFA Document	Document Contents
Interim Record of Decision (ROD) Amendment	Primary	The Interim ROD Amendment will document the selected remedial option for the landfill pit waste.
Remedial Design Document	Primary	These documents include engineering design specifications for remedial action (i.e. extraction and treatment systems), system descriptions, monitoring and construction schedules and cost estimates.
Closure/Post Closure Plan	Primary	These documents include the quality control and assurance, monitoring requirements, maintenance programs, and contingency plans.
Decision Document Modifications		Many of the characterization, evaluation, design, and closure documents will likely be produced post-ROD. Depending on the content and scope of the ROD, Explanation of Significant Differences documents or a ROD amendment may be required.

Table 6-3. General decision criteria for selection of landfill remedial approaches.

Potential Action	General Decision Criteria for Selection of Remedial Approach
Monitoring Only	<ol style="list-style-type: none"> 1. No unacceptable risk, hazard, or actual or potential impacts to ground water from the waste are identified.
Capping	<ol style="list-style-type: none"> 1. Unacceptable risk, hazard, or actual or impact to ground water is identified which could be mitigated by capping the landfill, and 2. Direct infiltration of precipitation into the waste is significant enough to cause leaching of contaminants from the waste which could be greatly reduced by constructing a cap over the waste, and 3. No contaminant release due to inundation of waste from rises in ground water is anticipated, and 4. No discrete areas of high contaminant concentrations in the waste are identified.
Partial Excavation with Capping	<ol style="list-style-type: none"> 1. Unacceptable risk, hazard, or actual or potential impact to ground water is identified which could be mitigated by partial excavation of the waste and constructing a cap over the remaining waste, and 2. Direct infiltration of precipitation into the waste is significant enough to cause leaching of contaminants from the waste which could be greatly reduced by constructing a cap over the remaining, unexcavated waste, and 3. No contaminant release due to inundation of waste from rises in ground water is anticipated, and 4. Discrete areas of high contaminant concentrations in the waste are identified.
Partial Excavation without Capping	<ol style="list-style-type: none"> 1. Unacceptable risk, hazard, or actual or potential impact to ground water is identified which could be mitigated by partial excavation of the waste, and 2. Direct infiltration of precipitation into the waste is not significant enough to cause leaching of contaminants from the waste, and 3. Contaminant release due to inundation of waste from rises in ground water is possible, and 4. Discrete areas of high contaminant concentrations in the waste are identified.
Total Excavation	<ol style="list-style-type: none"> 1. Unacceptable risk, hazard, or actual or potential impact to ground water is identified which can only be mitigated by total excavation of the waste, and 2. Contaminant release due to inundation of waste from rises in ground water is possible, and 3. No discrete areas of high contaminant concentration in the waste are identified.

Table 6-3. General decision criteria for selection of landfill remedial approaches (Cont. Page 2 of 2).

Potential Action	General Decision Criteria for Selection of Remedial Approach
Off-site waste disposal	1. Cost.
Placement of excavated waste in an on-site engineered containment unit:	
1. Constructed within the area of an existing landfill or area of existing contamination (AOC)	1. Cost. 2. Stakeholder approval. 3. Siting considerations and approval.
2. Constructed outside the areas of existing contamination within a CAMU.	1. Cost. 2. Stakeholder approval. 3. CAMU designation approval by regulatory agencies. 4. Siting considerations and approval.