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Five-Year Review for the Lawrence Livermore National Laboratory Livermore Site

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November 1997

*Weiss Associates, Emeryville, California

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Summary

Lawrence Livermore National Laboratory's (LLNL's) Livermore Site Record of Decision (ROD) was signed in August 1992 by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency. A five-year review is required to evaluate whether the remedial actions defined in the ROD remain protective of public health and the environment. This is the first five-year review for the Livermore Site. To date, the Livermore Site remedial actions continue to meet all ROD remediation objectives and remain protective of public health and the environment.

Since the ROD was signed, DOE/LLNL have successfully refined their Livermore Site remedial strategy. Some of these successes include western margin hydraulic capture, hydrostratigraphic unit analysis, fate and transport modeling, portable treatment unit remediation, Engineered Plume Collapse, completion of fuel hydrocarbon remediation, and development of catalytic reductive dehalogenation technology.

Currently operating are four permanent ground water treatment facilities and seven portable treatment units that treat about 25 million gallons of ground water per month. Through September 1997, about 303 kg (668 lb) of volatile organic compounds have been removed from the subsurface. One vapor extraction and treatment facility is currently operating at the Livermore Site. At least 18 ground water treatment locations and one vapor treatment facility are planned for operation in the future.

Over the course of the Livermore Site project, DOE/LLNL have learned important lessons about: conducting pump-and-treat remediation, remediating or controlling contamination in source areas, managing fluctuating budgets, effective characterization, flow and contaminant transport modeling, the need for Stakeholder's support, extraction well material selection, ultraviolet oxidation technology drawbacks, the importance of new technology development, reassessing discharge requirements, cost reduction and aggressive cleanup through use of portable treatment units, sampling and reporting cost-savings initiatives, and integrating disciplines and Stakeholders.

Current remedial actions at the Livermore Site remain protective of public health and the environment. DOE/LLNL plan to work with the regulatory agencies and the Stakeholders to evaluate risk-based cleanup standards appropriate for the Livermore Site, and alternative approaches to site closure. The next five-year review will be conducted by August 2002.

1. Introduction

Lawrence Livermore National Laboratory's (LLNL's) Livermore Site Record of Decision (ROD) (U.S. Department of Energy [DOE], 1992) was signed in August 1992 by DOE and the U.S. Environmental Protection Agency (EPA). This five-year review fulfills the requirement to prepare a review every five years after the date of the ROD to evaluate whether the remedial actions defined in the ROD remain protective of public health and the environment and are functioning as designed. The scope and format of this report are based on EPA Directive 9355.7-02A and discussions with the EPA, the San Francisco Bay Regional Water Quality Control Board (RWQCB), and the California Department of Toxic Substances Control (DTSC) (Lamarre and Littlejohn, 1996). This is the first five-year review for the Livermore Site.

1.1. Authority Statement

This five-year review was conducted pursuant to Section 300.430(f)(4)(ii) of the National Oil and Hazardous Substance Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300, which implements Section 121(c) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). The authority for this review is policy according to EPA Directive 9355.7-02A.

The lead regulatory agency for this Five-Year Review is the EPA. In addition to the EPA, the RWQCB, and the DTSC oversee the LLNL Livermore Site remediation and are parties to the Livermore Site Federal Facility Agreement (FFA).

This document will be available for review in the LLNL repositories. One repository is located at the Livermore Public Library, 1000 South Livermore Avenue. Library hours are currently Monday through Thursday, 10:00 a.m. to 9:00 p.m.; Friday, 10:00 a.m. to 6:00 p.m.; Saturday, 10:00 a.m. to 5:00 p.m.; and Sunday 1:00 to 5:00 p.m. A second repository is at the LLNL Visitors Center on Greenville Road. Visitor Center hours are Monday through Friday, 1:00 to 4:00 p.m. The Visitors Center also contains the Administrative Record, which contains all documents that are the basis for the Livermore Site ROD. An additional repository is located at the DOE Oakland Office public reading room, Federal Building North, 1301 Clay Street, in Oakland, California. The public reading room is open Monday through Friday, 9:00 a.m. to 5:00 p.m.

1.2. Site Characteristics and History

Livermore Site characterization and history are briefly summarized in Sections 1.2.1 and 1.2.2. Site description, history, and characterization were presented in the ROD, the Livermore Site Remedial Investigation Report (Thorpe et al., 1990), and the Feasibility Study (Isherwood et al., 1990).

1.2.1. Site Characterization

The Livermore Site is a research and development facility owned by DOE and operated by the University of California, located approximately three miles east of the downtown area of Livermore, California (Fig. 1). The Livermore Site comprises approximately 800 acres. A Drainage Retention Basin, roughly 800 × 300 ft, is located near the center of the Livermore Site (Fig. 2) and receives storm water runoff and treated ground water. The basin is lined to prevent infiltration of ponded surface water. A Recharge Basin is located south of the site near the southwest corner (Fig. 2), which receives treated ground water from Treatment Facility A (TFA).

The Livermore Site ground surface slopes approximately 1% to the northwest. Hills of the Diablo Range flank the site to the south and east. The site is underlain by several hundred feet of interbedded alluvial and lacustrine sediments.

Ground water beneath the site is partly within the Spring and Mocho I hydrologic subbasins (California Department of Water Resources, 1974). Depth to ground water at the site varies from about 130 ft in the southeast corner to about 25 ft in the northwest corner. Ground water about two miles west of the site is used for the municipal supply of downtown Livermore. Ground water south and west of the site is used for domestic and agricultural irrigation. Two intermittent streams, Arroyo Seco and Arroyo Las Positas (Fig. 2), traverse the area and recharge the ground water during wet periods.

Land immediately north of the Livermore Site is zoned for industrial use. To the west, the land is zoned for high-density urban use. Sandia National Laboratories, California (SNL) is located south of the site (Fig. 2) in an area zoned for industrial development. The area east of LLNL is zoned for agriculture and is currently used as pasture land (Thorpe et al., 1990).

1.2.2. History

The Livermore Site was converted from agricultural use by the U.S. Navy in 1942. The Navy used the site until 1946 as a flight training base and for aircraft assembly, repair, and overhaul. Solvents, paints, and degreasers were routinely used during this period. Between 1946 and 1950, the Navy housed the Reserve Training Command at the site. In 1950, the Navy allowed occupation of the site by the Atomic Energy Commission (AEC), which formally received transfer of the property in 1951. Under the AEC, the site became a weapons design and basic physics research laboratory. In 1952, the site was established as a separate part of the University of California Radiation Laboratory. Responsibility for the site was transferred to the Energy, Research, and Development Administration in 1975. In 1977, responsibility for LLNL was transferred to DOE, which is currently responsible for the site.

Initial releases of hazardous materials occurred at the Livermore Site in the mid- to late-1940s when the site was the Livermore Naval Air Station (Thorpe et al., 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed volatile organic compounds (VOCs), fuel hydrocarbons (FHCs), metals, and tritium to the ground water and unsaturated sediments in the post-Navy era. The Livermore Site was placed on the EPA National Priorities List in 1987.

The identified compounds that currently exist in ground water at various locations beneath the site at concentrations above drinking water standards are:

- VOCs—trichloroethylene (TCE), perchloroethylene (PCE), 1,1-dichloroethylene (1,1-DCE), chloroform 1,2-dichloroethylene (1,2-DCE), 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), trichlorofluoromethane (Freon 11), and carbon tetrachloride.
- FHCs—benzene, ethylbenzene, toluene, and ethylene dibromide.
- Metals—chromium.
- Radionuclides—tritium.

1.2.3. Future Land Use

Statements from Congressional representatives and the Administration regarding the importance of the National Laboratories to the Nation's continued scientific and defense interests indicate that LLNL will continue to exist at its Livermore Site for the foreseeable future (McKereghan, 1996). LLNL's current and future mission and operation will include CERCLA compliance and cleanup specified in the FFA and ROD. Any change in land use will be discussed with the regulatory agencies and described in subsequent five-year review(s).

2. Remediation

2.1. Remediation Objectives and ROD Changes

2.1.1. Objectives

The remediation objectives for the Livermore Site are to:

- Prevent future human exposure to contaminated ground water and soil.
- Prevent further migration of contaminants in ground water in concentrations above Maximum Contaminant Levels (MCLs).
- Reduce contaminant concentrations in ground water to levels below the State and Federal MCLs, and reduce the contaminant concentrations in treated ground water to levels below State discharge limits.
- Prevent migration in the unsaturated zone of those contaminants that would result in concentrations in ground water above an MCL.
- Meet all discharge standards of existing permits for treated water and soil vapor.

The selected remedies in the ROD comply with all Federal and State Applicable or Relevant and Appropriate Requirements (ARARs). The ROD lists and describes the ARARs that will be attained by each selected remedy (DOE, 1992).

2.1.2. ROD Changes

Three Explanations of Significant Differences (ESDs) have been prepared for changes to the remedies selected in the ROD and are available in the Administrative Record, as discussed in

Section 1.1. An ESD is required when significant, but not fundamental, changes are made to the final remedial action plan described in the ROD. The three ESDs were prepared for: (1) a change to granular activated carbon (GAC) for treatment of vapor at Treatment Facility F (TFF) (Dresen et al., 1993b), (2) a change from ultraviolet light/hydrogen peroxide (UV/H_2O_2) and air stripping remediation to air stripping only at Treatment Facilities A and B (TFA and TFB) (Berg et al., 1997a), and (3) a change in metals discharge requirements based on wet season and dry season beneficial use (Berg et al., 1997b). The three ESDs for the Livermore Site are briefly described below.

2.1.2.1. Change to GAC for Treatment of Vapor at TFF

In 1993, the regulatory agencies agreed to change from catalytic oxidation to GAC for treatment of FHC vapor at TFF (Dresen et al., 1993b). GAC is an effective treatment alternative for FHC vapor and was considered Best Available Control Technology by the Bay Area Air Quality Management District. The cost of using GAC for vapor treatment at TFF was estimated to be about half of the original catalytic oxidation cost estimate (Dresen et al., 1993b). In addition, use of GAC precluded the possibility of producing toxic compounds by catalytic oxidation. As discussed further in Section 2.2.6, vadose zone remediation in the TFF area is complete, and the remediation system is no longer operating.

2.1.2.2. Change from UV/H_2O_2 and Air Stripping Remediation to Air Stripping only at TFA and TFB

To enhance offsite plume capture, the total flow rate to TFA was increased from an initial 50 gallons per minute (gpm) to 300 gpm. The higher flow rate caused TFA to become less efficient in remediating VOCs. In the summer of 1996, DOE/LLNL began investigating a higher efficiency air stripper and determined that all VOCs could be remediated below discharge limits at TFA, and also at TFB, without operating the UV/H_2O_2 unit. In April 1997, the regulatory agencies agreed to change from UV/H_2O_2 and air stripping remediation to air stripping only at TFA and TFB (Berg et al., 1997a). The benefits of this change include:

- Meeting cleanup objectives faster by increasing the treatment facility capacity.
- Increasing safety by eliminating the handling of hazardous material (H_2O_2).
- Reducing costs by eliminating purchase of H_2O_2, reduced equipment maintenance, and reduced electrical costs.
- Using an accepted and proven technology.

As discussed further in Section 2.4.1, the high efficiency air stripper began operation at TFA in June 1997, and the switchover to high efficiency air stripping at TFB is scheduled for July 31, 1998.

2.1.2.3. Change in Metals Discharge Requirements

In March 1996, DOE/LLNL informed the RWQCB that they did not plan to renew National Pollutant Discharge Elimination System (NPDES) permit No. CA0029289 when it expired on June 18, 1996, consistent with the CERCLA exemption for permits for remedial activities onsite, and proposed new discharge effluent limits for metals to meet the substantive requirements of the NPDES permit. Proposed changes to the discharge standards contained in the ARARs table in the ROD were discussed with the RWQCB, and an agreement was reached for new metals discharge limits that ensured protection of beneficial uses during the wet and dry seasons (Table 1). The new metals discharge limits were approved by the regulatory agencies through an ESD (Berg et al., 1997b), and became effective in August 1996. During the dry season (April 1 through November 30), metals discharge limits are the respective MCLs for the regulated constituents because the discharge infiltrates to a potential drinking water aquifer. During the wet season (December 1 through March 31), the effluent flows downstream in surface water and may impact aquatic life. The wet season discharge limits are protective of aquatic life, and are those set forth in RWQCB's Regional Board Order No. 94-087.

2.2. Remediation Highlights

Continuous re-evaluation and improvements to managing Livermore Site remedial activities has lead to notable successes for DOE, LLNL and the regulatory agencies, as briefly discussed below. Some of these successes have benefited other DOE facilities in their cleanup efforts.

2.2.1. Western Margin Hydraulic Capture

An important part of the cleanup remedy was to establish hydraulic capture along the western margin of the Livermore Site. Ground water extracted from extraction wells offsite or near the western margin of the site is transferred through pipelines to onsite facilities for treatment. The extraction wells and pipelines were phased-in as funding allowed. At the time of the ROD, extraction wells connected to the TFA East, TFA South and TFB East Pipelines were already operating. In September 1994, extraction wells to the TFA Arroyo Pipeline were activated. In July 1995, extraction wells to the TFA North Pipeline were activated, followed by the TFB North Pipeline in September 1995. By November 1995, additional extraction wells to the TFA Arroyo Pipeline were activated, which ensured hydraulic capture along Arroyo Seco. In September 1996, extraction wells to the Treatment Facility C (TFC) North Pipeline were activated, thus achieving hydraulic capture of the entire western margin of the Livermore Site (Figs. 3 through 5). Achieving western margin hydraulic capture has been a very high priority for the local community, regulatory agencies, and DOE/LLNL.

2.2.2. Hydrostratigraphic Unit Analysis

DOE/LLNL developed a hydrostratigraphic unit (HSU) analysis approach to characterize the Livermore Site for implementing the cleanup strategy detailed in the ROD (DOE, 1992). HSU analysis integrates chemical, hydraulic, geophysical, and geological data into a detailed three-dimensional (3D) model of the subsurface. Through HSU analysis, DOE/LLNL have been able to depict the location of underground contaminant plumes in relation to individual source areas, and gain a better understanding of contaminant transport and distribution. HSU methodology has allowed DOE/LLNL to target individual contaminant plumes, place extraction wells at optimum locations to meet cleanup objectives faster, and conduct a comprehensive and more cost-effective cleanup. The success of the process is drawing interest from Federal agencies and other National Laboratories.

2.2.3. Fate and Transport Modeling

LLNL has constructed a data-calibrated, 3D ground water flow and contaminant transport model to simulate subsurface behavior in the Livermore Basin, using the CFEST numerical code (Gupta, 1994). The objectives are to evaluate and optimize the planned ground water extraction remedial wellfield, support future wellfield design decisions, and estimate cleanup times. The model implements results of HSU analysis and incorporates data collected during source investigation drilling, well installation, ongoing ground water monitoring, and treatment facility performance evaluation.

CFEST simulations have been completed for the TFA and TFB areas, and the results closely match field data (Figs. 6 and 7, respectively). These simulations allow LLNL to predict the effectiveness of various remedial strategies by varying extraction well flow rates and evaluating proposed extraction locations. Use of models that represent the physical behavior of contaminants in the subsurface is the most accurate method for predicting future plume configurations, and forecasting cleanup times and costs. Therefore, DOE/LLNL plan to model the site using CFEST or another equivalent numerical code. Through this process, optimal wellfield configurations can be determined and potential hydraulic stagnation zones eliminated.

As we continue to refine and calibrate the model to observed field data, this tool will allow DOE/LLNL to: (1) demonstrate regulatory compliance, (2) evaluate alternative proposals for early site closure, (3) be cost effective in implementing site cleanup, and (4) show the effectiveness of cleanup technologies. Additional modeling is also planned to evaluate the impact of potential sources on the estimated time to cleanup.

2.2.4. Portable Treatment Units

The original design for Livermore Site ground water cleanup was permanent fixed treatment facilities with pipelines to transfer ground water from the extraction wells to the facilities. Due to the lack of space for conventional permanent treatment facilities, Portable Treatment Units (PTUs) were first designed for the Treatment Facility G (TFG) area (Berg et al., 1995). Each PTU is more compact than a permanent facility, and is contained within a 20-ft-long × 8-ft-wide × 9-ft-high cargo container. Not only are PTUs less costly and more space efficient, they increase cleanup flexibility because they are easily moved to different locations for aggressive remediation of areas with high VOC concentrations, or to fill “gaps” near plume margins. PTU construction has reduced the capital costs of building the remaining fixed treatment systems by approximately $9 million. In addition, PTUs eliminate complicated and expensive piping required for permanent facilities. PTUs are moved to appropriate extraction wells to optimize contaminant mass removal, and are a vital part of DOE/LLNL’s approach to expediting the cleanup, as discussed in Section 2.2.5.

2.2.5. Engineered Plume Collapse

The Livermore Site cleanup is being expedited by an Engineered Plume Collapse (EPC) strategy, which incorporates HSU analysis, smart pump and treat, source isolation, PTU technology, and treatment of VOCs in fine-grained sediments. EPC is further optimized using three-dimensional fate and transport modeling. Elements of EPC include:

- Phase 1: targeting source areas and high concentration distal areas with aggressive pump and treat using multiple PTUs to remove large quantities of contaminant mass quickly in the coarse-grained materials. Contaminant source areas are hydraulically isolated using extraction wells, thereby systematically collapsing contaminant plumes back to their source. An example of plume collapse through pump-and-treat is presented in Figure 8.
- Phase 2: applying new technologies to remove VOCs from the fine-grained material at the source areas. Technologies may include electro-osmosis, hydrous pyrolysis (steam and oxygen injection), vapor extraction, or other innovative technologies that may be developed. Ground water extraction will prevent VOCs from migrating away from the source areas.
- Using computer simulations to estimate optimum EPC scenarios and mass transfer of contaminants from coarse-grained and fine-grained sediments.

2.2.6. Completion of Fuel Hydrocarbon Remediation

In August 1995, the EPA, DTSC, and RWQCB concurred that remediation at TFF had successfully recovered the majority of the FHCs in the vadose zone, and that there was greatly diminished efficiency in continuing active remediation. The regulatory agencies also agreed that remediation efforts had met or exceeded ARARs in the Livermore Site ROD, and that remediation of the vadose zone was complete (Gill, 1995). TFF vadose zone remediation ceased in August 1995.

In December 1995, the TFF ground water treatment system for FHCs in HSU-3 was damaged by wind and rain. The regulatory agencies agreed to a temporary shutdown of TFF until a PTU could replace the damaged equipment. During the shutdown, DOE/LLNL prepared an application for Containment Zone for the FHCs at TFF (Happel et al., 1996), which showed that passive biodegradation will continue to degrade, contain, and reduce the residual FHC plume. At the July 2, 1996 Remedial Project Managers' (RPMs') meeting, the RPMs agreed that DOE/LLNL would apply for No Further Action status instead of Containment Zone status. DOE/LLNL submitted the application for Containment Zone in support of their request for No Further Action. In October 1996, the RWQCB confirmed completion of active remedial action for the FHC-impacted ground water at TFF and granted No Further Action status instead of Containment Zone status (RWQCB, 1996).

2.2.7. Catalytic Reductive Dehalogenation

A treatment method is being developed to remediate ground water containing both VOCs and tritium that will remediate VOCs *in situ*, while keeping tritium in the subsurface to eventually self remediate through natural decay. The treatment method is based on reductive dehalogenation of dissolved VOCs by hydrogen in the presence of a palladium catalyst, and produces rapid, complete dehalogenation of dissolved VOCs. This method will treat VOCs below ground surface in flow-through treatment columns placed in wells with multiple screened intervals.

Treatability studies have included laboratory bench-top testing to characterize performance and optimize column design, and ground water flow and contaminant transport modeling to simulate *in situ* performance. Pilot scale field testing and demonstration will commence in 1997.

2.3. Noncompliance

Remedial noncompliance over the last five years was limited to RWQCB's Waste Discharge Order requirements. As noncompliances occurred, the RWQCB was notified immediately, and the noncompliance was discussed and documented at the subsequent monthly RPM meeting. Noncompliances were generally remedied immediately. Longer term problems occurred such as exceeding hexavalent chromium discharge limits at TFB, exceeding nickel discharge limits at Treatment Facility D (TFD), and exceeding total VOC discharge limits at TFA. All of these problems have been rectified either by facility modifications or changes to the discharge requirements. Facility changes to TFA, and proposed changes to TFB, are documented in an ESD (Berg et al., 1997a). The RWQCB agreed to new discharge limits for metals, including nickel and hexavalent chromium, which are protective of beneficial uses during the wet and dry seasons (Bessette Rochette, 1996). These discharge limit changes are also documented in an ESD (Berg et al., 1997b). The longer term noncompliances and remedies at TFA, TFB and TFD are discussed in Sections 2.4.1.1, 2.4.1.2, and 2.4.1.4, respectively.

2.4. Remedial Action Status

DOE/LLNL regularly report on remedial actions at the RPM meetings. Meeting summaries are prepared for each meeting, and self-monitoring data are attached quarterly. An annual report is issued by March 31 of the subsequent year.

2.4.1. Active Facilities

Activities at each of the operating treatment facilities are summarized below. Table 2 summarizes each active treatment facility's technology, media treated, contaminants, operation dates, and discharge location. Table 2 also summarizes volumes and mass removed through September 1997. Table 3 presents the number of ground water wells and piezometers, and vadose zone installations in each treatment facility area over the last five years, as well as the total number over the life of the project. Modeling for the Feasibility Study (Isherwood et al., 1990) indicated that 18 extraction locations, comprised of one or more wells, may suffice to clean up the Livermore Site. The extraction wells were planned to be phased-in so actual performance could be compared to model estimates. HSU methodology was later incorporated to determine the best extraction locations that would target individual plumes and optimize ground water cleanup. About 45 extraction wells are currently operating at the Livermore Site.

2.4.1.1. Treatment Facility A

TFA is located in the southwest quadrant of the Livermore Site (Fig. 2). The selected ROD technology for TFA was UV oxidation and air stripping. The facility design was presented in Boegel et al. (1993). As discussed in Section 2.1.2.2, in 1997 TFA was changed to air stripping only.

Highlights of TFA activities over the last five years are:

- Extraction wells—Since August 1992, DOE/LLNL have connected 17 additional extraction wells in the TFA area.

- Pipelines—DOE/LLNL completed the Arroyo Pipeline in September 1994, the TFA North Pipeline in July 1995, and additional extraction wells were connected to the Arroyo Pipeline in November 1995 (Section 2.2.1).
- Flow rates—TFA was initially permitted for a flow rate of 100 gpm. In June 1995, the RWQCB agreed to increase the permitted discharge flow to 350 gpm. TFA currently operates up to 350 gpm.
- Treatment Modification—Beginning in June 1996, DOE/LLNL observed that higher flow rates at TFA resulted in less efficient VOC destruction. The regulatory agencies were informed that the effluent could occasionally exceed the discharge limit in the future. DOE/LLNL minimized the exceedences by reducing the flow rate and increasing maintenance frequency. DOE/LLNL then proposed replacing the current treatment system with a larger air stripper to: (1) meet cleanup objectives sooner by increasing the capacity of the treatment facility, (2) eliminate safety hazards associated with the handling of H_2O_2, and (3) reduce cost. The regulatory agencies and the Community Work Group agreed to this change. Prior to activating the new system on June 18, 1997, the effluent occasionally exceeded discharge limits.

2.4.1.2. Treatment Facility B

TFB is located north of TFA (Fig. 2). The selected ROD technology for TFB was UV oxidation and air stripping. The facility design was presented in Boegel et al. (1993). As discussed in Section 2.1.2.2, an ESD was prepared for a change to air stripping only. Treatment facility operation is planned by July 31, 1998. The benefits of air stripping only are the same as those discussed in Section 2.4.1.1.

Highlights of TFB activities over the last five years are:

- Extraction wells—Since August 1992, DOE/LLNL have connected 4 additional extraction wells in the TFB area.
- Pipelines—The TFB North Pipeline was activated in September 1995 (Section 2.2.1).
- Treatment Modifications—In early 1994, the facility did not meet fish toxicity bioassay criteria due to excess H_2O_2 in the treated water. Aqueous-phase carbon was installed between the UV/H_2O_2 system and the air stripper in November 1994, which reduced H_2O_2 concentrations to meet the fish bioassay criteria. In mid 1995, effluent hexavalent chromium concentrations began exceeding discharge limits. In late 1995, the aqueous-phase carbon was removed and DOE/LLNL began reducing hexavalent chromium to trivalent chromium by decreasing the pH and increasing the water residence time after the UV/H_2O_2 system prior to air stripping. The residence time allows the H_2O_2 to reduce hexavalent chromium to trivalent chromium. The pH was also lowered by adding carbon dioxide after the UV/H_2O_2 system. The increased residence time allowed a lower concentration of H_2O_2 to effectively reduce the hexavalent chromium. This method has kept the facility in compliance for discharging hexavalent chromium and for fish bioassays.

2.4.1.3. Treatment Facility C

TFC is located in the northwest quadrant of the Livermore Site (Fig. 2). The selected ROD technology for TFC was air stripping and ion exchange. The facility design was presented in Berg et al. (1993).

Highlights of TFC activities over the last five years are:

- Extraction wells—Since August 1992, DOE/LLNL have connected 7 extraction wells in the TFC area.
- Pipelines—The TFC North Pipeline was activated in September 1996 (Section 2.2.1). The proposed TFC Southeast Pipeline was replaced by the TFC Southeast PTU.
- PTUs—The TFC Southeast PTU was activated January 21, 1997, and currently treats ground water from two wells.

2.4.1.4. Treatment Facility D

TFD is located in the northeastern quadrant of the Livermore Site (Fig. 2). The selected ROD technology for TFD was air stripping and ion exchange. The facility design was presented in Berg et al. (1994a).

Highlights of TFD activities over the last five years are:

- Extraction wells—Since August 1992, DOE/LLNL have connected 6 extraction wells in the TFD area.
- Treatment Modification—Elevated nickel concentrations in well W-907 exceeded TFD discharge requirements. DOE/LLNL stopped pumping well W-907 in early 1995 to evaluate the source of the nickel. By late 1995, it was determined that corrosion of the stainless steel screen in this well was the probable cause of the elevated nickel in extracted ground water (discussed further in Section 3). After the nickel discharge limits were modified in August 1996 (Section 2.1.2.3), ground water from well W-907 was again pumped to TFD for treatment.
- Discharge location—DOE/LLNL began using a polyphosphate to reduce scaling in the equipment, but did not want to discharge excess polyphosphate into the Drainage Retention Basin. The TFD effluent was redirected in early 1994 to a pipeline that discharges to Arroyo Las Positas. TFD retains the capability to discharge to the Drainage Retention Basin, if needed.
- Receiving water sample—As agreed at the March 1995 RPM meeting, a single receiving water sample is collected downstream from TFC and TFD to reduce sampling costs. The sample is collected at the TFC receiving water station. DOE/LLNL retain the capability to collect a sample at the TFD receiving water sampling station, if needed.
- PTUs—A PTU was temporarily stationed at the TFD Southwest location beginning in January 1997 to increase mass removal. The TFD Southwest PTU will be operating in January 1999. TFD West PTU was activated April 22, 1997, and currently extracts and treats ground water from two wells. TFD East was activated September 16, 1997, and currently extracts and treats ground water from four wells.

2.4.1.5. Treatment Facility E

The Treatment Facility E (TFE) area is located in the southeastern quadrant of the Livermore Site. The selected ROD technology for TFE was UV oxidation and air stripping. As presented to the regulatory agencies in May 1995, a conventional permanent TFE facility and its associated pipelines will be replaced by PTUs TFE East, TFE West, TFE Southwest, TFE Southeast, and TFE Northwest utilizing air stripping (Fig. 2).

Highlights of TFE activities over the last five years are:

- PTUs—The TFE East PTU was activated November 25, 1996 and currently treats ground water from two wells.
- Well destruction—In April 1994, well W-358 was destroyed due to the possibility of a leaky annular seal, and was replaced with well W-1008.

2.4.1.6. Treatment Facility F-Treatment Facility 406

Extracted soil vapor containing FHCs was initially treated with GAC that was regenerated with steam. Due to higher than expected mass removal rates, the GAC was replaced with an internal combustion engine. As discussed in Section 2.2.6, the regulatory agencies concurred that remediation of the TFF area vadose zone was complete (Gill, 1995). TFF vadose zone remediation ceased in August 1995.

Ground water FHC remediation was conducted by UV oxidation and air stripping, along with a year-long Dynamic Underground Stripping demonstration project that used soil heating and steam injection to enhance FHC removal (Newmark, 1994). In October 1996, the RWQCB confirmed completion of the remedial action for the FHC-impacted ground water at TFF and granted No Further Action status (RWQCB, 1996).

VOC remediation at TFF has continued according to the ROD by using a PTU to extract and treat ground water from HSU-4 and HSU-5. The active VOC treatment system is called Treatment Facility 406 (TF406) instead of TFF. The PTU design was first introduced for the Treatment Facility G area in Berg et al. (1995). TF406 is currently treating ground water from one HSU-4 well.

2.4.1.7. Treatment Facility G-1

Treatment Facility G-1 (TFG-1) is located in the southwest quadrant of the Livermore Site (Fig. 2), which is extensively developed with buildings and underground utilities. For logistical and practical purposes, a PTU was designed to meet the space limitations and cleanup needs (Berg et al., 1995). The selected ROD treatment technology for TFG-1 was air stripping.

Highlights of TFG area activities over the last five years are:

- Extraction wells—Since August 1992, DOE/LLNL have connected one extraction well to TFG-1.
- Treatment Modification—Due to hexavalent chromium concentrations in the subsurface at TFG-1, an ion-exchange unit was added to meet discharge requirements.

- Receiving water sample—As agreed by the RWQCB in April 1996, the receiving water sample from TFG-1 is collected in Arroyo Seco about 350 ft downstream from the discharge point because local site conditions do not allow closer safe access.

2.4.1.8. Soil Vapor Treatment Facility 518

Soil Vapor Treatment Facility 518 (VTF518) is located in the southeastern quadrant of the Livermore Site (Fig. 2). The selected ROD remedy for treating the unsaturated zone is vapor extraction and treatment by GAC. The VTF518 design was presented in Berg et al. (1994b).

2.4.2. Planned Facilities

Planned facilities to remediate the Livermore Site pursuant to the ROD and to accelerate cleanup using EPC are discussed below. Facility locations are shown on Figure 2. Table 4 summarizes the technology, targeted HSU(s), and purpose of each facility.

2.4.2.1. TFG North

TFG North (formerly called Treatment Facility G-2 in Berg et al., 1995) will be located in the southwest quadrant of the Livermore Site, which is extensively developed with buildings and underground utilities. Similar to TFG-1, a PTU was designed to meet the space limitations and cleanup needs (Berg et al., 1995). The selected ROD treatment technology for the TFG area was air stripping.

2.4.2.2. Trailer 5475 Treatment Facilities

Both ground water and soil vapor will be treated in the Trailer 5475 (T-5475) area, located in the southeastern quadrant of the Livermore Site (Fig. 2). The remedial design for the ground water treatment facility (TF5475) and the vapor treatment facility (VTF5475) is discussed in Berg et al. (1997c). The ground water treatment method is based on reductive dehalogenation of dissolved VOCs by hydrogen in the presence of a palladium catalyst. This method will treat VOCs below the ground surface in flow-through treatment units placed in wells with multiple screened intervals. As discussed in the ROD and the Remedial Action Implementation Plan (RAIP) (Dresen et al., 1993a), tritium will be kept in the subsurface as much as possible where it will decay naturally. A field test of the treatment unit started in Summer 1997. The first TF5475 treatment unit is scheduled to begin operation by September 30, 1998 (Dresen et al., 1993a). Subsequent wells will be phased-in.

VTF5475 will consist of a closed-loop vapor extraction system with GAC to remove the VOCs. The treated vapor containing tritium will be reinjected into the subsurface where the tritium will decay naturally. The facility is scheduled to begin operation by June 29, 1999 (Dresen et al., 1993a).

2.4.2.3. Additional Portable Treatment Units

Additional PTUs are planned for locations throughout the Livermore Site to enhance mass removal and cleanup (Fig. 2; Table 4). These PTUs include: TF518, TFD Southeast, TFD South, TFD Southwest, TFE West, TF518 North, TFE Southwest, TFE Southeast, TFE Northwest, TFD Northwest, TF406 Northwest, TFC East, TFG North, TFD Northeast, and TFC Northeast.

TF406 South is planned if necessary. Status of these facilities will be reported at the RPM meetings and in the quarterly reports as they are activated.

2.4.3. Cleanup and Monitoring Activities

The following discusses the status of activities related to the National Ignition Facility (NIF) construction site, Building 292, Building 419, storm sewer maintenance, and future activities.

2.4.3.1. NIF Construction Site

From September 3 to 12, 1997, 112 capacitors containing polychlorinated biphenyls (PCBs) were unearthed at the NIF construction site (Fig. 9). The capacitors and about 766 tons of soil containing PCBs were removed and managed under an emergency removal action (Bainer and Berg, 1997). Complete removal of PCB contaminated soil protected public health and welfare, and the environment. Ground water monitoring in the area is ongoing.

2.4.3.2. Building 292

In September 1995, an underground tank that formerly stored tritiated rinse water was sealed in the Building 292 area (Fig. 9). DOE/LLNL continue to monitor nearby piezometers quarterly for tritium. Although ground water from one piezometer has had infrequent tritium concentrations above the tritium MCL, currently ground water from all piezometers in the vicinity of the former tank is below the MCL for tritium.

2.4.3.3. Building 419

In 1996, during a Resource Conservation and Recovery Act (RCRA) closure activity for Building 419 (Fig. 9), soil containing residual mercury, lead, and tritium was discovered during the removal of piping associated with an underground tank. All visible signs of mercury were removed. Tritium was detected in soil to approximately 30 ft. Three piezometers were installed downgradient of the Building 419 area to monitor the ground water. To date, no tritium, lead, or mercury have been detected above MCLs in the ground water, which is at a depth of about 100 ft. After discussions with the regulatory agencies, the Environmental Restoration Division issued a memorandum on December 20, 1996 to the Building 419 Coordinator and LLNL's legal department stating that an evaluation of environmental contamination needs to be conducted when Building 419 is decommissioned.

2.4.3.4. Storm Sewer Maintenance

Elemental mercury was discovered in a catch basin of the storm sewer near Building 253 (Fig. 9). The RPMs agreed with LLNL Operation and Regulatory Affairs Division's proposed action to use concrete to immobilize the mercury as an interim containment measure. LLNL's Plant Engineering Department will continue to perform maintenance and operation of the storm drains until Fiscal Year 2001 when funding is planned for retrofitting the storm drains. As storm sewer maintenance and repair occur, additional catch basins containing contaminants, primarily metals, may be discovered and will be assessed on a case-by-case basis.

2.4.3.5. Other Planned Activities

DOE/LLNL are currently reviewing all records and source investigation and remediation data pertaining to the northeast quadrant of the Livermore Site, to determine if additional field work is warranted, as a follow up to the discovery of the capacitors at the NIF construction site.

2.5. VOC Mass Estimate

2.5.1. VOC Mass Remaining in Ground Water

As discussed in the Livermore Site Compliance Monitoring Plan (Nichols et al., 1996), this report includes a comparison of the estimated VOC mass beneath the Livermore Site in 1996 with the original 1990 mass estimate presented in the Feasibility Study (FS) (Isherwood et al., 1990). The 1996 mass estimate for the area where concentrations are greater than 5 parts per billion (ppb) is presented in Table 5. To obtain this value, we used procedures similar to those used for the FS to determine the 1990 mass estimate. As shown in Table 5, we estimate that 1,250 kilograms (kg) (2,750 pounds [lb]) of VOC mass were in the ground water in 1996. Approximately 130 kg (290 lb) of VOC mass have been removed from the ground water at Livermore Site treatment facilities through 1996 (Hoffman et al., 1996). As a result, we estimate that about 1,380 kg (3,040 lb) of VOC mass were in ground water in 1990. Although this value is higher than the original 1990 mass estimate of 880 kg (1,940 lb), the estimated volume of ground water containing VOCs is similar. As shown in Table 5, we estimate that about 3.1 billion gal of ground water contained VOCs in 1996. We estimated that the total volume of ground water containing VOCs in 1990 was about 2.9 billion gal (Isherwood et al., 1990). Therefore, we believe that the 1996 estimate provides a more realistic value of the total VOC mass in ground water beneath the site due to:

- Better characterization of source areas through our continuing drilling program;
- Improved procedures for incorporating saturated soil and source investigation ground water data into the mass estimate;
- Use of the hydrostratigraphic subsurface model; and
- Improvements in the software used to interpolate the chemistry data.

To calculate the new mass estimate, we first developed a 3D data set of total VOC concentrations. We then used the EarthVision 3.0 (EV) software, developed by Dynamic Graphics, Inc., to calculate the volume of aquifer containing VOCs. A previous version of this software was used during the original 1990 mass estimation. An assumed porosity of 30% was used to calculate the volume of ground water within the aquifer. The amount of VOC mass was calculated by multiplying the estimated volume of contaminated ground water within each isoconcentration interval by the geometric mean VOC concentration in that interval. The geometric mean was used because the isoconcentration contour interval is logarithmic (i.e., 1, 10, 100 ppb, etc.).

Similar to the original 1990 mass estimate, we omitted from our calculations VOCs that do not originate from the LLNL site (i.e., northwest of the Patterson Pass and Vasco Roads intersection; Fig. 2). The plume in that area is being investigated separately by the property owners under the direction of the RWQCB. A more detailed outline of the procedure used to obtain the 1996 VOC mass estimate is presented in Appendix A.

2.5.2. VOC Mass Removal Estimates

Estimates of mass removal in each HSU during the next five years (fiscal years 1998–2002) are presented in Table 6. HSUs exist in the subsurface throughout the Livermore Site and are not limited to specific treatment facility areas. Mass removal estimates in Table 6 were derived by using current flow rates and VOC concentrations from each extraction well. Mass removal at each extraction well was assumed to decrease 20% each year based on observations in existing wells. Mass removal from the Trailer 5475 treatment units was assumed to decrease 30% each year. New wells were incorporated according to the Priority List (Attachment A), which follows EPC strategy, and all wells were assumed to continue operation through the end of the five-year period. DOE/LLNL are currently working on a 3D ground water flow and contaminant transport model, which will help estimate mass removal and cleanup times. DOE/LLNL anticipate that cleanup will be less than the 53 years estimated in the Proposed Remedial Action Plan, although the impact from mass in the source areas is still unknown. The model is anticipated to be calibrated prior to the next Five-Year Review, and DOE/LLNL plan to share this information with the regulatory agencies and the community when available.

3. Lessons Learned

Throughout the course of the Livermore Site cleanup, DOE/LLNL have learned better ways to manage the project, expedite cleanup, and reduce costs. Some of these successes have benefited other DOE facilities in their cleanup efforts. The following lessons learned are described further in Table 7:

- The EPC strategy for cleanup is an effective ground water remediation approach.
- Remediating or controlling contamination in source areas is key to cost-effective remediation of the distal parts of ground water plumes.
- Budget fluctuations can be managed effectively by establishing project priorities.
- Effective characterization and hydrostratigraphic analysis is essential to a comprehensive and cost-effective cleanup.
- Use of 3D ground water flow and contaminant transport models is the most accurate method for predicting future plume configurations, and forecasting cleanup times and costs.
- Stakeholders' support facilitates rapid and cost-effective cleanup.
- Certain types of stainless steel used in constructing extraction wells may release nickel into solution.
- UV oxidation has technical and cost limitations.
- Developing new technologies is key to solving difficult technical problems.

- The use of PTUs and other cost-effective innovative technologies reduces costs while facilitating aggressive cleanup.
- Re-evaluating NPDES sampling frequency and discharge requirements results in reduced costs while remaining protective of the environment.
- Use of a Cost-Effective Sampling algorithm reduces sampling frequency and costs.
- Scope reduction in reporting saves costs that can then be applied to site cleanup.
- Integrating various disciplines and management at the site promotes more effective cleanup.
- At industrialized sites with histories similar to the Livermore Site, undocumented buried hazardous waste may be expected to be encountered during excavation and drilling operations.

4. Budget and Milestones

Since Fiscal Year 1993 (FY93), DOE's budget has been declining for LLNL's Environmental Restoration Program and Division. This declining trend is predicted to continue through FY98. To date, DOE/LLNL have met all Livermore Site milestones. With the current budget forecast, DOE/LLNL do not anticipate missing any future milestones. Upcoming RAIP milestones and dates are presented in Table 8, and the current Consensus Statement and the Livermore Site Restoration Activities Priority List are presented as Attachment A.

5. Recommendations

DOE/LLNL are effectively working toward the remediation objectives of the Livermore Site by: (1) preventing present day and future human exposure to contaminated ground water and soil, (2) preventing contaminant migration at concentrations above MCLs, (3) reducing contaminant concentrations in ground water, and (4) preventing migration of contaminants in the unsaturated zone that would result in concentrations in ground water above an MCL. DOE/LLNL are hydraulically controlling the western margin of the Livermore Site (Figs. 4 through 6) and are reducing the VOC plume sizes and concentrations (i.e., Fig. 8). Through September 1997, about 303 kg (668 lb) of VOCs have been removed from the site, and the facilities are currently treating about 25 million gallons of contaminated ground water per month. Two soil vapor extraction units (existing VTF518 and planned VTF5475) will prevent contaminant migration in the vadose zone that could result in concentrations in ground water above an MCL.

DOE/LLNL actively monitor treatment facilities to remain below discharge standards for treated water and soil vapor. Noncompliances over the last five years were generally remedied immediately. All longer term noncompliances have been rectified by facility modifications or changes to discharge requirements. Changes that affect the remedial actions proposed in the ROD have been documented in ESDs.

The current remedial actions at the Livermore Site remain protective of public health and the environment. DOE/LLNL plan to continue to work together with the regulatory agencies and other Stakeholders to investigate and evaluate alternative risk-based cleanup standards that would be appropriate for this site, while remaining protective of human health and the environment. DOE/LLNL also propose to continue to work with regulatory agencies and Stakeholders to investigate and evaluate alternative approaches to site closure, such as Containment Zone policies, No Further Action, natural attenuation, institutional measures, and continued ground water monitoring.

6. Statement of Protectiveness/Next Five-Year Review

I certify that the remedies selected for this site remain protective of the public health and the environment. The next five-year review will be conducted by August 2002.

12/2/97

Daniel Opalski
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U.S. Environmental Protection Agency
Region IX

Date

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8. Acronyms and Abbreviations

1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethylene
1,2-DCE	1,2-dichloroethylene
3D	three dimensional
AEC	Atomic Energy Commission
ARAR	Applicable or Relevant and Appropriate Requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CES	cost-effective sampling
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DTSC	California Department of Toxic Substances Control
DUS	Dynamic Underground Stripping
EPA	U.S. Environmental Protection Agency
EPC	Engineered Plume Collapse
ESD	Explanation of Significant Differences
EV	EarthVision 3.0
FFA	Federal Facility Agreement
FHC	fuel hydrocarbon
Freon 11	trichlorofluoromethane
Freon 113	trichlorotrifluorethane
FY	fiscal year
GAC	granular activated carbon
gpm	gallons per minute
H_2O_2	hydrogen peroxide
HSU	hydrostratigraphic unit
ICE	internal combustion engine
kft^3	thousands of cubic feet
kg	kilograms
lb	pound(s)
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
Mft^3	millions of cubic feet

Mgal	millions of gallons
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NIF	National Ignition Facility
NPDES	National Pollutant Discharge Elimination System
PCB	polychlorinated biphenyl
PCE	perchloroethylene
ppb	parts per billion
PTU	portable treatment unit
RAIP	Remedial Action Implementation Plan
RCRA	Resource Conservation and Recovery Act
RD4	Remedial Design Report No. 4
ROD	Record of Decision
RPM	Remedial Project Managers
RWQCB	California Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
SNL	Sandia National Laboratories
TCE	trichloroethylene
T-5475	Trailer 5475
TF406	Treatment Facility 406
TF5475	Treatment Facility 5475
TFA	Treatment Facility A
TFB	Treatment Facility B
TFC	Treatment Facility C
TFD	Treatment Facility D
TFE	Treatment Facility E
TFF	Treatment Facility F
TFG	Treatment Facility G
TFG-1	Treatment Facility G-1
TSCA	Toxic Substances Control Act
UV	ultraviolet
UV/H_2O_2	ultraviolet light/hydrogen peroxide
VOC	volatile organic compound
VTF518	Vapor Treatment Facility 518
VTF5475	Vapor Treatment Facility 5475

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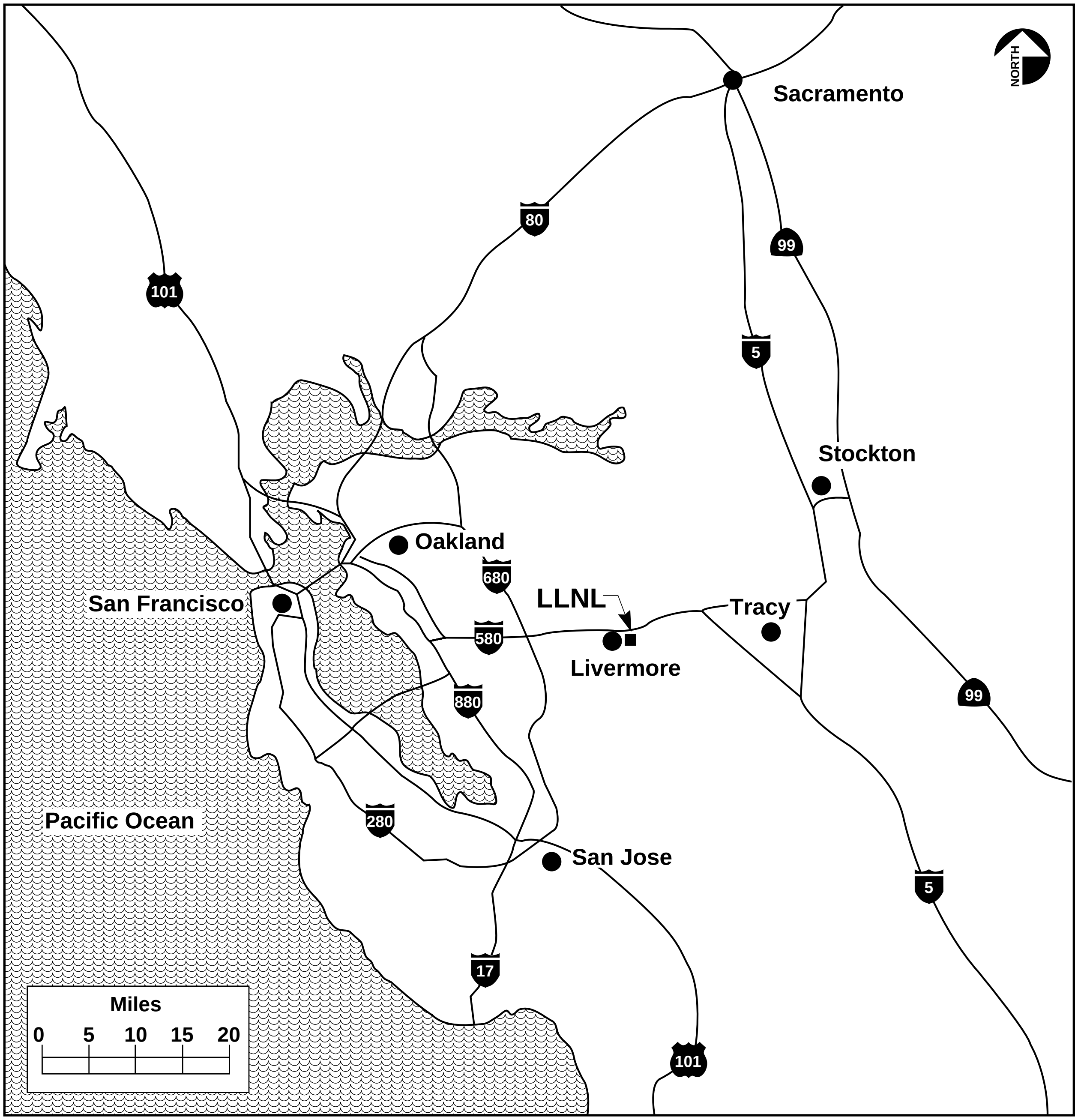
Figures



ERD-LSR-97-0027

Figure 1. Location of the LLNL Livermore Site.

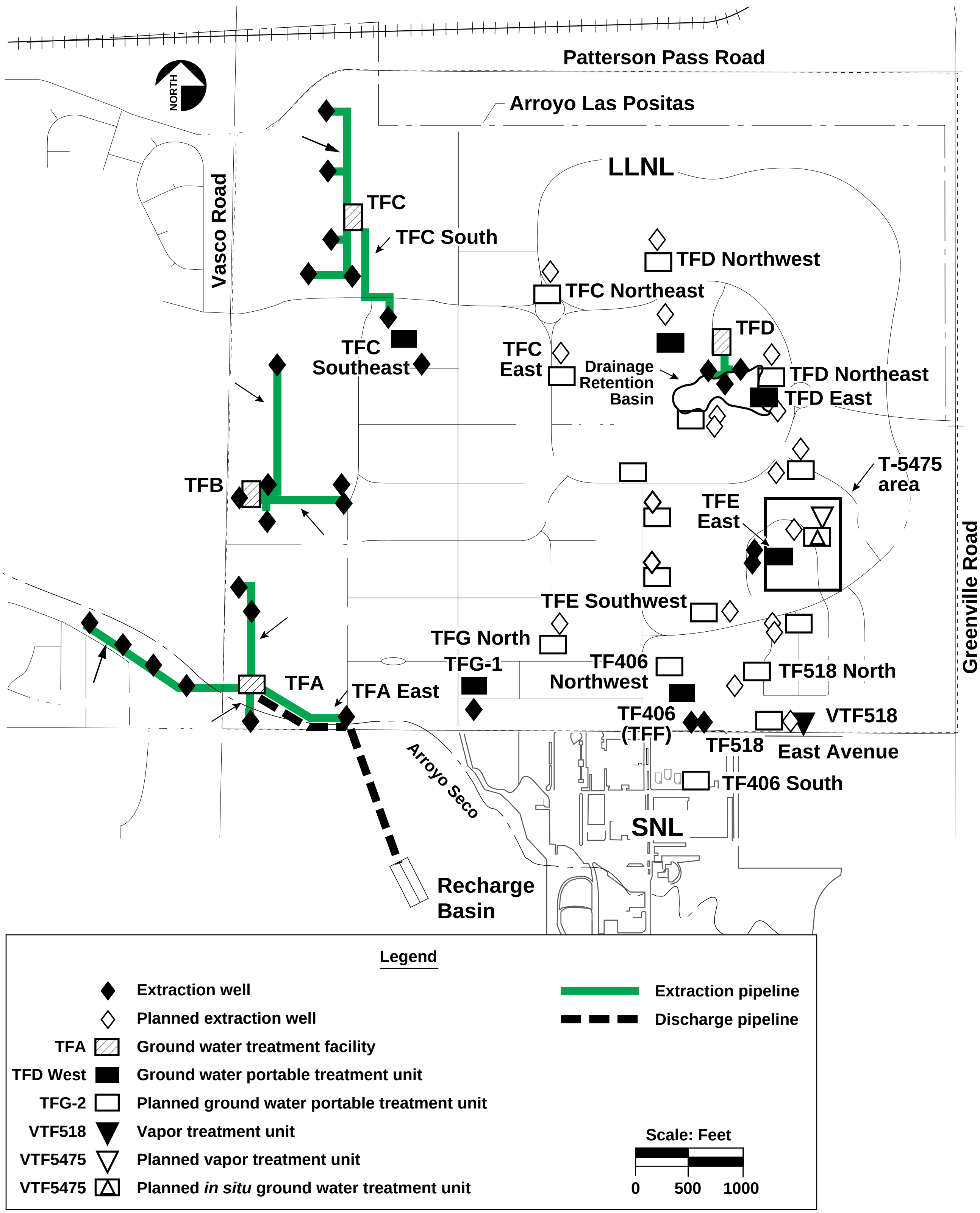


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Figure 2. Planned and existing ground water and soil vapor extraction locations at the LLNL Livermore Site.

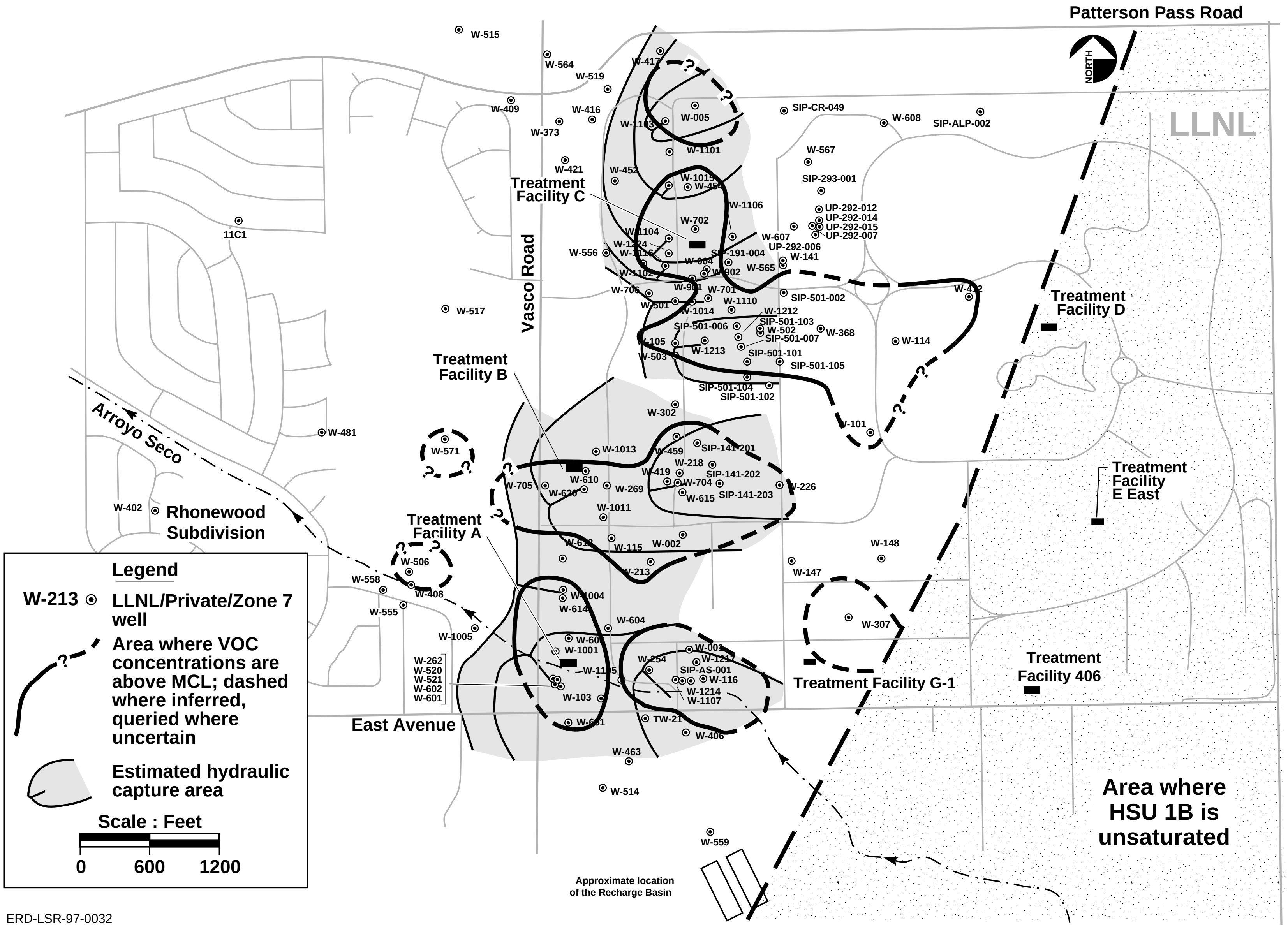
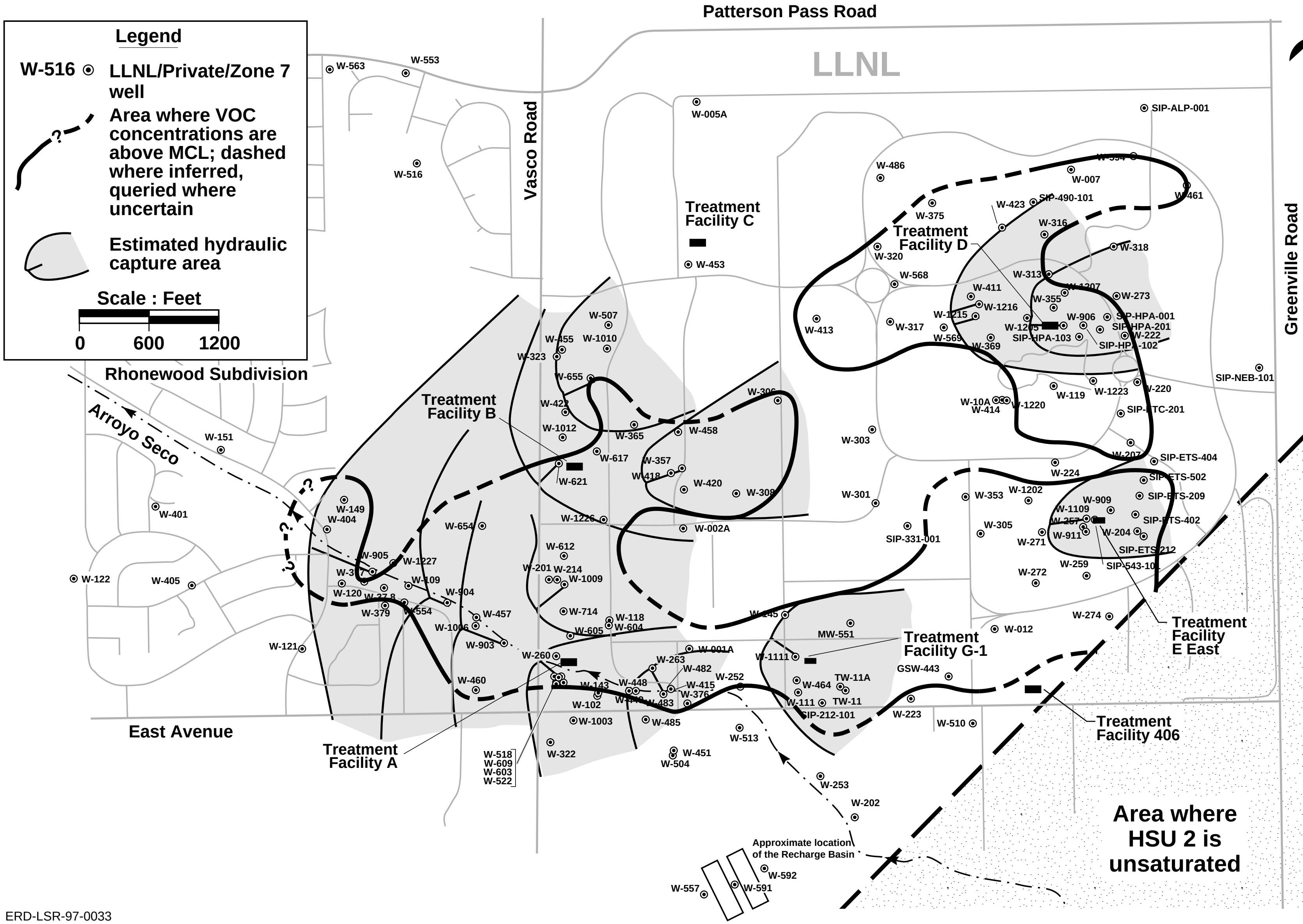


Figure 3. HSU-1B estimated hydraulic capture areas, and areas where VOCs exceed MCLs, first quarter 1997.



ERD-LSR-97-0033

Figure 4. HSU-2 estimated hydraulic capture areas, and areas where VOCs exceed MCLs, first quarter 1997.

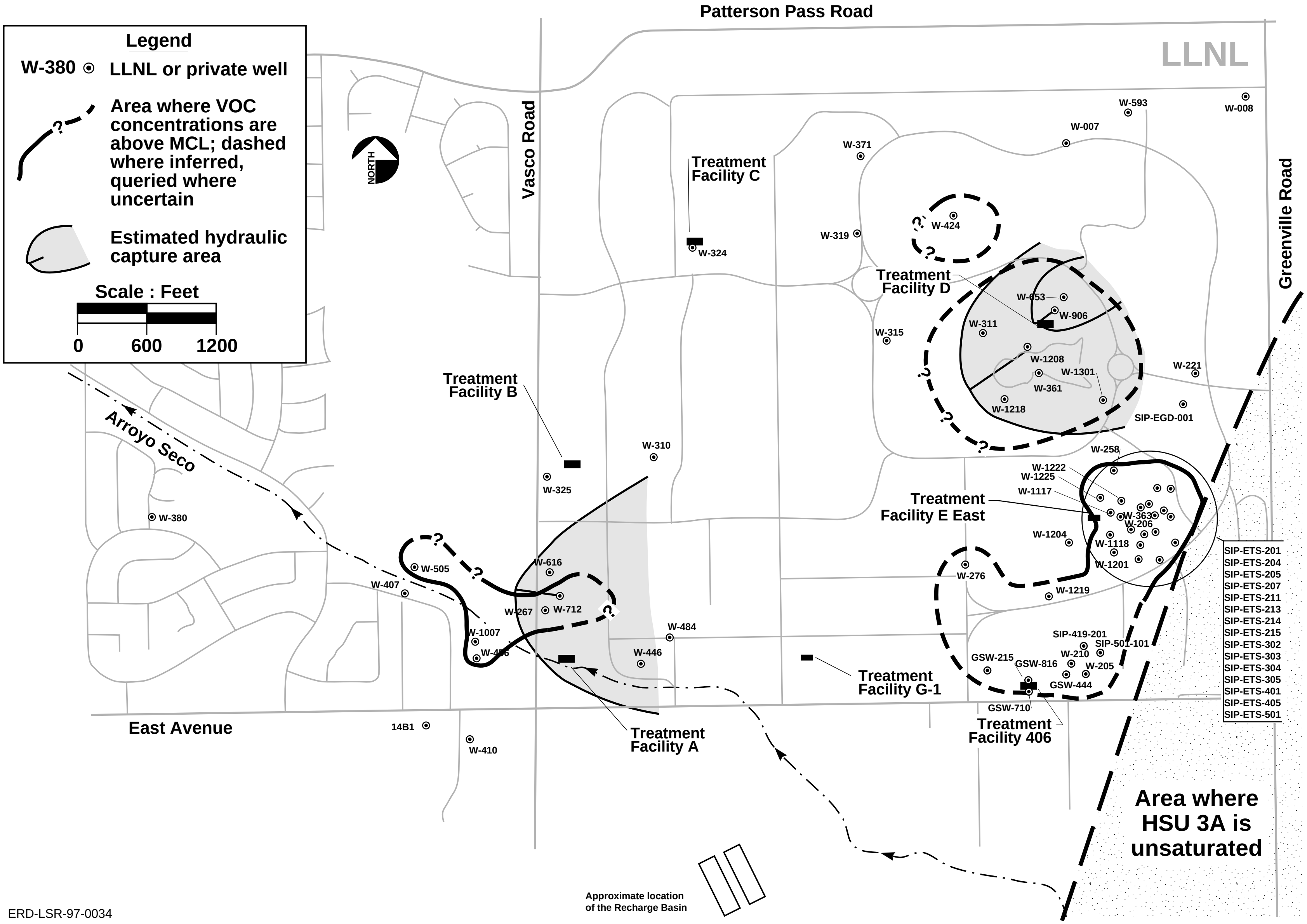
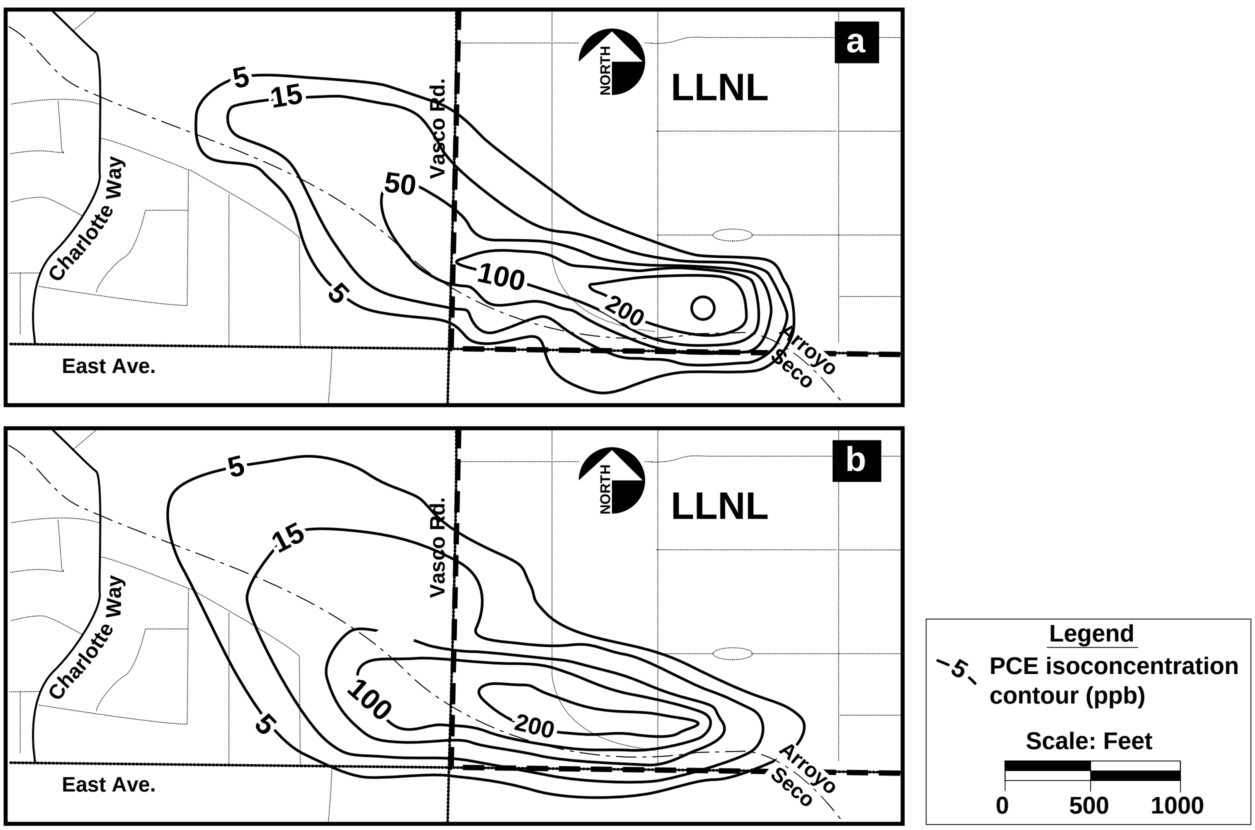
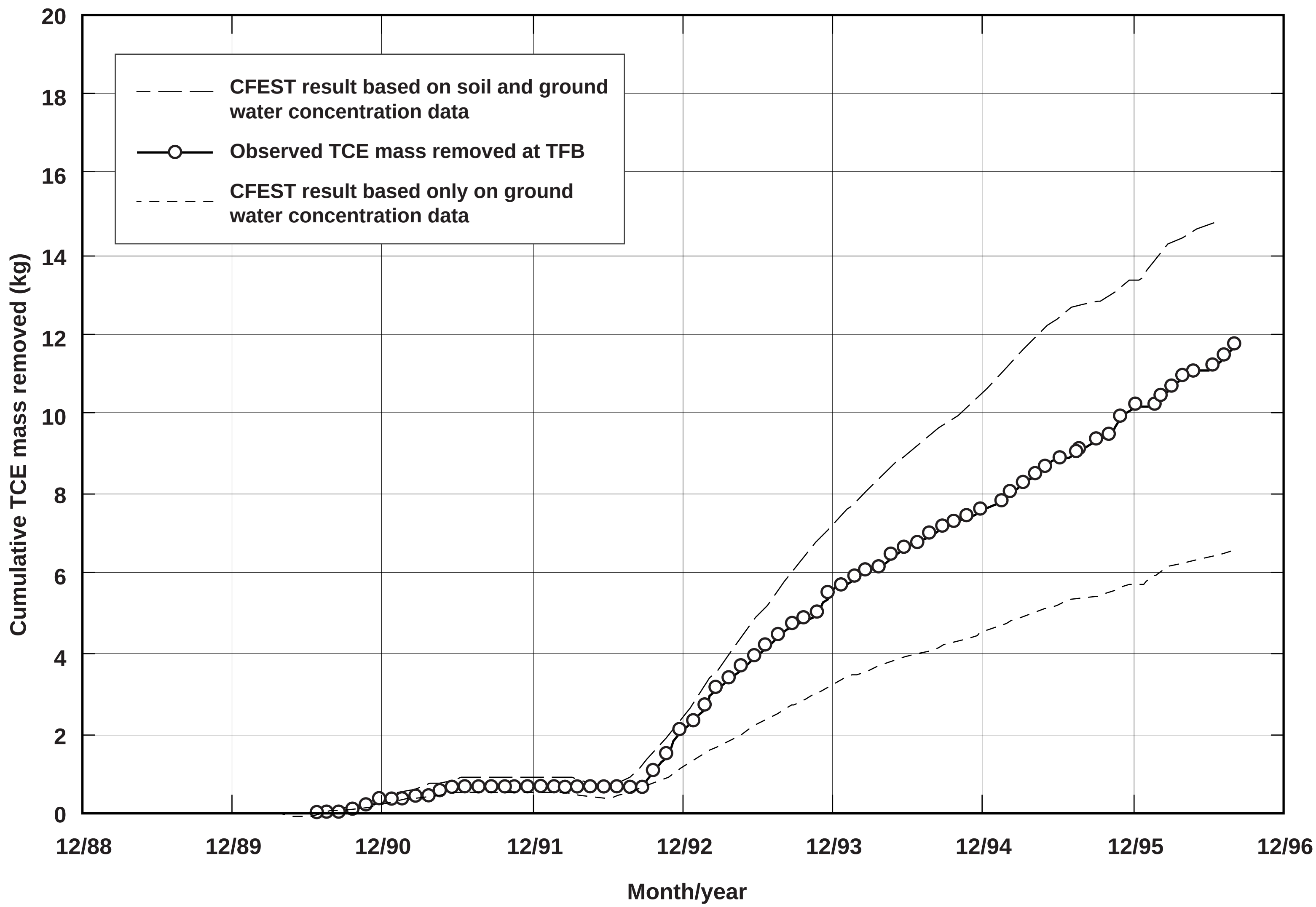


Figure 5. HSU-3A estimated hydraulic capture areas, and areas where VOCs exceed MCLs, first quarter 1997.



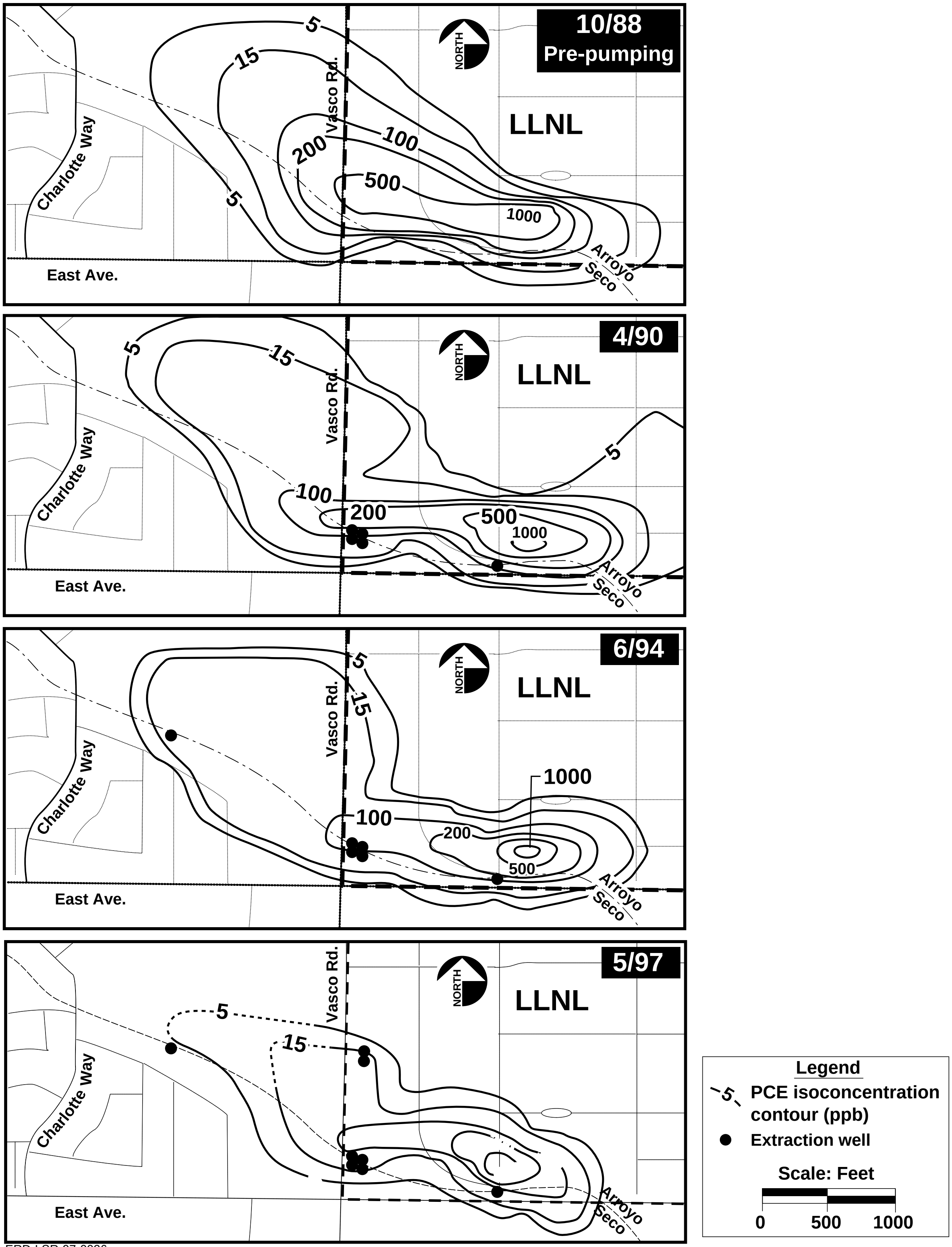
ERD-LSR-97-0031

Figure 6. Isoconcentration contour maps of PCE in HSU-1B: (a) measured October 1995, and (b) CFEST 3D model results.



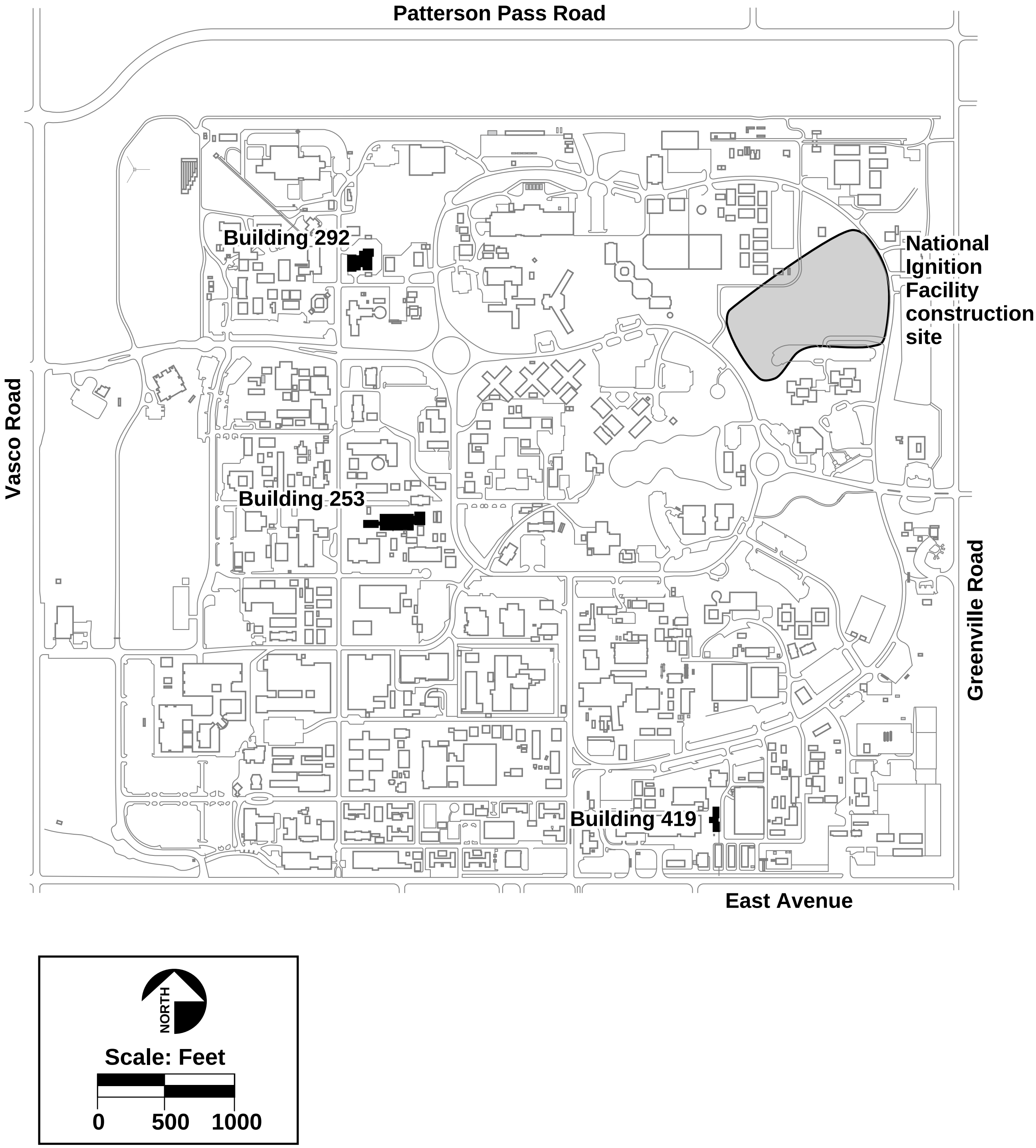
ERD-LSR-97-0030

Figure 7. Comparison of CFEST model results to observed cumulative TCE mass removed at TFB.



ERD-LSR-97-0026

Figure 8. Isoconcentration contour maps of PCE in HSU-1B from pre-remediation to May 1997 incorporating the Engineered Plume Collapse strategy.



ERD-LSR-97-0057

Figure 9. Locations of select cleanup and monitoring activities.

Tables

Table 1. Original and revised metals discharge limits (for all facilities except TFA).

	Discharge limit (μg/L)		
	Original	Revised: Dry season (MCLs) (April 1 - November 30)	Revised: Wet season (Order No. 94-087) (December 1 - March 31)
Antimony	1,460	6	NA[a]
Arsenic	20	50	10
Beryllium	0.7	4	NA[a]
Boron	7,000	NA[b]	NA[a]
Cadmium	5	5	2.2
Chromium (hexavalent)	11	NA[b]	22
Chromium (total)	50	50	NA[a]
Copper	20	1,300	23.6
Iron	3,000	NA[b]	NA[a]
Lead	5.6	15	6.4
Manganese	500	NA[b]	NA[a]
Mercury	1	2	2[c]
Nickel	7.1	100	320
Selenium	100	50	10
Silver	2.3	100	8.2
Thallium	130	2	NA[a]
Zinc	58	NA[b]	220

Notes:

LLNL will notify the Regional Board within 24 hours from initial analytical results indicating that concentrations exceed the discharge limits. If effluent discharge limits are exceeded, a second effluent sample and receiving water sample will be collected. If the second sample meets effluent limits, a third sample will be collected to verify that the second sample is valid. If the second effluent sample exceeds the discharge limits, the treatment system will be shut down to determine the cause of the violation.

μg/L = Micrograms per liter.
MCLs = Maximum Contaminant Levels.
NA = Not applicable.

[a] No limit is established for aquatic life protection; however, aquatic life is protected by quarterly bioassay analyses.

[b] No MCL is established for this metal.

[c] The mercury MCL of 2 μg/L is more conservative than the 1 gram per day limit in Order No. 94-087.

Table 2. Livermore Site active treatment facility summary.

Facility	Media treated	Contaminants	Technologies	Operating dates	Discharge location	Volume treated[a]	Mass removed[a]
TFA	Ground water	VOCs	UV/oxidation; air stripping with granular activated carbon (GAC)	UV/oxidation: April 1989 – May 1997; Air stripping only: June 1997 – present	Recharge Basin	362 Mgal	90.4 kg (199 lb)
TFB	Ground water	VOCs	UV/oxidation; air stripping with GAC	July 1990 – present	North-flowing drainage ditch that flows to Arroyo Las Positas	61 Mgal	24.0 kg (52.9 lb)
TFC	Ground water	VOCs; hexavalent chromium	Air stripping with GAC; ion exchange	TFC: October 1993 – present; TFC Southeast: January 1997 – present	North-flowing pipeline that empties into Arroyo Las Positas	30 Mgal	12.9 kg (28 lb)
TFD	Ground water	VOCs; hexavalent chromium	Air stripping with GAC; ion exchange	TFD: September 1994 – present; TFD West: April 1997 – present	North-flowing pipeline that empties into Arroyo Las Positas	48 Mgal	59.3 kg (131 lb)
TFE East	Ground water	VOCs	Air stripping with GAC	November 1996 – present	Drainage Retention Basin	8 Mgal	12.7 kg (28 lb)
TFF	Ground water	FHCs	UV/oxidation along with air stripping with GAC; Dynamic Underground Stripping (DUS)	UV/oxidation: February 1993 – December 1995; DUS: February 1993 – January 1994	Sanitary sewer	17 Mgal	7,280 kg (16,100 lb)
	Soil vapor	FHCs	GAC with steam regeneration; internal combustion engine (ICE)	GAC: February 1993 – March 1993; ICE: June 1993 – August 1995	Atmosphere	42.5 Mft^3	23,000 kg (51,000 lb)
TF406	Ground water	VOCs	Air stripping with GAC	August 1996 – present	Arroyo Las Positas	2.5 Mgal	1.1 kg (2.4 lb)
TFG-1	Ground water	VOCs; hexavalent chromium	Air stripping with GAC; ion exchange	April 1996 – present	Storm drain to Arroyo Seco	3.3 Mgal	0.7 kg (1.5 lb)
VTF518	Soil vapor	VOCs	GAC	September 1995 – present	Atmosphere	5,178 kft^3	101.6 kg (224 lb)

Notes:

lb = Pound(s).
kft^3 = Thousands of cubic feet.
kg = Kilograms.
Mft^3 = Millions of cubic feet.
Mgal = Millions of gallons.
[a] Totals through September 1997.

Table 3. Number of Livermore Site treatment facility ground water wells and piezometers, and vadose zone installations.[a]

Area	August 1992 – September 1997			Cumulative total through September 1997		
	Well(s)	Piezometer(s)	Vadose zone installations[b]	Well(s)	Piezometer(s)	Vadose zone installations
TFA	17	–	–[c]	111	1	–
TFB	5	3	–	37	3	–
TFC	14	19	–	50	27	–[d]
TFD	26	6	–	78	11	–
TFE	13	1	–	38	1	–
TFF/TF406	13	5	–[e]	74	51	–[e]
TFG	1	2	–	16	2	–
VTF518	–	1	8[f]	–	1	9[g]
TF5475	5	8	5[h]	10	27	5[h]

[a] Through September 1997.

[b] Includes soil vapor wells, inlet wells/probes, and SEAMIST or FLUTe installations. Soil vapor wells are similar to ground water monitoring wells, except the screened interval is in the vadose zone and not in the ground water. Inlet wells/probes are used to monitor pressure changes in the subsurface that result from vapor extraction. The vadose zone probes also act as air inlet wells to enhance vapor movement through the vadose zone. The SEAMIST system is an air-pressure driven impermeable, everting membrane that can carry soil vapor sampling instrumentation down an unlined borehole (Keller and Lowry, 1991). FLUTe is equivalent to SEAMIST.

[c] Does not include soil vapor instrumentation for an infiltration study.

[d] Does not include soil vapor instrumentation in the Building 292 area.

[e] Does not include soil vapor instrumentation for the Dynamic Underground Stripping Demonstration Project.

[f] Includes two soil vapor wells, four inlet wells/probes, and two SEAMIST vadose zone installations.

[g] Includes two soil vapor wells, five inlet wells/probes, and two SEAMIST installations.

[h] Includes two soil vapor wells and three SEAMIST or FLUTe installations.

Table 4. Livermore Site planned treatment locations.

Facility	Media treated	Contaminants	Technology	Hydrostratigraphic unit (s)	Purpose
TF518	Ground water	VOCs	Air stripping with GAC	HSU-5	Source area control
TFD Southeast	Ground water	VOCs	Air stripping with GAC	HSU-2 & HSU-4	Source area control
TFD South	Ground water	VOCs	Air stripping with GAC	HSU-2 & HSU-3A	Capture and treat distal portions of VOC plumes
TF5475	Ground water	VOCs; tritium	Hydrogen/palladium catalytic reductive dehalogenation for VOCs; tritium to remain *in situ*	HSU-2 & HSU-3A	Source area control
TFD Southwest	Ground water	VOCs	Air stripping with GAC	HSU-4	Capture and treat distal portion of VOC plume
VTF5475	Soil vapor	VOCs; tritium	GAC; reinject tritium	Vadose zone	Source area control
TFE West	Ground water	VOCs	Air stripping with GAC	HSU-2 & HSU-3B	Capture and treat distal VOC plume. May not be needed if plume is controlled by other TFE locations
TF518 North	Ground water	VOCs	Air stripping with GAC	HSU-3A	Source area control
TFE Southwest	Ground water	VOCs	Air stripping with GAC	HSU-2 & HSU-4	Capture and treat VOC plumes showing increasing concentrations
TFE Southeast	Ground water	VOCs	Air stripping with GAC	HSU-2 & HSU-5	Source area control
TFE Northwest	Ground water	VOCs	Air stripping with GAC	HSU-2	Capture and treat distal VOC plume margins
TFD Northwest	Ground water	VOCs	Air stripping with GAC	HSU-2 & HSU-3A	Source area control
TF406 Northwest	Ground water	VOCs	Air stripping with GAC	HSU-2, HSU-3A, & HSU-3B	Capture and treat VOC plumes showing increasing concentrations
TFC East	Ground water	VOCs	Air stripping with GAC	HSU-2 & HSU-1B	Capture and treat VOC plume
TFG North	Ground water	VOCs; possibly hexavalent chromium	Air stripping with GAC; may include ion exchange	HSU-1B & HSU-2	Capture and treat low VOC concentrations
TFD Northeast	Ground water	VOCs	Air stripping with GAC	HSU-2 & HSU-4	Source area control to accelerate cleanup in the TFD Area
TFC Northeast	Ground water	VOCs	Air stripping with GAC	HSU-2	Capture and treat VOC plume
TF406 South	Ground water	VOCs	Air stripping with GAC	HSU-5	Only installed if existing facilities do not control the offsite plume on Sandia National Laboratory site

Table 5. Estimated volume and mass of VOCs in saturated HSUs in the vicinity of the Livermore Site, 1996.

HSU	Estimated pore volume containing VOCs greater than 5 ppb[a] (million gal)	Estimated VOC mass dissolved in ground water[b] (kg)	(lb)
HSU-1A	0	0	0
HSU-1B	750	130	290
HSU-2	1,300	610	1,340
HSU-3A	420	310	680
HSU-3B	180	50	110
HSU-4	110	60	130
HSU-5	340	90	200
Total	3,100	1,250	2,750

Notes:

kg = Kilograms.

lb = Pounds.

ppb = Parts per billion.

[a] VOC pore volumes calculated using EarthVision 3.0 (Dynamic Graphics, Inc., Alameda, California) and an assumed porosity of 30%.

[b] Product of pore volume and geometric-mean VOC concentration. VOC concentrations less than 5 ppb not included in mass estimates.

Table 6. Five-year VOC mass removal estimates (fiscal years 1998–2002).

HSU	Estimated VOC mass removed (kg)	(lb)
HSU-1A	0	0
HSU-1B	46	100
HSU-2	180	400
HSU-3A	160	350
HSU-3B	1	2
HSU-4	77	170
HSU-5	45	99
Total	509	1,121

Notes:

kg = Kilograms.

lb = Pounds.

Table 7. Lessons learned from LLNL's Livermore Site remediation project.

Item	Discussion
Engineered Plume Collapse	Ground water extraction and treatment has been effective at the Livermore Site due to EPC, which incorporates "smart pump-and-treat" (Hoffman, 1993), HSU analysis, PTU technology, and active wellfield management to achieve plume capture and retraction, and to maximize contaminant mass removal. An example of the effectiveness of combining source containment with treatment of VOCs in the coarse-grained sediments is the offsite plume retraction toward the southwestern corner of the Livermore Site (Hoffman et al., 1997) (Fig. 8).
Contaminant source areas	Source areas for ground water plumes can have high concentrations of dissolved contaminants or dense, non-aqueous phase liquids in the vadose zone and below the water table in both coarse- and fine-grained geologic materials. Because of the low hydraulic conductivity of fine-grained materials and their tendency to adsorb contaminants onto clay and silt particles, these fine-grained materials serve as a long-term source of contaminants to ground water in coarse-grained materials. If the contaminants in these source areas are not removed, the distal parts of plumes will continue to grow and a cost-effective remediation will not be achieved.
Managing budget fluctuations	To deal with budget fluctuation, DOE/LLNL and the regulatory agencies have developed a Consensus Statement and Priority List for the Livermore Site project that establishes the order that work will be performed. In the Consensus Statement, DOE/LLNL and the regulatory agencies agree that tasks are accomplished in the order shown on the Priority List, independent of budget. Input from the community is solicited on the project priorities before establishing them. HSU analysis, cost-effective sampling (see below), and PTUs have lowered costs to meet project milestones.
Effective characterization	Through HSU analysis, DOE/LLNL have been able to depict the location of underground contaminant plumes in relation to individual source areas, and gain a better understanding of contaminant transport and distribution. HSU methodology also allows DOE/LLNL to target individual contaminant plumes, place extraction wells at optimum locations to meet cleanup objectives faster, and conduct a comprehensive and more cost-effective cleanup.
Model simulations	Model simulations have optimized the planned ground water extraction remedial wellfields, and have provided estimates of contaminant mass and volume of ground water containing VOCs. The simulations of plume collapse at TFA contributed to the development of the EPC concept. The model simulations predict future plume configurations, and forecast cleanup times and cost.
Stakeholder support	Constructive relationships with the Stakeholders greatly facilitate rapid and cost-effective cleanup. The Stakeholders have agreed to cost-saving changes when the changes remain protective of human health and the environment. Examples include reduced sampling and reporting, aggressive remediation through use of PTUs, treatability studies on promising technologies, and completion of FHC remediation at TFF. Without the Stakeholders support, these successes may not have occurred.

Table 7. (Continued)

Item	Discussion
Extraction well material selection	Welded screens of both Type 304 and Type 316 stainless steel have been used in extraction wells at the Livermore Site. DOE/LLNL determined that Type 304 stainless steel releases nickel into solution when in contact with the Livermore Site's ground water, and now only use Type 316.
UV oxidation technology drawbacks	Although UV oxidation destroys VOCs, UV oxidation technology drawbacks include: less effective destruction of single carbon-to-carbon bonds, safety hazards associated with the handling of H_2O_2, and the electrical power costs required to operate the system.
Importance of new technology development	Developing or evaluating new technologies is important for achieving the cleanup goals at the site. Technologies such as electro-osmosis, hydrous pyrolysis, and vapor extraction, can enhance VOC removal from the fine-grained material at the source areas and expedite cleanup. Technologies such as catalytic reductive dehalogenation will allow treatment of VOCs *in situ* in areas that also contain tritium, which will minimize the amount of ground water brought aboveground, and thus meet a strong community and regulatory desire.
Portable Treatment Units	Use of PTUs and the current testing of ground water GAC treatment increases cleanup flexibility and aggressive remediation. PTU construction has reduced the capital costs compared to building the remaining fixed treatment systems specified in the ROD.
Assessing discharge requirements	Re-evaluation of NPDES sampling frequency and discharge limits resulted in cost reduction while remaining protective of the environment. Cost savings were achieved by reducing staff time, analytical costs, and the costs of implementing unnecessary treatment technologies.
Sampling cost-savings initiatives	A Cost-Effective Sampling (CES) algorithm was developed at LLNL for estimating the lowest monitor well sampling frequency that will provide adequate data for remedial and compliance-related decision making (Nichols et al., 1996). Use of the CES has resulted in an approximate 40% reduction in the number of samples collected for VOC analysis, saving approximately $200,000 annually compared to the cost before CES was implemented.
Reporting cost-savings initiatives	To reduce costs, DOE/LLNL and the regulatory agencies negotiated reduced scope and frequency for documents. Paperwork was also reduced by recording all decisions, agreements, and policy changes discussed at the RPM meetings in the meeting summary, instead of preparing additional, separate documents. The cost savings from reduced document preparation has been applied to site cleanup.

Table 7. (Continued)

Item	Discussion
Multi-disciplinary integration	Integrating our scientific understanding of the subsurface hydrogeology and chemistry with appropriate engineering technologies has been effective in cleaning up the Livermore Site at reduced cost. In addition, DOE/LLNL integrate management at all levels to ensure remedial actions are implemented and appropriate resources are available. An example of this integration was implementing ground water cleanup in the TFG area. Only with the cooperation of various management programs throughout the Livermore Site was this remedial design implemented. This cooperative relationship between scientific disciplines, and DOE/LLNL management has been crucial to successfully working toward site cleanup.
Undocumented buried hazardous materials	At industrialized sites with histories similar to the Livermore Site, undocumented landfills and buried hazardous waste may be encountered during excavations and drilling operations. However, with a properly trained staff of environmental scientists available, removal of the undocumented waste can be performed quickly and safely without a threat to human health or the environment.

Table 8. Livermore Site Remedial Action Implementation Plan milestone dates.

Task	Completion date
Submit Draft RD1 to regulatory agencies and the community	10-10-92[a]
Submit Draft Final RAIP to regulatory agencies	11-6-92[a]
Receive regulatory comments on RD1	12-10-92[a]
Issue RAIP	1-6-93[a,b]
Submit Draft Revised Community Relations Plan to regulatory agencies and the community	1-31-93
Begin operation of TFF	2-93
Submit Draft Final RD1 to regulatory agencies	3-12-93[a]
Issue RD1	4-12-93[a]
Submit Draft RD2 to regulatory agencies and the community	5-10-93[a]
Submit Draft Final Revised Community Relations Plan to regulatory agencies	5-31-93
Receive regulatory comments on Draft RD2	6-25-93[a]
Issue Revised Community Relations Plan	6-30-93
Submit Draft Final RD2 to regulatory agencies	8-10-93[a]
Issue RD2	9-10-93[a,b]
Begin treatability study at Trailer 5475	9-30-93
Submit Draft RD3 to regulatory agencies and the community	9-30-93[a]
Begin operation of TFC	10-30-93
Receive regulatory comments on Draft RD3	12-1-93[a]
Submit Draft Final RD3 to regulatory agencies	2-1-94[a]
Issue RD3	3-1-94[a,b]
Complete investigation of B-518	6-1-94
Submit Draft RD6 to the regulatory agencies and the community	7-1-94[a]
Receive regulatory comments on Draft RD6	8-30-94[a]
Begin operation of TFD	9-30-94
Submit Draft Final RD6 to regulatory agencies	10-31-94[a]
Issue RD6	11-30-94[a,b]
Submit Draft RD5 to the regulatory agencies and the community	12-1-94[a]
Receive regulatory comments on Draft RD5	1-30-95[a]
Submit Draft Final RD5 to the regulatory agencies	3-31-95[a]

Table 8. (Continued)

Task	Completion date
Issue RD5	5-1-95[a,b]
Submit Draft Compliance Monitoring Plan to the regulatory agencies and the community	8-30-95
Begin operation of Building 518 vapor extraction system	9-29-95
Receive regulatory comments on Draft Compliance Monitoring Plan	10-30-95
Submit Draft Final Compliance Monitoring Plan to the regulatory agencies	12-29-95
Issue Compliance Monitoring Plan	1-29-96[b]
Begin operation of TFG-1[c]	4-18-96
Submit Draft Contingency Plan to the regulatory agencies and the community	7-1-96
Receive regulatory comments on Draft Contingency Plan	8-30-96
Begin operation of TF406 PTU	8-30-96
Submit Draft Final Contingency Plan to the regulatory agencies	10-29-96
Begin operation of TFE East PTU	11-27-96
Issue Contingency Plan	11-28-96[b]
Begin operation of TFC Southeast PTU	1-31-97
Begin operation of TFD West PTU	4-25-97
5 Year Review	8-5-97[a]
Submit Draft RD4 to the regulatory agencies and the community	8-25-97[a]
Begin operation of TFD East PTU	10-3-97
Receive regulatory comments on Draft RD4	11-4-97
Submit Draft Final RD4 to the regulatory agencies	1-16-98[a]
Begin operation of TF518 PTU	1-30-98
Issue RD4	2-16-98[a,b]
Begin operation of TFD Southeast PTU	3-27-98
Begin operation of TFD South PTU	6-26-98
Begin operation of TF5475 (Phase 1)	9-30-98
Begin operation of TFD Southwest PTU	1-29-99

Table 8. (Continued)

Task	Completion date
Begin operation of VTF5475	6-29-99
Begin operation of TFE West PTU	8-2-99
Begin operation of TF518 North PTU	1-28-00
Begin operation of TFE Southwest PTU	5-26-00
Begin operation of TF5475 (Phase 2)	9-29-00

[a] These dates are enforceable under the LLNL Livermore Site Federal Facility Agreement (FFA).

[b] These dates can be met only if there are few or no comments on the Draft Final version.

[c] TFG will consist of two separate units: TFG-1 and TFG Northeast.

Notes:

1) All primary FFA documents will be submitted to DOE 30 days prior to submission to the regulatory agencies.
2) There will be six phased Remedial Design (RD) submittals (RD1 through RD6).
3) Extraction wells will be phased-in.
4) Draft RD1 = TFA , TFB, and associated extraction wells and piezometers.
5) Draft RD2 = TFC, TFF, and associated extraction wells and piezometers.
6) Draft RD3 = TFD, TFE, associated extraction wells and piezometers, and Building 518 vapor extraction treatability study results.
7) Draft RD4 = Trailer 5475/East Taxi Strip Area.
8) Draft RD5 = TFG-1, TFG-2 (TFG Northeast), and associated extraction wells and piezometers.
9) Draft RD6 = Building 518 vapor extraction system.
10) PTU = Portable Treatment Unit.

Appendix A

VOC Mass Estimating Procedure

Appendix A

VOC Mass Estimating Procedure

The following outlines the procedures used to obtain the 1996 VOC mass estimate for the Livermore Site. We first developed a 3D total VOC concentration data set with sufficient horizontal and vertical data density to calculate an accurate estimate of the distribution of VOCs in the saturated zone beneath the Livermore Site. For the 1996 mass estimate, we used hydrostratigraphic boundaries to constrain the interpolation and volumetric calculations. The HSUs represent hydrogeological boundaries that control the migration of contaminants beneath the Livermore Site. The hydrostratigraphic model had not been developed at the time of the 1988 mass estimate (Isherwood et al., 1996), hence the previous estimate did not incorporate the effects of the HSU boundaries. To develop the 3D subsurface geology data set, we used HSU and lithology data from 683 wells and boreholes in the following manner:

- The lithology in each borehole was assigned to individual HSUs;
- Each HSU was further subdivided into high- and low-permeability zones; and
- Data points were established at one foot intervals along the length of the borehole to adequately define the distribution of VOCs in the saturated zone beneath the site.

The mass estimate was based primarily on total VOC concentrations in ground water samples collected during 1996. Source investigation ground water chemistry data and saturated soil chemistry data were also used to augment the data set. Source investigation ground water samples are collected from boreholes drilled using hollow stem augers. Saturated soil samples are obtained from deeper boreholes using the LLNL depth-sampling technique (Hoffman and Dresen, 1988).

The mass estimate presented in Table 5 was based on total VOC concentrations from 1,300 ground water samples collected from 430 wells during 1996. An additional 4,147 source investigation ground water samples and saturated soil samples from 571 boreholes were reviewed during compilation of the data. The following methods were used to develop the 3D VOC data set for each HSU:

- For each well, we calculated an arithmetic-mean total VOC concentration of all ground water samples collected during 1996.
- The arithmetic mean 1996 ground water total VOC concentration was assigned along the length of the screened interval of each well. The concentration values were also extended vertically to include any high-permeability zones that intersect the screened interval.
- Wellbore data points with no ground water data were assigned VOC concentrations based on available source investigation and saturated soil chemistry data.
- In high-permeability zones, the arithmetic mean concentration of all saturated soil or source investigation ground water samples was applied across the entire zone.

- In low-permeability zones, the concentration of the soil sample was assigned only at the depth from which it was collected.
- Because ground water samples collected from monitoring wells are more representative of *in situ* ground water concentrations, saturated soil and source investigation concentration data from boreholes were removed from the data set where adequate coverage of 1996 monitoring well data was available.
- Saturated soil and source investigation data were divided into two subsets: those containing VOCs, and those without detectable VOCs. The data without detectable VOCs were used, regardless of the date collected, to provide sufficient data to constrain the contouring. Saturated soil and source investigation data with detected VOCs that were collected prior to 1993 are no longer considered representative, and were removed from the data set unless sufficient monitor well data were not available for adequate contouring.
- Data points that were not assigned a concentration value were removed from the data set.

To develop the 1996 contaminated ground water volume estimate:

- A 3D VOC plume model was constructed for each HSU using Dynamic Graphics, Inc. Earth Vision (EV) 3.0 software;
- The unsaturated zone was excluded from the volume calculations; and
- The EV volumetric utility was used to calculate the volume of aquifer between isoconcentration shells; i.e., 3D-contour surfaces.

We calculated the amount of contaminant mass within each HSU based on the interpolated distribution of VOCs by:

- Assuming a uniform 30% porosity to calculate the total volume of ground water within the aquifer;
- Multiplying the geometric mean concentration value by the total volume of ground water within each isoconcentration shell interval. The geometric mean was used because the isoconcentration contour interval is logarithmic (i.e., 1, 10, 100 ppb, etc.); and
- Summing the VOC mass value for each isoconcentration shell per HSU (Table 5).

References

Hoffman, F., and M. D. Dresen (1990), "A Method to Evaluate the Vertical Distribution of VOCs in Ground Water in a Single Borehole," *Ground Water Monitoring Review*, **10**(2), 95–100.

Isherwood, W. F., C. H. Hall, and M. D. Dresen (Eds.) (1990), *CERCLA Feasibility Study for the LLNL Livermore Site*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-104040).

Appendix B

Responsiveness Summary

Appendix B

Responsiveness Summary

This Responsiveness Summary addresses EPA comments dated September 30, 1997 on the August 1997 version of the Five-Year Review.

Comment 1:

In general, we found the Five Year Review to be an excellent historical summary of the site work since the ROD was signed in 1992. Table 6 (Lessons Learned) is an especially useful part of the review. However, it would be appropriate to provide more detail about future activities and goals at the site. This is detailed in some of the following comments

Response to Comment 1:

Comment noted. Table 6 is now presented as Table 7 in the final Five-Year Review and contains language relating to the NIF capacitor excavation.

Comment 2:

More description of past, present and future source investigations and how they will be handled in the regulatory framework should be noted in the review. Discussions should include a status of the capacitor discovery and PCB contaminated soil removal at the NIF construction site, the mercury and tritium underneath Building 419 and the elemental mercury in the storm sewer system sediments. Future work associated with these and other sites, especially over the next five years, should be discussed in the review.

Response to Comment 2:

Section 2.4.3 has been added to the final Five-Year Review that discusses activities at Building 419, Building 292, the NIF construction site, and activities related to maintenance of the storm sewer. Figure 9 has been included in the final document to show the location of Buildings 419, 292, and 253, and the NIF construction site.

DOE/LLNL will continue to work closely with the regulatory agencies if new sources of contamination are found and will notify the appropriate regulatory agency with authority over the contaminant/media of concern (i.e., EPA and State of California authorities dealing with the Toxic Substances Control Act [TSCA] for TSCA materials, EPA and State of California authorities with RCRA oversight responsibility for RCRA releases/contaminants, etc.). In addition, we will continue to inform our CERCLA RPMs of all new finds and formulate proposed response action(s) with their input. If a removal action is going to be carried out under CERCLA, DOE will notify the regulatory agencies as required by the FFA and will take into consideration any comments received from the regulatory agencies regarding the proposed action.

Comment 3:

Page SUMM-1, last paragraph. The text states that "...no further recommendations for future actions are identified." This seems counter to what is stated in the last paragraph on page 15 (Section 5). Future work, which will include "alternative approaches to site closure, such as Containment Zone policies, No Further Action, natural attenuation, institutional measures and continued groundwater monitoring" will undoubtedly lead to recommendations to the agencies. Please clarify what is really meant by the statement "no further recommendations" on pages SUMM-1 and 15. In addition, are there any other recommendations to add?

Response to Comment 3:

The Summary in the final Five-Year Review now reflects the proposed future work discussed in Section 5. The statement referring to “no further recommendations” has been removed from the Summary and Section 5 of the final Five-Year Review.

Comment 4:

Section 2.1.2.2, page 4, last paragraph. Please provide an estimated date for switching over to the high efficiency air stripping unit at TFB. Same comment applies to the first paragraph of Section 2.4.1.2.

Response to Comment 4:

July 31, 1998 is the estimated date for switching TFB over to a high-efficiency air stripper. This date has been included in Sections 2.1.2.2 and 2.4.1.2 of the final Five-Year Review.

Comment 5:

Section 2.2.1, page 5. Please identify how many extraction wells were planned per the Feasibility Study, as opposed to how many were eventually installed.

Response to Comment 5:

The Feasibility Study only discussed the planned number of extraction locations, not the number of extraction wells. This initial extraction scenario was modified when HSU methodology was applied to the subsurface, which increased our understanding of individual plumes and source areas. The progression from the number of initial extraction locations in the Feasibility Study to about 45 extraction wells currently operating at the site has been added to Section 2.4.1 of the final Five-Year Review.

Comment 6:

Section 2.2.6, page 7. The second paragraph indicates that DOE/LLNL prepared an application for a Containment Zone for the FHCs at TFF. The regulating agencies neither requested nor did they review or approve it. A Containment Zone status was not granted; a No Further Action status was granted. Please clarify this in the text.

Response to Comment 6:

The application for Containment Zone status for the Livermore Site hydrocarbon-impacted zone at Treatment Facility F was discussed at RPM meetings, and it was decided at the July 2, 1996 RPM meeting that DOE/LLNL would submit the application for Containment Zone status, but request that the RWQCB grant No Further Action. Copies of the application for Containment Zone status were provided to all the regulatory agencies. After reviewing the document, the RWQCB confirmed completion of active remediation for the fuel hydrocarbons in ground water and granted No Further Action status. Section 2.2.6 of the final Five-Year Review clarifies that the RWQCB did not grant Containment Zone status, but did approve No Further Action status.

Comment 7:

Section 4, page 14. It is stated here that "DOE's draft Ten-Year Plan indicates a steady rise in funding from FY99 through FY03 for innovative technology implementation." What percentage of this increase would actually contribute to the overall environmental restoration work? We are skeptical that the budgets for environmental restoration will ever increase again and if the present downward trend continues, will eventually affect progress on cleanup. Because DOE has withdrawn this draft document, it should not be used for decision making. Until it is finalized, its reference in this review should be deleted.

EPA agrees with the position held by the State and the community, that this review should include a description of what DOE/LLNL expects to achieve at the site over the next five years, taking into account both budgets and technical ability, and a rough (modeled or otherwise) estimate of when cleanup goals are expected to be achieved. Much has been touted in project management meetings and in other forums about the increased mass removal rates due to PTUs and other aspects of the Engineered Plume Collapse strategy. By extrapolating from these optimistic results, DOE/LLNL should be able to roughly estimate how much the contamination levels in groundwater will decrease over the next 5 years. Possible ways to present this are to illustrate estimates of plume capture and mass removal on updated versions of Figures 3, 4, 5, and 7.

Response to Comment 7:

Reference to DOE's Ten-Year Plan has been deleted from Section 4 in the final Five-Year Review.

DOE/LLNL are currently working on a 3D ground water flow and contaminant transport model, which will help estimate mass removal and cleanup times. The model is anticipated to be calibrated prior to the next five-year review. DOE/LLNL anticipate that cleanup downgradient of source areas will be less than the 53 years estimated in the Proposed Remedial Action Plan, although the impact from mass in the source areas is still largely unknown. DOE/LLNL plan to share their modeling information with the regulatory agencies and the community when available. Estimates of mass removal by HSU were made for the next five years (fiscal years 1998–2002), and are presented in Table 6 of the final Five-Year Review. These estimates were derived by using current extraction well flow rates and VOC concentrations to estimate mass removal. Mass removal in each extraction well was assumed to decrease 20% each year based on observations in existing wells. Mass removal from the Trailer 5475 area treatment units was assumed to decline 30% each year. New wells were incorporated according to the EPC plan, and all wells were assumed to continue operation through the end of the five-year period.

Comment 8:

Figures 3 and 8 both depict VOC contamination contours above MCLs for HSU-1B. The snapshots represent data that is only one year apart, but radically different. We suggest that because there is such a difference in the contours, that the most up to date data be presented for both plots.

Response to Comment 8:

Figures 3 and 8 depict contours of differing data, and should not look the same. Figure 3 indicates areas with any VOC in ground water above MCLs, whereas Figure 8 shows isoconcentration contours for one compound only, and does not define a contour showing the area exceeding MCLs. As discussed with the EPA on October 15, 1997, Figure 8 in the final Five-Year Review is updated to include 1997 data.

Comment 9:

Table 7. As suggested by Peter Strauss in his correspondence of September 8, 1997, we agree that this table be replaced with the latest Remedial Action Implementation Plan schedule from July 1997. This would reflect both historical and future FFA milestones in the review. Also, adding the signed Consensus Statement to the review would show what milestones DOE/LLNL and the regulatory agencies consider to be priorities.

Response to Comment 9:

The complete July 1997 Remedial Action Implementation Plan schedule is presented as Table 8 in the final Five-Year Review. The schedule in Table 8 has been updated to include the new dates related to receiving regulatory comments and for submitting Draft Final and Final Remedial Design Report No. 4. The Consensus Statement and Priority List are now included as Attachment A of the final Five-Year Review.

Attachment A

Consensus Statement and Priority List for Environmental Restoration of the Lawrence Livermore National Laboratory Livermore Site

Consensus Statement for Environmental Restoration of Lawrence Livermore National Laboratory Livermore Site

The parties to this Consensus Statement — U.S. Department of Energy (DOE), U.S. Environmental Protection Agency, and the San Francisco Bay Regional Water Quality Control Board and Department of Toxic Substances Control of the California EPA — are those parties that entered into the Federal Facility Agreement (FFA) of November 2, 1988, for the Lawrence Livermore National Laboratory (LLNL) Livermore Site. This Consensus Statement does not amend the existing FFA.

Consensus Statement History

In a July 1994 Consensus Statement, the parties agreed to the following Livermore Site ground water cleanup priorities:

1. Western plume capture
   - Treatment Facility A North Pipeline
   - Treatment Facility B North Pipeline
   - Treatment Facility C North Pipeline

2. Southern plume capture
   - Building 518
   - Treatment Facility F
   - Treatment Facility G-1

3. Internal source control/mass removal
   - Trailer 5475/East Taxi Strip Area Treatment Facility
   - Treatment Facility G-2
   - Treatment Facility E

In September 1996, the parties signed a new Consensus Statement agreeing that DOE/LLNL had addressed western and southern plume capture (items 1 and 2 above), and had begun to address internal source control (item 3). DOE/LLNL and the regulatory agencies also agreed to use Portable Treatment Units (PTUs) instead of permanent facilities and pipelines to reduce cleanup time and cost.

Current Consensus

As agreed to in the September 1996 Consensus Statement, DOE/LLNL are currently using PTUs to augment remediation in areas throughout the interior of the Livermore Site. Through ongoing data collection and analyses, DOE/LLNL have expanded their understanding of subsurface contaminant distribution and recognize that remediating or controlling contamination in source areas is cost effective and key to remediating the distal portions of ground water plumes. Thus, this current Consensus Statement reflects changes to the Livermore Site remediation priorities to aggressively control or remediate source areas.

The signatures of the Remedial Project Managers below demonstrate that the parties have reached consensus to change the order of priorities for remediation as presented in Attachment A. These changes are consistent with Community Work Group concerns.

The tasks will be accomplished in the order shown in Attachment A independent of budget, unless agreed by all parties. Priorities can be reviewed at the request of any of the parties. This schedule of milestones is reflected in a July 1997 amendment to Table 5 of the Remedial Action Implementation Plan.

The following parties agree to this Consensus Statement:

7-17-97
Date

James Littlejohn
Remedial Project Manager
DOE/OAK Operations Office
U.S. Department of Energy

7-17-97
Date

Michael D. Gill
Remedial Project Manager
U.S. Environmental Protection Agency

7-17-97
Date

B. Robert Feather
Remedial Project Manager
California Environmental Protection Agency
Department of Toxic Substances Control

7/17/97
Date

Michael Rochette
Remedial Project Manager
California Environmental Protection Agency
Regional Water Quality Control Board
San Francisco Bay Region

LLNL Livermore Site Restoration Activities Priority List (Changes and Reprioritization, July 1997)

Task	Notes	Status
Regulatory compliance (monitoring, reporting, and analysis)	Operations	Ongoing
Facility operations and maintenance (existing and future facilities)	Operations	Ongoing
Technology development	Operations	Ongoing
Building 518 investigation	Source Inv.	Complete
TFC Area source investigation	Source Inv.	Complete
TFA Arroyo Pipeline	Western	Complete
Submit Draft RD6 to regulatory agencies and the community	Report	Complete
TFD startup	Interior	Complete
Submit Draft RD5 to regulatory agencies and the community	Report	Complete
TFC Area source investigation — continued	Source Inv.	Complete
TFF Area source investigation	Source Inv.	Complete
Building 518/Southeast Area source investigation	Source Inv.	Complete
TFA north pipeline[1]	Western	Complete
TFG Area source investigation	Source Inv.	Complete
TFB north pipeline[1]	Western	Complete
TFD Area source investigation	Source Inv.	Complete
Submit Draft Compliance Monitoring Plan to regulatory agencies and the community	Report	Complete
TFE Area source investigation	Source Inv.	Complete
Building 331 source investigation	Source Inv.	Complete
Building 419 source investigation	Source Inv.	Complete
Building 518 vadose zone treatment facility startup	Southern	Complete
TFC north pipeline[1]	Western	Complete
TFC Area source investigation — continued, if necessary	Source Inv.	Complete
TFC southeast pipeline[1]	Western	Complete
TFG-1 startup	Southern	Complete
TFG Area source investigation — continued	Source Inv.	Complete
Submit Draft Contingency Plan to regulatory agencies and the community	Report	Complete
TF406 PTU[1]	Southern	Complete
TFE East PTU[1]	Interior	Complete
TFC Southeast PTU[1]	Western	Complete
TFD West PTU[1]	Interior	Complete
Five-Year Review	Report	
Submit Draft RD4 to regulatory agencies and the community	Report	
TFD East PTU[1]	Interior	
TF518 PTU[1]	Southern	
TFD Southeast PTU[1]	Interior	
TFD Area source investigation — continued, if necessary	Source Inv.[2]	
TFD South PTU[1]	Interior	
TF5475 Phase 1	Interior	
TFD Southwest PTU[1]	Interior	
VTF5475	Interior	
TFE West PTU[1]	Interior	

LLNL Livermore Site Restoration Activities Priority List (Continued).

Task	Notes	Status
Building 518/Southeast Area source investigation — continued, if necessary	Source Inv.[2]	
TF518 North PTU[1]	Southern	
TFE Area source investigation— continued, if necessary	Source Inv.[2]	
TFG Area source investigation — continued, if necessary	Source Inv.[2]	
TFE Southwest PTU[1]	Interior	
TF5475 Phase 2	Interior	
TFA North upgrade and associated extraction well(s)/piezometers, if necessary	Western	
TF5475 Phase 3	Interior	
TFE Southeast PTU[1]	Interior	
TFE Northwest PTU[1]	Interior	
TF5475 Phase 4	Interior	
TFB north pipeline extension and associated extraction well(s)/piezometers, if necessary	Western	
TFD Northwest PTU[1]	Interior	
TF406 Northwest PTU[1]	Southern	
TFC East PTU[1]	Interior	
TFG North PTU[1]	Southern	
TFD Northeast PTU[1]	Interior	
TFC Northeast PTU[1]	Interior	
TFE reinjection pipeline and associated reinjection well(s)/piezometers, if necessary	Interior[2]	
TFD northeast reinjection pipeline and associated reinjection well(s)/piezometers, if necessary	Interior[2]	
TF406 South PTU[1], if necessary	Southern	

Abbreviations:

Western = Western plume capture
Southern = Southern plume capture
Interior = Interior source control
Source Inv. = Source investigation
Report = Post-Record of Decision report
PTU = Portable Treatment Unit

Footnote:

[1]Includes all associated extraction wells and piezometers

[2]Task will be implemented only if it is necessary for achieving plume capture/source area control