ADAPTIVE REMEDIATION USING PORTABLE TREATMENT UNITS

Sally Bahowick
Lawrence Livermore Nat'l Laboratory
P.O. Box 808, L-528
Livermore, CA 94551
(510) 423-6773

Ed Folsom
Lawrence Livermore Nat'l Laboratory
P.O. Box 808, L-619
Livermore, CA 94551
(510) 422-0389

Tristan Pico
Lawrence Livermore Nat'l Laboratory
P.O. Box 808, L-528
Livermore, CA 94551
(510) 422-9119

ABSTRACT

Lawrence Livermore National Laboratory (LLNL) is using adaptive remediation to optimize our environmental restoration strategy. Adaptive remediation uses hydrostratigraphic analysis to gain a better understanding of the subsurface characteristics, hydraulic tests to optimize contaminant transport models, and Portable Treatment Units (PTUs) as an alternative to fixed facilities. Hydrostratigraphic analysis is an optimization tool that improves our ability to identify and target contaminant migration pathways, identify the relationship between plumes and source areas, and better define hydraulic capture areas. Hydraulic tests, performed with PTUs, provide valuable data about subsurface characteristics. As clean up progresses, PTUs can be moved to the appropriate extraction wells to optimize contaminant mass removal. PTUs can also be placed to support innovative treatment technologies such as steam injection and microbial filters. Construction of PTUs will reduce by one-half the capital costs of building the rest of the fixed treatment system planned in the Record of Decision. Regulatory agencies are receptive to the use of the PTUs because the same treatment technology is being used and the PTUs will be able to clean up the plume cheaper and faster. Using adaptive remediation, LLNL is more effectively implementing remediation plans, improving cleanup time, and reducing project costs.

SITE DESCRIPTION

Lawrence Livermore National Laboratory (LLNL) is a research and development facility owned by the U.S. Department of Energy and operated by the University of California. LLNL is located about 40 miles east of San Francisco. The ground water near the Livermore site is used for drinking water and agriculture. In 1982, multiple plumes of volatile organic compounds (VOCs), predominantly trichloroethylene (TCE), were discovered in ground water beneath the Livermore site (see Figure 1). LLNL was placed on the U.S. Environmental Protection Agency's National Priority List in 1987. LLNL investigations have identified the location and nature of the source areas, and they have been identified as sites where solvents and other chemicals were known to be disposed of, where spillage from outdoor facilities occurred, and where releases from underground storage facilities and pipelines occurred. VOCs are the primary compounds that have been identified to exist in ground water at concentrations above the drinking water standards. Locally, fuel hydrocarbons, chromium, and tritium have also been found. The remediation area covers about 1.5 square miles, and the contaminants are distributed within a thick, complex sequence of alluvial sediments.

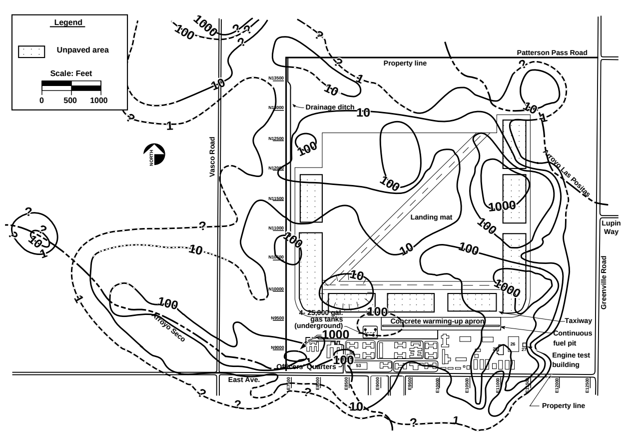

Figure 1. Two-dimensional VOC contour map showing extent of LLNL plume before ground water remediation.

EXISTING RECORD OF DECISION (ROD) REMEDIATION PLAN

The remedial alternative selected by the Department of Energy, LLNL, the stakeholders, regulatory agencies, and the public, as stated in the 1992 ROD[1], is pump and treat (Refer to Figure 2). The pump and treat plan will prevent further migration and achieve the most rapid cleanup. In this plan, ground water is extracted throughout the contaminated area, and treated at the surface using UV/oxidation or air stripping. To prevent any measurable air emissions, granular activated carbon (GAC) adsorption is used on the air stripping vapor effluent. Chromium in the ground water is treated by ion exchange. The cleanup is being phased in, with 24 extraction locations, eight ground water treatment facilities, and one vapor treatment facility. The original estimate of time to reduce contaminant concentrations to Maximum Contaminant Levels (MCLs) was 50 years.

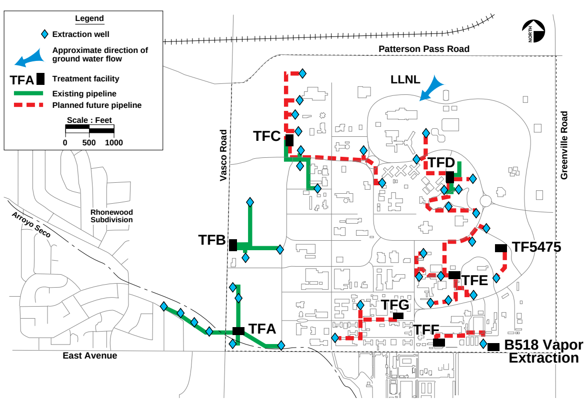

Figure 2. Record of Decision remediation plan, showing 1 vapor and 8 ground water treatment facilities, with 24 extraction locations.

There are 6 ground water treatment facilities and 1 vapor treatment facility currently in operation, treating water from a total of 22 extraction wells. As of December, 1995, 230 million gallons of water had been pumped, removing 109 kilograms of VOCs.

LLNL is actively working to reduce costs and cleanup time. We are building on the changing regulatory climate and good stakeholder working relationships to achieve earlier site closure. Regulatory agencies are working with us to reduce paperwork and reporting, which will enable us to devote more resources to the actual cleanup. We are working with the State of California's new containment zone policy, which may allow earlier closure of some sites through risk-based cleanup standards.

LLNL is implementing Adaptive Remediation as part of LLNL's Smart Pump and Treat strategy to increase the remediation plan effectiveness (see Figure 3). The Smart Pump and Treat strategy is based upon continuous measurement and improved characterization, modifications to the physical facilities as needed, and adaptive operations.[2] We expect Adaptive Remediation to reduce cleanup time and overall project costs. Important components of Adaptive Remediation are hydrostratigraphic analysis and portable treatment units (PTUs).

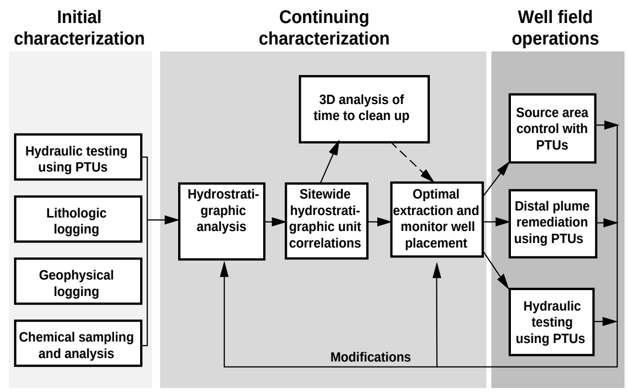

Figure 3. Diagram of the major components of Adaptive Remediation using portable treatment units. Implementing Adaptive Remediation will reduce overall project costs and shorten cleanup time.

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1 *Record of Decision for the Lawrence Livermore National Laboratory Livermore Site, LLNL, Livermore, CA*, UCRL-AR-109105 (1995).

2 Hoffman, F. *Ground Water Remediation Using Smart Pump and Treat*, Ground Water, *Vol. 31 (1), p. 98–106.*

HYDROSTRATIGRAPHIC ANALYSIS AND THE PORTABLE TREATMENT UNIT

The Livermore Site ROD describes fixed treatment facilities, with pipelines to the extraction wells. Strict implementation of the ROD plan assumes perfect knowledge of the subsurface, and does not allow for changes in the plume. A thorough understanding of the subsurface, including hydrogeologic factors controlling the flow and transport of contaminants, is required to achieve cost-effective ground water cleanup. LLNL is increasing its knowledge of the subsurface by using hydrostratigraphic analysis, based on the chemical, geological, and aquifer test data, to divide the subsurface into hydrostratigraphic units (HSUs). HSUs are defined as sedimentary sequences whose permeable layers show evidence of hydraulic communication.

Hydrostratigraphic analysis is used to determine the initial location and configuration of extraction wells. Hydraulic tests and initial remediation at these extraction wells further define the overall hydrostratigraphy of the site. As more information is gathered, or the plume changes with remediation, the optimum extraction locations change. A fixed system would incur further costs for reconfiguration, such as adding pipelines to new extraction locations. Using PTUs instead, the treatment facility can simply be transported to a new extraction location.

HSUs have been a useful management tool for optimizing site-wide remediation by improving our ability to identify and target contaminant migration pathways, delineate individual plume geometries, identify the relationship between plumes and source areas, and better define hydraulic capture areas.[3] We expect to augment the HSU analysis by additional hydraulic testing, which will show hydraulic interconnection between or within permeable layers, measured directly from response to ground water pumping. The data from the hydraulic tests will also be used to refine the transport models used in the 3D analysis of the time to clean up the site. The additional hydraulic tests will be done using PTUs, which provide on-line treatment of the ground water, allowing long term hydraulic tests.

An example of using HSUs as a management tool for optimizing remediations is at the southwest corner of LLNL at TFA. Here, phased installation of extraction wells allows their performance to be analyzed, so later extraction wells can be more optimally targeted. This plume has migrated offsite toward the city of Livermore. LLNL has stopped the down gradient migration and decreased VOC concentration of this off-site plume (Figure 4). (The “picket fence” of extraction wells along the western edge, completed in February 1996, will prevent the migration of the remaining on-site plume to the city of Livermore.) Capture analysis is being used to determine if and where additional extraction wells are needed along the western border.

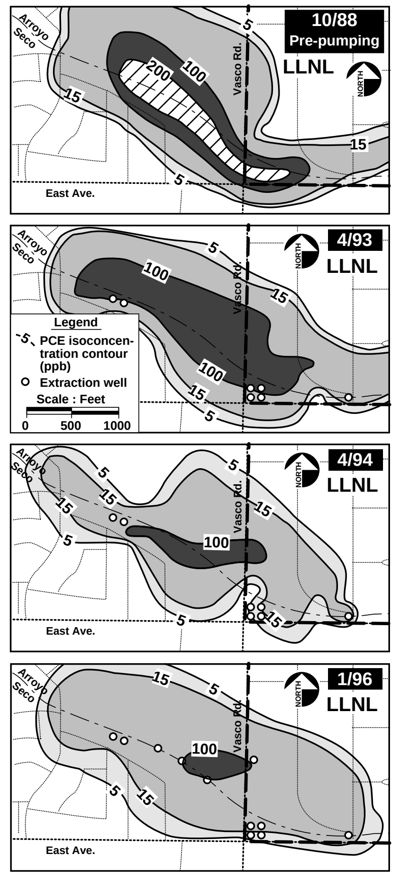

Figure 4. TFA plume time series showing progress of cleanup within hydrostratigraphic unit 2. This remediation is being optimized by the use of hydrostratigraphic analysis.

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[3] R.G. Blake, M.P. Maley, and C.M. Noyes, *Hydrostratigraphic Analysis: The Key to Cost-Effective Ground Water Cleanup at Lawrence Livermore National Laboratory, LLNL, Livermore, CA*, UCRL-JC-120614 (1995).

A second example of using HSUs to optimize remediation is in the interior of the site, where the highest concentrations are found. A hydrostratigraphic conceptual model of the VOC plume has been used to refine the remediation design to capture and prevent further migration in the TFE area. Hydraulic testing with PTUs will provide data to further refine the conceptual model. The improved hydrostratigraphic model will be used to optimize the targeting of extraction locations in this area of high concentrations. We expect to minimize the number of extraction and monitor wells necessary for performing and monitoring cleanup, resulting in a shorter cleanup time at reduced cost. In addition, the use of PTUs instead of a fixed facility with pipelines will save an estimated $4.2 million, or 75% of the construction costs. (Refer to Figures 5 and 6.)

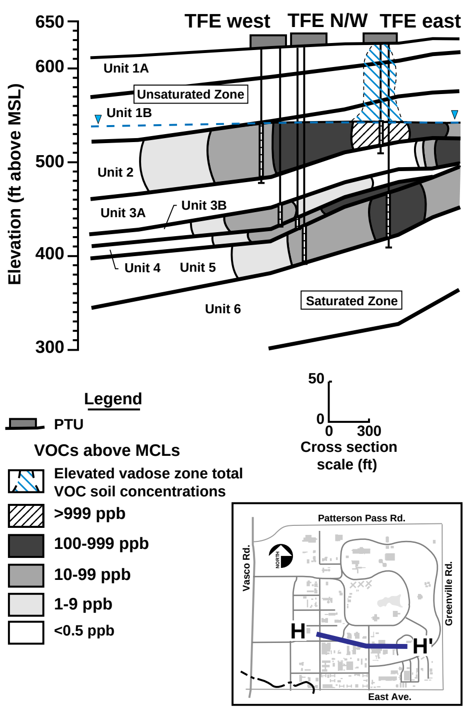

Figure 5. Cross section showing HSUs in the TFE area of LLNL. PTUs will be used to remediate this location instead of a fixed treatment facility.

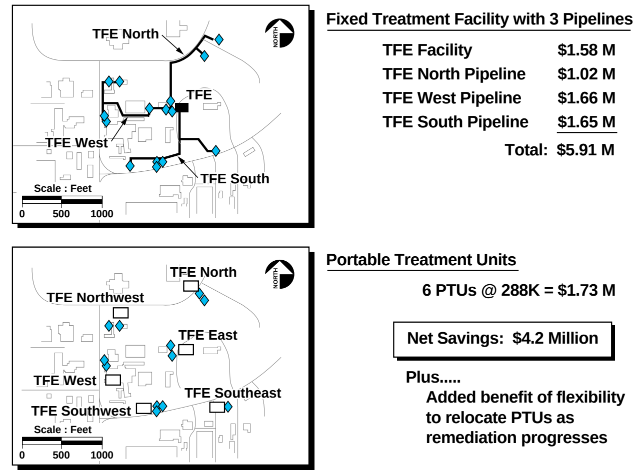

Figure 6. Figure showing the net savings in construction costs to be realized using PTUs instead of a fixed facility at TFE. The net savings of $4.2 million is 75% of the construction cost.

With a better understanding of the subsurface, made possible by hydrostratigraphic analysis and portable treatment units, we will more effectively implement remediation plans, improve cleanup time, and reduce overall project cost. An illustration of the Adaptive Remediation plan using PTUs is shown in Figure 7.

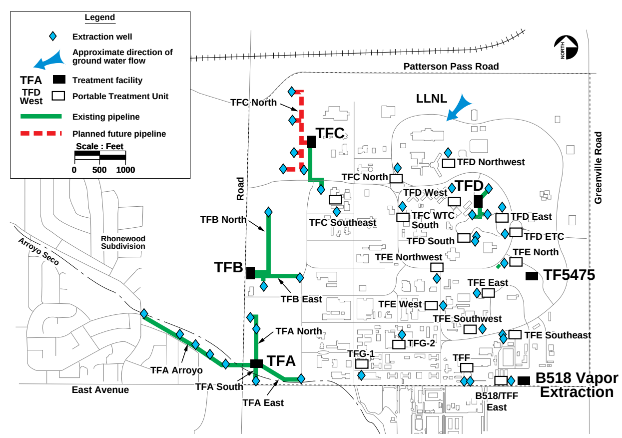

Figure 7. Adaptive Remediation using PTUs will result in half the construction costs of the ROD plan, for a total savings of $9 million.

PORTABLE TREATMENT UNIT

The PTU is a portable, relatively inexpensive treatment facility that will be used for hydraulic tests and contaminant mass removal throughout LLNL's Livermore Site. An entire PTU is contained within a 20 ft long by 8 ft wide by 8 ft high cargo container. The facility can be run off utility power, or be powered by a 60 KVA diesel generator. (See Figures 8 and 9.) The primary treatment components of the system are a particulate filter, air stripper, and a GAC canister. Ion exchange resin is added if needed. The PTUs range of 1 to 45 gpm is based on the hydraulic capacity of the air stripper. The operational flow rate is dependent on the concentration of VOCs in the ground water being treated. Based on field tests using LLNL ground water, for an influent TCE concentration of 2000 ppb, the PTU will be able to treat ground water up to 20 gpm, with the effluent water containing less than the detection limit of 0.5 ppb of VOCs. At a flow rate of 45 gpm, the maximum influent concentration that can be treated to non-detect is approximately 100 ppb.

Figure 8. PTUs are portable treatment facilities that will be used for hydraulic tests and contaminant mass removal at LLNL.

Figure 9. The PTU is constructed in an intermodal cargo container of dimensions 20' long, 8' wide, and 8' high.

Up to three wells can be connected to the PTU influent. The influent ground water travels through electromagnetic flow meters, where the flow rate is monitored and recorded by the Facility Control System (FCS). An injection point is provided for polyphosphate to control calcium carbonate scaling. The water travels through a particulate filter, where particulate and sediments are removed. The filter elements are rated to a nominal 5 microns, and are contained in a stainless steel housing. The filtered water travels through a stainless steel air stripper of low-profile, stacked-tray design. Water enters from the top and is aerated while it flows down through a series of trays. The treated water collects in a sump at the base, and is pumped out in batch mode by the stripper discharge pump. The air stripper is commercially available, and is supplied with its own blower and sump pump. The VOCs in the air stream are adsorbed into a vapor-phase GAC canister. If chromium treatment is necessary, the water is diverted, after the air stripper, through two ion exchange columns plumbed in series. The ion exchange resin in the columns will be regenerated at an existing fixed ground water treatment facility. The water flows through a pH monitor and is discharged to the ground at a location that will not interfere with the extraction well capture zone.

Incorporated into the FCS are object oriented modeling and design methods, rigorous validation and verification procedures, human factors engineering, and application of standard instrumentation and software. The system adheres to strict fail-safe design standards, is user friendly, and can operate unattended. The FCS can be adapted to future changes in the process, such as those due to well field management and remediation experiments. It is designed to provide extensive data and status reports and to maximize the efficiency of maintenance support over the facility lifetime. Implementation and testing efforts for installing the FCS were reduced by at least a factor of two because knowledge gained from previous system design was used instead of starting from scratch. These savings were realized because of the high degree of modularity that has been built into the control system design. Cost savings in future PTU deployments will be even greater, as the identical software can now be used in each of them.

As stated previously, PTUs will be used to conduct the hydraulic tests that may take from days to months for each test. For this hydraulic testing, a portable generator will be used to power the PTU. When a well is chosen for long term remediation, the PTU will be connected to utility power. As the clean up progresses, the PTUs can be moved to the appropriate extraction wells. PTUs can also be placed to support innovative treatment technologies such as steam injection and biotic or abiotic filters.

The cost of equipment for the PTU is approximately $138K. The estimated cost for complete construction (and activation) is approximately $288K. PTU construction will reduce by one-half the capital costs of building the remaining conventional treatment and pipeline systems planned in the ROD. The PTUs will augment Adaptive Remediation and help to bring the site cleanup to completion in the shortest time possible.

ACKNOWLEDGMENTS

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