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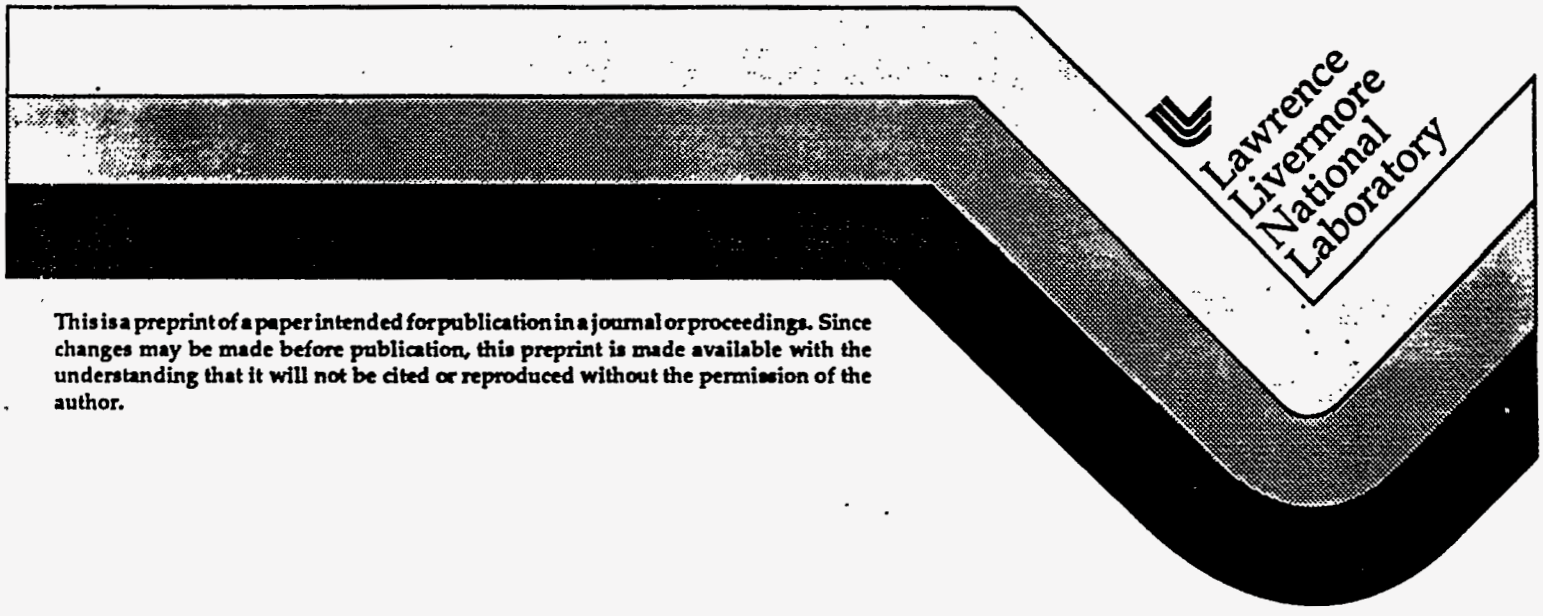

# Building 834–Cost-Effective and Innovative Design of Remediation Systems Using Surplus Equipment from Former Weapons Programs

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The Building 834 Complex at the Lawrence Livermore National Laboratory (LLNL) Site 300, has been used by the weapons development programs at LLNL as a testing facility for measuring component response to environmental stresses such as extreme temperature. The heat-exchange system at the facility used trichloroethene (trichloroethylene, TCE), at times with adjuvants, as the primary heat-transfer media for over 20 years. Accidental spills, pipe failures, and seal blowouts over that period contributed to a substantial contaminant plume in a perched water-bearing zone underlying the Complex. Individual wells near the source area have produced ground water samples with TCE concentrations exceeding 800,000 ppb, indicating the likelihood of dense, non-aqueous-phase liquid (DNAPL). The total volume of the plume is approximately 16 acre feet.

In the last several years, we have developed a modular ground water and soil vapor extraction system for remediating the plume source area. The modular facility design permits the testing of new technologies to expedite remediation, and/or reduce the quantity of hazardous wastes generated as byproducts of the primary remedial activities. To contain costs, we have used equipment and components recycled from the original Building 834 Complex heat-exchange system, and surplus equipment from other LLNL divisions.

We have executed two large-scale tests of energy injection systems for TCE destruction in air (a free-air electron beam and a pulsed, ultraviolet photolysis system), and a soil heating test for accelerating vapor extraction. Operating characteristics of the present extraction and monitoring system reflect lessons learned during those past efforts. New work plans for this unique site are being prepared, incorporating the lessons learned in developing new technology with recycled equipment.

## Introduction: Site History and Remedial Characterization

LLNL Site 300 is a Department of Energy (DOE) test facility operated by the University of California. Site 300 is located in the rugged Altamont Hills, 50 miles east of San Francisco (10 miles east of Livermore), and is primarily a high explosives test facility that supports the LLNL Weapons Program in research, development, and testing associated with weapon components. This work includes explosives processing; preparation of new explosives; and pressing, machining, and assembly of explosives components. Site 300 activities also include hydrodynamic testing for experimental verification of computer codes, obtaining equation-of-state data for weapons materials, evaluating material behavior at assembly joints and welds, evaluating the quality and uniformity of implosion, and evaluating the performance of post-weapons-test design modifications (LLNL, 1991).

Prior to August 1990, investigations of potential chemical contamination at Site 300 were conducted under the oversight of the California Regional Water Quality Control Board (RWQCB)–Central Valley Region. In August 1990, Site 300 was placed on the National Priorities List

(NPL). Since then, all investigations have been conducted in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) under the oversight of the three supervising agencies: the EPA, the RWQCB, and the California Department of Toxic Substances Control (DTSC).

The Building 834 Complex is a testing facility where weapons components are subjected to physical stresses, including extreme temperature. For more than 20 years, trichloroethylene (TCE) was used as a heat-exchange medium for heating or cooling test cells or chambers. TCE was heated or chilled in buildings adjacent to a central control building, and pumped in insulated pipes over earthen safety berms that isolated workers in the control area from the test cells. Because TCE is an extremely effective solvent, it aggressively dried seals and other components in the temperature control system, producing leaks and spills. To retard this action, an adjuvant synthetic oil, tetrakis (2-ethylbutoxy) silane (also known as tetra t-butyl orthosilicate, TBOS) was added to the TCE for several years of this operation. Both materials have significantly contaminated the soil and ground water at this Complex, and have produced a perched ground water plume that covers several acres (Fig. 1). TCE degradation products are also present (e.g., c-1,2-DCE or cis-1,2 dichloroethylene).

The water-bearing zone at the Building 834 Complex is relatively thin (<10 feet) and of low permeability. The depth to water varies from as little as 20 feet to more than 70 feet; shallower depths prevail at the core area of the Complex where the remediation facility is located. The extensive hydrogeologic characterization of the Complex is presented in Bryn (1994). At the core of the Complex, TCE, PCE, and c-1,2-DCE are present with varying ratios in several monitor wells. Recently, concentrations of TCE have been as high as 800,000 ppb in wells adjacent to the primary release site (a TCE chilling station, Building 834D), although the VOC concentrations vary strongly throughout the year. The varied, high concentrations are probably a consequence of infiltrating rain water coming in contact with DNAPL beneath Building 834D. In at least three wells in the core area, a floating layer is present that is primarily (>90%) TBOS, with TCE (0.1–1%) and other volatile organic compounds (VOCs).

Initial ground water treatment experiments at the Building 834 Complex began in 1988, when three monitor wells in the core area were used as simultaneous soil vapor and ground water extraction wells. Several problems were encountered during this series of experiments. The vacuum pump selected was a liquid-ring design that produced a combination of high vacuum but relatively low volumetric flow rate (~50–80 scfm @ 27 inches Hg). This process forced simultaneous pumping of ground water and soil vapor. Without such water extraction, the liquid-ring pump could lift shallow ground water into the vacuum extraction manifold.

Water was treated by sparging in 500-gallon polyethylene tanks. This volume could be filled in about 72 hours by pumping continuously from three wells, demonstrating the low yield of the formation. Initially, a sparging period of 48–72 hours was sufficient to reduce TCE levels to below detection levels (0.5 ppb by EPA 601 analysis). However, as the experiment proceeded over a few weeks, the sparging period had to be lengthened to achieve the same cleanup level. By the end of an initial 6-week run, the sparging time was in excess of 300 hours. Simple experiments quickly demonstrated that TCE was permeating into the plastic components of the system, and leaching back into the water when diffusion gradients became favorable. Also, the submersible turbine pumps spun the floating TBOS into a persistent emulsion that adsorbed in a

thick layer on many polymeric components of the system, forming an additional sink for VOCs during water treatment.

## Technology Demonstrations: Gas-Phase VOC Destruction

Soil vapor and sparge-gas flow rates and VOC yields were used to calculate carbon scrubbing requirements (S. M. Bryn and P. F. Daley, unpublished data). These data indicated that sole reliance on activated carbon could potentially be very costly, ranging up to hundreds of thousands of dollars per year of operation. In pursuit of alternatives to carbon adsorption, we performed two large-scale experiments at the Building 834 Complex to evaluate the potential for using electron beams (Matthews et al., 1993) and pulsed ultraviolet flashlamps (Blystone et al., 1991) for in-line destruction of VOCs. Both of these field trials were preceded by favorable laboratory experiments.

Both of these technologies were most successful in destroying the parent VOCs. Gas-phase concentrations as high as 10,000 ppm (in spiking experiments) were reduced by several orders of magnitude, and frequently to below detection levels. However, during the pulsed UV experiment, products of partial VOC oxidation severely mitigated the result. We found that the carbon-chlorine bonds of the VOCs were quite resistant to breakage by application of either energy source. Instead, the carbon atoms of the VOCs were oxidized, first producing (e.g., during TCE oxidation) dichloroacetyl chloride and then phosgene ($COCl_2$ or dichlorocarbonyl; Blystone et al., 1991). Owing to the greatly increased hazard of these products, we abandoned this approach to gas stream treatment. However, we realized the potential of the Building 834 remediation site as an ideal test facility for new remediation technologies, and began to redesign an integrated, modular soil vapor and ground water treatment facility with that in mind.

## Ground Water Treatment Innovations: Remediation Engineering in the Salvage Yard

We began to re-engineer the treatment facility with the following goals. 1) Create a base infrastructure of high-flow, low-vacuum soil vapor extraction, and low-turbulence ground water extraction wells. Installation of connecting piping would be underground where practical to facilitate safety and longevity of materials. 2) Use connectors, fittings and other components where practical that would facilitate installation of equipment for testing in a modular fashion. 3) Plan for initial manual operation of the water treatment equipment to evaluate components and performance, with eventual upgrading to support automated operation of both ground water and soil vapor extraction (SVE) subsystems as an integrated facility. 4) Develop a multipoint vapor analysis system to reduce long-term monitoring costs. 5) Develop analytical methods for TBOS in water, and include removal of this material as a treatment objective. 6) Reduce cost wherever practical by using equipment salvaged from the Building 834 facility, as well as other LLNL programs, through their various salvage operations.

The first test of the ground water treatment system was conducted in May 1994 (Proof-of-System Test 1, POS1). We had added a coalescing oil separation stage, spraying of contaminated ground water into the polyethylene sparging tanks to promote early volatilization of VOCs, and increased sparge-air injection rates. For this test, the TBOS removal requirement had not been imposed, so analysis of the system focused on VOC removal rates. Even with large increases in the sparging vigor, removal of VOCs to below analytical laboratory detection limits required more than 70 hours.

Following this test, we began aggressively pursuing replacement tanks, vessels, and piping, with the intent of eliminating plastic components as much as possible from the system. We acquired several stainless steel vessels, pumps, valves, and other equipment at no cost from the LLNL salvage system. Manual testing of this second-phase system was conducted in February 1995 (POS2); its schematic is shown in Figure 2. The stages of the treatment process indicated in the figure are: 1) ground water extraction from six to nine wells equipped with air-displacement pumps; 2) oil separation in a coalescing skimmer; 3) particulate removal (to 20μ); 4) sparger 1, a stainless steel high-vacuum vessel acquired from the Laboratory Laser Physics Program, incorporating a 35-gpm recirculating pump and 42 misting nozzles for air injection; 5) sparger 2, a sparging-only tank acquired as excess from our main-site remediation program; 6) TBOS and residual VOC removal (primarily 1,1,2-$Cl_3$-1,2,2-$F_3$-ethane or Freon 113) with woven carbon-impregnated filters; 7) pumping to short-term storage in two 500-gallon stainless steel tanks at the treatment pads.

Treatment at this site is now complete; however, discharge of the cleaned water is problematic. No sewer is present at the Complex, and local discharge to the soil surface may infiltrate back into the contaminated perched water bearing zone and/or cause significant surface erosion problems. To address these conditions, we developed a misting tower network approximately 100 yards away from the facility, that uses misting nozzles to eject a fine fog of water at a height of 25 feet. For this system, water is pumped to two storage tanks (item 9 in Fig. 2) where it is pumped through filters and then emitted through the misting towers (item 10). In freezing conditions, treated water in the transfer pipeline drains into a blowdown tank (item 8). The system is operated in a batch fashion, with the volume of each batch dictated by the working volume of sparger 1 (about 175 gallons).

The speed of VOC removal by the POS2 system was dramatically greater than in POS1 (Fig. 3). However, the second sparging stage apparently introduced Freon 113 that was either not detected, or only detected in sparger 1 at low ppb levels. Although this compound is efficiently removed by the woven carbon filters installed for TBOS removal, we are at present attempting to isolate its source, which appears to be associated with the treatment equipment. It is ironic to note that although much of the treatment system was assembled from components scavenged from a wide variety of LLNL operations, the only item that has apparently introduced contaminants into the treatment stream is one originally designed for water treatment. During the entire POS2 test, water emerging from the carbon filters was below detection levels for all organics.

Since completion of POS2, the system has been modified further to support automation. Stainless steel, pneumatic valves originally used in the Building 834 Complex TCE circulation system have replaced manual valves, and additional pressure transducers and switches have been installed to monitor water depths and pressure drops in various parts of the system. We estimate that the construction cost for the complete system has been reduced by over $200,000 through the use of recycled components.

A programmable logic controller (PLC) will be the primary automation control for the system. It will monitor water levels in tanks; operate pumps, blowers, and valves; and perform all interlock tests (Fig. 4). We selected a PLC over a dedicated microcomputer for reliability and resistance to system crashes or lockup conditions. A man-machine interface (MMI) for display of system status will be provided via serial communication between the PLC and a desktop computer. This computer will also perform analog data acquisition tasks and coordinate reporting to departmental

databases via custom software developed in the LabVIEW programming environment. A second LabVIEW station is dedicated to monitoring VOC concentrations in the system, using an expanded multipoint vapor sampling device patterned after that described by Daley (1992). Under computer control, the sampler can select from any of 15 points in the apparatus, direct the gas stream to a gas chromatograph equipped with a gas-sampling valve, and log the analysis to disk or remote database. Water in sampling streams can cause extreme condensation problems, and may even damage chromatographic equipment (Buettner and Daily, in press); here it is removed at the sampling point, using countercurrent, coaxial Nafion® gas line dehumidifiers. The system will also perform automated calibrations using up to eight standard gas mixtures. Any condition that could trigger maintenance operations (e.g., excessive pressure drop across a particulate filter) or alarm states (VOC breakthrough in an air-scrubbing stage) produces displays on the MMI, or sends radio pages to key operators through facilities provided by LLNL ethernet support operations. At this writing, all hardware has been installed and software integration and testing are underway.

## Conclusions

Through adherence to the concept of modular design and concerted use of recycled hardware, the Building 834 ground water treatment facility has become an economical and flexible testbed that can 1) support routine conventional pump-and-treat cleanup of a highly contaminated site, 2) provide a successful performance background against which new treatment technologies can be compared, and 3) be easily modified to incorporate new extraction and treatment technologies for field testing. While significant labor has been expended in acquiring recycled components, the effort has allowed us to build a more advanced facility that has greater potential throughput than would have been possible otherwise. We offer this test site to workers developing new methods for VOC cleanup.

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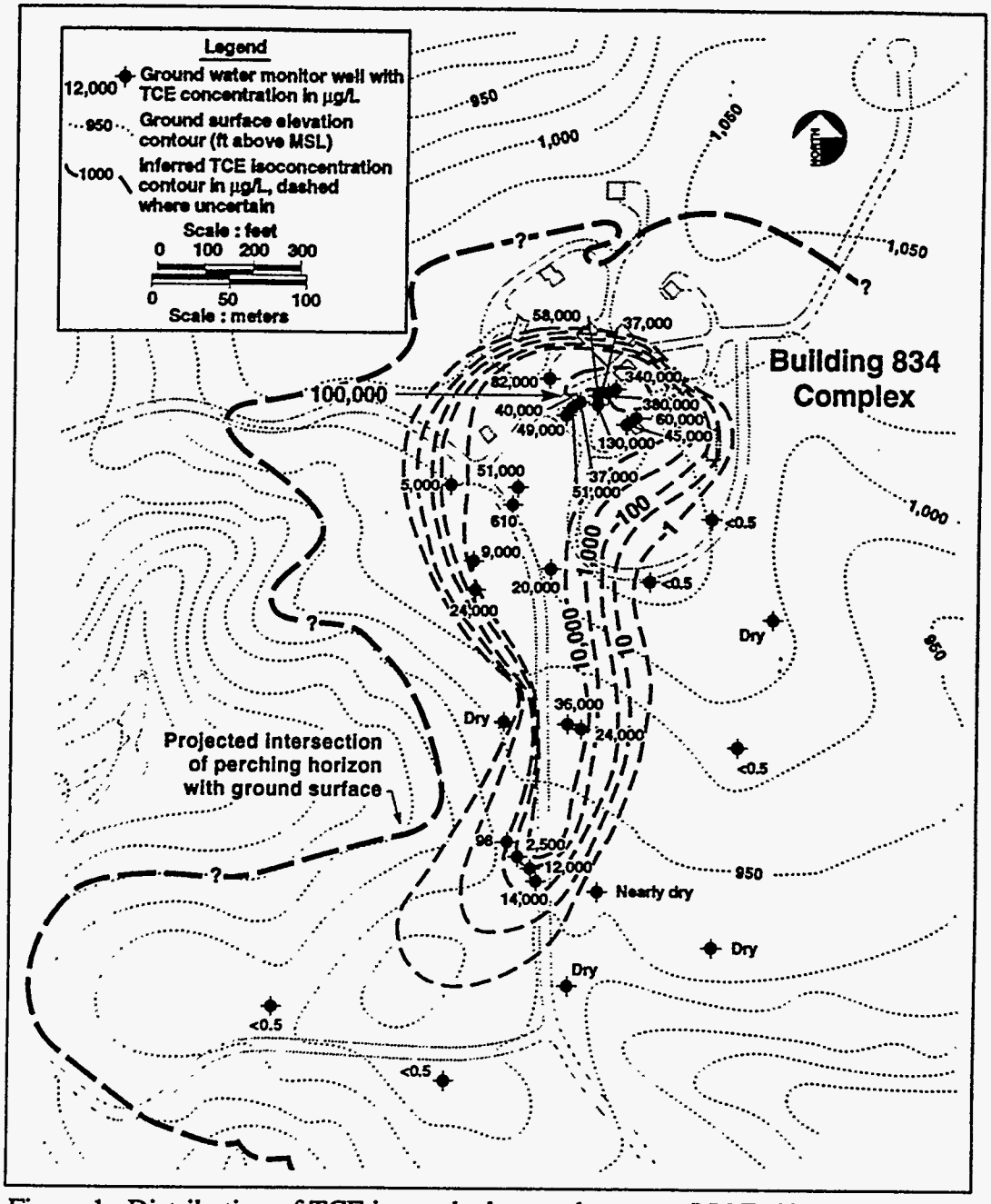


Figure 1. Distribution of TCE in perched ground water at LLNL Site 300 Building 834 Complex. Data from 1991 water sampling, for comparison; concentrations fluctuate strongly on a seasonal basis.

Figure 2. Building 834 ground water treatment facility, at the end of Proof-of-System Test 2 (POS 2), March 1995. Steps in the water treatment process are indicated numerically and described in the text. Soil vapor extraction (SVE) and sparge-gas handling lines are indicated by large-diameter piping; most vapor sampling lines are omitted for clarity.

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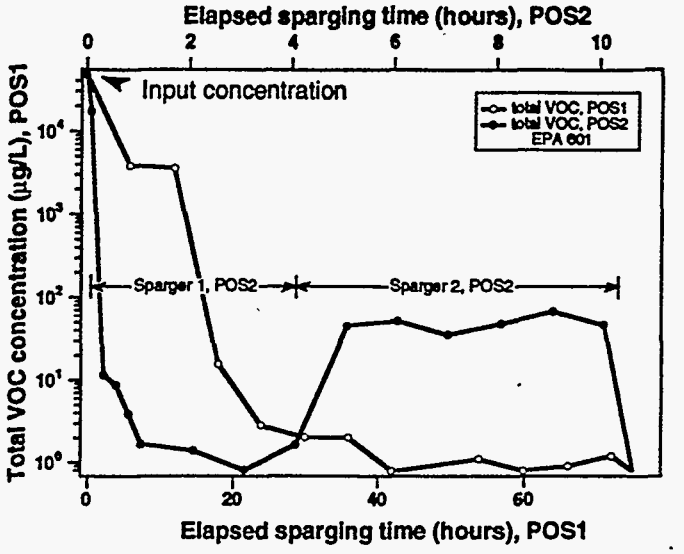


Figure 3. Comparison of total VOC removal from ground water during Proof-of-system 1 and 2 (POS1, POS2) testing. Note the use of different time scales for each test.

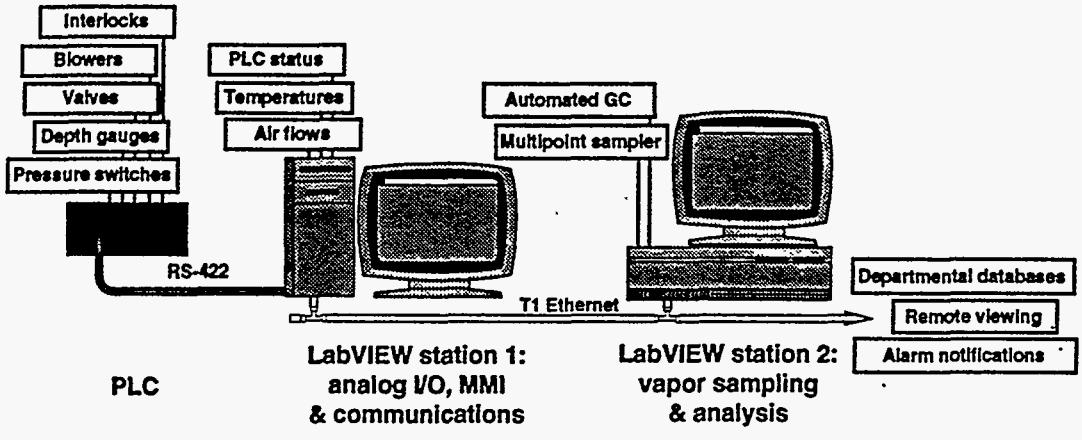


Figure 4. Schematic of control and data acquisition hardware selected for operation of the Building 834 ground water and SVE treatment system.

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