# Environmental Restoration, Protection, and Waste Management

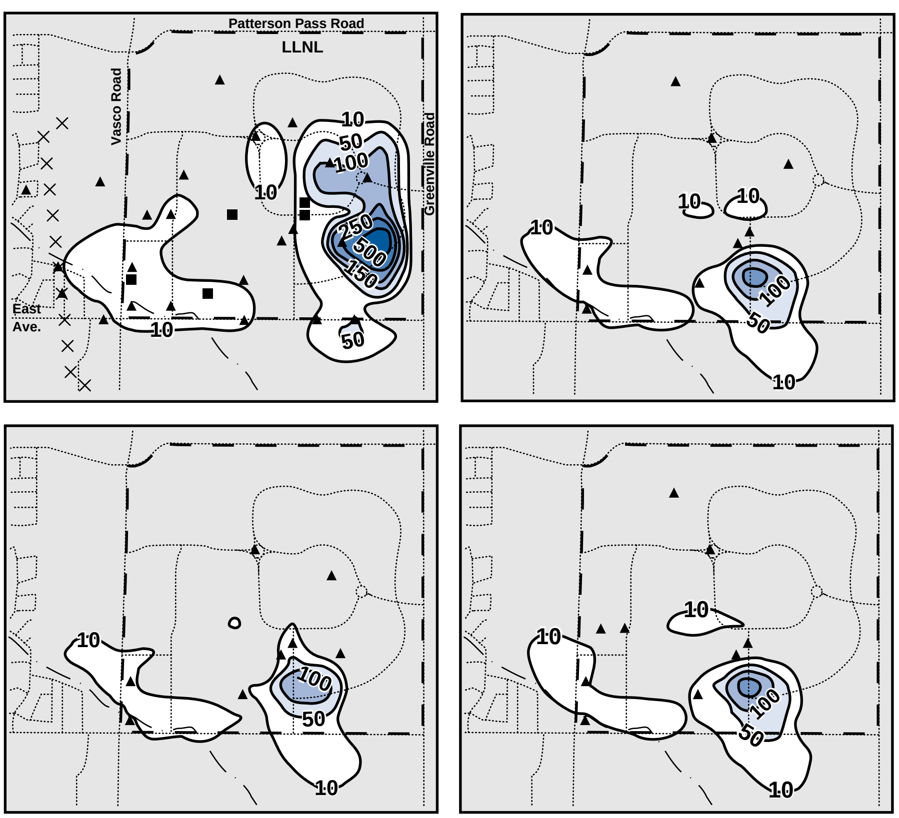
*We are cleaning up contamination from past activities and developing strategies to ensure that current and future activities do not adversely affect the environment.*

Many environmental concerns now facing LLNL are unforeseen and unintended consequences of activities that span more than 50 years—from its use as a Naval Air Station during World War II through its 40-plus years as the site of intensive research and development activities.

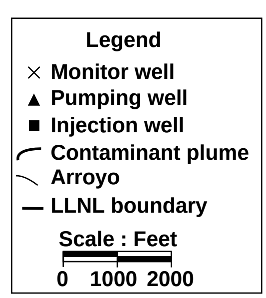
At LLNL, we are concerned about the impacts of environmentally harmful activities and are committed to complying with local, state, and federal environmental regulations. This commitment is expressed by our activities in environmental restoration, health and safety, hazardous waste management, air and water quality, and general environmental issues.

Specifically, we are

- Designing and applying cost-effective technologies for site restoration and remediation.
- Developing practices for monitoring, preventing, reducing, and cleaning up air emissions, wastewater discharges, and hazardous wastes and obtaining appropriate permits or exemptions.
- Conducting monitoring, risk assessment, and chemical analyses to meet regulatory requirements.
- Developing and implementing strategies to minimize waste and prevent pollution.
- Designing and implementing cost-effective ways to manage hazardous and nonhazardous waste streams.
- Implementing ways to mitigate potential impacts to natural and cultural resources.








*Computer simulations using artificial neural networks (ANNs) help identify optimal groundwater cleanup strategies.*

## Restoration and Remediation

Environmental restoration activities are aimed at restoring contaminated groundwater and soil to appropriate health and environmental levels. To accomplish this, we investigate hydrology, geology, soil properties, hydrogeology, contaminant fate, and transport mechanisms at both Livermore and Site 300. We also install piezometers; drill monitoring and extraction wells; analyze soil and groundwater; test aquifers; develop and apply computer and conceptual site models; assess health risks from contaminants in air, soil, and groundwater; and test and implement technologies for environmentally responsible cleanup.

Through predictive modeling, we evaluate the fate, transport, and potential health risks of contaminants in groundwater and soil; select extraction and injection well locations; and optimize hydraulic control and contaminant removal in remediation designs. Modeling helps cut cleanup time, thus reducing groundwater remediation costs.

### Smart Pump and Treat

Conventional flow-and-transport models are generally quite slow to predict the effectiveness of some groundwater remediation pumping strategies. Thus, we have been using a "smart" pump-and-treat approach, that is, employing artificial neural networks (ANNs) trained to predict time, effectiveness, and cost data, then harnessed to search for strategies that balance timely and effective cleanup with minimum cost.

In one training simulation, we analyzed 28 LLNL locations (areas thought to contain groundwater contamination and required to be cleaned up within 50 years) to identify the lowest-cost subset that was as effective as the full 28-location set. Analyses showed that treating 8 to 13 locations could meet our containment and removal goals and cost less than 35% of treating all 28 locations.

In the current simulation, we are using a grid of 225 pumping sites to evaluate strategies involving 50 extraction and 10 injection pumps. The use of ANNs is crucial to find low-cost alternatives to reduce the time and maximize the extent of cleanup in five-year management periods.

### Vadose Zone Modeling

We are using the one-dimensional VLEACH model to simulate trichlorethylene (TCE) migration through partially saturated, fractured sandstone and claystone to the regional drinking-water aquifer below part of Site 300.

We assign infiltrating rainwater a TCE concentration of 1600 ppb—the area's maximum in shallow groundwater samples—based on Site 300's arid climate and the water content (less than 17%) of the bedrock strata. We assume that TCE partitions into infiltrating rainwater and that 10% of the average (25 cm) annual precipitation infiltrates and migrates downward. We further assume vertical vapor diffusion transports the TCE through the fractures and use VLEACH to estimate transport through unfractured media. Then we use VLEACH to calculate the critical length (about 75 m) of a vertical fracture, or series of interconnected fractures, that would cause concentrations to exceed EPA's maximum 5-ppb contaminant level for drinking water.

Modeling shows fractures across 85% of the vadose zone (subsurface soil or rock lying above the groundwater) do not cause aquifer contamination. This suggests that extensive fracturing in a vadose system with lower water

## Highlights for 1994

- Used automated neural networks to aid in selecting fast, low-cost, groundwater cleanup strategies.
- Used vadose-zone modeling to estimate the impact of contaminant transport through fractured media at Site 300.
- Developed a track-mounted camera system to traverse animal burrows and transfer findings to surface observers and videotape.
- Maintained a radionuclide-release detection network, and developed a system to assess exposures to and deposition of tritium releases.
- Developed a microwave digestion system to increase the efficiency of the preparation of hazardous waste samples for radiological analyses.
- Developed an air emissions measurement and information tracking system (EMITS) to calculate air emissions by source and regulatory program.
- Implemented an expandable, automatic, archiving remote reagent system for treating wastewater.
- Built a microfiltration unit to remove radioactive particles from liquid waste streams.
- Organized and set up a CHemical Exchange Warehouse (CHEW) for collecting, storing, and exchanging excess usable chemicals.
- Implemented a waste certification program at the AAICF Facility, Ann Arbor, Michigan, so the mixed and radioactive waste could be shipped.

*The truck-mounted miniature optic lair explorer (MOLE) is used to locate, identify, and protect endangered animals at Site 300.*

content may not increase contamination. In the future, application of models like VLEACH will help assess the potential for groundwater contamination with vadose-zone contamination.

The two-dimensional NUFT flow and transport code, recently developed at LLNL, is being used in carrying out DOE and LLNL commitments to clean up contaminated soils and groundwater at LLNL. Simulations using NUFT in conjunction with field data were recently carried out to help understand the multiphase flow and transport of volatile organic compounds (VOCs) in the sediments. The objective of this modeling work was to evaluate potential impacts to groundwater from VOCs in the vadose zone.

The NUFT code resolves more realistic conceptualizations of the actual heterogeneous subsurface with both advection and diffusion of gases and liquids, including rain and infiltration fluxes, which would not be fully resolved in our previous semi-analytic analyses and other numerical codes. In the future, three-dimensional modeling with NUFT will be used to evaluate cleanup system performance, extraction-well configurations, and cleanup-time estimates.

## Monitoring and Analysis

Eliminating or mitigating potential releases from current activities requires accurate measurement and monitoring techniques. LLNL has a network to detect significant effluent emissions. The 150,000 analyses made in 1994 demonstrate that the impacts of our activities are below regulatory limits. Evaluations of potential radionuclide emissions demonstrate compliance with standards and a decrease from past years.

Last year we worked with others to create a system to directly assess tritium releases and radiological exposures to people. The system, which combines real-time tritium monitoring and meteorological dispersion analyses, updates assessments of emissions from LLNL's Tritium Facility every 15 minutes. It also allows us to plan and control tritium releases and improve our reporting of impacts.

### Chemical and Isotopic Analysis Methods

The characterization of potentially contaminated environments is a powerful diagnostic when effluents have distinct isotopic compositions that are different from global background. We use mass spectroscopy (MS) to measure radionuclides because it is faster than traditional radiation counting methods and independent of radionuclide decay rate and mode.

Using inductively coupled, plasma-source spectroscopy (ICP–MS)—one MS method—we now can measure the amount and composition of uranium isotopes at trace levels in groundwater. Present methods of detection levels, expressed as minimum detectable activity, are better than $10^{-13}$ curies (Ci) per liter for $^{234}U$ and much better than $10^{-15}$ Ci per liter for $^{235}U$, $^{236}U$, and $^{238}U$. The technique is also more precise than conventional radiation counting for measuring minute amounts of anthropogenic uranium and more flexible and cost-effective than thermal ionization mass spectrometry.

Analyzing waste for possible radioactive contamination is expensive. We have implemented an automated microwave digestion system to reduce costs and increase analysis speed. The system can complete the digestion process in about an hour and uses less than 10% (0.1 liter/sample for oils) of the chemicals (i.e., nitric acid) required by the manual method, which required nearly two weeks to complete. In addition, automation also ensures reproducible chemical procedures and provides a safer work environment.

The system is operated by a personal computer. Commands are routed through a controller to a robotic arm manipulator, 6 reagent pumps, a

16-sample carousel, and a microwave oven. The system, which digests one sample at a time, allows different chemical procedures to be performed on each sample, provided the total number of reagents for all samples does not exceed six.

### Natural Resource Protection

The remote and relatively undeveloped Site 300 is a potential habitat for both common and protected animals. To locate, identify, and protect some of these burrowing animals, we developed a small subterranean, track-mounted vehicle known as a MOLE (Miniature Optic Lair Explorer). The MOLE maneuvers through the tunnels of ground squirrels, burrowing owls, badgers, and the like, carrying a camera with 360 degrees of rotation, high resolution, and infinite focus; it also has lights to illuminate underground dens. Camera images are transferred to the MOLE's surface monitor, which is also used to drive the MOLE. This allows us to study den structure, occupation, reproductive success, animal age, and species distribution. The images can also be recorded on videotape for future evaluation.

## Pollution Prevention and Waste Minimization

We are evaluating LLNL activities to find options that can reduce potential pollutants and waste. Successful options include using recyclable paint thinner in the Site 300 paint shop; using a nonhazardous cutting oil in defense-related programs; recycling metallic lead bricks, hammers, and shot; and using electronically generated graphics to eliminate photoprocessing waste.

When waste streams cannot be eliminated, we work with waste generators to minimize the amount of waste produced and retain those streams until they meet release requirements. We also developed a model "ideal" retention-tank system to facilitate tank design for new and upgraded wastewater retention-tank systems.

### Pollution Prevention

We are conducting pollution-prevention opportunity assessments (PPOAs) to help waste generators evaluate processes that generate pollution and identify prevention options. Staff engineers help process operators define material and energy flows for a given process and develop ways to reduce pollution at its source or to make the process more energy-efficient. They also evaluate the cost and technical feasibility of each option and prepare a final implementation report. Waste generators who invest in such options generally reduce operating and management costs. Options include using less hazardous raw materials, implementing a closed-loop system to eliminate discharge, and implementing controls for greater process efficiency. PPOAs are also consistent with DOE's commitment to quality and help us meet waste minimization measures in the contract between the DOE and UC.

### Nonhazardous Waste Minimization

We minimize nonhazardous waste through information networks, new-product testing, policy analysis, and promotional announcements. We also report on minimization planning and accomplishments such as the doubling of LLNL's voluntary paper-recycling program. Programs for recycling cardboard, ferrous and nonferrous metal, and wood are expanding, and we are now evaluating the recycling of colored paper, magazines, newspapers, and polystyrene.

### Tracking Air Emissions

We monitor Title III and Title V requirements under the 1990 Federal Clean Air Act Amendments. We also respond to the Precursor Organic Compound "No Net Increase" provisions of two local air districts and follow California's AB2588 reporting and risk assessment requirements. This means we must sort emissions, understand how each emission source contributes to each regulatory program, and manage facility emissions to ensure we do not cross critical thresholds. To simplify these tasks, we created an emission measurement and information tracking system (EMITS) that uses material safety data sheets, air-district emission factors, and updated throughputs to calculate emissions by source and regulatory program.

*Air-monitoring stations are part of LLNL's environmental surveillance network.*

*Our ideal tank-system model facilitated the design of this upgraded retention-tank system.*

Industry is interested in adopting EMITS for its own facilities, and cooperative agreements are in progress.

## Hazardous Waste Management

We work to ensure that hazardous wastes have a negligible effect on the environment. This includes investigating cost-effective methods for waste handling, stabilization, treatment, and disposal and designing and acquiring innovative facilities. Four Livermore facilities treat and store hazardous, low-level radioactive, transuranic radioactive, and mixed wastes. LLNL does not produce high-level radioactive wastes.

### Remote Reagent System

We implemented a remote reagent handling system to treat LLNL wastewater. This system interfaces to instruments that provide continuous-level readouts of the tank volume, content pH and temperature, and valve position. It is designed for easy expansion, automatic control sequencing, and archiving and uses a programmable logic controller, CRT displays, and backlight alarm annunciator panels. It also improves efficiency and operator and environmental safety. From the control and monitoring stations, operators can view the treatment facility, identify and respond to alarms, and control and monitor the treatment process. New process interlocks prevent unsafe operation.

### Microfiltration Treatment System

We constructed a microfiltration unit to determine whether all DOE-added radioactive particulates could be removed from liquid waste. The unit has a 100-gallon tank with two turbine mixers, a diaphragm metering pump, a temperature sensor, four inline filter housings, a bypass line, quick-disconnect sampling ports, a backflush line, a support rack, a skid, and a computer to log data during run time.

The first filter housing has polypropylene or compressed activated carbon; the second and third contain polypropylene fiber filters with smaller pores. The last, either a fibrous or etched pore filter, has pores of 1 $\mu$m or less. Liquid waste from the tank is pumped through the outside and toward the center of the first filter. It then travels through the annulus outside the housing and into the next filter. As the wastes deposit solids on each filter's outer surface, the pressure across the filter drops. When the liquid has penetrated all the filters, it is deposited in a drum near the microfiltration skid.

Preliminary tests show radioactivity drops a hundredfold when this technique and 1-$\mu$m filters are used to treat contaminated machining oils. We are negotiating with industry to use a membrane-separation technique to remove soluble metals, radioactivity, and water in oil-water wastes and to filter particulates in the remaining oil phase.

### Chemical Exchange Warehouse

LLNL's Chemical Exchange Warehouse stores excess usable chemicals and offers them free to LLNL users via a database. These chemicals, once part of the hazardous waste for disposal, can now be collected, identified, stored, and exchanged. At least 25% of them will be captured, and 25% of that volume will be recycled. The savings in procurement and disposal costs alone will offset transportation and storage costs once startup costs are paid.

## Radioactive Waste Certification

The Waste Certification Program ensures that LLNL's generation and management of radioactive waste meets the requirements of all waste-treatment, storage, and disposal facilities. Our quality assurance plan covers all aspects of radioactive waste management, particularly shipment of low-level radioactive waste to the Nevada Test Site (NTS). We achieved a critical milestone when waste shipments to NTS resumed after a three-year suspension. We have now received approvals for shipments of 23 waste streams, with 6 additional ones pending approval.

We submitted plans to sample and analyze waste streams such as liquid decontamination wastes, gravels, contaminated soil, high-efficiency particulate-air filters, and mixed wastes that have been stabilized to render them radioactive only.

NTS has approved four plans; two more await approval. In a related project, we developed a database system to document and evaluate the process knowledge used to characterize these waste streams. The use of process knowledge is critical in characterizing waste when sampling is not practical because of radiation exposure concerns.

At DOE's request, we sent a team to the Ann Arbor Inertial Confinement Fusion (AAICF) Facility at Ann Arbor, Michigan, to establish a waste management certification program that permits it to dispose of its radioactive waste at NTS. We also agreed to provide technical expertise to the facility. This project showed that LLNL's waste certification program could be deployed to a remote site and implemented in a timely and cost-effective manner.

## Environmental Training

We provide remediation training in both the U.S. and overseas to promote the transfer of U.S. environmental technology to European markets and to facilitate partnerships with European scientists and engineers. We also help LLNL employees comply with regulations and hope to develop a resource center to teach others how to apply state-of-the-art environmental technologies.

Domestically, we offer short courses under UCLA's Extension Engineering and Computer Science Program and expect to offer a soil and groundwater remediation course in 1995. Internationally, we gave a course on cleaning contaminated soils and groundwater, and we expect to offer another in 1995 on risk management issues at the International School of Innovative Technology for Cleaning the Environment in Erice, Italy. We also offer a course at the Joint Research Centre of the Commission of the European Communities at Ispra, Italy.

In 1994, we trained all required LLNL personnel (about 4000 employees) to meet Resource Conservation and Recovery Act (RCRA) provisions and radioactive waste certification. Other offerings included environmental laws and regulations, air-source management, tank management, spill prevention, controls and countermeasures, emergency response, and SARA/OSHA regulations. We provided support to DOE Headquarters in preparing a guidance document on RCRA training to be distributed to the DOE Defense Program sites. We are also developing training materials and trainers for equipment such as:

- HOTSPOT, a computer-based, atmospheric-dispersion system that models radioactive releases and provides data to formulate appropriate responses to accidental releases.
- A nonthermal, liquid abrasive cutter that workers dismantling nuclear arms and equipment can use to cut aluminum, stainless steel, titanium, bulletproof glass, and armor.

These projects will facilitate the transfer of accident-response equipment to the former Soviet Union.

## Summary

Our efforts to clean up contamination at the LLNL sites and ensure that current activities do not adversely affect the environment focus on developing a sound scientific foundation for risk-based environmental protection. As a national laboratory, we promote using the latest technologies and develop new technologies to reduce the cost of protection and cleanup. In that line, we evaluate groundwater and soil cleanup techniques and develop technologies for pollution prevention, waste minimization and management, environmental restoration, and environmental monitoring. Because the same technologies have wide use in industry and other government facilities, many will be made available through through potential partnerships with the private sector and educational institutions.

***For further information contact Harry Galles (510) 423-7983 or Ellen Raber (510) 422-3985.***

*Our environmental analysts receive specialized training in handling hazardous waste.*