U.S. Department of Energy

Office of Legacy Management

ANNUAL SITE ENVIRONMENTAL REPORT
CALENDAR YEAR 2009

for the

LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH
UNIVERSITY OF CALIFORNIA, DAVIS

Submitted to:

S.M. Stoller Corporation
2597 B ¾ Road
Grand Junction, Colorado 81503

Prepared by:

Weiss Associates
5801 Christie Avenue, Suite 600
Emeryville, California 94608-1827

October 2010
Rev. 0

Weiss Associates
30 YEARS OF SERVICE
1980 — 2010

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Approvals Page

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Approved by: _____ Date: October 13, 2010

Robert O. Devany, P.G., C.E.G., C.Hg.
Principal Hydrogeologist
Weiss Associates

Department of Energy
Office of Legacy Management

October 13, 2010

Dear Sir or Madam:

The 2009 Laboratory for Energy-related Health Research (LEHR) Annual Site Environmental Report (ASER) has been prepared and is available to the public. The ASER summarizes the environmental management performance at LEHR for calendar year 2009. ASER's are prepared annually for all DOE sites conducting significant environmental activities and are distributed to relevant regulatory agencies and other interested parties.

To the best of my knowledge, the 2009 LEHR ASER accurately summarizes results for the environmental monitoring and restoration programs at LEHR. The ASER is available electronically at http://www.lm.doe.gov/land/sites/ca/lehr/lehr.htm.

Please provide any questions or comments on this report directly to me at (304) 413-0810 or Vijendra.Kothari@lm.doe.gov.

Sincerely,

Vijendra Kothari
LEHR Project Manager

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CERTIFICATION OF ACCURACY FOR:

ANNUAL SITE ENVIRONMENTAL REPORT, CALENDAR YEAR 2009, LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH

I certify that the information submitted herein is true, accurate, and complete based on my familiarity with the information and my inquiry of those individuals immediately responsible for obtaining the information.

Signature:  Date: October 13, 2010

Robert O. Devany, Principal Hydrogeologist

ANNUAL SITE ENVIRONMENTAL REPORT
READER SURVEY

To Our Readers:

Each Annual Site Environmental Report publishes the results of environmental monitoring at the former Laboratory for Energy-Related Health Research (LEHR) and documents our compliance with environmental regulations. In providing this information, our goal is to give our readership—whether they are regulators, scientists or the public—a clear accounting of the range of environmental activities we undertake, the methods we employ, and the degree of accuracy of our results.

It is important that the information we provide is easily understood, is of interest, and communicates the Department of Energy's effort to protect human health and the environment. We would like to know from you, our readers, whether we are successful in these goals. Your comments are welcome.

1. Is the technical level ☐ too high? ☐ too low? ☐ uneven? ☐ just right?
2. Is the writing ☐ too concise? ☐ too verbose? ☐ uneven? ☐ just right?

	Yes	**No**
3. Do the illustrations help you understand the text better?	☐	☐
Are there enough illustrations?	☐	☐
Is the background information sufficient?	☐	☐
4. Are the methodologies being described understandable?	☐	☐
Interesting?	☐	☐
5. Are the data tables of interest?	☐	☐
Do they provide sufficient information?	☐	☐

Other comments:

_____

_____

A business reply envelope has been attached for returning these surveys to Vijendra Kothari, DOE, 610 Collins Ferry Road, Morgantown, WV 26507.

OPTIONAL

Name: _____ Occupation_____

Address:_____

CONTENTS

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
Ci	Curie
D&M	Dames & Moore
DOE	(United States) Department of Energy
EC	electrical conductivity
EMS	environmental management system
HSU	hydrostratigraphic unit
km	kilometer
LEHR	Laboratory for Energy-Related Health Research
µg/L	micrograms per liter
mg/L	milligram(s) per liter
mrem	millirem(s)
mrem/yr	millirem(s) per year
N	nitrogen
No.	number
pCi/g	picoCurie(s) per gram
person-rem/yr	person-Roentgen equivalent man per year
rem	Roentgen equivalent man
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
UC Davis	University of California, Davis
USCB	United States Census Bureau
US EPA	United States Environmental Protection Agency
Weiss	Weiss Associates

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EXECUTIVE SUMMARY

This Annual Site Environmental Report for the Laboratory for Energy-Related Health Research (LEHR or the Site) at the University of California, Davis (UC Davis) summarizes the United States Department of Energy's (DOE's) environmental performance at the Site in 2009, including environmental compliance; environmental monitoring data for air, soil, groundwater, storm water and ambient radiation; and environmental management programs. DOE operation of LEHR as a research facility ceased in 1989 after three decades of research on the health effects of low-level radiation exposure, primarily using beagles as research subjects. Contamination from prior site use including research activities resulted in the addition of the Site to the National Priorities List in 1994. In 1997, DOE and UC Davis reached an agreement on the responsibilities for site cleanup. During Calendar Year 2009, DOE continued environmental management at the Site in accordance with the requirements of the Comprehensive Environmental Response, Compensation and Liability Act. In general, these activities consisted of storm water runoff monitoring, reporting and maintenance of the Administrative Record. DOE conducted no construction or remediation activities in 2009.

In 1999, DOE entered into a Federal Facility Agreement with the United States Environmental Protection Agency (US EPA), California Department of Toxic Substances Control, California Department of Health Services, and the Central Valley Regional Water Quality Control Board. Under the Federal Facility Agreement, DOE is responsible for remediation of site facilities, including the Radium-226/Strontium-90 Treatment Systems, the DOE Disposal Box, on-site domestic septic systems, DOE disposal trenches, and the former Dog Pens (Figure 1-2). Under an Administrative Order on Consent with the US EPA, UC Davis is responsible for remediation of three landfills, disposal trenches located south and east of Landfill Number (No.) 2, a disposal trench located south of the Western Dog Pens, an old waste water treatment plant, and impacted groundwater (Figure 1-2) (US EPA, 2000).

Environmental Restoration Activities at LEHR

DOE has successfully completed removal actions at LEHR and has thereby significantly reduced impacts to human health and the environment. However, residual contaminants remain at the site at concentrations that prevent its unrestricted use or that have the potential to impact groundwater quality above background concentrations in the future. A number of alternatives to clean up the residual contamination were evaluated in a Feasibility Study for the DOE areas of the Site approved by the regulatory agencies on March 7, 2008 (Weiss, 2008).

The preferred alternatives for site clean-up were presented in a Proposed Plan issued by DOE in October 2008 (DOE, 2008a). Comments on the plan were received at a public meeting held by DOE during the 30-day comment period. The comments received and DOE's responses to them are

summarized in the *Record of Decision for the DOE Areas* which is expected to be finalized in late 2009.

Overview of 2009 Water and Air Environmental Monitoring Results

Per the Memorandum of Agreement with DOE (DOE, 1997), in 2009 UC Davis was responsible for conducting groundwater monitoring at LEHR. A report developed for UC Davis (Weiss, 2010c) provides a complete description of the groundwater-monitoring program and analytical results for 2009. In 2009, groundwater samples were collected and analyzed for volatile organic compounds (VOCs), chromium, nitrate, carbon-14, tritium, and total dissolved solids (TDS). Carbon-14 and tritium were not detected in any of the 2009 samples above reporting limits. Based on the findings presented by UC Davis, the 2009 groundwater monitoring results were similar to previously established chemical concentration trends.

UC Davis also reported that storm water samples collected and analyzed in 2009 were consistent with results from previous years, and no new trends or concerns were identified.

Radiological Impact Assessment of the LEHR Environmental Restoration Project

An evaluation of air emissions from wind erosion of surface soil conducted to comply with the requirements of the *National Emissions Standards for Hazardous Air Pollutants* indicated that ambient radionuclide activities were well below all applicable radiation dose standards for members of the public (Weiss, 2010b).

1. INTRODUCTION

This Annual Site Environmental Report describes environmental restoration and waste management activities conducted by the Department of Energy (DOE) in 2009 at the Laboratory for Energy-related Health Research (LEHR) at the University of California, Davis (UC Davis) (Figure 1-1). This report is prepared according to the requirements of DOE Order 231.1A, Environmental Safety and Health Reporting. The purpose of this report is to summarize environmental data, confirm compliance with environmental standards and requirements, and highlight significant programs and efforts. This report describes activities conducted by DOE during 2009 in support of site environmental restoration efforts, and provides information about the impact of these activities on the public and the environment. A ground, surface, and storm water-monitoring program performed by UC Davis includes information important to the overall environmental restoration of the Site and is briefly summarized herein.

1.1 Site History

The Atomic Energy Commission first sponsored radiological studies on laboratory animals at UC Davis in the early 1950s. Initially situated on the main campus, the project was relocated to its present location in 1958 (Figure 1-1). Research at LEHR through the late 1980s focused on health effects from chronic exposure to radionuclides, primarily strontium-90 and radium-226, using beagles as research subjects. Other related research was conducted at the Site concurrent with these long-term studies. In the early 1970s, a cobalt-60 irradiation facility was constructed at the Site to study the effects of chronic exposure to gamma radiation on humans, again using beagles.

A campus landfill with two waste burial units that were used from the 1940s until the mid-1960s is located at the Site (Figure 1-2). Several low-level radioactive waste burial areas were also present at the Site, and campus and LEHR research waste was buried in these areas until 1974, in accordance with regulations in effect at the time. The principle environmental threats posed by these radioactive waste burial areas have been mitigated during several removal actions conducted at the Site since 1996.

In 1988, pursuant to the Memorandum of Agreement between DOE and the University of California, DOE's Office of Energy Research initiated activities to close out the research program at LEHR. In 1997, a second Memorandum of Agreement divided the responsibility for environmental remediation between DOE and UC Davis (DOE, 1997).

Under the Federal Facility Agreement effective in December 1999, DOE is responsible for remediation of the Radium/Strontium Treatment Systems, a waste burial area known as the DOE Disposal Box, on-site domestic septic tanks and associated leach fields and dry wells, DOE disposal

trenches, and the former Dog Pens (Figure 1-2). UC Davis is responsible for remediation of three landfills, disposal trenches located south and east of Landfill No. 2, 49 waste holes, an old waste water treatment plant, groundwater impacted by the Site, and surface and storm water runoff impacted by UC Davis's activities.

Prior to 2009, DOE successfully completed removal actions at LEHR and has thereby significantly reduced impacts to human health and the environment. However, residual contaminants remain at the site at concentrations that prevent its unrestricted use, or that have the potential to impact groundwater quality above background concentrations in the future.

1.2 Site Management

Restoration of the Site began in October 1989 and continued through February 1990. It was managed under an interim contract with UC Davis. From 1990 to 1996, Battelle Environmental Management Operations managed the LEHR remediation project. In 1996, the project was transferred to Weiss Associates (Weiss) of Emeryville, California, who managed all aspects of the project. From late 2003 to 2005, site activities were managed by New World Technology. In 2005, management of the environmental restoration of the DOE-impacted areas at the Site was transferred from the DOE Oakland Operations Office to the DOE Office of Legacy Management. The Office of Legacy Management contracted S.M. Stoller Corporation to oversee management of the Site, who subcontracted Weiss to perform environmental engineering and monitoring tasks for the Site. S.M. Stoller Corporation and Weiss continued to support DOE in 2009.

1.3 Environmental Restoration

In May 1994, the United States Environmental Protection Agency (US EPA) added the Site to the National Priorities List. A site remedial investigation and feasibility study work plan was developed to ensure that investigation and remediation were conducted in accordance with applicable regulatory requirements. Remedial Project Manager meetings are held every four to six weeks to evaluate the progress of remediation and identify actions needed to facilitate the process.

Primary DOE restoration/remediation activities that have been performed at the Site include soil and groundwater characterization; building assessment; decontamination and decommissioning of above-ground structures; removal of contaminated underground tanks, trench structures, and contaminated soil; and waste management. In support of the remediation activities, chemical and radiological risk assessments have been developed, and DOE has prepared various documents required by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). In 2002, DOE completed all removal actions planned for the Site, and in 2004, DOE shipped the remaining waste generated during these removal actions for disposal. Additional waste was disposed in 2007, which comprised the concrete curbs from the former Eastern Dog Pens generated during maintenance activities at the Eastern Dog Pens.

In 2005, UC Davis issued a revised draft human health risk assessment that served as the basis for the DOE Areas Feasibility Study that was approved by the regulatory agencies on March 7, 2008 (Weiss, 2008). A number of alternatives to clean up the residual contamination were evaluated in the Feasibility Study. The preferred alternatives were presented in a Proposed Plan issued by DOE in October 2008 (DOE, 2008a) and after public comment, the selected alternative was an documented in a Record of Decision (DOE, 2009) signed by the regulatory agencies. DOE is presently developing a Remedial Design and Remedial Action Work Plan that sets out how the selected alternative will be implemented. DOE expects to finalize the work plan by the end of 2010.

1.4 Site Description

The Site is a 15-acre parcel owned by the Regents of the University of California. It is 1.5 miles south of the main UC Davis campus in a rural agricultural area (Figure 1-1) and is presently occupied by the UC Davis Center for Health and the Environment. Research at the Center for Health and the Environment includes toxicology, epidemiology, radiation biology, and radiochemistry.

Site facilities currently consist of 16 buildings, including a main administration and office building, two former animal hospitals, a laboratory, and support buildings (Figure 1-2). Former facilities include radioactive wastewater treatment systems, an indoor/outdoor Co-60 irradiation field, a radioactive waste burial area, and outdoor dog pens. Presently inactive campus landfill units and numerous disposal sites (i.e., trenches and holes) were used to dispose of waste from campus activities and are being evaluated by UC Davis. Figure 1-2 shows areas that have potentially impacted the environment at the Site and those areas where DOE removal actions have been completed.

1.5 Population Data

1.5.1 Site Population

The UC Davis Center for Health and the Environment conducts ongoing research in toxicology, epidemiology, radiation biology, and radiochemistry with a staff of approximately 200 researchers and support personnel. Center for Health and the Environment staff have varying schedules and are not all present at the Site at the same time.

In 2009, the LEHR remediation project had no full-time workers at the Site. Contract personnel conducted periodic site inspections and collected storm water samples at LEHR. During these activities, DOE contractors deployed up to two workers to conduct and oversee site work.

1.5.2 Local Population

The Site is located in a semi-rural area in northeastern Solano County on the UC Davis South Campus (Figure 1-1). In fall of 2009, a student population of 32,153 and approximately 30,770 faculty and staff (including student staff and medical center staff) were reported at the UC Davis campus (University of California, 2010). The population within a 2-mile radius of the site is estimated to be about 5,000, based on 2008 US Census data for Yolo and Solano Counties. The majority of this population resides within the southern portion of the city of Davis. The population of the City of Davis is reported at 64,259 residents (California Labor & Workforce Development Agency, 2008), and the populations of Yolo and Solano County are 168,660 and 411,680, respectively (USCB, 2000). The more densely populated and metropolitan Sacramento area is approximately 13 miles east of the site. Approximately 407,018 people live in the City of Sacramento and about 1,223,499 people live in Sacramento County (USCB, 2000).

1.6 Environmental Setting

The Site is located on a relatively flat plain bordered on the south by the Putah Creek Levee. The Site is mostly open and slopes gently to the east. The Site lies outside of the Putah Creek 100-year floodplain.

1.6.1 Land Use

The land within a one-mile radius of the Site is owned both privately and by UC Davis. It is used for animal research, agriculture, and recreation (e.g., fishing and swimming). Privately-owned lands south and east of the Site are used to produce wheat, tomatoes, corn, barley, and oats, and include permanent rural residences. The South Fork of Putah Creek and UC Davis land holdings (Figure 1-1) separate private property to the south of the Site. Private property to the east is adjacent to non-LEHR, UC Davis-owned research facilities and land. The property immediately west, east, north, and south of the Site (Putah Creek Reserve) is owned by UC Davis and is currently used for various types of animal, agricultural, and health research.

1.6.2 Hydrogeology

Unconsolidated Pliocene and Pleistocene sedimentary deposits are the major groundwater sources for public and private water supplies in the Sacramento Valley (California Department of Water Resources, 1978), in which the Site is located. Both unconfined and confined fresh water aquifers are present in the uppermost 3,000 feet of the valley subsurface. Groundwater generally flows from the valley sides toward the valley axis. In the site vicinity, regional groundwater generally flows east from the Coast Ranges toward the Sacramento River (D&M, 1993).

At various depths beneath the valley floor, saline water is present as a result of entrapment during the deposition of sediments in a marine environment. The depth to the base of fresh water in the Sacramento Valley varies from 400 feet to over 3,000 feet, and is 2,600 feet to 3,100 feet below ground surface in the Davis area (State of California Division of Oil and Gas, 1982).

Previous investigations identified five hydrostratigraphic units (HSUs) beneath the Site (D&M, 1999). These include the vadose (unsaturated) zone and HSUs 1 through 4. The vadose zone extends from the ground surface to the top of groundwater, which has historically ranged from 15 feet to 55 feet below ground surface. The vadose zone consists primarily of unsaturated clay and silt with lesser amounts of interbedded sand and gravel. HSU-1 extends from the bottom of the vadose zone to depths of approximately 76 feet to 88 feet below ground surface. This unit is lithologically similar to the vadose zone and consists primarily of silt and clay, with lesser amounts of sand and gravel. HSU-2 extends from the bottom of HSU-1 to depths of approximately 114 feet to 130 feet below ground surface. This unit is composed primarily of sand in the upper portion of the unit and gravel in the middle to lower portions. HSU-3, investigated in off-site areas, extends from the bottom of HSU-2 to a depth of about 250 feet below ground surface and is approximately 120 feet thick. The unit consists primarily of relatively fine-grained sediments varying from very fine-grained sandy silt to clayey silt and silty clay. HSU-4, also investigated in off-site areas, extends from the bottom of HSU-3 to a depth of about 280 feet below ground surface and is approximately 32 feet thick. This unit consists of coarse sand and gravel. Beneath HSU-4, a sharp contact with a bluish, dark gray silt was encountered 282 feet below ground surface in wells UCD4-41 and UCD4-43 (Figure 3-1). The bottom of this unit has not been penetrated in any of the site borings (D&M, 1999).

Irrigation water, rainfall, and Putah Creek recharge groundwater in the site vicinity (D&M, 1997). Groundwater pumping associated with agriculture is responsible for the great majority of groundwater withdrawal. Locally, UC Davis extracts contaminated groundwater from HSU-2 for treatment and diverts the treated groundwater to its waste water treatment facility to minimize off-site migration of volatile organic compounds, particularly chloroform.

Generally, there is a 20- to 30-foot seasonal fluctuation in the water table beneath the site, caused predominantly by the lack of surface recharge and nearby agricultural pumping in the summer. Vertical gradients vary both temporally and spatially. The magnitude of the vertical gradient is greatest when groundwater elevations are rising or falling sharply. Short-term activities, such as local agricultural pumping, can produce downward vertical gradients during periods of an otherwise rising water table.

The HSU-1 lateral gradient across the site typically ranges from 0.01 feet/foot to 0.04 feet/foot, and the direction of groundwater flow is predominantly northeastern. Representative values of HSU-1 horizontal hydraulic conductivity are between 1×10^{-4} and 1×10^{-7} centimeters per second (D&M, 1999). The lateral gradient across the site within HSU-2 typically ranges from 0.005 feet to 0.015 feet. The direction of flow appears to be predominantly to the northeast, although it can occasionally be to the east-southeast. Based on pumping tests, hydraulic conductivity in HSU-2 ranges from 0.26 centimeters per second to 0.43 centimeters per second (D&M, 1997).

Groundwater in HSU-1, HSU-2, and HSU-4 has been impacted by site activities. Based on investigations to date (Weiss, 2003; UC Davis, 2004), significant groundwater impacts appear to be predominantly associated with releases that have occurred within or near the UC Davis disposal areas.

1.6.3 Groundwater Supply and Quality

Groundwater at depths between approximately 100 and 500 feet in the site vicinity is used for agricultural and domestic supply. Shallow groundwater quality, at depths above 100 feet, has been impacted by nitrates, probably from agricultural sources, and has insufficient yield that precludes its extraction for domestic or agricultural use.

1.6.4 Sanitary Sewer Systems

The Site discharges its sanitary waste water to the UC Davis Campus Waste Water Treatment Plant. UC Davis operates the plant under the conditions specified in its National Pollutant Discharge Elimination System permit, granted by the Central Valley Regional Water Quality Control Board under agreement with the US EPA.

1.6.5 Storm Drainage System

Storm water runoff from the DOE areas at the Site is mainly collected in an underground drainage system. Storm water from the paved area in the western part of the Site and around the southern buildings in the western area is collected in a storm water drainage system. This system drains to the site storm water lift station (LS-01 shown on Figure 3-1) and then to an outfall along the west side of Old Davis Road. Storm water in the northwestern area of the Site drains into a ditch along Old Davis Road. Storm water in the eastern and non-paved southern portions of the Site percolates into the ground, except for a section of the former Cobalt-60 Field where dog pens were once located and where drainage is connected to the sanitary sewer. During and after heavy rains, storm water runoff forms ponds in some areas of the Site. The re-grading of the Western Dog Pens area conducted in 2006 has reduced ponding in this area of the Site.

1.6.6 Biological Resources

A number of sensitive biological resources were identified in an Ecological Scoping Assessment (Weiss, 1997b) as potentially occurring in the vicinity of the Site. These species include the Giant Garter Snake, the Northern Harrier, the Coopers Hawk, the California Horned Lark, the Great Egret, the Burrowing Owl and the Valley Elderberry Longhorn Beetle, which lives in elderberry bushes. Although elderberry bushes are present at the Site, a focused biological survey

(IT Corporation, 1998) found no sensitive species actually present on site and concluded that the on-site elderberry bushes are not currently hosting the Valley Elderberry Longhorn Beetle.

An ecological risk assessment evaluating the impact of residual site contamination on ecological resources was issued by UC Davis and approved by regulatory agencies in August 2006. It concludes that residual contamination at the Site is not a concern for ecological receptors.

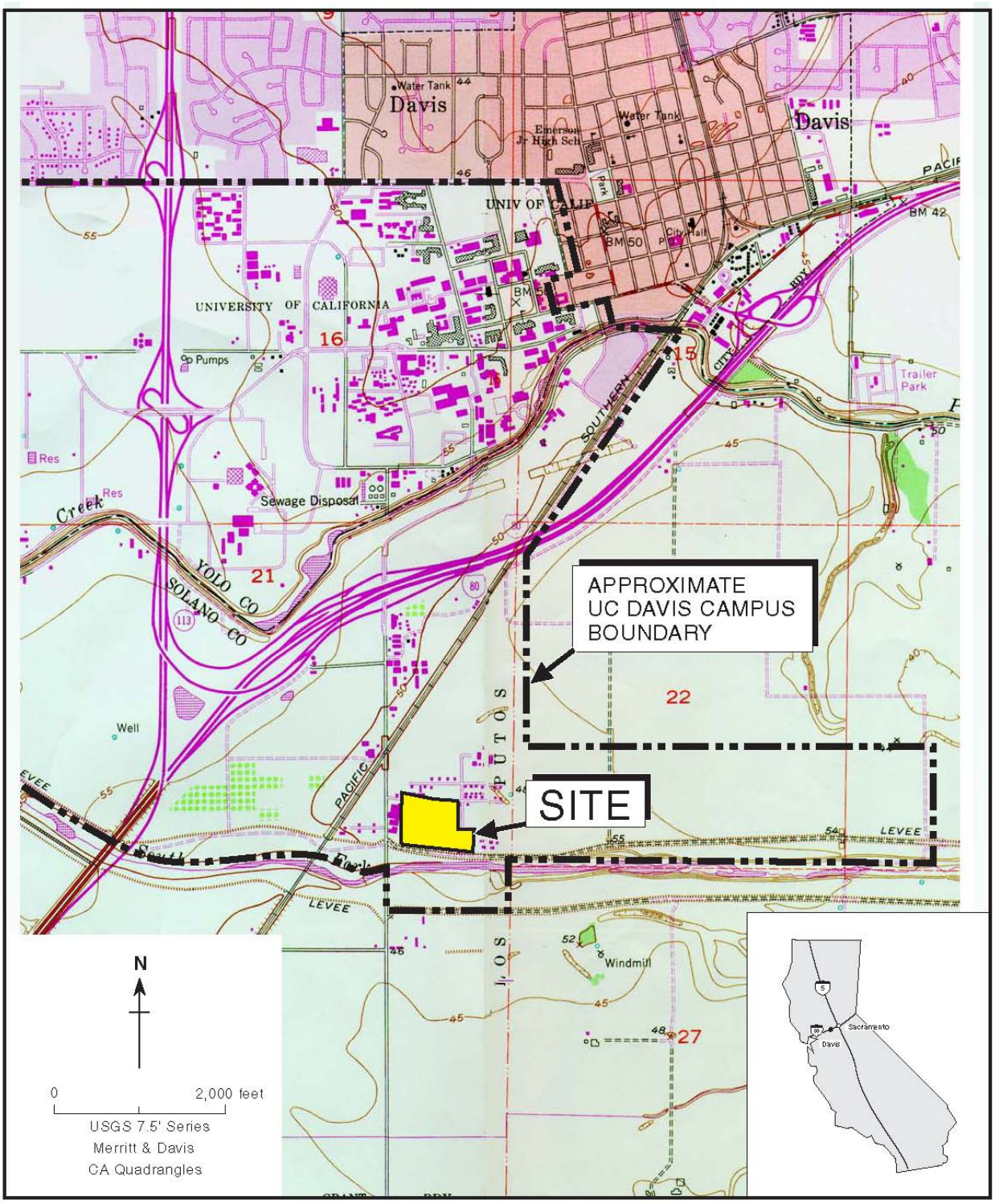

Figure 1-1. Location of the LEHR Site, UC Davis, California

Figure 1-2. Site Features and Potential Contaminant Source Areas

2. COMPLIANCE SUMMARY

This section summarizes LEHR's environmental regulatory compliance status during the environmental restoration and waste management activities conducted in Calendar Year 2009. No violations, fines, or penalties were issued for the Site in 2009.

2.1 Environmental Restoration and Waste Management

Activities at LEHR were conducted in compliance with CERCLA and the National Contingency Plan, and include compliance with applicable or relevant and appropriate requirements and DOE Orders, as described below.

2.1.1 Comprehensive Environmental Response, Compensation and Liability Act as Amended by the Superfund Amendments and Reauthorization Act

In 1995, a streamlined remediation process was initiated at the Site using the CERCLA non-time critical removal action approach. This approach enables expedited response to contamination problems without requiring the time-consuming investigations and preparation of lengthy documents required otherwise. By 2003, DOE had finished all removal actions planned for the Site.

In 2004, UC Davis developed draft site-wide human health and ecological risk assessments (each comprised of a risk estimate and a risk characterization component). The human health risk estimate was finalized in 2005 and served as a basis for DOE's human health risk characterization of the DOE areas. Also in 2005, separate human health and ecological risk assessments were conducted by DOE to evaluate the potential risks associated with reuse of soil in the Western Dog Pens that had been removed from the Southwest Trenches area. In 2005, DOE issued a risk characterization for the DOE areas based on the site-wide human health risk characterization. The human health risk estimate and characterization for the DOE areas and the human health and ecological risk assessments for the Western Dog Pens formed the basis for selection of contaminants of concern to be evaluated in a feasibility study report.

A site-wide ecological risk assessment was revised by UC Davis in 2005 and 2006, and finalized in August 2006. The assessment concludes that residual contamination at the Site is not a concern for ecological receptors. The results of the site-wide ecological risk assessment were incorporated into the feasibility study report.

A feasibility study report, which evaluates remedial alternatives for the DOE areas, was issued and approved by the regulatory agencies on March 7, 2008. A number of alternatives to clean up the residual contamination were evaluated in the Feasibility Study. The preferred alternatives were presented in a Proposed Plan issued by DOE in October 2008 (DOE, 2008a) and after public comment, the selected alternative was an documented in a Record of Decision (DOE, 2009) signed by the regulatory agencies. DOE is presently developing a Remedial Design and Remedial Action Work Plan that sets out how the how the selected alternative will be implemented. DOE expects to finalize the work plan by the end of 2010.

2.1.2 Resource Conservation and Recovery Act

No hazardous waste requiring compliance with the Resource Conservation and Recovery Act was generated, managed, shipped, or disposed in 2009.

2.1.3 Federal Facilities Compliance Act

The Federal Facilities Compliance Act amends the Solid Waste Disposal Act and states that all federal agencies are subject to all substantive and procedural requirements of federal, state, and local solid and hazardous waste laws in the same manner as any private party. The act requires that a site treatment plan be prepared for each DOE site that generates or stores mixed radioactive waste. A final site treatment plan for LEHR was approved and issued in October 1995. No revisions have been made to this plan. The Site continues to be in compliance with the Federal Facilities Compliance Act.

2.1.4 National Environmental Policy Act

Consistent with DOE policy and guidance, environmental considerations of proposed actions are evaluated concurrent with CERCLA studies such as feasibility studies. The integration of National Environmental Policy Act requirements with the CERCLA process eliminates the need for a separate National Environmental Policy Act analysis and streamlines the cleanup process. The feasibility study report for the DOE areas issued and approved in March 2008 includes an environmental assessment in compliance with the National Environmental Policy Act.

2.1.5 Toxic Substances Control Act

In 1976, concern over the toxicity and persistence in the environment of polychlorinated biphenyls led Congress to enact Section 6(e) of the Toxic Substances Control Act. The Act included, among other things, prohibitions on the manufacture, processing, and distribution in commerce of polychlorinated biphenyls. The Toxic Substances Control Act contains legislation for the management of polychlorinated biphenyls from manufacture through disposal. No polychlorinated biphenyl-containing material or waste was generated, managed, or disposed in 2009.

2.1.6 Federal Insecticide, Fungicide and Rodenticide Act

The US EPA, under the Federal Insecticide, Fungicide and Rodenticide Act, regulates the sales, distribution, and use of pesticides by requiring their registration. Registration includes approval by the US EPA of the pesticide's label, which must give detailed instructions for its safe use. The US EPA must classify each pesticide as either "general use," "restricted use," or both. Only registered general use herbicides are applied at the Site by the UC Davis Agricultural Services Department to control weeds. The herbicides are used in accordance with the safe use instructions and in compliance with UC Davis campus requirements, and local, state and federal laws.

2.2 Radiation Protection

Under the Atomic Energy Act of 1954, as amended, DOE has the responsibility of controlling the activities of its contractors and operations in a manner that protects the public and the environment from radiation hazards associated with its operations. Title 10 Code of Federal Regulations (CFR) Part 835, Occupational Radiation Protection, provides implementing regulations applicable to DOE. No activities that would have created a potential for exposure to radiation occurred at the Site in 2009.

2.2.1 Occupational Radiation Protection (10 CFR Part 835)

All work at LEHR is performed in compliance with Title 10 CFR Part 835. Environmental monitoring aspects of all operations and activities at LEHR must be addressed in the work plans developed for specific activities. All activities at LEHR complied with the requirements of Title 10 CFR Part 835 in 2009.

2.2.2 DOE Order 5400.5, Radiation Protection of the Public and the Environment

The *Final Report on the Radiation Protection of the Public and the Environment* (Weiss, 2001) was developed in 2001. The purpose of this report was to evaluate LEHR operations and document their compliance with DOE Order 5400.5, Radiation Protection of the Public and the Environment. LEHR operations continued to be in compliance with DOE Order 5400.5 in 2009.

2.2.3 DOE Order 450.1A, Environmental Protection Program

This Order requires DOE to develop environmental management systems to implement sound stewardship practices that are protective of air, water, land, and other natural and cultural resources impacted by DOE operations, and by which DOE meets and exceeds compliance with applicable environmental, public health, and other resource protection laws, regulations and DOE

requirements. Activities conducted at LEHR in 2009 were in compliance with DOE Order 450.1A, as discussed in Section 3.

2.2.4 DOE Order 435.1, Radioactive Waste Management

No radioactive waste was managed at the Site in 2009.

2.3 Air Quality and Protection

2.3.1 Clean Air Act

Under the Clean Air Act, the US EPA defined six criteria pollutants (carbon monoxide, nitrogen dioxide, lead, ozone, particulate matter, and sulfur dioxide), and set National Ambient Air Quality Standards for these pollutants. Of these, the only air pollutant emitted at the Site is particulate matter with aerodynamic size less than or equal to 10 micrometers from uncovered soils in the Eastern and Western Dog Pens. The Site is not a major source of air emissions.

Ambient air monitoring was routinely conducted between 1995 and 2001 by DOE. This prior data and current post-removal action site conditions indicate that surface soil contamination does not impact air quality at the Site. In 2009, the Site was in compliance with all Clean Air Act requirements administered by the Yolo-Solano Air Quality Management District.

2.3.2 National Emission Standards for Hazardous Air Pollutants

Subpart H of Title 40 CFR Part 61 protects the public and the environment from the hazards of radionuclide emissions other than radon from DOE facilities. It sets a limit on the emission of radionuclides that ensures that no member of the public in any year receives an effective dose of more than 10 millirem per year (mrem/yr).

The National Emission Standards for Hazardous Air Pollutants requirements primarily target point-source/stack emissions. There are currently no point sources of radionuclide emissions at the Site. However, the Memorandum of Understanding between DOE and the US EPA (DOE, 1995) applies the point-source criteria to potential diffuse area sources at the Site.

The 2009 estimated dose to the public from the Site's diffuse area sources was calculated using available surface soil concentrations and assuming that wind-blown fugitive dust from the Western and Eastern Dog Pens, including re-entrainment and dispersion of surface soil dust, were the only potential sources of emissions. The analysis of potential diffuse airborne radiological effluent sources at the Site is included in the *Final Radionuclide Air Emission Annual Report (Subpart H of 40 CFR 61) Calendar Year 2009* (Weiss, 2010b). Emissions modeling indicated that the total

contribution to the maximum effective dose equivalent to a member of the public from diffuse-source emissions for reporting year 2009 is estimated to be 2.8E-4 mrem/yr (about 0.005% of the 10 mrem/yr standard). This result is more than two orders of magnitude lower than the results for the previous years, when grading and demolition activities were conducted at the DOE areas and is similar to the lowest results over the previous nine years. This analysis is discussed in more detail in Section 4 of this report.

2.4 Water Quality and Protection

2.4.1 Clean Water Act

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. The Site discharges its sanitary waste to the UC Davis Waste Water Treatment Plant, which is subject to the conditions in National Pollutant Discharge Elimination System Permit CA0077895, issued to UC Davis, and Waste Discharge Requirement Order No. 92-040, granted by the Central Valley Regional Water Quality Control Board. No waste water, other than sanitary waste, was discharged from LEHR to the waste water treatment plant in 2009.

Under the Clean Water Act, the US EPA also controls polluted storm water runoff. In California, this function is delegated to the California Regional Water Quality Control Board, under state-wide National Pollutant Discharge Elimination System General Permits for Storm Water Discharges Associated with Industrial and Construction Activities. A storm water sampling program described in the *Final Revised Field Sampling Plan* (D&M, 1998) is implemented at the Site and meets the state General Permit requirements. Best management practices are used at the Site to mitigate any potential contamination in storm water runoff.

Under the Final Revised Field Sampling Plan (D&M, 1998), storm water samples are usually collected twice a year, once near the beginning of the rainy season, after the first significant storm of the season, and once near the end of the rainy season. Details of the sampling and analyses are provided in the 2009 Comprehensive Annual Water Monitoring Report (Weiss, 2010c) and are summarized herein in Section 3.

2.4.2 Drinking Water Requirements

Under the Safe Drinking Water Act, the US EPA sets standards to protect drinking water quality and drinking water sources, including rivers, lakes, reservoirs, springs and groundwater wells. The California Porter-Cologne Water Quality Act authorizes the State Water Resources Control Board and Regional Water Quality Control Board to coordinate and control water quality in the state. The regional boards establish and enforce water quality standards for both surface and groundwater by issuing permits for discharges of waste water into state water bodies. The Safe Drinking Water

and Toxics Enforcement Act prohibits discharge or release of chemicals known to the State of California to cause cancer or reproductive toxicity into water, or onto land where such chemicals pass, or probably will pass, into any source of drinking water.

Historically, contaminated liquid waste was discharged from DOE research activities to the Imhoff Treatment Facility, the Domestic Septic Systems, and the Radium/Strontium Treatment Systems and associated leach fields, which resulted in releases to site soils. These structures and associated contaminated soils have been removed and shipped off-site for disposal. Current DOE activities at LEHR do not discharge contaminants to any drinking water sources.

According to the Memorandum of Agreement between UC Davis and DOE (DOE, 1997), potential impacts to groundwater from past site activities are to be addressed by UC Davis. UC Davis is conducting a groundwater interim remedial action consisting of groundwater extraction from HSU-2, air stripping of volatile organic compounds, primarily chloroform, and discharging the treated groundwater to the UC Davis Campus Waste Water Treatment Plant. Groundwater and surface water monitoring has been conducted since November 1990. Surface water monitoring at Putah Creek ceased after 2007. Monitoring activities conducted in 2009 are summarized in Sections 4, 5, and 6.

2.5 Other Environmental Statutes

2.5.1 Endangered Species Act

In 1997, an ecological scoping assessment (Weiss, 1997b) was conducted to support the *Draft Final Determination of Risk-Based Action Standards for DOE Areas* (Weiss, 1997a). The ecological scoping assessment identified special status species that have a high potential to exist in or near Putah Creek, including two plant species, five invertebrates, nineteen birds, two reptiles, one amphibian, and four mammals. Habitat for the Valley Elderberry Longhorn Beetle, a threatened species under the Endangered Species Act, was identified in the Western Dog Pens, Eastern Dog Pens, and the former Cobalt-60 Field. As discussed in Section 2.1.1, a draft ecological risk assessment was developed by UC Davis in 2004, revised in 2005, and a final assessment was issued by UC Davis and approved by regulatory agencies in August 2006. It concludes that residual contamination at the Site is not a concern for ecological receptors.

No activities that could potentially result in habitat modifications or adverse effects on listed species were conducted at the Site in 2009.

2.5.2 National Historic Preservation Act

An archeological evaluation was conducted during the Phase II soil and groundwater characterization of the Site (D&M, 1992). No evidence of cultural resources, historical or archeologically sensitive areas was encountered in 2009.

2.5.3 Migratory Bird Treaty Act

The Migratory Bird Treaty Act governs the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests. No activities resulting in taking of any migratory birds, their eggs, parts, or nests occurred at the Site in 2009.

2.6 Executive Orders

2.6.1 Executive Order 13148, "Greening the Government through Leadership in Environmental Management" replaced by Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management

Executive Order 13423 (EO, 2007a), sections 2(e)(i) and 3(a)(vi) require compliance with the Emergency Planning and Community Right-to-Know Act, also known as the Superfund Amendments and Reauthorization Act (SARA) Title III. SARA Title III requires facilities to provide information on the presence of hazardous chemicals and on the releases, both accidental and routine, of such chemicals into the environment. This information is used by state and local emergency agencies, hospitals, police and fire departments, and emergency response teams in responding to chemical emergencies, and is also available to the public to inform them of chemical hazards present in their neighborhood. The toxic release inventory requirements of SARA apply to facilities that use large amounts of certain chemicals. All hazardous materials stored at the Site were transferred to UC Davis's control on April 14, 2005, and no chemicals were stored and used at LEHR in 2009; therefore, the SARA Title III planning and notification requirements and TRI reporting requirements were not applicable to the operation in 2009.

2.6.2 Executive Order 11988, "Floodplain Management"

No activities that would be subject to floodplain management requirements were conducted in 2009.

2.6.3 Executive Order 11990, "Protection of Wetlands"

No portion of the Site is designated as a wetland.

2.7 Other Major Environmental Issues and Actions

No violations, compliance orders, or negative audit findings were issued to LEHR in 2009.

No new environmental programs and procedures were developed, approved, or implemented in 2009.

2.8 Continuous Release Reporting

In accordance with CERCLA, non-permitted hazardous substance releases in quantities exceeding the CERCLA reportable quantity must be reported to the National Response Center. No such releases occurred at the Site in 2009.

2.9 Unplanned Releases

No unplanned releases occurred at the Site in 2009. No reports of unusual or off-normal occurrences under DOE Order 232.1A, the governing DOE Order for occurrence reporting under S.M. Stoller Corporation's contract with DOE, were made in 2009.

2.10 Summary of Permits

DOE is not required to obtain any environmental permits for remediation and waste management activities conducted under CERCLA at LEHR.

3. ENVIRONMENTAL MANAGEMENT SYSTEM

According to the objectives of DOE Order 450.1A (DOE, 2008c), DOE sites should implement sound stewardship practices protective of the air, water, land, and other natural and cultural resources potentially impacted by their operations. Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management* (EO, 2007a), Instructions for Implementing EO 13423 (EO, 2007b), and DOE Order 450.1A (DOE, 2008c) require DOE sites to have an environmental management system (EMS) in place and audited by June 2009. DOE Office of Legacy Management and S.M. Stoller developed a joint EMS, which underwent an independent audit in March of 2009. Full conformance with these orders and DOE Order 430.2B, *Departmental Energy, Renewable Energy, and Transportation Management* (DOE, 2008b) was achieved by June 30, 2009.

The EMS defines a systematic approach for minimizing the environmental impacts associated with work activities and services performed by, as well as products developed or procured by, the DOE Office of Legacy Management and DOE's contractors. The joint EMS implementation strategy is documented in three manuals, which include the Environmental Management Description (DOE, 2008d), the Environmental Management Systems Programs Manual (DOE, 2008e), and the Environmental Protection Manual (DOE, 2008f). The DOE LM/Stoller EMS adheres to the "Plan-Do-Check-Act" principles, mandates environmental compliance, and integrates green initiatives into all phases of work including scoping, planning, construction, subcontracts, and operations. The EMS provides specific procedures for planning and mitigating negative impacts of proposed projects or actions on the environment by promoting utilization of recycled materials; recycling to the extent practicable; conserving fuel, energy, and natural resources; minimizing the generation of green house gases; and minimizing use of toxic chemicals and the generation of hazardous wastes.

Environmental management at the Site is conducted under the umbrella of the joint EMS and ensures protection of air, water, land, and other natural and cultural resources potentially impacted by site operations. Each year, DOE collects and evaluates environmental samples to monitor the air, water, and soil conditions at the Site and evaluates relevant sample data obtained from UC Davis. This section describes the LEHR environmental monitoring program and summarizes the environmental monitoring activities conducted in 2009. The analytical results generated by this monitoring program are discussed in Sections 4, 5, and 6.

3.1 Environmental Management Policy and System Elements

In 2009, environmental management was integrated into the overall management framework for site environmental restoration by integrating the evaluation of applicable environmental

requirements and objectives into the CERCLA process and ongoing environmental compliance monitoring activities.

3.1.1.1 Environmental Management System Elements

All legal and regulatory requirements are evaluated for all proposed actions undertaken at the Site as part of the applicable or relevant, and appropriate requirements development process. Environmental objectives and targets for remediation of the Site are set in CERCLA documents such as risk assessments, feasibility studies, and others. Waste minimization and source reduction are included in waste management activities, as discussed in Section 3.2. The quality assurance program plan defines roles, responsibilities, authorities, and resources of site staff; operational controls; training requirements (Section 3.5); document control and retention; compliance evaluation; nonconformity; preventive and corrective actions; and internal surveillance and management audit requirements. The monitoring results are discussed in Section 3.3.

With the decrease in scope of site activities and the transition of site management to a small business, the scope of environmental and other compliance programs implemented at the Site has been scaled back proportionately.

3.2 Pollution Prevention and Waste Minimization

The LEHR waste management program is committed to minimizing waste volumes by giving preference to source reduction, material substitution, decontamination, and recycling. Applicable pollution prevention and waste minimization activities include:

- Avoiding the use of porous materials that cannot be decontaminated;
- Minimizing personal protective equipment waste through effective planning;
- Using real-time analyses to delineate the extent of contamination;
- Optimizing waste container utilization and recycling;
- Removing surface contamination from subsurface structures and pipes; and
- Reusing uncontaminated soil and materials on site.

Waste minimization was considered in the development of remedial alternatives in the feasibility study for the DOE areas.

3.2.1 Recycling

A recycling program instituted in 2001 continued at LEHR in 2009 to the extent that personnel were present at the Site. To the extent practicable, all paper, plastic, and cardboard wastes generated by the project are recycled and volumes are reported through the Stoller EMS Waste Minimization, Pollution Prevention Program.

3.3 Environmental Monitoring and Surveillance

Environmental monitoring was performed by S.M. Stoller Corporation, Weiss, and/or their subcontractors, with the exception of groundwater monitoring, which was performed by UC Davis.

Environmental monitoring at LEHR is composed of two activities: effluent monitoring and environmental surveillance. Effluent monitoring involves the collection and analysis of liquid and gaseous effluent samples to characterize and quantify contaminants released to the environment. These data are used to assess the exposure of and risk to the public, and to demonstrate compliance with applicable regulations. Environmental surveillance involves the collection and analysis of air, water, soil, terrestrial foodstuffs, biota, and other media on or near DOE sites, and the measurement of external radiation. These data are used to assess potential exposure to the public, evaluate impacts on the environment, and demonstrate compliance with applicable regulations. Because activities at the Site are conducted under Superfund requirements, water, soil, and biota monitoring is integrated into the Superfund process, as discussed in the following sections.

3.3.1 Pre-Operational Monitoring

An environmental study must be conducted prior to the start of any new process that has the potential for significant adverse environmental impact. The study should be not less than one year, and preferably two years, before the start of any new process to evaluate seasonal changes, and should be consistent with National Environmental Policy Act requirements. The study shall:

- Characterize existing physical, chemical, and biological conditions that could be affected;
- Establish background levels of radioactive and chemical components;
- Characterize pertinent environmental and ecological parameters;
- Identify potential pathways for human exposure or environmental impact; and
- Provide a basis for developing routine operational and emergency effluent monitoring and environmental surveillance programs.

No activities with potential for significant adverse environmental impacts were conducted at the Site in 2009. Proposed remedial activities were evaluated in the feasibility study in compliance with National Environmental Policy Act requirements.

3.3.2 Water Monitoring

There are currently no active process-based effluent discharges from LEHR facilities to the environment that would require effluent stream monitoring. Storm water runoff is the only potential liquid effluent sources of contamination.

Certain storm drains at LEHR are directed into the UC Davis combined storm and sanitary sewer system and subsequently treated by the UC Davis Waste Water Treatment Plant. The plant operates under National Pollutant Discharge Elimination System Permit No. CA0077895, which contains the waste water discharge requirements for the facility. Environmental monitoring and surveillance of the UC Davis Waste Water Treatment Plant is conducted by UC Davis, and is discussed in Sections 4.3 and 5.3 of this report.

In accordance with the Memorandum of Agreement between DOE and UC Davis (DOE, 1997), in 2009 DOE collected storm water samples from a lift station located on the western border of the Site (LS-01 on Figure 3-1), and UC Davis collected samples from the UC Davis areas of the Site (LF-01 and LF-03 on Figure 3-1). The LS-01 collection point is a lift station located on the western side of the Site, which pumps runoff to a ditch along the west side of Old Davis Road. All the storm water monitoring data collected by UC Davis and DOE are included in an annual report prepared by UC Davis.

In accordance with the *Final Revised Field Sampling Plan* (D&M, 1998), storm water sampling is conducted for two separate rainfall events: 1) the first significant storm event of the rainy season to sample runoff that may carry material that accumulated on the ground surface during the summer months; and 2) a large storm event late in the rainy season.

Electrical conductivity, pH, and temperature are measured in the field during the rain events, and storm water samples are analyzed for the following possible contaminants: selected metals (arsenic, antimony, barium, cobalt, copper, chromium, iron, lead, nickel, manganese, mercury, and vanadium); volatile organic compounds (2-butanone, chloroform, acetone, toluene); total oil and grease; suspended and dissolved solids; total organic carbon; nitrate; nitrite (as nitrogen); hardness; aquatic toxicity; and selected radionuclides (tritium, carbon-14,). Analyses for radium-226, strontium-90, and pesticides/PCBs in storm water ceased in 2008, when a more limited suite of analytes was proposed and approved in the Annual Water Monitoring Report (Brown and Caldwell, 2008).

In 2009, UC Davis monitored storm water runoff from the UC Davis areas of the Site. DOE monitored storm water runoff from the DOE areas only. The monitoring results are discussed in detail in Sections 4.3.1 (radiological) and 5.3.1 (non-radiological).

3.3.3 Groundwater Monitoring

DOE and UC Davis signed a Memorandum of Agreement (DOE, 1997) to divide responsibility for site areas of contamination according to historical site use and operation. UC Davis has assumed responsibility for groundwater monitoring and remediation activities. The locations of groundwater monitoring wells are shown on Figure 3-1. In 2009, UC Davis performed all site groundwater monitoring.

In 2009, UC Davis began a field pilot test to assess the effectiveness, implementability, and cost of field injections of calcium polysulfide to reduce concentrations of hexavalent chromium in

groundwater HSU-1 and -2 (Weiss, 2010a). Fourteen new wells were installed for this purpose and samples were collected from these wells in late November 2009 to establish the baseline condition. Groundwater from these wells was monitored in 2009 after injections of calcium polysulfide, and will continue to be monitored until the end of 2010. A report of this investigation will be issued in 2011. Thirteen of the new wells (CrPMW1-015d, -015i, and 015s; CrPMW1-025d, -025i, and -025s; CrPMW2-020a through c; CrPMW2-040a through c; and CrPIW2-01) were installed in the eastern portion of the site. The 14th well (UCD1-067) was installed northwest of the other wells (Figure 3-1) to further define the extent of chloroform and chromium in groundwater (Weiss, 2010c).

The groundwater monitoring results are discussed in Section 6.

3.3.4 Air Monitoring

There are currently no point sources of radionuclide or chemical emissions at LEHR. Sampling for hazardous materials is not required because there are no appreciable quantities of uncontained hazardous materials in the surface soil (D&M, 1992; Bechtel Environmental, Inc., 1991).

Radioactive and non-radioactive materials in air were monitored at a number of locations at and near the Site, from August 1995 through 2002, during site remediation activities. The majority of radionuclide analytical results for samples collected during this period were close to or below the minimum detectable activity for the laboratory analysis methods. Due to the completion of remediation activities, and with the concurrence of EPA, DOE discontinued surveillance air monitoring at the Site at the end of 2002.

Airborne emissions of radioactive and hazardous materials from DOE-controlled facilities are subject to US EPA regulations. The primary regulatory driver for air monitoring programs at DOE facilities is Title 40 CFR Part 61, Subpart H, National Emission Standards for Hazardous Air Pollutants for Emissions of Radionuclides from DOE Facilities. Subpart H of the National Emission Standards for Hazardous Air Pollutants requirements primarily target point-source/stack emissions. However, a Memorandum of Understanding between the DOE and the US EPA (DOE, 1995) applies the same criteria to potential diffuse area sources as are required of point sources. The National Emission Standards for Hazardous Air Pollutants regulations require that radionuclide emissions not exceed levels that would result in an effective dose equivalent of 10 mrem/yr. Measurement of emission rates is required for all release points with the potential to release radionuclides into the air that would cause an effective dose equivalent in excess of one percent of the standard (i.e., an effective dose equivalent greater than 0.1 mrem/yr) and all radionuclides which could contribute to greater than 10 percent of the potential effective dose equivalent for a release point. A discussion of compliance with Subpart H of the National Emission Standards for Hazardous Air Pollutants is provided in Section 4.1.1.

3.3.5 Ambient Radiation Monitoring

An ambient radiation monitoring program to quantify penetrating gamma radiation from DOE activities at LEHR was discontinued at the end of 2004 after completion of site removal actions.

3.4 Protection of Biota

Order 5400.5 (1991) requires that populations of aquatic organisms be protected to a dose limit of one rad per day. Recommended dose limits of one rad per day for terrestrial plants and 0.1 rad per day for terrestrial animals are to be applied in the evaluation of terrestrial systems. The DOE Technical Standard, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE-STD-1153-2002), is available for use in the evaluation and reporting of compliance with both aquatic and terrestrial biota dose limits.

As discussed in Section 2.1.1, an ecological risk assessment evaluating the impact of residual site contamination on ecological resources, including aquatic and terrestrial species, was approved by regulatory agencies in August 2006. It concludes that residual contamination at the Site is not a concern for ecological receptors.

3.5 Training

Due to completion of site removal action and waste management activities, on-going site training has been reduced to the minimum required for conducting routine site inspections and collection of samples.

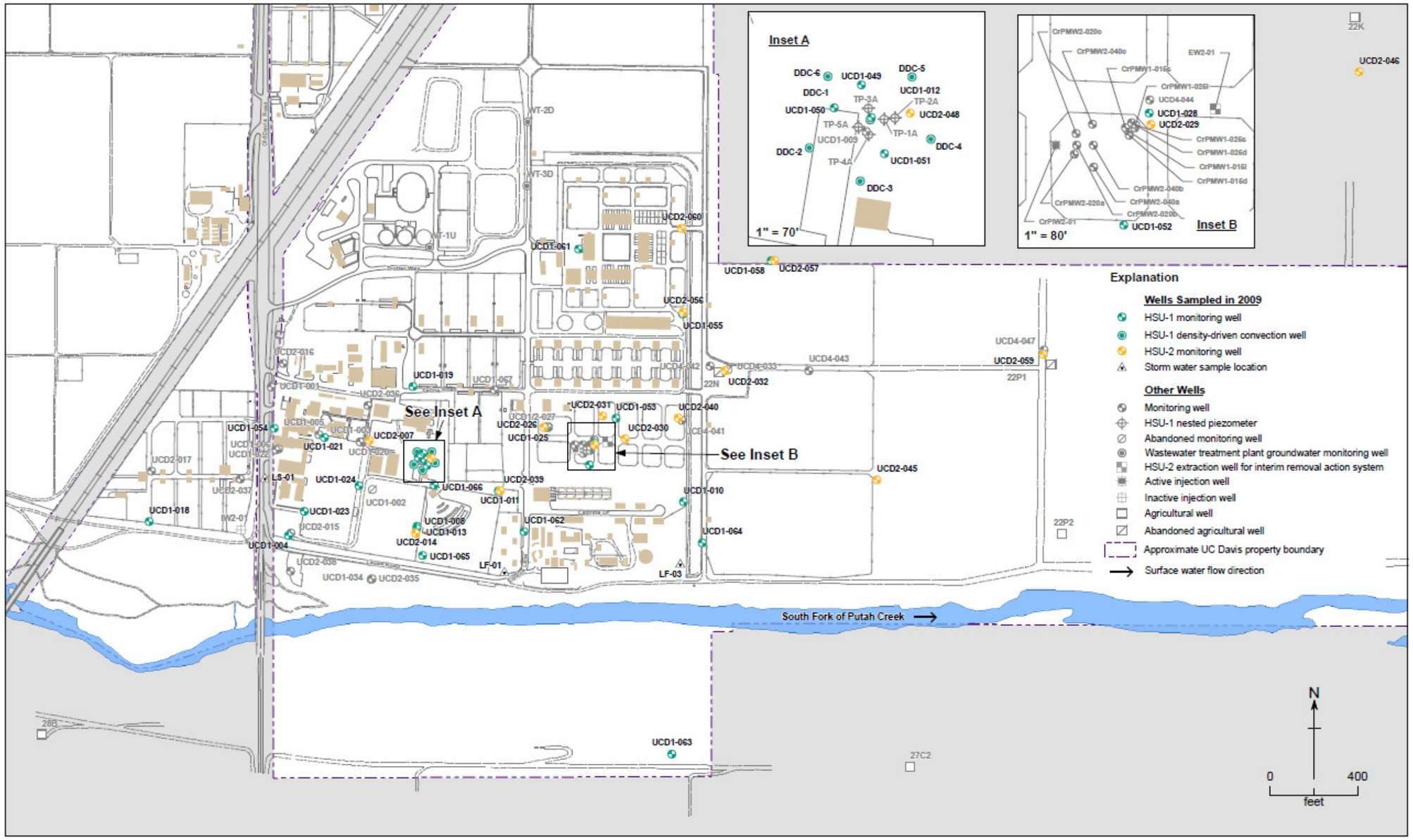

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Figure 3-1. Groundwater and Storm Water Monitoring Locations

4. ENVIRONMENTAL RADIOLOGICAL PROTECTION PROGRAM INFORMATION

This section summarizes significant results and trends in radiological air, soil, and water monitoring data for 2009. The majority of radionuclide sample results for samples collected at the Site in 2009 were close to or below the minimum detectable activity for the laboratory analysis methods. Table 4-1 provides a summary of calculated public radiological dose exposure from DOE activities at the Site.

4.1 Radiological Discharges and Doses

Inhalation of site air emissions constitutes the only major exposure pathway for radiological dose at LEHR. There is no exposure to drinking water at the Site and occupational exposures to contaminated soil are managed in accordance with the CERCLA process and DOE Orders discussed in Section 2.

Radioactive and non-radioactive particulates or constituents in air have been monitored at a number of locations at and around the Site from August 1995 through 2002 during remediation activities. This monitoring indicated that the maximum concentrations of air contaminants of concern were well below their respective derived concentration guide values, and did not pose health risks to site workers or laboratory personnel at LEHR. The concentrations only marginally exceeded the concentrations at the background monitoring station. Since the completion of removal actions in 2002, surveillance air monitoring at the Site was discontinued.

4.1.1 National Emission Standards for Hazardous Air Pollutants Dose Estimation Calculations

Calculations were performed to determine the estimated radiation dose from site sources to the public. During 2005, the Western and Eastern Dog Pens were identified as the only remaining potential sources of non-point, diffuse radionuclide emissions. Radionuclide air emissions could potentially be generated by wind-blown, fugitive dust containing residual radioactivity above the site background concentrations. The Western Dog Pens ceased to be a source of emissions in September 2006, when the area was capped with a layer of clean imported soil.

Compliance with the National Emission Standards for Hazardous Air Pollutants requirements for diffuse, non-point source emissions was assessed using the US EPA atmospheric dispersion/radiation dose calculation computer code, CAP88-PC Version 1.0. This code was used to

calculate the effective dose equivalent to individual receptors at various distances from the only source of radionuclide air emissions at the Site in 2009, the Eastern Dog Pens area.

CAP88-PC computer code was used to calculate the effective dose equivalent to individual receptors at various distances from the Eastern Dog Pens. Doses were calculated for potential receptors in buildings at LEHR and receptors immediately outside of LEHR.

Based on the CAP88-PC model output, the maximally exposed individual at the LEHR facility would be a worker at the Geriatrics Building Nos. 1 and 2 with an effective dose equivalent of 2.81E-04 mrem/yr. The results are presented in Table 4-2.

The CAP88-PC computer model was also used to calculate the collective population dose as required by DOE Order 5400.5. The estimated collective population dose for 2009 was 1.2E-05 person – Roentgen(s) equivalent man per year (person-rem/year). The calculated effective dose equivalent for the off-site, maximally exposed individual is lower than in 2008 and several orders of magnitude below the 10 mrem/yr standard codified in Title 40 CFR Part 61, Subpart H.

4.2 Radiological Soil Measurements

No soil sampling for radiological analyses was performed in 2009.

4.3 Radiological Water Monitoring

Quarterly surface water sampling was terminated in 2007. Storm water sampling continued in 2009. Trends and conclusions drawn from storm water monitoring results are briefly discussed below. A detailed discussion of results, including tables summarizing the analytic data, can be found in the 2009 Comprehensive Annual Water Monitoring Report (Weiss, 2010c).

4.3.1 Storm Water Monitoring

The storm water samples collected by DOE from LS-01 on February 13, 2009 (one primary sample and one duplicate sample) were analyzed for carbon-14 and tritium. All sample results were below the contract required detection limits.

4.4 Ambient Radiation Monitoring Program

A radiation monitoring program using passive thermoluminescent dosimeters to monitor gamma radiation was maintained at the Site through the end of 2004. The total dose measurements from all locations monitored were well below the DOE limit of 100 mrem/yr for public exposure. The program was discontinued at the end of 2004 due to completion of all site activities.

Table 4-1. LEHR Radiological Dose Reporting Table for Calendar Year 2008

Pathway	Dose to Maximally Exposed Individual [1]		% of DOE 100-mrem/yr Limit	Collective Population Dose [2]		Estimated Population within 80 km
	(mrem)	(mSv)	%	(person-rem)	(person-Sv)	
Air	5.1E-04	5.1E-06	0.0005	2.2E-05	2.2E-07	3,650,000
Water [3]	-	-	-	-	-	-
Other Pathways [4]	N/A	N/A	N/A	N/A	N/A	N/A
All Pathways	5.1E-04	5.1E-06	0.0005	2.2E-05	2.2E-07	3,650,000

Notes

[1] The maximum total dose is the sum of effective dose equivalents modeled for each maximally exposed individual member of the public from potential radionuclide fugitive dust emission non-point sources. Additional information may be found in the 2009 National Emission Standards for Hazardous Air Pollutants Report (Weiss, 2010b).

[2] The collective population dose is for a population within 80 km of the Site.

[3] The water pathway dose was not estimated, but is assumed to be negligible.

[4] There are no other exposure pathways contributing to a radiological dose at LEHR.

Abbreviations

DOE	United States Department of Energy
km	kilometer
LEHR	Laboratory for Energy-related Health Research
mrem	millirem
mrem/yr	millirem per year
mSv	milliSievert
N/A	not applicable
rem	Roentgen equivalent man
Sv	Sievert
UC Davis	University of California, Davis

Table 4-2. Modeled Effective Dose Equivalents to Potentially Exposed Members of the Public Resulting from Radionuclide Emissions from Potential Non-Point Source of Fugitive Dust Emissions

Receptor location[1]			
Description	UC Davis Building Number	Distance and direction from Eastern Dog Pens[3]	Effective dose equivalent[2] (mrem/yr)
Geriatrics Buildings Nos. 1 and 2	H-292 and H-293	94 m N	**5.1E-04**
Specimen Storage Building	H-216	132 m WNW	2.6E-04
Inter-Regional Project No. 4 Building	H-217	143 m WNW	2.2E-04
Clinical Pathology	H-215	150 m WNW	2.0E-04
Cellular Biology Laboratory	H-294	155 m NNW	2.2E-04
Animal Hospital Buildings Nos. 1 and 2	H-219 and H-218	165 m NW	1.7E-04
UC Davis Building E of LEHR Site	N/A	180 m E	3.1E-05
Main Office	H-213	187 m NW	1.3E-04
Off-Site Receptor W of LEHR Site	N/A	500 m W	1.5E-05
Off-Site Receptor S of Putah Creek	N/A	1,000 m S	3.1E-06

Notes

[1]The list of receptor locations is in order of distance from the source.

[2]The effective dose equivalent to the potentially exposed member of the public is taken as the maximum modeled dose within a 45° sector in the direction and at the distance indicated. For example, the dose 94 m north of the Eastern Dog Pens area would be the maximum modeled dose within the sector bounded by 94 m NNE and 94 m NNW. See Appendix A for the modeled results for each distance and direction. Value in **bold face** is the modeled dose to the maximally exposed individual.

[3]The distance from an area source to a receptor is defined by CAP88-PC as the distance from the centroid of the area source to the receptor (US EPA, 1992). For the CAP88-PC modeling at the Site, the distance from an area diffuse source to a receptor is measured as the approximate distance from the centroid of the diffuse source to the centroid of the building assumed to house the receptor.

Abbreviations

°	degrees
E	east
LEHR	Laboratory for Energy-related Health Research
mrem/yr	millirem(s) per year
N	north
N/A	not applicable
NNE	north by northeast
NNW	north by northwest
m	meters
No(s).	number(s)
S	south
UC Davis	University of California, Davis
W	west
WNW	west by northwest

5. ENVIRONMENTAL NON-RADIOLOGICAL PROGRAM INFORMATION

This section summarizes significant results and trends in 2009 non-radiological LEHR air, soil, and water monitoring.

5.1 Non-Radiological Air Monitoring

No air monitoring was performed in 2009.

5.2 Non-Radiological Soil Monitoring

No soil monitoring for non-radiological constituents was performed in 2009.

5.3 Non-Radiological Water Monitoring

Surface water sampling was terminated at the end of 2007. Storm water monitoring continued in 2009. Trends and conclusions drawn from the storm water monitoring results are discussed briefly below. A detailed discussion of results and tables summarizing the analytical data can be found in the 2009 Comprehensive Annual Water Monitoring Report (Weiss, 2010c).

5.3.1 Storm Water Runoff Monitoring

Storm water runoff samples were collected at three monitoring locations, LF-01, LF-03, and LS-01 (Figure 3-1), during or after the following storm events throughout the 2009 rainy season:

- LF-01—February 6, February 12, and October 13;
- LS-01—February 13 and October 13, 2009; and
- LF-03—October 13

These samples were analyzed for constituents listed in Section 3.3.2. Three constituents exceeded U.S. EPA benchmark values for storm water. The results exceeding the benchmark values were as follows:

- Concentrations of total iron exceeded the benchmark of 1,000 micrograms per liter (µg/L) in at least one sample from each location. The sample results ranged from 1,300 to 15,600 µg/L.
- Concentrations of total suspended solids exceeded the benchmark of 100 milligrams per liter (mg/L) in a sample collected on February 6 (448 mg/L) from LF-01 and in a sample collected from LS-01 on February 13 (208 mg/L).
- Concentrations of nitrate and Nitrite as N exceed benchmarks (0.68 mg/L for both) in at least one sample from each location. Concentrations ranged from 1.0 to 4.3 mg/L.

Exceeding the benchmark values is not a permit or discharge violation, but it does require a discharger to review its best management practices to identify opportunities to reduce contaminant concentrations (RWQCB, 2007).

Mercury concentrations exceeded the U.S. EPA's water quality criterion for mercury (0.050 µg/L) promulgated under Section 303(c)(2)(B) of the Clean Water Act (California Toxics Rule). The criterion was exceeded in two samples collected from LF-01 (at concentrations of 0.17 and 0.59 µg/L on February 12 and 6, 2009, respectively) and LS-01 (at concentrations of 0.0824 and 0.0972 µg/L on October 13 and February 13, 2009, respectively). Concentrations of mercury in samples collected at LF-01 (duplicate sample) and LF-03 on October 13, 2009 were below this criterion.

A storm water sample and a field duplicate collected at LS-01 on February 13, 2009 were analyzed for aquatic toxicity with the test organism *Pimephales promelas* or fathead minnow. The 96-hour percent survival for the sample and the field duplicate were 75% and 95%, respectively. The 96-hour percent survival for a control sample and a dechlorinated control sample and field duplicates were 90%.

The data from these sampling events is presented in the 2009 Comprehensive Annual Water Monitoring Report (Weiss, 2010c).

5.3.2 National Pollutant Discharge Elimination System Data

The Site discharges its sanitary waste to the UC Davis Waste Water Treatment Plant according to National Pollutant Discharge Elimination System permit requirements. Current DOE activities do not contribute to hazardous discharges.

6. WATER MONITORING AND PUBLIC DRINKING WATER PROTECTION PROGRAM

Groundwater monitoring has been conducted at the Site since November 1990 and has been the responsibility of UC Davis since 1997. UC Davis submits quarterly and annual reports on groundwater monitoring to DOE for review and comment.

6.1 Uses of Groundwater in the LEHR Vicinity

As discussed in Section 1.6.3, local groundwater is utilized for both domestic supply and agricultural purposes. The major groundwater sources for both public and private water supplies in the Sacramento Valley are unconsolidated deposits of Pliocene and Pleistocene age, and older alluvium (DOE, 1992). Water from the first HSU is not used for drinking or irrigating purposes due to inadequate yield. A number of domestic and irrigation wells in the site vicinity produce water from HSU-2.

6.2 Potential Sources of Groundwater Pollution

Sources contributing to groundwater pollution at the Site include the UC Davis Landfill No. 2 (apparent source of volatile organic compounds) and the UC Davis Waste Burial Holes (Figure 1-2) (apparent source of tritium and carbon-14 contamination). UC Davis landfills and the former animal handling facilities at LEHR may be potential sources of nitrate contamination in the site groundwater.

6.3 Groundwater Monitoring

In 2009, UC Davis continued to monitor groundwater at the Site. Groundwater monitoring included measuring field parameters and/or collecting samples for laboratory analysis from 58 groundwater monitoring locations screened in two different HSUs. Approximately 105 samples were collected for laboratory analysis this year from monitoring and remediation wells.

No samples were collected during the third quarter. The wells were anticipated to be dry due to low water levels observed during sample collection in the second quarter.

The analytical results for samples from the groundwater monitoring wells were consistent with previously established chemical concentration trends. Monitoring results for this year indicate that:

- Chloroform concentrations continued to decline in 2009 from both HSU-1 (up to 760 µg/L at UCD1-051) and HSU-2 wells (up to 28 µg/L at UCD2-030), especially in wells near the groundwater extraction well EW2-01. The highest concentrations of chloroform were detected in HSU-1 groundwater immediately north of the Eastern Trenches. This area has been identified as the primary source area for chloroform, and is also the location of the DDC remediation system. Generally, chloroform concentrations in HSU-1 wells are higher with increasing depth of the well screen (DDC-1C has the deepest screen interval and historically has the highest HSU-1 concentrations).
- Total chromium was detected at concentrations up to 455 µg/L, which is consistent with historical results that have remained steady over time. As in recent years, samples with the highest chromium concentrations were collected from an area of HSU-1 around well UCD1-028 and located approximately 500 feet northeast of Landfill Unit No. 1. Chromium concentrations in HSU-2 wells ranged up to 83.6µg/L, about the same as in the previous year.
- Concentrations of nitrate as nitrogen (N) in both HSU-1 (up to 81 mg/L at UCD1-050) and HSU-2 (up to 18 mg/L at UCD2-007) are generally above concentrations in wells designated as background for each of these zones.
- Carbon-14 and tritium activities in groundwater in HSU-1 and HSU-2 have declined over time, and this trend continued in 2009. The highest carbon-14 activity for 2009 was 228 picocuries per liter (pCi/L), and the maximum tritium activity was 1,620 pCi/L.
- Elevated concentrations of 1,4-dioxane in two HSU-1 wells previously reported in 2008 (up to 14 µg/L) were not replicated in 2009. Concentrations of 1,4-dioxane in 2009 samples were low (maximum concentration of 5.3 µg/L) and concentrations in HSU-2 were below reporting limits.
- Field measurements of electrical conductivity (EC) in 2009 were used to show that TDS concentrations remained the same as previous years.
- Formaldehyde was not present above the reporting limit (20µg/L) in samples collected from four HSU-1 wells.

UC Davis re-surveyed the site groundwater monitoring wells for vertical control to verify well reference elevations.

The groundwater monitoring program and the 2009 sampling results are discussed in detail in the 2009 Comprehensive Annual Water Monitoring Report (Weiss, 2010c).

7. QUALITY ASSURANCE

Quality assurance is a key element of the environmental protection program for the Site. A Quality Assurance Project Plan (Weiss, 2000) describes the requirements for all quality-related work on the LEHR project and is fully implemented. The Quality Assurance Project Plan and other quality-assuring documents, such as standard quality procedures, standard operating procedures and task-specific work plans, govern all phases of the LEHR program, including site characterization, investigation, risk assessments, decontamination and decommissioning, waste management, and site restoration. The purpose of the Quality Assurance Project Plan and the other documents are to identify the specifications and methods employed to establish technical accuracy, precision and validity of measurements and statistics; and to provide a sound basis for management decisions based on environmental information collected from the Site. The LEHR Quality Assurance Project Plan, which was last revised in June 2000, was prepared in accordance with US EPA quality assurance specifications. It also conforms to DOE Order 414.1a; the Nuclear Safety Management Quality Assurance Requirements in Title 10 CFR, Part 830; and incorporates requirements of DOE Order 5400.1, General Environmental Protection, to ensure that DOE quality and environmental goals are met.

Environmental samples collected by DOE that are discussed in this report were collected, analyzed, reviewed, and validated according to the Quality Assurance Project Plan and other relevant standard operating procedures and/or task-specific work plans. To assure quality, quality control is integrated into all aspects of environmental sampling. Included in the Quality Assurance Project Plan and related documents are sections identifying quality control for sample collection requirements and specific quality assurance objectives for the measurement data. Quality control samples are run with each sample batch at the analytical laboratory to validate the method of analysis and the proficiency of the analyst. Because holding times are important to sample quality, they are carefully controlled. To ensure comparability of analytical data, all samples are analyzed by US EPA-approved methods, when available. When analytical results are received, they are reviewed according to the appropriate data quality objectives and data review procedures. All of the 2009 site air and water monitoring data have been presented in other reports. The specific review and validation process for each data set are presented in these reports, and are not discussed in detail herein.

7.1 Field Quality Assurance

Quality assurance for field sampling is accomplished by collecting field duplicates, decontamination rinsates, trip blanks, and field blanks, as appropriate. For each round of sampling, duplicate samples are collected from a selected sample point at the same location as the original sample to check for consistency in the sampling process. The duplicate sample serves as a check on the precision of the sampling and analytical procedures. Decontamination rinsates are analyzed

whenever the potential exists for cross-contamination from sampling equipment. Trip blanks are sent with each shipment of water samples requiring analysis for volatile organic compounds. Field blanks are collected to check for contamination during the water sampling process. Calibration records for each field instrument are maintained in the project files.

7.2 Laboratory Quality Assurance

Contracted laboratories providing analytical services for the LEHR project were evaluated by Weiss, S.M. Stoller Corporation, or UC Davis to ensure compliance with the quality assurance program requirements. Laboratory quality assurance is analyzed externally by submitting split samples, spiked samples, and blanks to the laboratories analyzing environmental samples. Laboratories must submit their analytical procedure for review if it differs from standard procedures. Each contract laboratory is required to maintain participation, as applicable, in DOE, State of California and/or US EPA-approved inter-laboratory quality assurance programs such as DOE's Environmental Measurement Laboratory Inter-Laboratory Comparison Program or US EPA's Water Pollution/Water Supply Program.

7.3 Summary of Quality Control Data Validation

The overall LEHR quality assurance objective is to collect and analyze environmental samples from the Site in a manner that ensures technical data are accurate and representative, are able to withstand scientific and legal scrutiny, and are useful for evaluating site conditions and remedial actions. The criteria used to specify quality assurance goals are precision, accuracy, representativeness, completeness, and comparability for evaluation of quality control data. These parameters are evaluated through data validation. Table 7-1 summarizes the components used to monitor and evaluate the quality of LEHR environmental data.

Table 7-1. Components of the LEHR Quality Control Program in Support of Data Quality Objectives

Data Quality Objective	Quality Control Component	Evaluation Criteria
Precision	• Field duplicate • Matrix spike • Matrix spike duplicate	Relative percent difference
Accuracy	• Matrix spike • Matrix spike duplicate • Surrogate spikes	Percent recovery
Representativeness	• Trip blanks • Field duplicate • Method blanks	Qualitative degree of confidence
Completeness	• Holding time • Valid data points	Percent valid data
Comparability	• Analytical methods • Field duplicates	Qualitative degree of confidence

8. DEFINITIONS

The following definitions are adapted from DOE Order 5400.5 and the US EPA.

Term	Definition
absorbed dose	The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest in that material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).
as-low-as-reasonably-achievable (ALARA)	A phrase (acronym) used to describe an approach to radiation protection to control or manage exposures (both individual and collective to the work force and the general public) and releases of radioactive material to the environment as low as social, technical, economic, practical, and public policy considerations permit. As used in United DOE Order 5400.5, ALARA is not a dose limit, but rather it is a process that has as its objective the attainment of dose levels as far below the applicable limits of the DOE Order as practicable.
collective dose equivalent and collective effective dose equivalent	The sums of the dose equivalents or effective dose equivalents of all individuals in an exposed population within an 80-kilometer (km) radius, for the purposes of DOE Order 5400.5, expressed in units of person-Roentgen equivalent, man (rem), (or person-Sievert). When the collective dose equivalent of interest is for a specific organ, the units would be organ-rem (or organ-Sievert). For purposes of DOE Order 5400.5, the 80-km distance shall be measured from a point located centrally with respect to major facilities or DOE program activities.
committed dose equivalent	The predicted total dose equivalent to a tissue or organ over a 50-year period after a known intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem (or Sievert).
committed effective dose equivalent	The sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem (or Sievert).
confirmation samples	Analysis for metals, nitrate, pesticides/polychlorinated biphenyls, semi-volatile organic compounds, volatile organic compounds and hexavalent chromium.
Curie (Ci)	A unit of radioactivity equal to 3.7×10^{10} disintegrations per second.
derived concentration guide	The concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in an effective dose equivalent of 100 mrem (1 milliSievert). Derived concentration guides do not consider decay products when the parent radionuclide is the cause of the exposure (derived concentration guide values are presented in Chapter III of DOE Order 5400.5).

Term	Definition
designated level	Cleanup levels for specific constituents of a waste that provide a site-specific indication of the water quality impairment potential of the waste. Designated levels are calculated by first determining the bodies of water that may be affected by a waste and the present and probable future beneficial uses of these waters. Next, site-specific "water quality goals" are selected, based on background water quality or accepted criteria and standards, to protect those beneficial uses. Finally, these water quality goals are multiplied by factors that account for environmental attenuation and leachability. The result is a set of Soluble and total designated levels that are applicable to a particular waste and disposal site and which, if not exceeded, should protect the beneficial uses of waters of the State. Wastes having constituent concentrations in excess of these designated levels are assumed to pose a threat to water quality and are, therefore, classified as 'designated wastes' and directed to waste management units that isolate these wastes from the environment.
DOE Orders	DOE directives intended to direct, guide, inform and instruct DOE employees in the performance of their jobs, and enable them to work effectively within the DOE and with agencies, contractors, and the public.
dose equivalent	The product of absorbed dose in rad (or gray) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or Sievert).
effective dose equivalent	The summation of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health-effects risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent due to penetrating radiation from sources external to the body. Effective dose equivalent is expressed in units of rem (or Sievert).
effluent monitoring	The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying contaminants, assessing radiation exposures of members of the public and demonstrating compliance with applicable standards.
environmental surveillance	The collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media from DOE sites and their environs, and the measurement of external radiation for purposes of demonstrating compliance with applicable standards, assessing radiation exposures of members of the public, and assessing effects, if any, on the local environment.
hazard index	The health impact of the non-carcinogenic compounds is quantified through the hazard index, which is the ratio of the expected concentration of a compound to the acceptable concentration of the compound. When more than one toxic compound is emitted, the hazard indices of the compounds are summed to give the total hazard index. A total hazard index of 1.0 or less is considered to be not significant and the resulting impact on public health is deemed acceptable.
maximally exposed individual	The maximally exposed individual is the representative member of the public who receives the highest estimated effective dose equivalent based on the sum of the individual pathway doses.

Term	Definition
members of the public	Persons who are not occupationally associated with a DOE facility or operations (i.e., persons whose assigned occupational duties do not require them to enter the DOE site). Also see: public dose.
picoCurie (pCi)	A unit of radioactivity equal to 1 x 10^{-12} Curies or 2.2 disintegrations per minute.
preliminary remediation goal	Initial cleanup goals that 1) are protective of human health and the environment; and 2) comply with applicable or relevant and appropriate requirements. Preliminary remediation goals are developed early in the remedy selection process based on readily available information and are modified to reflect results of the baseline risk assessment. They also are used during analysis of remedial alternatives in the remedial investigation/feasibility study.
public dose	The dose received by member(s) of the public from exposure to radiation and to radioactive material released by a DOE facility or operation, whether the exposure is within a DOE site boundary or off site. It does not include dose received from occupational exposures, doses received from naturally occurring "background" radiation, doses received as a patient from medical practices or doses received from consumer products.
quality factor	The principal modifying factor used to regulate the dose equivalent from the absorbed dose. For the purposes of DOE Order 5400.5, quality factors taken from DOE Order 5480.11 are to be used.
rad	Historical unit of measurement of the radiation energy absorption (dose) in matter. The rad is defined as the amount of radiation required for absorption of 100 ergs (1 erg = 10^{-7} joule) per gram of irradiated material.
radioactivity	Property or characteristic of radioactive material to spontaneously "disintegrate" with the emission of energy in the form of radiation. The unit of radioactivity is the Curie (or Becquerel).
reference man	A hypothetical aggregation of human (male and female) physical and physiological characteristics arrived at by international consensus (International Council for Radiation Protection Publication 23). These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological effects from ionizing radiation to a common base. The "reference man" is assumed to inhale 8,400 cubic meters of air in a year and to ingest 730 liters of water in a year.
remedial action	Those actions consistent with permanent remedy taken instead of, or in addition to, removal action in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment.
residual radioactive material	Any radioactive material which is in or on soil, air, equipment, or structures as a consequence of past operations or activities.
RESRAD	Residual Radioactivity model. Argonne National Laboratory computer model for evaluating radioactively contaminated sites (Argonne National Laboratory).
risk-based action standard	Site-specific, soil contaminant-specific concentrations above which an unacceptable risk to human health is predicted to exist. An unacceptable risk to human health is defined as exceeding a one-in-one million excess cancer risk over a 60-year exposure period.

Term	Definition
Roentgen	A unit of radiation exposure equal to the quantity of ionizing radiation that will produce one electrostatic unit of electricity in one cubic centimeter of dry air at zero degrees Celsius and standard atmospheric pressure.
Roentgen equivalent man (rem)	The dosage of ionizing radiation that will cause the same biological effect as one roentgen of x-ray or one gamma-ray dosage.

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10. ACKNOWLEDGMENTS

The following LEHR Project personnel worked on the Annual Site Environmental Report:

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