ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH
(U.S. DEPARTMENT OF ENERGY)
[a/k/a OLD CAMPUS LANDFILL (UNIVERSITY OF CALIFORNIA, DAVIS)]
DAVIS, SOLANO COUNTY, CALIFORNIA
EPA FACILITY ID: CA2890190000
JUNE 17, 2004

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Yolo County Library
Copy
DOE-039

DOCS
Lehr

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Agency for Toxic Substances & Disease Registry. . . . . Julie L. Gerberding, M.D., M.P.H., Administrator
Henry Falk, M.D., M.P.H., Assistant Administrator

Division of Health Assessment and Consultation. . . . . William Cibulas, Jr., Ph.D., Acting Division Director
Sharon Williams-Fleetwood, Ph.D., Deputy Director

Community Involvement Branch . . . . . .Germano E. Pereira, M.P.A., Chief

Exposure Investigations and Consultation Branch. . . . . .Susan Moore, Acting Chief

Federal Facilities Assessment Branch. . . . . .Sandra G. Isaacs, Chief

Program Evaluation, Records, and Information . . . . . Max M. Howie, Jr., M.S., Chief

Superfund Site Assessment Branch. . . . . Richard E. Gillig, M.C.P., Chief

Use of trade names is for identification only and does not constitute endorsement by the Public Health Service or the U.S. Department of Health and Human Services.

Additional copies of this report are available from:
National Technical Information Service, Springfield, Virginia
(703) 605-6000

You May Contact ATSDR TOLL FREE at
1-888-42ATSDR
or
Visit our Home Page at: http://www.atsdr.cdc.gov

PUBLIC HEALTH ASSESSMENT

LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH
(U.S. DEPARTMENT OF ENERGY)
[a/k/a OLD CAMPUS LANDFILL (UNIVERSITY OF CALIFORNIA, DAVIS)]

DAVIS, SOLANO COUNTY, CALIFORNIA

EPA FACILITY ID: CA2890190000

Prepared by:

Energy Section
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. (The legal definition of a health assessment is included on the inside front cover.) If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Interactive Process: The health assessment is an interactive process. ATSDR solicits and evaluates information from numerous city, state and federal agencies, the companies responsible for cleaning up the site, and the community. It then shares its conclusions with them. Agencies are asked to respond to an early version of the report to make sure that the data they have provided is accurate and current. When informed of ATSDR's conclusions and recommendations, sometimes the agencies will begin to act on them before the final release of the report.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E60), Atlanta, GA 30333.

Table of Contents

Foreword i

List of Tables v

List of Figures vi

List of Abbreviations vii

I. Summary 1

II. Background 5
- II.A Site Description and Operational History 5
- II.B Environmental Management and Restoration Activities 6
- II.C ATSDR Involvement 9
- II.D Demographics and Land Use 9
- II.E Quality Assurance and Quality Control 10

III. Evaluation of Environmental Contamination and Potential Exposure Pathways 12
- III.A Introduction 12
  - III.A.1 Evaluating Environmental Data 12
  - III.A.2 Evaluating Exposure 13
- III.B Groundwater 15
  - III.B.1 Site Hydrogeology and Groundwater Use 15
  - III.B.2 Groundwater Monitoring Programs 18
  - III.B.3 Nature and Extent of Groundwater Contamination 18
  - III.B.4 Groundwater Exposure Pathways 23
- III.C Soil 26
  - III.C.1 Nature and Extent of Contamination and Remedial History 26
  - III.C.2 Soil Exposure Pathway 33
- III.D Surface Water and Sediment (South Fork of Putah Creek) 35
  - III.D.1 Surface Water Hydrology and Sources of Surface Water Contamination 35
  - III.D.2 Nature and Extent of Surface Water and Sediment Contamination 39
  - III.D.3 Surface Water Exposure Pathways 40
- III.E Air 42
  - III.E.1 Air Monitoring Programs 42
  - III.E.2 Nature and Extent of Air Contamination 43
  - III.E.3 Air Exposure Pathways 44

III.F Biota (Edible Plants, Fish, and Shellfish) 45
III.F.1 Locally Grown Crops 45
III.F.2 Putah Creek Fish and Crayfish 47
III.G. Ambient Radiation 50

IV. Public Health Implications 51
IV.A Introduction 51
IV.B Special Considerations of Women and Children 52
IV.C Evaluation of Public Health Hazards from Private Drinking Water 53
IV.D Evaluation of Public Health Hazards from Exposure to Contaminants in Surface Water of Putah Creek 55
IV.E Evaluation of Public Health Hazards from Ingestion of Putah Creek Fish 57

V. Community Health Concerns 60

VI. Conclusions 67

VII. Recommendations 70

VIII. Public Health Action Plan 71

IX. Preparers of Report 74

X. References 75

Tables 80

Figures 110

Appendix A. Glossary A-1

Appendix B. Comparison Values B-1

Appendix C. ATSDR's Health Effects Evaluation C-1

Appendix D. Responses to Public Comments D-1

List of Tables

Table 1. Evaluation of Potential Public Health Hazards Associated with Study Areas at LEHR .81

Table 2. Chronological Summary of Environmental Restoration Activities at LEHR 86

Table 3. Evaluation of Exposure Pathways at LEHR 88

Table 4. Maximum Contaminant Concentrations Greater Than ATSDR Comparison Values in On-Site Groundwater Monitoring Wells 91

Table 5. Maximum Contaminant Concentrations Greater Than ATSDR Comparison Values in Off-Site Groundwater Monitoring Wells 93

Table 6. Maximum Contaminant Concentrations Greater Than ATSDR Comparison Values in Off-Site Private Domestic Wells 95

Table 7. Maximum Chemical Concentrations Greater Than ATSDR Comparison Values in Off-Site Irrigation Wells 96

Table 8. Maximum Contaminant Concentrations Greater Than Comparison Values in US Department of Energy (DOE) Source Areas Surface Soil 97

Table 9. Maximum Contaminant Concentrations Greater Than Comparison Values in University of California, Davis (UCD) Source Areas Surface Soil.....99

Table 10. Maximum Contaminant Concentrations Greater Than Comparison Values in On-Site Surface Soil Outside DOE and UCD Source Areas 100

Table 11. Maximum Contaminant Concentration Greater Than Comparison Values in Off-Site Surface Soil Samples 101

Table 12. Maximum Contaminant Concentrations Greater Than ATSDR's Comparison Values in the Sewage Treatment Plant Outfall (STPO): 1990-2001 102

Table 13. Maximum Contaminant Concentrations Greater Than ATSDR's Comparison Values at Storm Water Sampling Locations: 1996–2000.....104

Table 14. Maximum Contaminant Concentration Greater Than ATSDR's Comparison Values in Surface Water of Putah Creek, Downstream (PCD) Sampling Locations 106

Table 15. Maximum Contaminant Concentrations Greater Than ATSDR's Comparison Values in Surface Water of Putah Creek, Upstream (PCU) Sampling Location 108

List of Figures

Figure 1. Area Map 111
Figure 2. Site Location Map 112
Figure 3. ATSDR GIS Map 113
Figure 4. Exposure Pathways 114
Figure 5. UC Davis Domestic Supply Wells 115
Figure 6. Private Irrigation and Drinking Water Well Locations 116
Figure 7. Groundwater Monitoring Wells and Surface Water Sampling Locations 117

List of Abbreviations

AM#	Air monitoring location or station
ATSDR	Agency for Toxic Substances and Disease Registry
BHC	Benzene hexachloride, alpha- or beta-
BOD	Biochemical oxygen demand
Bq	Becquerel(s), one decay per second, or 2.703×10^{-11} Ci, or 27.03 pCi
Bq/kg	Becquerel(s) per kilogram
Bq/L	Becquerel(s) per liter
C-14	Carbon-14
CDC	Centers for Disease Control and Prevention
CDFA	California Department of Food and Agriculture
CDFG	California Department of Fish and Game
CDHS	California Department of Health Services
CDTSC	California Department of Toxic Substances Control
CEL	Cancer effect level
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CHE	Center for Health and the Environment
Ci	Curie(s) (1 Ci is equal to 10^{12} pCi)
CREG	ATSDR's Cancer Risk Evaluation Guide
CRWQCB	California Regional Water Quality Control Board
Cs-137	Cesium-137
CSF	Cancer slope factor
cu yds	Cubic yards
CV	Comparison value
D&D	Decontamination and decommissioning
dL	Deciliter (0.1 liter)
DOE	U.S. Department of Energy
DSCSOC	Davis South Campus Superfund Oversight Committee
DSS	Domestic Septic System
DST	Domestic Septic Tank
DW	Drinking Water Well
EDP	Eastern Dog Pens
EMEG	Environmental Media Evaluation Guide
EPA	U.S. Environmental Protection Agency
ESAADI	Estimated Safe and Adequate Daily Intake
ft bgs	Feet below the ground surface
g	Gram(s)

List of Abbreviations (continued)

GPR	Ground penetrating radar
H-3	Hydrogen-3 (tritium)
HSU	Hydrostratigraphic unit
ICRP	International Commission on Radiological Protection
IRA	Interim Remedial Action
ITEH	Institute of Toxicology and Environmental Health
IW	Irrigation well
kg	kilogram(s)
L	liter
LEHR	Laboratory for Energy-Related Health Research
LF	Landfill
LFI	Limited Field Investigation
LOAEL	Lowest-observed-adverse-effect level
LS	Lift station
LTHA	Lifetime Health Advisory
m^3	Cubic meter(s)
MCL	EPA's maximum contaminant level
mg	Milligram(s)
mgd	Million gallons per day
mg/kg	Milligram(s) per kilogram
mg/kg/day	Milligram(s) per kilogram of body weight per day
μg	Microgram(s)
μg/dL	Microgram(s) per deciliter
μg/L	Microgram(s) per liter
$\mu g/m^3$	Microgram(s) per cubic meter
MOA	Memorandum of Agreement
MRL	ATSDR's minimal risk level
MWSF	Mixed waste storage facility
N	Nitrogen
NAREL	National Air and Radiation Laboratory
NCRP	National Council on Radiation Protection and Measurements
NOAEL	No-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission (also used as an abbreviation for "National Research Council" in Appendix C)
Pb-210	Lead-210

List of Abbreviations (continued)

PCB	Polychlorinated biphenyl
PCD	Putah Creek Downstream
pCi	Picocurie(s) (1 pCi is equal to 10^{-12} Ci)
pCi/g	Picocurie(s) per gram
pCi/L	Picocurie(s) per liter
PCU	Putah Creek Upstream
PHA	Public health assessment
PHAP	Public Health Action Plan
ppb	Part(s) per billion
ppm	Part(s) per million
Ra-226	Radium-226
RBC-c or -n	Risk-based concentration (based on cancer or non-cancer effects)
RCRA	Resource Conservation and Recovery Act
RfD	EPA's reference dose
RMEG	ATSDR's Reference Dose (or Concentration) Media Evaluation Guide
RPM	Remedial project manager
SARA	Superfund Amendments and Reauthorization Act
SD	Storm drain
Sr-90	Strontium-90
STPO	Sewage Treatment Plant Outfall
SVOC	Semivolatile organic compound
SWT area	Southwest Trench Area
SWAT	Solid Waste Assessment Test
TAG	Technical Advisory Group
TDS	Total Dissolved Solids
Th-234	Thorium-234
U-235	Uranium-235
U-238	Uranium-238
UC	University of California
UCD	University of California, Davis
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USDA	U.S. Department of Agriculture
VOC	Volatile Organic Compound
WDP	Western Dog Pens
WWTP	Waste Water Treatment Plant

I. Summary

The Laboratory for Energy-Related Health Research/Old Campus Landfill (LEHR) site is in northeast Solano County, just outside of Davis, California, on the University of California (UC), Davis campus. The 15-acre site is surrounded by farmland and UC Davis property and is 12 miles west of Sacramento. The South Fork of Putah Creek flows east approximately 125 feet from the southern boundary of the site.

From 1958 through 1989, the site was used for U.S. Department of Energy (DOE)–sponsored research, conducted by UC Davis, to simulate radiation effects on humans by studying the biodistribution and long-term effects of primarily radium-226 and strontium-90 on beagle dogs. Dogs were also dipped in chlordane, for flea control, from 1960 until 1968. Between the late 1950s and the early 1970s, low-level radioactive waste, feces, gravel from the on-site dog pens, and laboratory waste from LEHR were disposed of on site.

Before 1967, UC Davis operated three landfills on the site for the disposal of university waste. Two of these former disposal areas, are located within the fenced area where DOE research activities later occurred. The third is located on the far eastern edge of the site.

The site is currently occupied by the UC Davis Center for Health and the Environment (CHE) (formerly the Institute of Toxicology and Environmental Health [ITEH]). CHE conducts research in toxicology, epidemiology, radiation biology, and radiochemistry. This research is not related to past LEHR activities.

Restoration of the LEHR site began in 1989. DOE began decontamination and decommissioning of site facilities, leading to investigations of the environmental impact of past activities. Because of the findings of these investigations and the potential contamination to groundwater, the site was placed on the U.S. Environmental Protection Agency (EPA) National Priorities List (NPL) in May 1994. Contaminants of concern include pesticides (specifically chlordane), certain metals, volatile organic compounds (VOCs) (particularly chloroform), and radioactive contaminants (e.g., radium-226 and strontium-90). In 1997, a Memorandum of Agreement (MOA) between DOE and UC Davis divided the responsibility for environmental restoration of the site between UC Davis and DOE, based on historical site use.

In 1995 and 2000, the Agency for Toxic Substances and Disease Registry (ATSDR) visited the site and met with community members and other stakeholders to learn more about site conditions and community health concerns. In 1997 and 1998, ATSDR released three health consultations about nitrates in the water and the safety of eating fish from Putah Creek.

Using the information obtained during site visits, discussions with community members, findings of site investigations conducted by DOE and UC Davis, and the results and recommendations of previous ATSDR studies, ATSDR closely examined the nature and extent of chemical and radioactive contamination associated with the site. The findings of this comprehensive evaluation are presented in this public health assessment (PHA).

As part of its evaluation process, ATSDR evaluated whether the public has been exposed to harmful levels of site contaminants. Past, current, and potential future exposure situations were considered. The focus of ATSDR's assessment was on public exposures occurring beyond the LEHR site boundaries. Sources other than LEHR (e.g., local agricultural practices and former mining activities) may be the predominant source of some of the contaminants associated with these exposures. ATSDR evaluated possible health hazards associated with *off-site exposures* to drinking water, water and sediments in the South Fork of Putah Creek, and fish from the creek, and concluded the following:

I. ***Use of private well water.*** *ATSDR determined that there is the potential for exposure to detected contaminants (particularly metals and nitrate) in off-site groundwater by way of private drinking water wells and irrigation wells.* The potential for exposure to site-related contaminants is low, because few drinking water wells exist in the path of groundwater flow from the site and few people come into direct contact with irrigation well water.

Based on its review of available data, ATSDR has concluded that the highest nitrate levels detected in off-site wells could pose a risk to infants ingesting water directly or water mixed with formula. As such, ATSDR categorizes the potential for nitrate exposure in private wells as a *public health hazard.*[1]

ATSDR recommends that private well users in the area continue to have their wells tested regularly and restrict use if elevated nitrate levels (i.e., levels greater than 10,000 parts per billion) are reported. ATSDR also recommends that UC Davis continue to test groundwater as part of its ongoing groundwater treatment and monitoring program to ensure that contaminants are not reaching groundwater used for drinking water supplies.

[1] ATSDR's public health conclusion categories depend on the degree of hazard, if any, identified during the public health assessment process. A description of each of the conclusion categories is provided in the glossary in Appendix A of this report.

(The contaminants detected in tested private wells are not believed to be related to the LEHR site. Also, public drinking water supplies have not been affected by groundwater contamination associated with the LEHR site, including UC Davis supply wells.)

II. ***Recreational use of Putah Creek.*** *ATSDR determined that people currently using Putah Creek for swimming or fishing are not expected to come in contact with harmful levels of site-related contaminants.*

Putah Creek receives treated waste water and storm water drainage from all parts of the UC Davis campus. Based on available monitoring data (1989 to present), there is a potential for exposure to contaminants in surface water and storm water, but chemical and radioactive contamination was detected infrequently and at concentrations below health-based screening values. Because creek water is not used as a drinking water source, exposure is likely limited to dermal contact by anglers or swimmers, and/or incidental ingestion (e.g., accidental ingestion when swimming in Putah Creek). Direct contact with waste water and storm water before dilution in the creek is also possible, but less likely. Such exposures are not harmful. *ATSDR therefore categorizes current and future exposures as posing no apparent public health hazard.*

No sampling data for surface water are available prior to 1989, however. This represents a data gap in assessing *past* exposure conditions, when LEHR-related discharge to the creek was likely the greatest. Thus, *past exposures to Putah Creek surface water are categorized as an indeterminate public health hazard.*

III. ***Consumption of fish from Putah Creek.*** *ATSDR determined that many of the largemouth bass from Putah Creek near the LEHR site had elevated levels of mercury, making them a public health hazard for any fetus or nursing child whose mother eats the fish.* ATSDR evaluated fish sampling data in areas of Putah Creek near the LEHR site. Recognizing that other contamination sources exist in the area, including local agriculture and mines further upstream known to leach mercury, ATSDR also evaluated available fish data collected upstream and further downstream from the LEHR site. Comparable levels of mercury were detected throughout the area.

To date, no fish consumption advisory has been issued by the California Department of Fish and Game (CDFG) for the area of Putah Creek near the LEHR site. ATSDR recommends that pregnant women and nursing mothers refrain from eating largemouth bass to prevent exposure of their developing or nursing infants to mercury.

ATSDR also evaluated possible *on-site contamination sources* (groundwater, soil, and air emissions) and concluded the following: *The public is not expose to harmful levels of chemical or radioactive contamination detected on the LEHR site.* Contamination was detected in

groundwater beneath the site, but this water is not used as a drinking water source and therefore can pose no harm. As such, *ATSDR categorizes the on-site groundwater pathway as posing no public health hazard for past, current, and potential future exposures*. As mentioned previously, ATSDR recommends that UC Davis continue to test groundwater to ensure that contaminants are not reaching groundwater used for drinking water supplies.

Lastly, our assessment indicated that exposures to contaminants detected in on-site soil and air, or to ambient radiation, are not associated with any known harmful effects: exposure to the general public either is unlikely, has been prevented, or involves contaminant concentrations too low to pose a health hazard. Further, cleanup activities have removed all of the contamination sources from the LEHR site. Therefore, *ATSDR categorizes these pathways as posing no apparent public health hazard for past, current, or potential future exposures*.

II. Background

II.A Site Description and Operational History

The Laboratory for Energy-Related Health Research/Old Campus Landfill (LEHR) site is a 15-acre site currently owned by the Regents of the University of California, and includes areas used in the past for research and waste disposal by both DOE and University of California, Davis (UC Davis). The site is 1.2 miles south of the main UC Davis campus site, just outside of Davis, California, in northeast Solano County, near Yolo County. Property to the west, south, and east of the LEHR site is farmland, and UC Davis property lies to the north of the site. The Sacramento metropolitan area is approximately 12 miles east of the LEHR site. The south fork of Putah Creek flows east approximately 125 to 250 feet from the southern boundary of the site (Weiss Associates 1999a) (see Figures 1 and 2).

The past mission of LEHR was research—sponsored by the U.S. Department of Energy (DOE) and its predecessor, the Atomic Energy Commission, and conducted by UC Davis from 1958 through 1989—to simulate radiation effects on humans, mainly by studying the biodistribution and long-term effects of radium-226 (Ra-226) and strontium-90 (Sr-90) on beagle dogs. Dogs involved in Ra-226 and Sr-90 research activities were housed in the Eastern and Western Dog Pens on the LEHR site. The radionuclide-dosed dogs were initially kept indoors in the Animal Hospital building for approximately 30 days after dosing, although the amount of time varied depending upon the radioactivity levels. Then they were moved to the dog pens, where they would generally remain for the remainder of their lives (10 to 12 years). Dogs were dipped in chlordane, for flea control, from 1960 until 1968. This practice took place near the western boundary of the Western Dog Pens, and was halted after excess exposure to chlordane impacted the health of the dogs. Chlordane had also been sprayed on the ground near the pens to combat fleas. An estimated 25 to 50 gallons of chlordane were used each year (Weiss Associates 1999b).

Facilities associated with past DOE-related activities at LEHR include the radium and strontium waste water treatment systems, an indoor/outdoor cobalt-60 beam irradiator, disposal trenches, animal hospitals, outdoor dog pens, Domestic Septic Systems, and a DOE Disposal Box (Figure 2). In addition, there are three closed landfills that received UC Davis campus waste in the past. UC Davis Landfill Unit 1 is located on the site southeast of the Cobalt-60 irradiation field and was used from the 1940s to the mid-1960s. The Eastern Dog Pens were built over UC Davis Landfill Unit 2. UC Davis Landfill Unit 3 is located along the eastern border of the site. All three landfills have been closed since 1967. Several other on-site disposal areas also received campus and LEHR research waste until 1974. Dog feces and gravel that were removed from the dog pens were disposed of in trenches and waste holes on the LEHR site. Some gravel may have also been disposed of off site. The primary on-site disposal area, the Southwest Trench Area, is a flat, unpaved area covering approximately 0.5 acres in the southwest corner of the site. Between the

late 1950s and the early 1970s, low-level radioactive waste, feces, gravel from the on-site dog pens, and laboratory waste from LEHR were disposed in these trenches (Weiss Associates 1999a, 1999c; ATSDR 1995). In addition, the South Fork of Putah Creek, which flows within a man-made channel south of LEHR, has received treated waste water and storm water drainage from all parts of the UC Davis campus. Historical waste water discharges included more than 3 million gallons of low-level radioactive waste, which were directed to the Imhoff building for treatment prior to discharge to the associated leach fields or dry wells.

In 1988, based on a Memorandum of Agreement (MOA) between DOE and the University of California, DOE initiated activities to close out the research program at LEHR (Weiss Associates 1999a); DOE research activities at LEHR ceased in 1989. Several removal actions have been performed to decontaminate affected areas. (Removal actions are discussed in Section II.B and Table 2 of this public health assessment [PHA].) The site is currently occupied by the UC Davis Center for Health and the Environment (CHE), which conducts research in toxicology, epidemiology, radiation biology, and radiochemistry; this research is not related to past LEHR activities. The site currently consists of 15 buildings, including a main administration and office building, animal handling facilities, a laboratory, and support buildings (Weiss Associates 1999a).

II.B Environmental Management and Restoration Activities

The 1988 MOA between DOE and UC Davis ended the research program at LEHR and began the closure of DOE facilities (Weiss Associates 1999a). Restoration of the LEHR site, including the removal of some buildings, cages, and the contents of waste tanks, began in 1989. As part of the California State Solid Waste Water Quality Assessment Test Program, UC Davis began an investigation of the landfill areas in 1989–1990. DOE began decontamination and decommissioning (D&D) of site facilities in 1992, leading to investigations of the environmental impact of past activities. Based on the findings of these investigations and the potential contamination to groundwater, the LEHR site was placed on the U.S. Environmental Protection Agency (EPA) National Priorities List (NPL) in May 1994 (Dames & Moore 1998). The principal regulatory agencies overseeing investigations and restoration activities are the U.S. EPA, the California Regional Water Quality Control Board (CRWQCB), the California Department of Toxic Substances Control (CDTSC), and the California Department of Health Services (CDHS) Radiologic Health Branch.

Through environmental investigations and site assessments conducted at the LEHR site, DOE and UC Davis have identified several sites with evidence of contamination. These sites, which are described in more detail in Table 1, include:

- DOE disposal areas—the Southwest Trenches and DOE Disposal Box, where low-level radioactive waste, fecal material from the dog pens, and/or laboratory waste were disposed of.

- Radium and strontium treatment systems—the Ra-226 or Sr-90 treatment tanks and accompanying leach fields and dry wells or leach systems.

- Dog pen areas—the Eastern Dog Pens, the Western Dog Pens, and the North Chemical Dispensing Area, which housed the research dogs. Chlordane for flea control was sprayed in and around these areas.

- The Domestic Septic System—the seven septic tanks associated with the domestic septic systems for buildings on site.

- Landfill Units 1, 2, and 3—UC Davis used these three landfill areas to dispose of campus solid waste during the 1940s, 50s and 60s. Sanitary and limited chemical and radioactive wastes are thought to have been buried there (Weiss Associates 1997a)

- 49 waste holes—Located along the southern edge of the Eastern Dog Pen area, the waste holes received radioactive waste from UC Davis Campus Laboratories (Weiss Associates 1997a).

- South and east disposal trenches—Located along the south and east side of the dog pen areas, these trenches received chemical and radioactive waste from UC Davis laboratories from 1957 to 1960 (Weiss Associates 1997a).

- Old Waste Water Treatment Plant—This treatment plant processed UC Davis campus waste water until 1949, when it was replaced by a new facility on the main campus. Currently, the California Raptor Center is housed in this area of the site.

In 1997, another MOA between DOE and UC Davis divided the responsibility for environmental restoration of the site between the two parties, based on historical use. That is, DOE is responsible for contamination related to its past activities, including their buildings, dog pens, and associated disposal areas. UC Davis is responsible for investigating and remediating landfills and other waste disposal areas used by UC Davis, groundwater, and surface water. Environmental restoration responsibilities were broken down as follows (Weiss Associates 1997a):

DOE

- DOE buildings
- Southwest Trench Area (disposal trenches)
- Dog pens and associated gravels
- Radium and Strontium Treatment Systems area
- 7 Domestic Septic System areas
- DOE disposal box area
- Cobalt-60 irradiation field

UC Davis

- Landfill Units 1, 2, and 3
- 49 waste holes
- UC Davis Disposal Trenches (south and east of the landfills)
- Old Waste Water Treatment Plant
- Groundwater
- Surface water

Environmental investigations associated with LEHR began in 1984, when surface and subsurface soil sampling was first performed. Subsequent investigations have been conducted in all areas where contamination was suspected (e.g., dog pens, areas of historical waste disposal) to characterize the extent of soil contamination and to assist and direct restoration activities (Weiss Associates 2003). Groundwater monitoring has been conducted quarterly for the LEHR site since 1987. Surface water sampling began in November 1990. DOE conducted quarterly sampling at three locations through 1996. UC Davis took over the surface water sampling in 1997, and in 2000 began sampling in four locations. Since the fall of 1994, storm water sampling has been conducted twice yearly (once during the first major rain event of the rainy season, and once near the approximate end of the rainy season). Radioactive and nonradioactive materials in air have been monitored at a number of locations on and around the LEHR site since 1995 (Weiss Associates 2003). Fish and shellfish from Putah Creek were tested for selected radionuclides, metals, volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), and pesticides in a number of studies from 1995 through 1998 (ATSDR 1997, Slotton et al. 1999).

Primary DOE restoration/remediation activities that have been or will be performed at the LEHR site include soil and groundwater characterization; building assessment; decontamination and decommissioning of aboveground structures; waste management; chemical and radiological risk assessment; and remediation of contaminated trenches, soil, and underground tanks (Weiss Associates 1999a). Ongoing restoration/remediation activities being conducted by UC Davis include soil and groundwater characterization; excavation of buried radiologic waste; operating and monitoring of the groundwater treatment system; monitoring groundwater (quarterly); and monitoring surface water and storm water (biannually) (Dames & Moore 2001). See Table 2 for a more detailed chronology of site restoration activities.

The investigation and restoration activities of each exposure pathway are discussed in more detail in the "Evaluation of Environmental Contamination and Potential Exposure Pathways" section (Section III) of this PHA.

II.C ATSDR Involvement

Through the PHA process, ATSDR assesses conditions at sites from a public health perspective to determine whether people can be exposed to site-related contaminants through contact with the groundwater/drinking water, surface water, soil, biota, or air. As part of the PHA process, ATSDR visited the LEHR site in 1995 to collect information about environmental contamination and possible exposure situations at the site. ATSDR met with community members, including representatives of the Davis South Campus Superfund Oversight Committee (DSCSOC); DOE; DOE contractors; U.S. EPA; UC Davis; the CDHS; the California EPA; and the state and regional water control boards (ATSDR 1995). Based on the visit and a preliminary review of the data, ATSDR did not find any health threats at LEHR requiring *immediate* attention. ATSDR did, however, identify concerns among the community about consumption of Putah Creek fish and nitrate in local private wells.

Following the site visit, ATSDR prepared a site summary report (1995) and published three health consultations in 1997 and 1998. The first two health consultations focused on fish sampling and analysis in Putah Creek; the third health consultation focused on nitrate in groundwater. The results and recommendations of these ATSDR studies are discussed in this PHA.

In April 2000, ATSDR revisited the LEHR site. The visit included viewing the site and surrounding area by foot and vehicle with DOE and UC Davis staff; attending a town meeting; holding meetings with representatives of the CRWQCB, UC Davis, DOE, the Yolo County Health Department, and a representative of DSCSOC; and attending a meeting of remedial project managers (RPMs) that was also attended by regional EPA and state CRWQCB staff. Again, ATSDR did not find any situations requiring immediate attention. The information provided during this site visit has been incorporated into this PHA.

II.D Demographics and Land Use

The LEHR site is located in a rural area in northeast Solano County just outside of Davis, California. The main UC Davis campus, located 1.2 miles north of the site, has a student population of approximately 26,000 and approximately 17,000 full-time faculty and staff according to fall 2000 figures (UC Davis 2002a). The current population of Davis is approximately 60,000 (including students), and the current population of nearby Yolo County is approximately 169,000 (U.S. Bureau of Census 2000). The Sacramento metropolitan area is approximately 12 miles east of the LEHR site. The estimated population of the city of

Sacramento is approximately 407,000, and the estimated population of Sacramento County is approximately 1,225,000 (U.S. Bureau of Census 2000). Figure 3 displays the demographics of the area within a 1-mile radius of the LEHR site.

The LEHR site is currently used by UC Davis's CHE. CHE consists of several research facilities where approximately 200 university researchers and support staff work. In addition, six full-time personnel have been on site to oversee ongoing environmental restoration activities (Weiss Associates 1999a).

The LEHR site is located on a flat to gently sloping plain outside the 100-year floodplain designated by the Federal Emergency Management Authority. It is situated on largely open land with few trees and bushes and no natural surface water bodies. Approximately 40% of the 15-acre site is paved or covered by structures. The former outdoor Western and Eastern Dog Pens occupied approximately 3.4 acres or 20% of the LEHR site. Prior to the removal actions, about 30% was unpaved and relatively free of vegetation and less than 5% was covered by large, deep-rooted vegetation (Weiss Associates 2003).

UC Davis owns much of the land surrounding the site. The property immediately north, west, and south of the site, including the Putah Creek Reserve, is owned by UC Davis and is used for animal, agricultural, and health research, including an equine research facility west of the site. To the northeast, east, and south of the site—past the land owned by UC Davis—the land is primarily used for private farming of fruits, vegetables, nuts, and grains. There are also permanent private residences there. The private property to the south is separated from the site by the South Fork of Putah Creek, and the private property to the east is adjacent to UC Davis-owned research facilities (Weiss Associates 1999a).

The natural surface water body nearest to LEHR is the South Fork of Putah Creek, an intermittent stream that flows through a man-made channel about 125 feet south of the LEHR facility. The creek was redirected into the man-made channel in 1872 to divert flood water from the city of Davis and the UC Davis campus (Weiss Associates 2003). Putah Creek is considered a "losing stream," as a portion of its flow recharges local groundwater sources.

II.E Quality Assurance and Quality Control

In preparing this PHA, ATSDR reviewed and evaluated information provided in the referenced documents. The environmental data presented in this PHA are from reports produced by UC Davis, Weiss Associates, and Pacific Northwest Laboratory for DOE, and by Dames and Moore and MWH Americas, Inc., for UC Davis. Most of these reports were developed according to the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Additional environmental data were provided by UC Davis for off-site private wells, collected in accordance with the field sampling plan developed by Dames and Moore. ATSDR

also reviewed comments provided by local scientists and DSCSOC many questioning the overall quality and adequacy of available data. Documents prepared for CERCLA programs must meet specific standards for adequate quality assurance and control measures for chain-of-custody procedures, laboratory procedures, and data reporting. Nonetheless, throughout its assessment, ATSDR examined the quality and representativeness of available data sets to determine its suitability for use in our health evaluation. After evaluating the data, ATSDR determined that the overall quality of environmental data available in site-related documents for LEHR is adequate to make public health decisions. Any limitations of the data identified in the various reports are discussed in the next section of this PHA.

III. Evaluation of Environmental Contamination and Potential Exposure Pathways

III.A Introduction

In this section, ATSDR reviews information about releases of contaminants from the site and evaluates how people might come in contact, or be exposed to, the contaminated media. The "Public Health Implications" section analyzes whether health effects may be associated with any identified exposures.

To acquaint the reader with terminology and methods used in this PHA, Appendix A provides a glossary of environmental and health terms presented in subsequent discussions.

What is exposure?

Chemical or radioactive contaminants disposed of or released into the environment have the potential to cause adverse health effects. However, ***a release does not always result in exposure.*** People can only be exposed to a contaminant if they come in contact with it—if they breathe, eat, drink, or touch (i.e., make dermal contact with) a substance containing the contaminant.

When do health effects occur?

Exposure does not always result in health effects. The type and severity of health effects an individual experiences because of contact with a contaminant depend on that contaminant's chemical properties, the exposure concentration (how much), the frequency and/or duration of exposure (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (combination of contaminants). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, life style, and health status of the exposed individual influence how the individual absorbs, distributes, metabolizes, and excretes the contaminant. Together, these factors and characteristics determine the health effects that may occur as a result of exposure to a contaminant.

III.A.1 Evaluating Environmental Data

ATSDR scientists review environmental data collected for a site to determine whether and to what extent chemical or radioactive substances released from the site are present in water, air, soil, or biota (plants and animals). Environmental levels are compared against medium-specific comparison values (CVs). Generally, if a contaminant's concentration exceeds one or more medium-specific CVs, then ATSDR evaluates the contaminant further. For inorganic compounds (metals) and radionuclides, we may also consider background values, since some of these substances occur naturally. ATSDR scientists also consider what community health concerns have been noted and the quality and extent of the available sampling data when selecting contaminants for closer examination.

CVs are not thresholds for adverse health effects, so contact with contaminants at concentrations above the CVs will not necessarily make you sick. ATSDR sets CVs at concentrations many times lower than levels at which no effects were observed in experimental animals or human epidemiologic studies. If several CVs are available for a specific contaminant, then ATSDR generally selects the CV that is based on the most conservative or protective exposure assumptions. This generally protects the most sensitive segment of the population. If contaminant concentrations are above CVs, ATSDR further analyzes exposure variables (for example, duration and frequency), the toxicology of the contaminant, other epidemiologic studies, and the weight of evidence for health effects. In this PHA, such analyses appear in the "Public Health Implications" section (Section IV).

Some of the CVs used for screening by ATSDR scientists include ATSDR's Environmental Media Evaluation Guides (EMEGs), Reference Dose Media Evaluation Guides (RMEGs), and Cancer Risk Evaluation Guides (CREGs), and also EPA's Maximum Contaminant Levels (MCLs) for drinking water, Lifetime Health Advisory (LTHA) for drinking water, and media-specific Risk Based Concentrations (RBCs). MCLs are enforceable drinking water regulations developed to protect public health. CREGs, EMEGs, RMEGs, LTHAs, and RBCs are non-enforceable, health-based CVs developed by ATSDR and EPA as a way to screen environmental contamination for further evaluation. Appendix B discusses the basis for the CVs used in this evaluation.

III.A.2 Evaluating Exposure

While identifying contaminants above ATSDR's CV screening values, ATSDR also evaluates whether and how people have been or are currently exposed to these contaminants. In doing so, ATSDR identifies possible "exposure pathways." It is important to understand that a release of a hazardous substance does not always result in human exposure. *People can only be exposed to a contaminant if they come in contact with that contaminant.* People can be exposed by breathing, eating, or drinking a substance containing the contaminant or by coming into skin contact with a substance containing the contaminant. Figure 4 illustrates the components of ATSDR's exposure pathway evaluation.

ATSDR scientists then identify "completed" or "potential" exposure pathways or eliminate pathways from further evaluation. This is done by carefully studying and identifying elements of an exposure pathway that might lead to human exposure. These elements include: 1) a source of site-related contamination, such as drums or waste pits; 2) an environmental medium in which the contaminants might be present or from which they might migrate, such as groundwater, surface water in streams or rivers, soil, air, and locally grown or raised foods (biota); 3) points of human exposure, such as drinking water wells or work areas; 4) routes of exposure, such as breathing, eating, or skin contact; and 5) a receptor population, such as nearby community

members or visitors to the site. A completed exposure pathway exists for a past, current,[2] or potential future exposure if we can link the contaminant source to a receptor population. A potential pathway is one that ATSDR cannot rule out, even though we may not be able to identify all of the five elements described above.

ATSDR analyzed available data for *groundwater, soil, surface water and sediment, air, ambient radiation,* and *biota* for the LEHR site to determine if the nature and extent of contamination and the likelihood of past, current, or future exposures. Our evaluation of possible exposure situations is summarized in Table 3 and described in greater detail in the following discussion. The three primary completed exposure pathways (past, current, and potential future) identified for populations at or near the LEHR site are:

- Drinking contaminated groundwater/drinking water (off-site).
- Contact with contaminated surface water of Putah Creek.
- Eating fish caught from Putah Creek.

[2] For the purposes of this PHA, ATSDR defines "current" exposures as having occurred at any time from the 1990s through the present.

III.B Groundwater

In this section, ATSDR discusses groundwater contamination in and around the LEHR site and how people might come in contact with this contamination. ATSDR first addresses groundwater hydrogeology and use for LEHR and surrounding communities. ATSDR then presents an overview of groundwater monitoring programs and discusses the results of these monitoring efforts. Finally, ATSDR evaluates whether exposure to contaminated groundwater is possible. The public health implications of known groundwater exposures is evaluated in Section IV.

III.B.1 Site Hydrogeology and Groundwater Use

LEHR is in the Sacramento Valley, which is characterized by flat or gently sloping deposits of the Tehama Formation of the Pliocene and Pleistocene ages and older alluvium (the water bearing material, that is the source of groundwater, is made up of sediments laid down over millions of years), overlain by alluvial deposits of the Putah Creek fan. Both unconfined and confined hydrostratigraphic units[3] (HSUs) are contained in the upper 3,000 feet below the ground surface (ft bgs) (Weiss Associates 1997c). There are two unconfined HSUs in the Putah formation, HSU-1 and HSU-2, and they are hydraulically connected. The top unit, HSU-1, extends from the ground surface to a depth of about 80 feet and consists primarily of fine-grained, alluvial-fan sediments composed of clayey silt, sandy silt, and silty fine sand with thin beds or lenses of sand and/or gravel. HSU-1 is not very permeable and does not transmit groundwater easily. It is also not laterally continuous throughout the region. The groundwater gradient within HSU-1 is primarily vertical and recharge is largely dependent on HSU-2 (Dames & Moore 2001). HSU-2 ranges from about 80 ft bgs to

> Understanding *site hydrogeology* is important in 1) studying how contaminants might travel in the groundwater beneath and near the site and 2) learning where and how people may be exposed to groundwater contamination. By studying site hydrogeology, ATSDR learned that contaminants from former site operations seeped through the soil into the underlying unconfined *hydrostratigraphic units (HSUs)*. Some contamination has been detected in the unconfined *aquifer* (HSU-2) in areas "downgradient" of source areas, located east/northeast of the site boundary on UC Davis property. An *aquitard* beneath the contaminated aquifer effectively limits contaminant flow to the deeper, confined aquifer that serves as the major source of drinking and irrigation water for UC Davis and the city of Davis. (See the footnote on this page or Appendix A [Glossary] for definitions of the italicized terms.)

[3] *Hydrostatigraphic units* (HSUs) are geologic area within which everything has the same hydrogeologic properties. A groundwater *aquifer* is a deposit of rock containing water that can be used to supply wells. An *aquitard* is a layer of rock having low permeability that stores groundwater but delays its flow. The integrity of this layer can be jeopardized with the improper installation of wells in the deeper aquifer.

130 ft bgs and consists of relatively coarse-grained alluvial-fan sediments including sand, gravel, and cobble-sized sediments. The hydraulic conductivity of HSU-2 is approximately 750 to 1,200 feet per day. HSU-2 is laterally continuous (unlike HSU-1) on a regional scale and represents the first aquifer underlying the Davis area (Weiss Associates 1999a).

This unconfined aquifer (HSU-2) is underlain by an approximately 120-foot-thick aquitard, HSU-3. HSU-3 consists of mostly clays and silts, which separates and essentially prevents groundwater flow between HSU-2 and the deeper, confined HSU-4 aquifer. HSU-4 is a sand and gravel aquifer extending approximately from 250 ft to 280 ft bgs. Below HSU-4 is a silt layer separating it from deeper layers, the thickness of which has not been determined by current investigations (Weiss Associates 1999a). HSU-4 and lower layers represent the most productive aquifers.

Groundwater flow in HSU-1 generally flows northeast from the LEHR site, although local, temporary changes in flow direction and gradient occasionally occur. Groundwater flow in HSU-2 and HSU-4 is toward the east/northeast. Generally, groundwater flows are lower in winter and fall, and higher in spring and summer (Weiss Associates 1997c, 1999a). Local groundwater is recharged by streams and rivers and direct infiltration from precipitation and irrigation. At the LEHR site and near Putah Creek, recharge rates are highest immediately after precipitation events. Putah Creek is a "losing stream" in the vicinity of LEHR and, as such, does not receive any groundwater as source water (Weiss Associates 1997c).

People living in the area rely on groundwater for domestic (i.e., drinking and bathing) and agricultural uses. The major groundwater source for area water supplies comes from HSU-4 (and underlying layers). Some local private wells, however, draw water from HSU-2 for domestic use and irrigation. Groundwater from the low-permeability HSU-1 is not used for domestic or agricultural uses. The text and table below summarize water use in the LEHR vicinity.

Public water supplies in the area of LEHR include the water supplies of UC Davis and the city of Davis.

UC Davis operates two separate water supply systems, a domestic water supply system and a utility water supply system. (UC Davis also has a system of wells used solely for agricultural purposes.) UC Davis's *domestic* water system is supplied by six wells drawing at depths greater than 800 ft bgs, none of which are located on the LEHR site. The closest domestic supply well is located approximately 400 feet north of LEHR and the remaining five wells are at least ½-mile north and northwest of the site (Weiss Associates 2003). Figure 5 shows the locations of UC Davis's domestic supply wells. Water in the domestic system is used for drinking and washing as well as heating, cooling, and other industrial functions in buildings and laboratories on the UC Davis campus. It is chlorinated for disinfection and maintains low coliform levels. The university's *utility* water system is served by six wells that draw water from 150 to 800 ft bgs and

below the HSU-3 aquitard. This system provides water for nonagricultural irrigation, greenhouse use, and certain laboratories that prefer the utility water because of its hardness and lack of chlorination (UC Davis Water Management Plan Task Force 1997). The groundwater from a system of 21 additional wells is used for irrigating crops and watering livestock after being mixed with surface water. These wells are drilled below HSU-4 at approximately 250 ft bgs (DOE 1988).

The city of Davis operates a water supply system that relies on 22 wells located north and northeast, and more than 2 miles from the LEHR site boundary. These wells draw water from aquifers at 300 and 1,700 ft bgs, below the aquitard. The system served more than 13,000 households in 2000. While the water is not treated centrally, it is treated with chlorine for disinfection (City of Davis 2003).

Private domestic and irrigation well use is documented in the vicinity of the LEHR site. While many of the wells obtain water from the HSU-4 aquifer, a number of these wells draw water from HSU-2, approximately 60 to 200 ft bgs (Weiss Associates 1999a; CRWQCB 2000). These private drinking water and irrigation wells are located south, east, and northeast of the site, and as close as 1,500 feet from the site. Figure 6 shows the locations of these private drinking water and irrigation wells.

Drinking Water Supplies in the Vicinity of the LEHR Site

Water System	Use	Aquifer	Number of Wells	Proximity to LEHR
UC Davis	domestic	below HSU-4 (800 ft bgs)	6	More than 400 feet north of the site
	utility	HSU-4 and below (150–800 ft bgs)	6	More than 1.5 miles from the site boundary
	agricultural	below HSU-4 (285 ft bgs)	21	More than 3,000 feet west and northwest
Public: City of Davis	domestic	below HSU-4 (300–1,700 ft bgs)	22	More than 2 miles north and northeast
Private Wells*	domestic	HSU-2	13	At least 1,500 feet south, east, and northeast
	irrigation	HSU-2	9	

Sources: Weiss Associates 2003; UC Davis Water Management Plan Task Force 1997; City of Davis 2003
* Other area private wells draw from HSU-4.

III.B.2 Groundwater Monitoring Programs

Groundwater monitoring has been conducted for the LEHR site since 1987, with a comprehensive program initiated in 1990. Monitoring wells have been installed and tested upgradient (west) of the site, within the site boundaries ("on site"), and downgradient of the site boundaries ("off site") on the UC Davis property (see Figure 7 for monitoring well locations). Monitoring wells are used not for drinking water but to characterize groundwater quality and movement from the site. The groundwater monitoring program began with nine on-site monitoring wells, primarily in HSU-1, sampled under DOE supervision (Dames & Moore 1998). By 1993, the monitoring network had expanded to 18 monitoring wells in both on and off site, all in HSU-1 and HSU-2, and sampled quarterly for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), metals, radionuclides, and general chemical parameters (PNL 1994; MWH 2003). Certain monitoring wells were used only to measure groundwater elevation.

UC Davis assumed control of the groundwater monitoring program from DOE in 1997. In 1997, UC Davis sampled 35 wells for VOCs and radionuclides, 33 for metals, 27 for SVOCs, and 19 for pesticides and PCBs (Dames & Moore 1998). In 1999 and 2000, UC Davis installed three additional monitoring wells downgradient of the site and included them in the sampling program to observe whether contamination was moving beyond site boundaries in HSU-2 and HSU-4. In 2000, 30 on-site and off-site monitoring wells (7 in HSU-1, 18 in HSU-2, and 5 in HSU-4) were sampled periodically (annually, quarterly, or, in areas of interest, monthly) for a total of 213 samples (Dames & Moore 2001). Currently, there are 49 groundwater wells (24 in HSU-1, 19 in HSU-2, 5 in HSU-4, and 1 that is screened in seven zones within HSU-1 and HSU-2) (MWH 2003).

III.B.3 Nature and Extent of Groundwater Contamination

Results gathered from the DOE and UC Davis monitoring efforts from 1990 through 2002 indicate that the groundwater beneath the LEHR site is contaminated with metals, VOCs, nitrate, carbon-14 (C-14), and hydrogen-3 (H-3) at levels that exceed (or exceeded) ATSDR's CVs. ATSDR studied both the horizontal extent (across LEHR and extending beyond the northeast site boundary) and vertical extent (down through the hydrostratigraphic units HSU-1, HSU-2, and HSU-4) of groundwater contamination. Some of the highest levels of contaminants were detected in the uppermost unit, HSU-1, while generally lower levels of certain contaminants have migrated down to the HSU-2 and HSU-4 aquifers, which are tapped in off-site areas by local private wells and municipal suppliers. UC Davis site investigators identified chromium, chloroform, and nitrate as the primary chemical contaminants of concern in groundwater for the LEHR site, based on the frequency and magnitude with which these chemicals were measured in the various monitoring wells (Dames & Moore 2001). After conducting its own examination of analytical results for all tested groundwater parameters (see Tables 4 and 5 for the maximum

concentration of contaminants detected above ATSDR CVs), ATSDR concurs with UC Davis's selection of the chemicals of concern in groundwater. Of the radioactive contaminants detected, H-3 has been detected at concentrations above ATSDR's CV in on-site wells in HSU-1 (UCD-8) and HSU-2 (UCD2-14) but has not been detected above its CV in off-site monitoring wells. Although C-14 concentrations exceeded ATSDR's CV in HSU-1 on site (UCD1-13), concentrations of C-14 have not been detected above ATSDR's CV in HSU-2 on or off site. For these reasons, ATSDR has focused the groundwater discussion that follows on chloroform, chromium, nitrate, and H-3.

To evaluate potential threats to area drinking water supplies, ATSDR further discusses the nature and extent of chromium, chloroform, nitrate, and H-3 contamination in the sections that follows, both in on-site and off-site locations. Doing this enables a closer look at the potential, if any, for site groundwater contamination to impact off-site drinking water supplies. Private well monitoring data are discussed later in this section. Tables 4 and 5 summarize available contaminant data greater than ATSDR's CVs for on-site and off-site locations, respectively, including maximum detected concentrations in monitoring wells and the location of these detections.

On-Site Groundwater Monitoring Wells

Chemical sampling results show chloroform, total and hexavalent chromium, and nitrate (the primary chemical contaminants of concern) at levels above ATSDR's CV in on-site monitoring wells. The highest concentrations of these contaminants were generally found in HSU-1 beneath the site—particularly along the eastern boundary of the LEHR fenceline, where some of the highest concentrations of chloroform (17,000 parts per billion [ppb]), total chromium (450 ppb), and hexavalent chromium (350 ppb) were detected. Nitrate was measured at 135,000 ppb, above its CV of 10,000 ppb, in a monitoring well (later abandoned) in the center of the site (Dames & Moore 1990; PNL 1994). Lower levels of these contaminants were generally measured in the deeper HSU-2 and HSU-4 aquifers, some sporadically exceeding ATSDR CVs. On-site chemical concentrations have remained fairly steady over time according to a review of groundwater monitoring data from each sampling event. Concentrations, however, vary spatially across the site. Chloroform in the HSU-2 aquifer appears to move as a plume from the center-eastern portion of the site, extending beyond the eastern site perimeter.

Early radiological sampling events (in 1990 and 1993) identified H-3 in HSU-1 and HSU-2 predominantly in two areas beneath the site at levels above the ATSDR CV of 20,000 picocuries per liter (pCi/L) (741 becquerels per liter [Bq/L]). The highest concentration (79,548 +/- 1,261 pCi/L; 2,946 +/- 47 Bq/L) was detected in a HSU-1 groundwater monitoring well (UCD1-4) in the southwestern corner of the site (Southwest Trench Area). This measurement, taken during the Solid Waste Assessment Test (SWAT) Investigation, was of suspect quality: a re-analysis of a diluted fraction of the sample was below the detection limit (Dames & Moore 1990). During the

1992–1993 sampling season, this well measured 2,022 pCi/L (75 Bq/L), and subsequent measurements have continued to decrease (Dames & Moore 1998). The next highest H-3 value measured in the same vicinity was 37,241 +/- 945 pCi/L (1,379 +/- 35 Bq/L) collected from well UCD1-8 and also reported in the SWAT (Dames & Moore 1990). That well has not been sampled regularly since that time. The HSU-2 groundwater monitoring well (UCD2-15) located in the same area was not installed and tested until 1990. The highest detected concentration of H-3 in HSU-2 was 5,302 +/- 582 pCi/L (196 +/- 22 Bq/L) during 1992–1993. In more recent sampling, the H-3 concentrations in this area have decreased substantially. By 1997, the H-3 concentrations in both UCD1-4 and UCD2-15 had decreased to less than 500 pCi/L (18.5 Bq/L) (Dames & Moore 1998).

A second area beneath the site where H-3 concentrations exceeded ATSDR's CV was found on the eastern side of the Eastern Dog Pens, which were built over UC Davis Landfill Unit 2. The highest concentration (69,743 +/- 1,201 pCi/L; 2,583 +/- 44.5 Bq/L) was detected in monitoring well UCD2-14 in 1990; as with the UCD1-4 sample mentioned above, though, a distillate of this sample contained less than 800 pCi/L (29.6 Bq/L) of H-3, making the original analysis questionable (Dames & Moore 1990). A re-sampling of this well in 1992/1993 showed a maximum concentration of 5,949 +/- 869 pCi/L (220 +/- 32 Bq/L) (PNL 1994). The maximum sampling results for this well in 1997 and 2000 were 9,540 +/- 700 pCi/L (353 +/- 26 Bq/L) and 3,920 +/- 329 pCi/L (145 +/- 12 Bq/L), respectively (Dames and Moore 1998, 2001). Monitoring well UCD1-13 is near UCD2-14 but is drilled into HSU-1. The maximum H-3 concentrations reported for this well for 1992/1993, 1997, and 2000 are 29,838 +/- 828 pCi/L (1,105 +/- 31 Bq/L), 19,400 +/- 1,300 pCi/L (718.5 +/- 48 Bq/L), and 12,500 +/- 318 pCi/L (463 +/- 12 Bq/L), respectively (PNL 1994; Dames and Moore 1998, 2001).

Off-Site Groundwater Monitoring Wells

DOE and UC Davis sampling has detected chloroform, hexavalent chromium, and nitrate at levels above ATSDR's CVs in off-site monitoring wells. Elevated levels of chloroform were measured in one HSU-2 monitoring well located 800 feet downgradient of the LEHR boundary on UC Davis property. Since 1998, an extraction well has been operated as part of a Groundwater Interim Removal Action Treatment System (IRA) to reduce the concentrations of chloroform and other VOCs detected in groundwater beneath and downgradient of the site (Dames & Moore 2001). Chloroform concentrations at most off-site monitoring wells have decreased each year since 1997, and have been below the CV since 1999; this suggests that the IRA is succeeding in reducing the chloroform migrating off site. Sampling conducted in 2000 indicated that the highest chloroform concentrations (280 ppb) were in the off-site HSU-2 well UCD2-029, which is located east of the LEHR eastern boundary and upgradient of the Groundwater IRA extraction well (Dames & Moore 2001). No corresponding increases were reported for nearby monitoring wells. For comparison, the closest private well (which is used for irrigation) is still more than 1,000 feet from well UCD2-029, where the highest detections were observed.

Total and hexavalent chromium concentrations in off-site monitoring wells were higher than detected on site. The highest concentrations of 613 ppb and 560 ppb, respectively, were observed in samples collected from HSU-1 (Dames & Moore 2001). The distribution of chromium concentrations in HSU-1 has not changed much from year to year. In fact, the chromium plume from 2000 looks the same as it did from 1997 to 1999 (Dames & Moore 2001). Much lower chromium concentrations were detected in the HSU-2 and HSU-4 aquifers, where total chromium concentrations were below the corresponding CV. Hexavalent chromium at 62 ppb (UCD2-46) and 39.9 ppb (UCD4-47) slightly exceeded the CV in HSU-2 and HSU-4, respectively, in 2000 (Dames & Moore 2001).

Nitrate concentrations in off-site monitoring wells reached levels up to 53,400 ppb in HSU-1, with lower concentrations in the deeper HSU-2 and HSU-4 aquifers. Nitrate is reported as a regional shallow groundwater problem as a result of area-wide agricultural practices; not enough information is available about nitrate concentrations to determine whether an on-site source of nitrate is contributing to off-site migration in groundwater (Dames & Moore 2001). Nitrate has been measured above ATSDR's CV (10,000 ppb) in upgradient wells and downgradient wells. In 1996, for example, nitrates were detected at 27,000 ppb in the upgradient HSU-1 well UCD1-018 (Weiss Associates 2003). Nitrate levels detected in HSU-2 monitoring wells generally fall below 15,000 ppb. Further, all nitrate detections in HSU-4 monitoring well samples collected between 2000 and 2002 are below ATSDR's CV.

Samples were collected from the off-site monitoring wells (UCD2-38 and UCD2-35) located between the site and South Fork of Putah Creek, closest to the Southwest Trench Area where radionuclides were detected in on-site groundwater samples. These off-site monitoring wells were not installed and sampled until 1997, at which time the H-3 concentrations in both were less than 500 pCi/L (18.5 Bq/L) (Dames & Moore 1998). In 2000, however, the maximum H-3 concentrations recorded were +/- 132 pCi/L (22 +/- 4.9 Bq/L) for UCD2-38 and 886 +/-146 pCi/L (32.8 +/- 5.4 Bq/L) for UCD2-35 (Dames & Moore 2001). These data points were noted to be associated with blank contamination, and their validity is therefore questionable. The maximum H-3 concentration reported for off-site monitoring wells in HSU-4 is 571 +/- 132 pCi/L (21.2 +/- 4.9 Bq/L) for UCD4-44 east of the site (Dames & Moore 2001). This value was also cited for blank contamination, as mentioned above. Although all three values are above background, they are well below ATSDR's CV of 20,000 pCi/L.

Off-Site Private Wells

In addition to monitoring the groundwater monitoring programs conducted by DOE and UC Davis, UC Davis has conducted a groundwater sampling program for neighboring off-site domestic, agricultural, and abandoned wells. Beginning in 1989, UC Davis sampled nine off-site private/irrigation/abandoned wells for VOCs, metals, nitrate, and radionuclides (UC Davis 2001).

The sampling plan was expanded to 22 private/irrigation/abandoned wells by 1996. UC Davis released a revised field sampling plan in May 1997 that focused the sampling on VOCs, nitrate, and total chromium because no radionuclides had been found up to that point (Weiss Associates 1999a). UC Davis continues to sample domestic and irrigation wells on a quarterly basis for VOCs, nitrate, and total chromium.

Domestic Drinking Water Wells (DW)

Thirteen private wells are located within the vicinity of the LEHR site. Few of the wells exist in the path of typical groundwater flow from the site area and none are located close to the contamination plumes identified at and near LEHR (UC Davis 2001, 2002b). Sampling of private wells by DOE and UC Davis found several metals (antimony, arsenic, chromium, lead, mercury, molybdenum, and thallium) and nitrate at levels above ATSDR CVs. Table 6 summarizes the maximum contaminant concentrations detected in the sampled off-site domestic drinking water wells. A summary of findings follows:

- Only one VOC exceeded ATSDR CVs—since vinyl chloride was detected in only one sample at a concentration slightly higher than its CV, it will not be considered a contaminant of concern.

- Hexavalent chromium was the most frequently detected metal (79%). Concentrations of hexavalent chromium above ATSDR's CV were reported for all years from 1989 to 1999, with a maximum concentration of 180 ppb in 1993. Locations of high total and hexavalent chromium concentrations varied from time to time, but the highest concentration was detected in DW-8, which is south of, and not in the general direction of, groundwater flow from the LEHR site. Concentrations of the metals antimony, arsenic, lead, mercury, molybdenum, and thallium were above CVs in 1989 and/or 1991, but were not included in subsequent sampling analyses.

- Nitrate, which was tested for regularly, was detected above its CV in domestic wells from 1989 through 2002, although not always in the same wells. The maximum nitrate concentration (53,900 ppb) was detected in DW-5, located 2 miles northeast of the site, in 1999. Overall, the levels of nitrate in private drinking water wells do not show any particular spatial pattern, and it is uncertain whether the source of the contamination is related to LEHR.

- Radionuclide concentrations were below ATSDR's CVs in all samples (collected between 1989 and 1996).

Irrigation Wells (IW)

Nine irrigation wells exist in the vicinity of LEHR, some within the path of groundwater flow and closer (from approximately 1,500 feet to 1.5 miles) to the LEHR site than domestic wells (UC Davis 2001, 2002b). Sampling of these irrigation wells for chemical contaminants indicates that a few VOCs (particularly chloroform, but also 1,2-dichloroethane), metals (antimony, arsenic, total and hexavalent chromium, molybdenum, and thallium), and nitrate were detected at levels above ATSDR CVs. Arsenic, total and hexavalent chromium, thallium, and nitrate were not detected above CVs in the off-site irrigation wells immediately downgradient of and in the direction of groundwater flow from the LEHR site (IW 3, IW 5, IW 6, IW 9); therefore, LEHR may not be a likely source of these contaminants. The highest levels of antimony, chloroform, and 1,2-dichloroethane detected off site and above the CV were detected in IW 3, which was closed in 1997. LEHR could be a source of these contaminants, since IW 3 is the closest off-site well (although it is approximately 1,500 feet from the site boundary) (see Figure 6). Of the radioactive contaminants analyzed in samples collected between 1989 and 1996, only gross alpha (up to 53 +/- 5 pCi/L [2.0+/- 0.2 Bq/L] detected at IW-2 in 1990) exceeded its CV, but it was detected only once at such a high level; gross alpha was detected below its CV in all subsequent samples. Table 7 summarizes the maximum contaminant concentrations in the nine off-site irrigation wells near LEHR.

III.B.4 Groundwater Exposure Pathways

ATSDR next examined whether anyone who lives/works at or near the LEHR facility has been or could be exposed to the contaminants in groundwater, and presents its findings in the discussion that follows. Potential public health hazards associated with completed groundwater exposure pathways are further evaluated in the "Public Health Implications" section (Section IV) of this PHA.

On-Site Groundwater Exposure Pathways

No past, current, or potential future exposure to contaminants in on-site groundwater exists.

People at UC Davis, CHE, and the former LEHR facility were not and are not exposed to contaminants because neither the drinking water supply nor the utility water supply for UC Davis, including the CHE facility housed in former LEHR buildings, draws from groundwater beneath the site. Furthermore, all but one of UC Davis's drinking water wells are located more than 400 feet from the LEHR site; that one nearby well is located north of the site and is not considered directly downgradient of detected contamination (see Figure 5). Lastly, the UC Davis drinking water supply comes from an aquifer more than 800 ft bgs (UC Davis Water Management Plan Task Force 1997). As noted previously, to date, groundwater contamination has only been found in the shallow HSUs—ranging from the ground surface to 300 ft bgs.

Off-Site Groundwater Exposure Pathway: Drinking Water Wells

While most residents live upgradient or outside of known groundwater plumes, a completed exposure pathway for contaminants in groundwater is possible through private drinking well water (past, current, and potential future) downgradient of the site. DOE has been supplying owners of nitrate-contaminated wells with bottled water since 1989 when the source of contamination in these wells was not clear. DOE will stop supplying bottled water in the near future because investigations have not established that LEHR is the source of the nitrate contamination.

Some contaminants (primarily metals and nitrate) have been detected above ATSDR's CVs in area private drinking water wells. People could be exposed to these contaminants when they drink or otherwise use water from their wells, but presumably exposures ended with the supply of bottled water to owners of affected wells in 1989. Some residents, however, may continue to come in contact with groundwater via skin exposure and inhalation while using the water for non-drinking purposes. Further, ATSDR has no way of knowing the full extent to which residents use supplied bottled water rather than water from their taps.

Note that the potential for contaminants to have originated from LEHR is considered to be low because few of the private drinking water wells exist in the path of typical groundwater flow in the area and none of them are close enough that is likely that they will be contaminated by LEHR. The closest private drinking water well in the path of typical groundwater flow direction (northeast and east) is approximately 2 miles from the LEHR site (see Figure 6). There are other, closer private drinking water wells (as close as 3,000 feet to the south, southeast, and southwest), but these are not in the path of the documented groundwater flow or suspected contaminant migration. Regardless of the source, however, ATSDR examined the possibility of harmful effects occurring from past, current, and potential future exposures to the nitrate and metals that were detected in area private wells at levels above ATSDR CVs. Our findings are described in the "Public Health Implications" section (Section IV) of this PHA.

No exposure occurs through consumption of water from UC Davis or the city of Davis's municipal water supply. Contamination found in off-site monitoring wells is not affecting the UC Davis or municipal water supplies. All but one of UC Davis's deep aquifer drinking water wells are more than 400 feet from the LEHR site, and the one nearby well is located north of the site, not downgradient of detected contamination. The city's water supply wells are all at least 2 miles from the site boundary. These wells tap into the deep aquifers more than 300 ft bgs and are hydrogeologically separated from and unaffected by contaminated groundwater in HSU-1 and HSU-2.

Off-Site Groundwater Exposure Pathways: Irrigation Wells

Limited potential, if any, exists for contact with or incidental ingestion of groundwater used for irrigation in the area of the LEHR site. Potential exists for indirect exposure to contaminants in groundwater through ingestion of irrigated, locally grown crops.

Local residents should not come in direct contact with contaminants in irrigation water frequently or for long periods of time because the water is not used for either drinking or bathing. Some agricultural workers and gardeners who use these wells may be exposed to contaminants in the irrigation water through skin contact or incidental ingestion of water. Even so, the potential exposure via this scenario is expected to be limited and not of health consequence. Eating locally grown foods irrigated with contaminated groundwater water is a possible exposure pathway. ATSDR further evaluates this potential pathway of exposure in the "Biota" section (Section III.F) of this PHA.

III.C Soil

Chemicals and radionuclides used in former operations at LEHR have contaminated soil in certain areas of LEHR. This section presents an overview of soil contamination at LEHR and discusses cleanup actions planned or completed. It then evaluates whether people on site or off site have come, or still could come, into contact with contaminated soil. An evaluation of the public health implications of known soil exposures is presented in Section IV.

III.C.1 Nature and Extent of Contamination and Remedial History

Several rounds of *surface* and *subsurface* soil sampling have occurred at the LEHR facility since 1984 (Weiss Associates 2003). Most samples were collected on site, with some limited soil sampling off site. Sampling focused primarily on potential source areas and samples were often collected at depth; during past investigations, relatively few *surface* samples were collected. During 2002, additional surface soil samples were collected at the six UC Davis source areas and various other areas within the site boundary (MWH 2003). Since there are limited sampling results for offsite soils, ATSDR reviewed on-site surface soil sampling data and the locations of the contaminants in relation to offsite locations.

> Since there are limited soil sampling results for off-site soils, ATSDR evaluated on-site surface soil concentrations, locations of the contaminants, and the impact that these soils could have on off-site exposures.

At three of the five DOE source areas (the DOE Disposal Box, Radium and Strontium Treatment Systems, the Domestic Septic Systems), only subsurface soil sampling results are available (Weiss Associates 2003). The sources and contaminated soil at these areas were located at depth and were inaccessible to the public, and no exposure occurred. In addition, all of these three source areas have been removed. For a summary of contaminant detections in subsurface soil and the remedial history of these areas, see Tables 1 and 2. Because the public is unlikely to contact the subsurface soil, ATSDR has focused its evaluation of the soil exposure pathway to the available surface soil (the top 0 to 6 inches of soil) sampling data. As a result, subsurface samples and samples of unknown depth are discussed only to a limited extent in the remainder of this assessment. The remainder of this discussion focuses on areas where surface sampling was conducted (i.e., two DOE source areas—the Southwest Trenches and the dog pen areas—and six UCD source areas).

The primary nonradioactive contaminants that were detected in on-site surface soils are pesticides and metals; both were generally found at levels below ATSDR CVs. Radioactive contaminants (e.g., Ra-226 and Sr-90) have been detected in soil at many surface and subsurface sampling locations on site (Weiss Associates 1997a, 2003; MWH 2003). Several cleanup and source removal actions have been completed at the LEHR site to restore soil conditions and prevent further movement of contaminants within or across site media (e.g., contaminants

moving from soil to groundwater). Many removal actions were completed prior to EPA's inclusion of LEHR to the NPL in 1994, and CERCLA removal actions were performed through the years 1996 to 2002 (Weiss Associates 2003).

This section briefly reviews the scope and findings of surface soil investigations at the LEHR facility (DOE and UCD source areas) and outside of its boundary. Tables 8, 9, 10, and 11 present an overview of contaminant levels detected in DOE areas, UCD areas, other on-site areas, and off-site surface soil, respectively.

On-Site Surface Soil

DOE Source Areas

Surface soils sampling was only conducted at two DOE source areas within the site boundary. At these two areas (the Southwest Trenches and the dog pens) only two pesticides and three metals were detected above their CVs; all maximum detected values were measured in the dog pen areas and are summarized in Table 8. What follows is a summary of sampling events, contaminants measured, and removal actions at these sites.

Southwest Trench (SWT) Area

Three surface soil samples from this area were analyzed for radionuclides in June 1995 (Weiss Associates 1997a). Cesium-137 (Cs-137), gross alpha, and gross beta were reported above background levels; however, the Cs-137 results (maximum 0.12 pCi/g) were less than ATSDR's CV. A surface radiation survey and soil sampling were performed in 1996 in the SWT area to locate contaminated areas and burial trenches (Weiss Associates 1998b). Several radionuclides (e.g., C-14, H-3, Sr-90, Cs-137, Th-234) were detected in the SWT area but primarily in subsurface samples.

Surface soil sampling was also conducted at the SWT area in 1998 in conjunction with remedial activities (Weiss Associates 1999c). Both surface and subsurface samples were collected in 1998 to guide excavation activities for the removal of chlordane-contaminated soil. During site evaluation and remedial activities, chlordane hot spots were identified on the surface at the Southwest Trenches. These hot spots were areas where chlordane concentrations in soil were higher than in adjacent areas. As much as 450 cubic yards of chlordane-contaminated surface soil (0 to 1 ft bgs) was removed, initially stockpiled in the Western Dog Pens, and properly disposed of off site in 1999. Additionally, 1,106 cubic yards of soil, gravel, and low-level waste were removed from the SWT area and shipped off site for treatment. Confirmation sampling was conducted at the surface as well as at depth, and the area was backfilled with clean soil. The confirmation sampling showed the maximum remaining concentrations of 0.110 parts per million

(ppm) of alpha chlordane and 0.0948 ppm gamma chlordane (no total chlordane measurements were available) (Weiss Associates 1999c). These results are less than ATSDR's CVs.

Additional site restoration activities included the installation of a fence along the northern portion of the SWT area and clearing the area of construction debris and trash (Weiss Associates 1999c).

Dog Pen Area

The main contaminants of concern at the dog pens are radioactive elements (particularly Ra-226 and Sr-90) from animal waste and chlordane used for flea control at the LEHR facility from 1960 to 1968. The dogs were reportedly dipped in chlordane near the Western Dog Pens (WDP) and in the SWT Area, and the pesticide was sprayed around the dog pen area as well (Weiss Associates 2003). Because the source in this area was at the surface, surface soil samples are available here, and this area has the greatest concentration of surface soil contamination at the LEHR facility.

Soil sampling in the dog pen area began with the initial assessment survey in 1984 (Weiss Associates 2003). Further sampling was performed in 1987/1988 and 1990 to determine the type and extent of contamination. The 1990 Phase II investigations included surface and near-surface soil sampling in 25 dog pens (Weiss Associates 1997a). In December 1994, 19 soil borings were drilled and 44 subsurface soil samples were collected in the dog pens (Weiss Associates 1997a). Arsenic (8.2 ppm) and iron (41,700 ppm) were detected above ATSDR's CVs in the surface soil. For radioactive contaminants, only Ra-226 (0.57 +/- 0.26 pCi/g) was detected slightly above ATSDR's CV (0.513 pCi/g) (Weiss Associates 1997a).

In 1996, all above grade structures and internal fencing were removed from the eastern and western dog pens and later sent off site for recycling. During the removal of concrete pedestals in the dog pens, scans were conducted for alpha and beta/gamma radiation (Weiss Associates 1997a). Twenty-four surface soil samples were also collected (12 at random locations, 12 in areas where alpha and beta/gamma scans were above background levels). Although Ra-226 was detected in 17 of the 24 samples, the concentrations were not statistically significant from background. Fifteen of the 24 samples were also analyzed for chlordane. Chlordane was detected in all 15 samples, but only one sample (15 ppm) exceeded ATSDR's CV (Weiss Associates 1997a). Because this investigation was conducted primarily for health and safety purposes, not for contaminant characterization, there was no sampling plan and the investigation did not meet CERCLA standards. As a result, these values are of suspect quality (Weiss Associates 1998a). Nonetheless, ATSDR examined the investigation's data because they gave us some perspective of possible exposures.

Between September 1997 and March 1998, an investigation was conducted to characterize areas of contamination at the WDPs for the primary purposes of isolating easily removable hot spots

and making additional remedial decisions (Weiss Associates 1998a). During this investigation, 12 dog pens were selected and between four and seven surface soil samples were collected from each pen. In addition, six soil borings were drilled in areas suspected of contamination and a total of 106 soil samples from various depths were collected. The samples were analyzed for selected pesticides, selected metals (e.g., mercury and hexavalent chromium), nitrate, and radionuclides. Low levels of pesticides and metals were detected in surface soils, but only chlordane (alpha + gamma chlordane, 2.2 ppm at 1.6 ft bgs) exceeded ATSDR's CVs in one sample. Ra-226 was detected in the samples but at concentrations less than background. Several radionuclides (Sr-90, Cs-137, C-14, Th-234, U-235, U-238, and Pb-210) were detected above background but did not exceed ATSDR's CVs. (Weiss Associates 1998a).

In March 1999, an investigation was conducted to further characterize soil contamination at the former Eastern Dog Pen (EDP) area (Weiss Associates 1999b). Surface soil samples (i.e., from 0 to 6 inches bgs) were collected from 19 locations in the EDP. A total of 37 samples were collected and analyzed for selected radionuclides, metals, pesticides, and nitrogen compounds. One pesticide (dieldrin at 0.223 ppm) and one metal (chromium at 251 ppm) were detected above respective CVs. Although no record exists of dieldrin being used at LEHR, dieldrin has also been detected in on-site groundwater wells and in one surface water sample taken from Putah Creek (Weiss Associates 1997a). No other chemical contaminants were detected at levels above ATSDR's CVs. Sr-90 was statistically above background in the EDP area; however, the concentrations were less than ATSDR's CV.

Remedial activity began at the WDPs in April 2001 (Weiss Associates 2003). Approximately 3,220 cubic yards of gravel, asphalt, concrete curbing, and metal grating were removed, in addition to soil contaminated with chlordane that had been stockpiled in the WDP area during a 1998 removal action of the SWT area. During remediation, contaminated gravel was separated from the soil. Soil was screened for Ra-226 and Sr-90 on site and returned to the excavation while the gravel was placed in stockpiles for further characterization. After remediation, 38 confirmation soil samples were collected and analyzed for Ra-226, Sr-90, chlordane, mercury, and hexavalent chromium. All Ra-226 concentrations were below background concentrations. Sr-90 was detected above background in 11 samples but did not exceed ATSDR's CV. Two surface (0.5 ft bgs) soil confirmation samples, collected from the former location of SWT contaminated soil stockpiles, had total chlordane concentrations of 2.12 ppm and 4.34 ppm (Weiss Associates 2003), slightly above the CV of 2 ppm. Perimeter fencing was retained around the WDP area until removal actions were complete.

To date, no soil has been removed from the EDP. Possible remedial options are still under study. It is possible that the EDP will be capped as part of the Landfill Unit 2 capping action. In the interim, the area will be fenced and posted to prevent public access (Weiss Associates 2003).

While arsenic was measured at 8.2 ppm (Weiss Associates 1997a), approximately 15 times higher than its CV (0.5 ppm) in on-site surface soil, the maximum detected arsenic concentration fell within the range of background concentrations of arsenic in soil from the general Davis area (8.14 ppm [Weiss Associates 2003] to 9.6 ppm [Weiss Associates 1998a]). Similarly, iron was detected up to 41,700 ppm (Weiss Associates 1997a), which is above its 23,000 ppm CV but below the background concentration of 44,000 ppm. These two metals, along with a third (chromium) that measured slightly above its CV, are not likely to pose a health hazard at such low concentrations, and access to this area by the general public is limited.

Although maximum concentrations of both chlordane (15 ppm) (Weiss Associates 1997a) and dieldrin (0.223 ppm) (Weiss Associates 1999b) were more than 5 times higher than their respective CVs, such concentrations were measured in only one or two samples; most soil samples appeared to have very little, if any, of these pesticides. Chlordane contamination has been removed in both the SWT and the WDP (Weiss Associates 1999c, 2003). Pesticide contamination in the past, while widespread in the case of chlordane, was typically measured in low concentrations below those that would pose a health concern.

UC Davis Source Areas

UC Davis source areas (Landfill Units 1, 2, and 3, the Eastern and Southern Trenches, and the Waste Burial Holes) were investigated as part of Limited Field Investigations (LFI) conducted in the mid-1990s. The investigations focused on primarily subsurface conditions. Exploratory trenching and soil borings were used to characterize waste and soil contamination beneath the surface. During these subsurface investigations, pesticides, metals, naphthalene, PCBs, dioxin and furans, nitrate, and radiological contaminants (Ra-226, Cs-137, and H-3) were discovered in the soil above background concentrations. Limited surface soil sampling was also conducted during these investigations (MWH 2003).

As part of a Data Gaps Investigation conducted in 2002, UC Davis collected 36 *surface* soil samples from Landfill Units 1 and 2 and the Eastern and Southern Trenches. Each sample was analyzed for metals, pesticides, SVOCs, general chemistry, and radionuclides. Arsenic, chromium, iron, and Ra-226 were detected slightly above their CVs in many of the UC Davis areas tested, but generally at levels comparable to background (MWH 2003). Surface soil conditions are discussed in more detail below. The maximum concentrations of contaminants exceeding CVs in tested surface soils are summarized in Table 9.

Landfill Unit 1

Two investigations analyzed surface soil at Landfill Unit 1: the 1995 data gaps LFI and the 2002 Data Gaps Investigation (MWH 2003). Each sample was tested for metals, PCBs, pesticides, and radionuclides. Arsenic (8.95 ppm), chromium (200 ppm), iron (44,100 ppm), and lead (3,640

ppm) were detected above ATSDR CVs. Each of these maximum values was reported in samples collected 6 inches bgs in 2002. While the arsenic, chromium, and iron concentrations fall within background levels, the lead concentration reported in a sample collected along the southern boundary of the landfill area is much higher than lead measured elsewhere in the LEHR vicinity. This sample appear to be an isolated measurement, not representative of soil conditions in the area; all other concentrations are at least 10 times lower and below ATSDR's CV of 400 ppm. The next highest lead concentration in the 11 soil samples collected in the Landfill Unit 1 area was 61.2 ppm. As a result, lead is not considered a contaminant of concern in surface soils.

Landfill Unit 2

Surface soil samples were collected at Landfill Unit 2 during the 1995 LFI and the 2002 Data Gaps Investigation (MWH 2003). During these two investigations, arsenic (11.2 ppm) and iron (42,220 ppm) were detected above CVs in surface soil. Both of these concentrations are near background levels. In addition, Ra-226 was detected up to 0.59 pCi/g (+/- 0.2), slightly above ATSDR's CV (0.513 pCi/g). Part of Landfill Unit 2 is covered by the Eastern Dog Pen area. This area was not tested during Landfill Unit 2 investigations, but is addressed as part of the DOE source area investigations discussion above (MWH 2003).

Landfill Unit 3

Surface soil data from the data gaps LFI in 1995 reported arsenic (9.4 ppm) and iron (57,300 ppm) concentrations above CVs (MWH 2003). That particular iron concentration, the highest measured anywhere in the LEHR vicinity, is approximately two times higher than iron's CV. Ra-226 (0.59 +/- 0.18 pCi/g) was also measured just above its CV in surface soil at Landfill Unit 3 (MWH 2003). UC Davis determined that the 1995 sampling of this area was sufficient and therefore collected no additional samples during its 2002 Data Gaps Investigation.

Eastern Trenches

In 1995, an Eastern Trench data gaps LFI found levels of pesticides and H-3 above background during exploratory trenching and sampling (MWH 2003). No surface soil sampling was conducted during this time, however, and the only surface soil samples available in this area are from the 2002 Data Gaps Investigation. Twelve surface soil samples from the 2002 investigation were analyzed for metals, VOCs, SVOCs, PCBs, nitrate, and radionuclides. Arsenic (8.26 ppm), chromium (283 ppm), and iron (38,500 ppm), as well as the pesticide dieldrin (0.063 ppm), were detected above CVs. Ra-226 (0.615 pCi/g +/-0.164) was also measured above its CV (MWH 2003).

Southern Trenches

UC Davis also collected surface soil samples from the Southern Trenches during the 2002 Data Gaps Investigation. As in the other UC Davis areas, only arsenic (7.68 ppm), iron (37,100 ppm), and Ra-226 (0.532 pCi/g +/- 0.0874) were detected above CVs (MWH 2003).

Waste Burial Holes

Because of extensive surface soil sampling during the 1995 and 1999 investigations, no surface soil samples were collected from this area in 2002 during the Data Gaps Investigation. The two previous studies revealed concentrations of arsenic (8 ppm), iron (47,600 ppm), H-3 (39,360 +/- 9,500 pCi/g [1,455,556 +/- 351,852 Bq/kg]) and Ra-226 (0.878 +/- 0.152 pCi/g [33 +/- 6 Bq/kg]) exceeding CVs (MWH 2003).

Non-OU Areas

In addition to the source areas sampled in 2002, UC Davis collected 10 surface soil samples within the LEHR site not associated with specific source areas (MWH 2003). Samples were analyzed for SVOCs, metals, pesticides, and radionuclides. Benzo(a)pyrene (0.710 ppm), benzo(b)fluoranthene (0.890 ppm), arsenic (10.8 ppm), chromium (227 ppm), and iron (35,700 ppm) were detected above CVs. The highest concentrations were found in the eastern portion of the site near the waste water treatment plant. Findings are summarized in Table 10.

Off-Site Surface Soil

Only a few sampling results are available to assess off-site soil conditions. As part of the 1996 LFI, four samples were collected from the storm water ditch along Old Davis Road to assess the potential impact from overflows of the Radium Treatment System. These samples were analyzed for radionuclides, metals, VOCs, and SVOCs. Ra-226 (1.73 pCi/g [64 Bq/kg]) and total chromium (230 ppm) were the only contaminants detected above their CVs (Weiss Associates 1997a).

In November 1997, a total of 15 soil samples (including eight surface samples) were collected from eight off-site locations based upon the results of a gamma survey taken the previous day (Weiss Associates 1998a). The samples were analyzed for selected radionuclide compounds (e.g., Sr-90 and Ra-226), VOCs, SVOCs, pesticides, selected metals, and nitrate. Some metals were detected in one or two surface soil samples (e.g., total chromium [705 ppm] and mercury [1.8 ppm]) above background and low concentrations of pesticides were also detected in surface soil samples. Chromium and arsenic (9.7 ppm) were the only two contaminants to exceed ATSDR's CVs. Cs-137, Ra-226, Pb-214, and Bi-214 were detected in surface soils west of the site near the drainage ditch that runs along Old Davis Road above background concentrations;

however, only the highest Ra-226 concentration (1.28 pCi/g [47.4 Bq/kg]) exceeded ATSDR's CV (Weiss Associates 1998a).

In 1998, an off-site investigation was conducted because Cs-137 had been detected in 1996 and 1997 in surface soil samples collected from an off-site drainage ditch mentioned previously (Weiss Associates 1999a). The results of this investigation concluded that the Cs-137 concentrations detected in the ditch were within the range reported for activities associated with global fallout, that the concentrations were comparable to concentrations found in a "background" ditch ½ mile from the site, and that the concentrations were not high enough to cause adverse health effects.

III.C.2 Soil Exposure Pathways

The potential for past *exposure existed through skin contact, incidental ingestion, and inhalation of contaminants from surface soil for former LEHR workers. Limited, if any, exposure potential existed for site visitors or the general public.*

Most soil contaminants found above CVs, including radionuclides, SVOCs, and metals, were located on site at depth; therefore, exposure was not possible. Some pesticides (chlordane and dieldrin), some metals (arsenic, chromium, iron, and lead), and one radionuclide (Ra-226) were, however, measured above ATSDR CVs in on-site surface soil. As discussed above, lead concentrations exceeded the CV only once. The next highest maximum concentration in 55 surface soil samples collected in all UC Davis areas was 316 ppm (in Landfill Unit 3), still below the CV. LEHR workers may have been exposed to the other contaminants (particularly in the vicinity of the dog pens and SWT) in the past, when surface soil contamination existed in these areas. Before the remediation of the SWT areas, there was no fencing blocking access to this area. Therefore, some limited potential for exposure existed for other UC Davis visitors and staff who may have visited the area infrequently.

There is no current or potential future exposure to soil: contaminated soil has been removed from the site, with few exceptions. Some confirmation sampling in the WDP revealed some slightly elevated chlordane concentrations, but in localized areas and unlikely to pose a health hazard. A few metals and Ra-226 have been detected in some UC Davis source area surface soils (Landfill Units 1, 2, and 3; UC Davis Disposal Trenches; and Waste Burial Holes). The UC Davis areas have not yet been remediated and remain unpaved. Although some public access to these areas is permitted, exposure is expected to be limited and should not pose a public health concern at the concentrations observed. Further, the SWT area, the only other surface soil source, has been paved in areas and is fenced. Although the EDP has not yet been remediated and concentrations of pesticides above CV have been found, the area is now fenced and posted to prevent public access and is expected to remain so until the area is remediated.

There is no past, current, or future exposure to contaminants in off-site soil that would cause adverse health effects. Although off-site soil sampling data are limited, air monitoring data and known on-site surface soil conditions and concentrations lead ATSDR to expect that soil contamination from the LEHR facility did not, does not, and will not migrate off site at levels that would be of health concern. In addition, contaminants detected in the few available off-site samples were detected at low concentrations and are not considered to be a public health concern.

III.D Surface Water and Sediment (South Fork of Putah Creek)

In this section, ATSDR discusses surface water and sediment contamination in and around the LEHR site and how people might come in contact with these contaminants. This section provides background information regarding regional surface hydrology and possible sources of surface water contamination. It also describes the sampling programs conducted to date and their key findings. The LEHR site does not contain any natural surface water bodies, but the South Fork of Putah Creek is just south of the LEHR site, flowing in an easterly direction. Although sampling data for waste water effluent and storm water collected from the site and discharged to Putah Creek were considered, ATSDR focused on evaluating surface water data from the creek itself. No surface water sampling data are available from before 1989—a data gap that affects our assessment of possible past exposure conditions when LEHR-related discharge to the creek was likely the greatest. Section IV describes the public health implications of surface water exposures.

III.D.1 Surface Water Hydrology and Sources of Surface Water Contamination

As previously noted, the LEHR site does not contain any natural surface water bodies. The only natural surface water body within a 1-mile radius of LEHR is the South Fork of Putah Creek (Weiss Associates 1999a) (see Figures 1 and 2). Water flows in the South Fork year-round, but is greatly diminished in the dry summer months. Still, area residents use the South Fork of Putah Creek for recreational activities such as fishing and swimming (but not for drinking water).

The South Fork of Putah Creek receives waste water and storm water drainage from all parts of the UC Davis campus, including the LEHR site. Also, Putah Creek receives contributions from other sources upstream of LEHR. These sources are summarized in the following discussion and table.

Waste Water Releases

Treated *waste water* from the UC Davis Waste Water Treatment Plant (WWTP) empties into the South Fork of Putah Creek via a sewage treatment plant outfall (STPO), approximately 0.25 miles from the WWTP, just south of the LEHR site. The LEHR facilities, which originally used six domestic septic tank systems, were not connected to the old WWTP until 1971 (DOE 1988). Prior to 1971, these septic tank systems received all the liquid waste water from the LEHR facilities, except for 1) liquid waste water primarily contaminated with Sr-90 that went to the Imhoff treatment system and 2) liquid waste water that went to the Ra-226 septic system. The original WWTP was upgraded to handle a total average capacity of 4.16 million gallons per day (mgd) and a peak capacity of 5.5 mgd (DOE 1988). A new WWTP, built in 2000, replaced the original WWTP to provide increased treatment capabilities; it is permitted to handle 2.8 mgd (Lapin 1999).

Reports on the annual quantities of Sr-90–contaminated waste water processed through the Imhoff treatment system suggest that the beagle studies used the largest quantities of Sr-90 between 1966 and 1968 (DOE 1988). By 1971, the year LEHR was connected to the old WTTP, the quantity of Sr-90 used had decreased by at least 50 times. It continued to decrease until the research was discontinued. Ra-226 was used in the beagle studies from October 1963 through January 1969 (DOE 1988).

The CRWQCB issued UC Davis a National Pollutant Discharge Elimination System (NPDES) permit for the WWTP on April 27, 1979, which required the effluent to be tested for biochemical oxygen demand (BOD), total suspended matter, settleable matter, coliform organisms, and chlorine residue (DOE 1988). The permit has been revised on several occasions since that time, most recently in January 2003 (EPA 2003). Before 1990, effluent from the plant was also analyzed for different constituents at different times, including: trace metals (1977 and 1978); gross alpha, gross beta, and some chemicals and metals (1983) (DOE 1988). Beginning in 1990, a quarterly sampling regime was instituted at the STPO (PNL 1999). UC Davis also discharged untreated waste water to Putah Creek, under a permit from the CRWQCB's Central Valley Region, from two fish research facilities, approximately 30 cooling towers, and the U.S. Department of Agriculture (USDA) Aquatic Weed Control Laboratory (Yolo County Department of Public Health 1995). Discharges from the cooling towers were discontinued in 1999. Most of the waste water discharge data reviewed by ATSDR were collected during the 1990s, when sampling occurred quarterly. Usually one and occasionally two samples collected during each quarter were analyzed for VOCs, SVOCs, PCBs, pesticides, metals, and radionuclides.

Table 12 summarizes the sampling results of the maximum concentration of contaminants exceeding ATSDR's CV at the STPO. Detected VOCs, SVOCs, pesticides, metals, and one other inorganic exceeded drinking water CVs sporadically, mostly in earlier sampling rounds (pre-1997). Further, detected concentrations were generally no more than 10 times the CVs.[4] No PCBs or radionuclides exceeded ATSDR's CVs.

Storm Water Releases

Storm water runoff from LEHR reaches the South Fork of Putah Creek via several outfalls or ditches located along the creek, or via percolation through soil to an underground drainage system that eventually discharges into Putah Creek (Weiss Associates 1999c, 2003). Storm water

[4] ATSDR does not have a CV for surface water, waste water, or storm water releases. In the absence of CVs for these media, ATSDR uses its CVs for drinking water. Using the drinking water CVs serves as a very protective screen because they are based on assumptions that people could safely drink the water over the course of a lifetime.

measurements have been collected since 1994 from four on-site storm water locations to monitor the runoff from the southwestern (LS-1, lift station), central (SD-1, storm drain), and southeastern (LF-1 and LF-3, south of landfills 1 and 3) portions of the site. The SD-1 location was eliminated in the winter of 1996/1997 because water flowed from SD-1 to LS-1, which was already being sampled (Weiss Associates 2003). Each year samples are collected during two sampling events that coincide with significant rain events (or sometimes only one sampling event, if weather conditions have been unfavorable) and analyzed for VOCs, SVOCs, pesticides, PCBs, metals, and radionuclides. Storm water data were available for ATSDR's review for the years 1996 (fall only), and 1997 through 2000.[5]

Table 13 summarizes the maximum concentrations for constituents detected in storm water at levels above ATSDR's CVs. Some VOCs, pesticides, and metals were detected, but only a few of these analytes had more than one concentration detected higher than their drinking water CVs. PCB concentrations were below CVs. Of the radionuclides, only gross beta was detected above its CV. This concentration could be attributed to C-14, which is a beta emitter detected at essentially the same concentration at the same location; however, the C-14 concentration does not exceed its CV. Sampling in 1990 of effluent from the drainage ditch that runs down the west side of Old Davis Road beyond the LS-1 station reported gross beta, but at levels below the ATSDR CV. C-14 was below the minimum detectable activity (Dames & Moore 1990). Since the elevated result was not repeated, it appears to be an anomaly. The highest hits were generally detected in LS-1, a lift station located at the southwest corner of the site which pumps runoff under Old Davis Road to Putah Creek, and LF-1, at a discharge pipe located south of the eastern portion of the Landfill Unit 1 that eventually drains by culvert to Putah Creek. DOE is currently remediating the area around the LS-1 and SD-1 monitoring stations, while UC Davis is remediating the areas around the LF-1 and LF-3 monitoring stations.

Other Potential Contamination Sources for Putah Creek

Within a 1-mile radius of the site, land is used for animal research and agriculture (Weiss Associates 1999a). Both of these may release waste water, as well as pesticides and other contaminants, to Putah Creek via storm water runoff. There are no other permitted point source discharges to Putah Creek in the vicinity other than UC Davis (Yolo County Department of Public Health 1995). A study by Slotton et al. (1999) identified historical mercury mining and abandoned mercury mines upstream from the LEHR site as likely predominant sources of any

[5] ATSDR reviewed storm water runoff data for 1998 and 1999 for constituents of concern showing detections only: 1,1-dichloroethene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 2-butanone, 2-hexanone, 4-methyl-2-pentanone, acetone, benzene, chlorobenzene, methylene chloride, tetrachloroethene, toluene, trichloroethene, 4,4'-DDD, 4,4'-DDT, alpha-chlordane, beta-benzene hexachloride (BHC), dieldrin, endosulfan sulfate, endrin, gamma-chlordane, heptachlor, aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, thallium, vanadium, and zinc.

mercury in Putah Creek. The study further suggested that mercury-contaminated sediment is likely present in the stream bed and adjacent banks of Putah Creek and is re-exposed, transported, and re-distributed during high flow events (Slotton et al. 1999).

Contaminant Contribution to Putah Creek		
Contaminant Release to Putah Creek	**Source or Mechanism of Release**	**Comment**
LEHR		
Waste water	UC Davis: campus WWTP (treated waste water)	Waste water reaches the South Fork of Putah Creek via an outfall, located about 0.25 miles from the WWTP. The releases are operated under conditions of the NPDES.
	UC Davis: fish research and USDA aquatic weed control (untreated waste water)	Specific discharge points to Putah Creek were not documented. Discharges are permitted by CRWQCB.
Storm water	Runoff from unpaved areas of LEHR	Storm water runoff percolates through soil or collects as small ponds and infiltrates to groundwater. Because Putah Creek is a "losing stream," the storm water will not reach the surface water of Putah Creek unless the water table rises above the level of the creek.
	Runoff from paved areas of LEHR	Storm water discharges into Putah Creek via an unlined ditch along Old Davis Road along the southwestern portion of the site; a storm drain on the west side of the western dog pen that collects water from the central portion of the site; a discharge pipe located south of the eastern portion of Landfill Unit 1 that eventually drains by culvert to Putah Creek; and the main north–south drainage ditch at the southeast corner of the site, southeast of Landfill Unit 3.
Non-LEHR		
Upstream releases to Putah Creek	Historical mercury mining and abandoned mines; agriculture; and animal research	These various activities may also feed surface water runoff into Putah Creek.

Key: CRWQCB = California Regional Water Quality Control Board; LEHR = Laboratory for Energy-Related Health Research; NPDES = National Pollutant Discharge Elimination System; UC = University of California; USDA = U.S. Department of Agriculture; WWTP = Waste Water Treatment Plant

III.D.2 Nature and Extent of Surface Water and Sediment Contamination

Surface water monitoring was conducted near the site to study the effects of possible contamination on Putah Creek surface water quality. Through the 1990s, surface water quality data were collected by DOE and then UC Davis, which took over the program for surface water and storm water sampling from DOE in 1997 (Weiss Associates 2003).[6] The lack of a comprehensive surface water monitoring program for the LEHR site or for the South Fork of Putah Creek prior to the 1990s makes it impossible to assess past environmental impacts of LEHR operations on nearby surface waters at the height of the research activities. Essentially no data exist to support or refute whether significant impacts occurred in the past. There has been more recent sampling in Putah Creek, though. This sampling has generally occurred at two sampling locations: Putah Creek Downstream (PCD) and Putah Creek Upstream (PCU). (Refer to Figure 7.) In addition, off-site surface water was sampled in 1997 for metals only at "fishing locations" 1, 2, 3, 4, and 5 and evaluated in ATSDR's health consultations (ATSDR 1998b, 1998c).

ATSDR also reviewed Putah Creek sediment collected by EPA in its 1997 health consultation. ATSDR's review of the sediment data found that none of the tested analytes (metals and radionuclides) exceeded ATSDR's CVs, so measured levels were not of health concern (ATSDR 1998b, 1998c). ATSDR focuses the remainder of this discussion on a review of available surface water monitoring data for Putah Creek.[7]

ATSDR looked at the surface water sampling data available for PCD and fishing locations 1, 2, 3, and 5 separately from PCU and fishing location 4 to distinguish between locations potentially impacted by LEHR inputs and locations not impacted by LEHR inputs. PCD and fishing locations 1, 2, 3, and 5 are located adjacent to or downstream from the LEHR site. PCU and fishing location 4 are upstream from the STPO and (usually) do not receive LEHR waste water discharges or storm water runoff—their purpose is to serve as background locations.[8]

ATSDR reviewed data collected from PCD and PCU for the years 1992, 1993, and 1997 through 2000.[9] Sampling events occurred on a quarterly basis, with usually one and occasionally two

---

[6] ATSDR reviewed a subset of data for 1998 and 1999, limited to constituents of concern showing detections. See the following sections for further details.

[7] Four soil samples were also collected from the storm water ditch along Old Davis Road during the 1996 LFI to assess the potential impact from overflows of the Radium Treatment System. These samples were analyzed for radionuclides, metals, VOCs, and SVOCs. Total chromium (230 ppm) was the only contaminant detected above ATSDR's CV (Weiss Associates 1997a).

[8] PCU is located approximately 600 feet upstream from STPO and was established as a background location; however, it appears that PCU is occasionally impacted by LEHR waste water discharges when either the summer or fall are dry.

[9] For 1998 and 1999 samples collected at PCD, ATSDR reviewed data for contaminants of concern

samples collected during each quarter and analyzed for VOCs, SVOCs, PCBs, pesticides, metals, and radionuclides. Data on metal concentrations in samples from fishing locations 1, 2, 3, 4, and 5 are available for 1997 only.

- *Downstream monitoring results:* VOCs, SVOCs, and pesticides were detected relatively infrequently and usually at concentrations no greater than two times the CV. Only dibromochloromethane, bis(2-ethylhexyl)phthalate, alpha-benzene hexachloride (alpha-BHC), arsenic, boron, and hexavalent chromium exceeded CVs in 20% or more samples. None of the radionuclides exceeded CVs. Table 14 summarizes the data for the downstream locations.

- *Upstream monitoring results:* Most VOCs, SVOCs, pesticides, and metals were detected infrequently and usually at levels below the drinking water CVs. Only bis(2-ethylhexyl)phthalate, antimony, arsenic, and boron were measured above their CVs in 20% or more samples. No PCBs or radionuclides exceeded CVs. Table 15 summarizes the data for PCU and fishing location 4.

Overall, the sampling results show little variation by type or extent of contamination between upstream and downstream surface water sampling locations.

III.D.3 Surface Water Exposure Pathways

ATSDR examined whether anyone who lives near or frequents the LEHR facility has been or could be exposed to the contaminants in surface water of the South Fork of Putah Creek. The following discussion evaluates possible surface water pathways of human exposure. Potential public health hazards associated with an exposure is further evaluated in "Public Health Implications" section of this PHA.

Direct contact with waste water from the STPO and LEHR storm water are not likely exposure situations: much of the captured storm water flows underground or in drainage ditches. It is probably rare for the public to come into contact with these waters during storm events. The potential for future exposure is even less likely, as some of the contaminant sources that contribute to waste water or storm water releases at LEHR have been remediated or are nearly remediated, including the Southwest Trenches and East and West Dog Pens.

ATSDR has determined that a *completed exposure pathway is possible for contaminants in surface water of Putah Creek.* The South Fork of Putah Creek is used for various recreational

---

showing detections only: acetone, bromodichloromethane, bromoform, chloroform, dibromochloromethane, ethyl ether, methylene chloride, toluene, chromium, and hexavalent chromium.

purposes (e.g., fishing and swimming), but not for drinking water. Consequently, some limited contact with surface water may occur. People who might be exposed to contaminants in Putah Creek water include Davis residents and UC Davis students, faculty, and staff who may use Putah Creek for recreation. Exposure would be limited to dermal contact (which might be frequent for people such as anglers or swimmers) and/or incidental ingestion (e.g., accidental ingestion when swimming in Putah Creek). Based on surface water data collected since 1992, contaminants of concern in the surface water of Putah Creek include VOCs, SVOCs, pesticides, and metals. Roughly similar concentrations of these contaminants were detected upstream and downstream of the LEHR site, suggesting that these contaminants may be originating from sources other than LEHR. As noted earlier, there was no comprehensive surface water monitoring program for the LEHR site or for the South Fork of Putah Creek prior to the 1990s at the height of the research activities at LEHR. Without data from such a program, ATSDR cannot fully assess possible past exposure.

III.E Air

Ambient air samples were collected on the site during the 1990s, primarily in association with soil cleanup activities. ATSDR reviewed the available sampling data to understand whether and to what extent people might be exposed to these contaminants in air. This section provides details on the sampling programs conducted to date and the key findings of those sampling programs. It discusses sampling conducted during a baseline study in 1995 and sampling during site remedial activities starting in 1997. The public health implications of ambient air exposures are described in Section IV.

III.E.1 Air Monitoring Programs

Historically, air sampling has not been required under the Site Environmental Monitoring and Surveillance Plan because LEHR does not have any active air releases (effluent discharges) from DOE-operated facilities. A 1-year baseline air sampling program, however, was *begun* in August 1995 to complete a comprehensive risk assessment for the site (Weiss Associates 1997a). This monitoring effort was extended through the summer of 1998. Also, air monitoring was conducted during four remedial actions conducted at the LEHR site between 1998 and 2001 to access airborne impacts during these activities (Weiss Associates 2003).

Initially, the air sampling network at LEHR included five monitoring stations located near the perimeter of the site, as well as one background station and one meteorological station. Air monitoring locations were based on historical records of site activities, planned investigation activities, and soil and water monitoring data (Weiss Associates 1999c). The stations were located as follows: AM-1, used from 1995 to 1996, was in the northwest corner of the site; AM-2, used from 1995 through 2001, was in the upper northeast corner of the Toxic Pollutant Health Research Laboratory; AM-3, used since 1995, was near UC Davis Landfill Unit 3 and approximately ¼ mile east of the site; AM-4, used from 1995 to 1996, was in the southeast corner of the site; and AM-5, used since 1995, was initially south of the Western Dog Pens but was moved to the southwest corner of the pens in 2000. The on-site meteorological station provided measurements of wind speed, wind direction, temperature, and barometric pressure. The UC Davis Climatological Data Center, located 1 mile northwest of the site, provided additional meteorological data.

Airborne contaminants were sampled at the stations by continuously operating samplers. Twenty-four-hour samples were collected in August 1995, September 1995, October 1995, January 1996, April 1996, and July 1996. Hourly average measurements were recorded by an automated data collection system and the samples were analyzed for VOCs, airborne dust, chlordane, metals, and selected radionuclides (e.g., H-3 and total gross alpha and beta radioactivity) (Weiss Associates 1999a).

In January 1997, the program was modified to continue monitoring at AM-2, AM-3, and AM-5, and to add locations AM-6 (a background station located at the Long Term Research on Agricultural System approximately 9 miles northwest of the LEHR site) and AM-7 (a mobile monitoring station initially used in the SWT area). The modified program continued to monitor for total gross alpha and beta radioactivity biweekly and gamma emitters and radon quarterly; however, the frequency of sampling for H-3 and nonradioactive analytes was reduced to monthly (Weiss Associates 2003).

In June 1998, the air sampling program was modified to monitor during remedial activities only. Four DOE remedial activities were conducted between 1998 and 2001: Southwest Trenches (1998), Radium/Strontium Treatment System Phase I (1999), Radium/Strontium Treatment System Phase II (2000), and Western Dog Pens (2001).

III.E.2 Nature and Extent of Air Contamination

Chemical Contamination

Chemical (nonradioactive) air contaminant concentrations detected at the on-site air monitoring stations were generally similar to those detected at the background station. The majority of contaminants analyzed were reported below the laboratory detection limits. The pesticide chlordane was detected at a maximum concentration in air of 0.03 microgram per cubic meter ($\mu g/m^3$), which slightly exceeds ATSDR's CVs (a CREG of 0.01 $\mu g/m^3$ and a chronic EMEG/MRL of 0.02 $\mu g/m^3$). Another pesticide, heptachlor (up to 0.002 $\mu g/m^3$) was also detected above its CV (a CREG of 0.0008 $\mu g/m^3$). Lastly, benzene at levels up to 18 $\mu g/m^3$ was detected above ATSDR's CVs (a CREG of 0.1 $\mu g/m^3$), along with a few other VOCs. The air contaminants that exceeded ATSDR's CVs were sampled from the SWT area's air monitoring location (AM-7), where air concentrations were generally higher than at the two other on-site monitoring stations (AM-2 and AM-5). The higher ambient air levels detected at AM-7 are attributed to excavation activities at the Southwest Trenches as part of removal actions being conducted at the time of testing (Weiss Associates 1999c). The removal of contaminated soil from SWT area was completed in 1998. (See the description of AM-7 in Table 1 for more details on the removal action at this site.)

Radioactive Contamination

Although 12 radionuclides were detected above their detection limits in air samples collected between 1996 and 1998, it was determined that the on-site data were statistically identical to the off-site background data and were not at a level to pose a public health concern (Weiss Associates 2003). During the four remedial actions, some radionuclides were detected above their detection limits; however, the median and the maximum results were statistically the same

as off-site background data and were not at a level to pose a public health concern (Weiss Associates 2003).

III.E.3 Air Exposure Pathways

The public is not likely to have come in contact in the past, or to come in contact now or in the future, with elevated levels of air contaminants from LEHR. Certain airborne contaminants have been detected at elevated concentrations at the Southwest Trenches during excavation, but public exposure to on-site air concentrations is minimal if it occurs at all. Access restrictions prevent the public from entering on-site areas where the highest levels of airborne contamination were detected. Furthermore, concentrations were shown to decrease greatly by the time contaminants reach the LEHR boundaries and with the completion of the removal activity. For this reason, no harmful levels of contamination are expected to reach off-site communities, now or in the future. There are no historical data on which to base an assessment of past exposures. However, the fact that more recent data collected during the disturbance of contaminated soils showed little or no airborne contamination, especially near site boundaries, suggests limited potential for any past off-site air releases.

III.F Biota (Edible Plants, Fish, and Shellfish)

Plants and animals are collectively known as *biota.* Certain chemicals and radionuclides can accumulate in biota. This can become a concern when people consume foods that have taken in harmful levels of environmental contaminants. Agricultural products (e.g., nuts, fruits, and grains) are grown locally and fish from Putah Creek are caught for consumption. Because of the use of groundwater for local irrigation of crops and releases to Putah Creek, ATSDR assessed potential environmental impacts on the locally grown crops and Putah Creek fish and crayfish and associated exposure situations. (See Section IV for the evaluation of public health implications and recommendations.)

III.F.1 Locally Grown Crops

Irrigation wells exist in the vicinity of LEHR, some within the path of groundwater flow and closer (from approximately 1,500 feet to 1.5 miles) to the LEHR site than private drinking water wells. Beginning in 1989, sampling identified chloroform, 1,2-dichloroethane, antimony, arsenic, chromium, molybdenum, thallium, and nitrate in irrigation wells. As noted in Section III.B.3, these detected contaminant levels exceed drinking water CVs. The source of some of these chemicals, such as the metals and nitrate, is not certain. Some probably come from natural processes or agricultural fertilizer use rather than LEHR site activities. In 1990, gross alpha was detected in one water sample at a concentration above ATSDR's CV; however, this well was sampled 18 times since then (from 1990 through 1996) with no other values above the CV—most analyses showed nothing detectable. No sampling data from before 1989 are available for the irrigation wells in the area; therefore, ATSDR does not know if they could have been affected by contaminants prior to 1989.

Limited plant tissue data were available for our evaluation of the contaminant uptake by crops grown in the area of LEHR. The only available plant data were results from an investigation measuring radioactivity of leaves from a fruitless mulberry tree located 3.5 feet from the northern boundary of LEHR's DOE Disposal Box area. The results found no measurable amounts of radioactivity in the leaves.

In the absence of sufficient monitoring data, ATSDR reviewed scientific literature that studies relationships between irrigation sources and crop uptake to determine whether detected contaminants might accumulate to excess concentrations in locally grown and irrigated crops. ATSDR found, however, that little information exists to describe the association between contaminated irrigation water and contaminant concentrations in plants. Consequently, the extent to which plants may directly take in certain contaminants from irrigation sources remains unclear.

Some information described how contaminants might reach edible portions of plants from soil. Uptake of the contaminants from irrigated soil through the roots of crops is influenced by several factors, including plant species, soil type, and physical and chemical characteristics of the contaminant, in addition to the frequency with which the crops were watered with the contaminated irrigation water (ATSDR 1992a, 1992b, 2000a, 2000b). ATSDR does not have specific information about site conditions that influence uptake (such as which crops were irrigated with a particular well or for how long), nor do we have any soil data.

The general body of information on plant uptake from soil suggests that VOCs would not be expected to remain in soil to contribute any appreciable amount to the plant. Findings of bioaccumulation studies also show that plants, in general, do not appear to take in high levels of metals (e.g., arsenic, antimony, chromium, hexavalent chromium, molybdenum, thallium) or nitrate into their edible portions (ATSDR 1992a, 1992b, 2000a, 2000b; CDFA 1998).[10] Several natural processes that may serve to protect plants against significant uptake and toxicity from these inorganic constituents (and perhaps others) in soil are described below:

- Some inorganic compounds, such as nitrate, exhibit high water solubility. As the nitrate level in soil exceeds what is actually needed by the plant, water filtering through the soil causes the excess compound to leach from soil to groundwater (EPA 1995a).

- Most elements, including arsenic, antimony, and chromium, are tightly bound to soil or plant roots and are insoluble in water such that they are not transferred into edible plant parts, even when concentrations in the soil are high (ATSDR 1992a, 2000a, 2000b, 2001; EPA 1995a).

- Certain plants exhibit a tolerance to arsenic and other metals. When the soil metal concentration is high, metals such as arsenic can be taken up by plants at levels toxic to the plants but not to humans. The edible parts of plants would be stunted or the plants would exhibit visible symptoms of toxicity from high levels of metals. As a result, the yield of viable plants would be reduced (EPA 1995a; ATSDR 2001). For example, vegetables (e.g., beans, legumes, spinach, cucumbers) have shown signs of toxicity such as yellowing or browning of roots and wilting when stressed by arsenic.

Molybdenum and thallium are the only elements detected in irrigation water that have been reported to show some absorption potential from soil to plant roots (ATSDR 1992b; ATSDR 2001; WHO 1996). Among crops, leafy vegetables could transfer the highest amounts of

[10] Plants can also take up contaminants from the underlying groundwater. This usually occurs when a plant's root system extends down to the contaminated groundwater layer. Since the contaminated HSU-1 is more than 20 feet below ground surface, we would not expect vegetables grown in the area to reach the contaminated groundwater or to take in contaminants from contaminated groundwater.

molybdenum from soils. However, no human poisonings from soil molybdenum through garden food plants have been reported (ATSDR 2001). The uptake of thallium depends on multiple factors, for example the soil pH and the type of root system. When thallium is absorbed, it tends to concentrate in the chlorophyll-containing regions of the plants or vegetables (IPCS 1996).

Without specific information on the actual contaminant concentrations in crops, ATSDR does not know with certainty if crops grown near LEHR have accumulated any contaminants. It appears, however, that *most contaminants would not have an adverse impact on off-site vegetation or pose past, current, or potential future risk to consumers of this produce.* This determination is based on the types and levels of contaminants in groundwater used for irrigation and on the results of a sampling of leaves from a fruitless mulberry tree on site that indicated no measurable radioactivity. The only question that remains is the extent, if any, to which thallium might be present in local crops.

III.F.2 Putah Creek Fish and Crayfish

Putah Creek is used for recreational fishing and shellfishing in the area of LEHR. As noted in the "Surface Water and Sediment" discussion, Putah Creek's water quality and sediment have been impacted by pollutants from LEHR and other contaminant sources, including local agriculture and mines further upstream known to leach mercury. Studies conducted at LEHR have shown that metals and some pesticides are the primary contaminants of concern in the creek (ATSDR 1997, 1998b, 1998c; Slotton et al. 1999). Certain contaminants, such as metals, do not decompose easily, so they remain in the environment for many years after release. Even though the levels of the contaminants are relatively low in the surface water and sediment, the contaminants can still accumulate in fish tissue. Fish take in contaminants when they eat smaller fish or contaminated sediment. In this way, larger and older fish can build up high levels of contaminants under certain circumstances (EPA 1995b).

No fish consumption advisory for the area of Putah Creek near the LEHR site has been issued by the California Department of Fish and Game (CDFG); however, CDFG has issued a fish consumption advisory for Lake Berryessa, which is part of Putah Creek, approximately 25 miles upstream of the LEHR site. This fish advisory, issued because of elevated mercury levels, sets monthly limits for adults and children aged 6 to 15 years, and recommends that pregnant women, nursing mothers, and children younger than 6 years not eat fish from the lake (Stratton et al. 1987). However, in 2003 the U.S. EPA approved the recommendation of the CRWQCB's Central Valley Region to designate Lower Putah Creek an impaired waterway under Section 303(d) of the Clean Water Act. That designation is based on elevated mercury levels reported in fish in lower reaches of Lower Putah Creek below Lake Solano.

Fish Monitoring Data (EPA 1996–1997)

ATSDR examined available Putah Creek fish data collected upstream and downstream from the LEHR site during two separate health consultations. In the first health consultation, ATSDR reviewed a total of 141 fish and crayfish collected in a 2-week period during the summer of 1996 by EPA Region IX scientists at the National Air and Radiation Laboratory (NAREL) (ATSDR 1997). NAREL scientists filleted the fish and removed the crayfish tails. NAREL combined many of the fish fillets and crayfish tails to obtain composite samples, allowing sufficient sample sizes to perform all planned analyses. Samples were analyzed for metals, pesticides, and PCBs. ATSDR determined that many of the fish samples from Putah Creek near the LEHR site had elevated levels of mercury and lead and were considered a public health hazard to people who eat the fish. Because the analysis involved compositing different species of fish, the specific types of fish containing elevated mercury and lead levels could not be identified. ATSDR's first health consultation thus recommended an additional fish study that would better define the concentrations of mercury and lead in different fish species (ATSDR 1997).

ATSDR's 1998 health consultation further assessed Putah Creek fish contaminant issues (ATSDR 1998b, 1998c). EPA Region IX scientists, assisted by an independent contractor, Thomas R. Payne & Associates, collected a total of 152 fish and crayfish in the fall of 1997. NAREL scientists homogenized whole fish or crayfish. In a few cases, composite samples of two or more fish were prepared of a single species and size range from a single location. NAREL analyzed the fish and shellfish samples for metals and radionuclides. The second health consultation provided more details on the levels of mercury and lead in specific fish and shellfish species. After evaluating data collected for both health consultations, ATSDR concluded that:

- Concentrations of *mercury in some largemouth bass* (up to 0.8 ppm) in Putah Creek are at levels of potential health concern for fetuses and nursing children whose mothers eat these fish.

- Concentrations of lead, other metals, PCBs, pesticides, and radionuclides in fish and crayfish in Putah Creek are not at levels of health concern.

- Sampling location did not have any significant effect on mercury levels; that is, mercury levels were overall fairly similar at all sampling locations along Putah Creek, whether upstream, adjacent, or downstream of the LEHR site.

- Data describing concentrations of toxic organic substances, such as pesticides, in the fish in Putah Creek are not complete. (The NAREL laboratories did not analyze any of the fish collected in its second survey for toxic organic substances.)

Fish Monitoring Data (Slotton 1997–1998)

Since ATSDR's health consultations were completed, the UC Davis Department of Environmental Science and Policy conducted a study to determine the mercury distribution in Putah Creek (Slotton et al. 1999). The study analyzed edible muscle samples from adult fish of 16 different species in a range of sizes (127 individual samples); a wide variety of small and juvenile fish in consistent, multi-individual, whole-body composites (48 total); and muscle in 80 individual samples of adult crayfish. Samples were collected in 1997 and 1998 and analyzed for mercury only. The study confirmed that many of the Putah Creek fish species contained mercury in edible muscle, with larger animals of the top predatory fish species most contaminated. Two adult largemouth bass taken at the furthest downstream locations had the highest detected concentrations of mercury (0.62 ppm and 0.73 ppm) in the LEHR vicinity. Similar levels of mercury were detected in white crappie (0.63 ppm) and two downstream samples of squaw fish (0.72–0.73 ppm) at the same locations. Higher levels of mercury were noted in crayfish and a few juvenile fish caught several miles upstream of LEHR. It was noted that stream flow appeared to be dramatically reduced in most seasons at the locations where the fish with the highest mercury concentrations had been caught, suggesting that a reduced flow creates conditions that might be favorable for mercury uptake in fish. With the exception of these areas, similar concentrations of mercury were observed among the different fish species sampled throughout Putah Creek.

The study concluded that the UC Davis region of Putah Creek was not found to significantly alter "biological mercury trends" in any of the species sampled, including those fish that might stay in close proximity to the LEHR site. Where closely comparable data could be collected, the stretch of Putah Creek adjacent to LEHR and downstream to a distance of at least 3 miles frequently contained among the lowest relative levels of mercury. Slotton et al. (1999) concluded that remnant, mining-derived mercury (together with some level of ongoing mercury transfer through Lake Berryessa, upstream of UC Davis) constituted the primary source of ongoing mercury contamination in the South Fork of Putah Creek.

Biota Exposure Pathways and Exposed Populations

People are known to eat fish and shellfish from the South Fork of Putah Creek, including areas potentially receiving inputs from LEHR. Data collected for ATSDR's 1997 and 1998 health consultations and by Slotton et al. (1999) have shown that some Putah Creek fish and crayfish have accumulated mercury to levels above ATSDR CVs. *Fish and crayfish in the South Fork of Putah Creek therefore represent a completed past, current, and potential future exposure pathway, particularly in regard to mercury exposure.* While ATSDR does not have data from before 1996 on mercury concentrations in Putah Creek fish, we assume that current concentrations are fairly representative of past exposure conditions because mercury is a persistent chemical for which concentrations are unlikely to decrease over time. See the "Public Health Implications" section (Section IV) of this PHA for further discussion.

III.G Ambient Radiation

From 1968 until 1985, a cobalt-60 irradiator located in the southeast corner of the LEHR property was used to irradiate beagles in an outdoor fenced-in area. The irradiator consisted of a 349-curie cobalt-60 source mounted on the roof of a concrete building in such a manner as to provide irradiation to a segment of the outdoor fenced-in field or to the enclosed room beneath. Until 1985, many of the irradiation procedures used the outdoor field (DOE 1988).

The maximum ambient radiation levels at the irradiator pen fence-line were measured in 1976 (ATSDR 1995). The highest annual ambient radiation level was recorded for the west fence (on-site within the LEHR property boundary) and the lowest was recorded for the east fence (next to the UC Davis Raptor Center); however, if someone were constantly present (24 hours per day, 365 days per year) anywhere at the LEHR fence line, his or her exposure would have exceeded the regulatory limits for the general public.

By 1985, the ambient radiation levels at the fence line were not as high; however, an investigation by UCD and DOE revealed that there was no feasible corrective actions that would reduce the possible exposure levels at the LEHR boundary to the new DOE action level (below 25 millirems/year effective dose equivalent) (DOE 1988). The use of the irradiator was discontinued in October 1985. In January 1986, LEHR asked for and was given permission to use the irradiator for indoor use only. By 1987, although regulatory limits were not being exceeded, the DOE action level was being exceeded at the North-1 and East-1 measurement locations, but not at the East-2, South-1, and South-2 locations (DOE 1988). Use of the irradiator was discontinued in 1988. The cobalt-60 source was removed and shipped to an off-site facility in 1993 (Weiss Associates 1997a).

Since no one was present at the fence line constantly when the outdoor uses were occurring and persons at the LEHR site were kept away from the area when the irradiator was being used, it is doubtful that any individual would have received a dose similar to the ambient radiation measurements. For a worst-case scenario outside the LEHR boundary, ATSDR assumed that an individual could have been tending to the birds at the Raptor Center in 1976 close to the fence for 2 hours per day, 5 days per week, and 50 weeks per year. This person would not have received a radiation dose that would cause an adverse health effect (ATSDR 1995). Since radiation exposure levels drop off significantly with distance, ATSDR determined that residents at nearby farmhouses south of the cobalt-60 source and people who fished in Putah Creek would not have received enough radiation dose to cause adverse health effects (ATSDR 1995).

IV. Public Health Implications

IV.A Introduction

> Human exposure does not always result in adverse health effects. Determining public health implications involves carefully studying what is known overall about the toxicity of the chemical or radioactive contaminant of concern and the likelihood of it causing harm under site-specific exposure conditions.

In this section, ATSDR further evaluates contaminants that have been detected in completed exposure pathways at levels above ATSDR's CVs. As part of this evaluation, ATSDR estimates exposure doses using assumptions about site-specific exposure conditions. Protective, but realistic assumptions are made about the frequency, duration, and magnitude of site-specific exposures. These estimates allow ATSDR to evaluate the likelihood, if any, that contaminants at detected levels are associated with adverse health effects. ATSDR then compares the estimated exposure dose for a contaminant to either the ATSDR oral minimal risk level (MRL) or EPA oral reference dose (RfD). MRLs and RfDs are calculated from the scientific literature available on exposure and health effects for a chemical. These values are established at concentrations generally *many times lower* than levels at which no effects were observed in experimental animals or human epidemiologic studies. Therefore, if site-specific exposure doses are below the MRL or RfD, ATSDR can safely conclude that *no* harmful effects are likely.

For estimated doses found to exceed MRL or RfDs or for contaminants known or suspected to cause cancer, ATSDR closely examines relevant scientific literature to assess the overall weight of evidence about a contaminant's potential to cause adverse effects at the detected levels and under site-specific conditions. In addition, where possible, ATSDR examines whether characteristics of the exposed populations—such as age, gender, nutritional status, genetics, lifestyle, and health status—could influence how a person absorbs, distributes, metabolizes, and excretes contaminants. A balanced review and integration of exposure and health effects information helps us determine whether adverse health effects are likely or unlikely.

As discussed in the previous section, ATSDR identified contaminants in three completed exposure situations requiring closer evaluation: 1) exposure to nitrate and metals in private well water; 2) exposure of recreational users of Putah Creek to VOCs, SVOCs, pesticides, and metals in surface water; and 3) consumption of mercury-contaminated fish caught from Putah Creek. *A description of the method and assumptions used in estimating exposures is presented in Appendix B.*

IV.B Special Considerations of Women and Children

Women and children can sometimes be affected differently from the general population by contaminants in the environment. Both tend to be smaller than the average person, which means they can be affected by smaller quantities of contaminants. The effect of hormonal variations, pregnancy, and lactation can change the way a woman's body responds to some substances. Past exposures experienced by its mother, as well as exposure during pregnancy and lactation, can expose a fetus or infant to chemicals through the placenta or in the mother's milk. Depending on the stage of pregnancy, the nature of the chemical involved, and the dose of that chemical, fetal exposure can result in problems like miscarriage, stillbirth, and birth defects.

ATSDR's Child Health Initiative recognizes that developing young people, whether fetuses, infants, or children, have unique vulnerabilities. Children are not small adults; a child's exposure can differ from an adult's exposure in many ways. A child drinks more fluids, eats more food, and breathes more air per kilogram of body weight than an adult, and furthermore has a larger skin surface area in proportion to body volume. A child's behavior and lifestyle also influence exposure. Children crawl on floors, put things in their mouths, play close to the ground, and spend more time outdoors. These behaviors may result in longer exposure durations and higher intake rates.

Children's metabolic pathways, especially in the first months after birth, are less developed than those of adults. In some cases, children are better able than adults to deal with environmental toxins, but in others, they are less able and more vulnerable. Some chemicals that are not toxins for adults are highly toxic to infants.

Children grow and develop rapidly in the first months and years of life. Some organ systems, especially the nervous and respiratory systems, can experience permanent damage if exposed to high concentrations of certain contaminants during this period. Also, young children have less ability to avoid hazards, because they lack knowledge and depend on adults for decisions that may affect children but not adults.

In the following discussions, ATSDR will indicate whether women and children were, are, or may be exposed to contaminants of concern and discuss the possible health concerns related to these exposures.

IV.C Evaluation of Public Health Hazards from Private Drinking Water

Nitrate levels detected in certain private wells may pose health risks to infants who regularly drink the contaminated water directly or mixed with formula. ATSDR does not believe that the concentrations of metals in the private wells are likely to result in adverse health effects in people drinking the water.

Sampling of the neighboring private wells showed that some wells contained nitrate and metals (antimony, arsenic, chromium [total and hexavalent], lead, mercury, molybdenum, thallium) at levels above ATSDR CVs. People could have been exposed to these contaminants when they drank water from their wells. (The VOC vinyl chloride was detected once above the CV in a well located away from the direction of groundwater flow from the LEHR site. It is unlikely that this level resulted from site activity or caused harmful health effects for those drinking the water.) What follows is ATSDR's evaluation of the potential for health effects from exposure to the detected levels of nitrate and metals in private domestic drinking water wells near LEHR.

Nitrate

Nitrate (at levels up to 53,900 ppb) was detected in 13 neighboring domestic-use wells. Nitrate is a form of nitrogen (N), which is a component of fertilizers used in agricultural practices. After detecting nitrate in the local wells, DOE began supplying bottled drinking water to affected home owners in 1989. People could have been exposed to nitrate when they drank or otherwise used water from their wells before that time, but presumably exposures ended with the supply of bottled water in 1989. Some residents, however, may continue to drink the water from their wells as well as coming in contact with it via skin exposure and inhalation while using the water for non-drinking purposes.

Several historical studies investigated—and still provide the most convincing evidence of—the effects from drinking nitrate-contaminated water, particularly in small children (Bosch et al. 1950; Walton 1951). High levels of nitrate have been reported to cause a serious illness in infants—known as methemoglobinemia—in which the blood is unable to transport oxygen normally. The condition results because nitrate, which is relatively nontoxic, is converted into nitrite by bacteria in the infant's stomach. The infant's gastrointestinal tract normally has high pH levels (i.e., is less acidic) that favor the growth of nitrate-reducing bacteria. Nitrite present in the infant's body then interferes with the oxygen carrying capacity of the blood. The lack of oxygen causes shortness of breath and blueness of the skin. Although the condition can be serious, it is easily reversed with treatment. Most infant cases of methemoglobinemia have been associated with nitrate water concentrations greater than 20,000 ppb. No cases have been reported at exposure concentrations less than 10,000 ppb.

In 1998, ATSDR evaluated nitrate concentrations in private well water near LEHR and the possible dangers of methemoglobinemia. ATSDR's review suggested that nitrate-induced health effects may occur in infants after ingestion of the some of the highest nitrate concentrations (over 50,000 ppb) detected in private wells near the LEHR site. ATSDR concluded that elevated levels of nitrate in certain private drinking water wells near LEHR pose a risk to infants 6 months of age or younger who could ingest the private well water directly or mixed in formula. Adults are not considered at risk of nitrate-related health effects at detected levels; even the maximum detected nitrate level falls below ATSDR's CV of 60,000 ppb for adults. We presented our findings and provided recommendations for the community (see the text box) in a public health consultation released in 1998 (ATSDR 1998a).

Since that consultation was released, ongoing sampling of the private wells has detected concentrations up to 53,900 ppb (at Drinking Water Well 5 [DW5] during 1999 sampling). Estimated doses for an adult and child exposed to the maximum detected concentration are 1.5 mg/kg/day and 3.3 mg/kg/day, respectively. The dose for a child was found to slightly exceed the RfD/MRL for nitrate of 1.6 mg/kg/day. Most nitrate concentrations detected in the private wells were less than 20,000 ppb. Four wells located southeast of the site (DW4, 8, 9, 11) had nitrate levels less than 10,000 ppb. As described in Appendix C and consistent with ATSDR's earlier findings, infants are the most vulnerable population, with effects reported as low as 10,000 ppb nitrate but more notably above 20,000 ppb.

ATSDR's recommendations for private well users in Yolo/Solando County:

- Regularly test well water for nitrate/ nitrite levels.
- Avoid giving infants under 6 months of age private well water if nitrate/nitrite levels approach or exceed EPA's maximum contaminant level of 10,000 ppb.
- Avoid boiling private well water, which tends to concentrate nitrate/nitrite level. Provide alternate water source if bacteriological contamination is a concern.

Metals

The metals antimony, chromium (total and hexavalent), lead, mercury, molybdenum, and thallium were detected at levels above ATSDR's CVs in various neighboring private wells, but these metals are not necessarily present as a result of LEHR activities. As noted above, people with wells containing elevated nitrate are believed to have stopped using their private wells for drinking water when DOE supplied bottled water in 1989. People would continue, however, to come in contact with groundwater via skin exposure and inhalation while using the water for non-drinking purposes. The detected metals are not volatile nor are they absorbed to any great extent through the skin. ATSDR focused, therefore, on evaluating possible ingestion exposures, not knowing the full extent to which people may still be using private wells for drinking purposes even if they are provided with bottled water.

ATSDR found that a child drinking water containing the highest detected concentration of antimony, hexavalent chromium, or molybdenum was likely to be exposed to amounts greater than the oral chronic RfD for these metals. Also, an adult was likely to be exposed to hexavalent chromium at levels greater than its RfD. Exposures of an adult or child to the detected levels of the *other* metals found in the private wells are below MRLs or RfDs. (Appendix C further describes the methodology and assumptions used in deriving the exposure doses for the contaminants reported in drinking water.)

ATSDR reviewed scientific literature on antimony, hexavalent chromium, and molybdenum to evaluate whether adverse health effects would be likely to occur at the estimated doses. The RfDs for antimony and hexavalent chromium are based on exposure levels in laboratory animal studies at which no adverse effects have been seen and have safety factors built into them. ATSDR's estimated doses for antimony and hexavalent chromium are actually much lower—260 to 500 times lower—than the levels at which no adverse health effects were observed in the laboratory animal studies.[11] The RfD for molybdenum is based on the lowest reported health effect in humans exposed to molybdenum-contaminated food. Our estimated dose for molybdenum in private wells is about 18 times lower than the lowest level reported to cause effects in humans. Current toxicologic literature suggests that none of these metals are thought to cause cancer via the oral route of exposure. Considering this information, ATSDR finds that people who drank water from the wells containing the detected concentrations of these metal contaminants are not likely at risk of developing adverse health effects.

IV.D Evaluation of Public Health Hazards From Exposure to Contaminants in Surface Water of Putah Creek

People using Putah Creek for swimming or fishing are not expected to come in contact with harmful levels of site-related contaminants.

Sampling conducted since 1992 has identified VOCs, SVOCs, pesticides, and metals in surface water samples collected from both upstream and downstream portions of Putah Creek relative to the LEHR site. Overall, chemicals were detected infrequently and at relatively low concentrations, most often occurring in as few as 1 of the 14 tested samples at levels above ATSDR's health-based CVs. Further, concentrations of these constituents varied little between upstream and downstream sampling locations. However, as a next step in the evaluation, ATSDR examined the likelihood for exposure to contaminants in the Putah Creek surface water detected at levels above ATSDR's CVs to cause adverse health effects.

[11] While a direct comparison of exposure doses from animals may not be entirely appropriate for a number of reasons (e.g., differences in exposure situations, differences in how animals and humans process the chemical within the body), it can provide a relative sense of the potential for effects to occur.

Surface water from Putah Creek is not used for drinking water, but some exposure might occur via incidental ingestion of or dermal contact with surface water for those who swim or fish along in the creek. In evaluating possible exposure, ATSDR derived doses for current and potential future exposure from incidental ingestion of chemical contaminants that were detected at levels above our health-based CVs in Putah Creek to estimate how much of a chemical a person was exposed to during long-time recreational use of the creek. The lack of surface water data prior to 1992, however, makes it difficult to sufficiently estimate possible exposures that might have occurred in the past.

ATSDR does not have site-specific knowledge about how long or how often people swim in the creek. In the absence of these data, ATSDR used conservative—or protective—assumptions about possible exposures. For example, ATSDR assumed that an adult or child spends about 3 hours a day at the creek (365 days per year). In all likelihood, people swam or waded in the creek sporadically throughout the year and possibly not at all during low flow periods. ATSDR further assumed that a person might incidentally ingest 0.15 liters of surface water (EPA 2000a) and consume the most-contaminated water (that is, water with the maximum detected contaminant concentration) during each swimming event. Average body weights for adults and children are assumed to be about 150 pounds (70 kilograms) and 35 pounds (16 kilograms), respectively. These assumptions allow ATSDR to determine the highest possible level of exposure when evaluating possible effects. It is unlikely that most people near LEHR were exposed to the highest (most conservative) levels of contamination or swam every day.

VOCs can be fairly readily absorbed through the human skin. The scientific literature suggests that VOCs can possibly contribute up to an additional 30% of the ingested dose following dermal (skin) contact (Andelman et al. 1989). Metals and other compounds are less likely to be absorbed through intact skin. Chloroform and dibromochloromethane were the only VOCs detected in Putah Creek's surface water. ATSDR assumed that dermal contact while swimming contributed an additional 30% to the estimated ingestion dose for both chloroform and dibromochloromethane. (Appendix B further describes the methodology and assumptions used in deriving the exposure doses associated with the contaminants reported in Putah Creek surface water.)

By comparing estimated doses to ATSDR's MRLs and EPA's RfDs, ATSDR found that the estimated maximum doses for exposure to the VOCs, SVOCs, metals, and pesticides (through incidental water ingestion, and also through dermal contact with VOCs) were generally much lower (more than 100 times lower) than their corresponding MRL or RfD. Estimated doses for a few contaminants, such as arsenic, antimony, and boron, approached but still did not exceed their MRL or RfD. Because of the protective nature of our estimates, which tend to overestimate actual exposure, we feel that these contaminants do not pose a potential health concern. Using this information, ATSDR concluded that the maximum concentrations of contaminants detected

in Putah Creek near LEHR are much lower than the level at which adverse health effects have been observed. As a result, ATSDR does not expect people who swim in the creek to incur harmful health effects now or in the future. Due to the lack of surface water data from before 1992, ATSDR could not estimate possible exposures that might have occurred in the past.

ATSDR also considered the potential for cancer effects, weighing what is known and not known about the carcinogenicity of detected contaminants. ATSDR found no studies providing evidence of cancer in humans after incidental oral exposure to these contaminants at the detected levels. Therefore, ATSDR concludes that incidental ingestion of surface water does not pose a health concern for cancer or noncancer effects.

IV.E Evaluation of Public Health Hazards from Ingestion of Putah Creek Fish

Mercury was detected at slightly elevated levels in certain fish from Putah Creek. Because mercury can cause health effects in a fetus or nursing child whose mother eats mercury-contaminated fish at high enough levels, limiting the amount of fish consumed is recommended as a prudent public health measure.

Elevated levels of mercury have been detected in largemouth bass collected from both upstream and downstream stretches of Putah Creek in the vicinity of the LEHR. These data were collected during three separate studies (ATSDR 1997, 1998b, 1998c; Slotten et al. 1999). Mercury concentrations in the largemouth bass were detected at a high of 0.8 ppm in samples collected by EPA for ATSDR's 1998 health consultation and at 0.73 ppm during the more recent Slotton et al. (1999) study. Mercury in Putah Creek fish was elevated even though much lower concentrations were measured in the surrounding water.

Mercury tends to build up in the fish food chain, accumulating in larger and larger amounts as smaller fish are eaten by larger fish. This is why we tend to see the highest levels in the top-level predatory species, such as largemouth bass. Once in the fish, mercury resides in the fish tissue and cannot be removed by cooking or cleaning.

At high enough levels, mercury can cause damage to the human nervous system. Of particular concern are its neurotoxicity to the developing fetus and the subsequent effects seen in the young child. Exposure occurs when mercury passes to the fetus through the placenta or to a nursing child through breast milk. Adults might experience short-term health risk if they frequently eat fish that contain mercury. Because the human body can eliminate smaller amounts of mercury over time, however, mercury rarely accumulates to harmful levels in the occasional adult fish consumer.

In the 1998 health consultation, ATSDR estimated exposure doses to the maximum detected concentration (0.8 ppm in a largemouth bass collected in 1997) of mercury detected in Putah

Creek fish. Information was not available on which fish species are eaten by local anglers or how much fish is eaten from Putah Creek. In the absence of specific information about exposure, ATSDR used a hypothetical exposure scenario based on conservative assumptions: that is, an adult consumes about two 8-ounce fish meals a week (or 1.9 ounces [54 grams] daily). ATSDR further assumed that anglers consume fish exclusively from the Putah Creek and that they consume fish containing the highest concentration of mercury detected in available samples.

ATSDR then compared the estimated exposure dose to the available health guideline (or the MRL) for mercury. At that time, the chronic oral exposure to methylmercury (the form of mercury most likely found in fish) was 0.0005 milligrams per kilogram per day (mg/kg/day).[12] As discussed earlier, the MRL is an estimate of daily human exposure to a substance that is likely to be without appreciable risk of adverse noncancer effects over a specified duration. The estimated dose (0.0007 mg/kg/day) slightly exceeds the MRL.

ATSDR estimates that about 0.56 ppm of mercury in fish for a 132-pound (60-kilogram) adult woman eating about two meals a week (or 1.9 ounces or 54 grams daily) equates to the ATSDR MRL. ATSDR used the 0.56 ppm value to screen for possibly unacceptable levels of mercury in Putah Creek fish. Mercury concentrations in fish samples collected from Putah Creek for the 1998 health consultation slightly exceeded 0.56 ppm in two large-sized (i.e., heavier than 1,200 grams) largemouth bass collected from two downstream locations. Based on this finding, ATSDR recommended in the 1998 health consultation that women of child-bearing age, especially those who are pregnant or are nursing, refrain from eating largemouth bass from Putah Creek.[13]

Using the same value (0.56 ppm) for comparison, ATSDR examined the Slotton et al. (1999) data for fish samples containing potentially harmful levels of mercury. Mercury concentrations (0.62–0.73 ppm) in 3 out of 8 of the largemouth bass samples slightly exceeded 0.56 ppm. All three samples were collected from downstream locations. These data further support ATSDR's recommendation that women of child-bearing years protect themselves against the risk of

---

[12] The MRL was based on a study in which children exposed to high levels of mercury *in utero* showed signs of delayed development in walking and talking. The level of mercury in the mothers' bodies, however, was four to five times lower than the levels shown to cause health effects in adults. Since that time, ATSDR has revised its chronic oral MRL to 0.0003 mg/kg/day, also based on a study of children exposed *in utero*. The MRL was based on a no-adverse-effect level of 0.0013 mg/kg/day, derived from examining mercury levels in the mothers' hair (ATSDR 1999).

[13] One should recognize, however, that exposures above the screening value does not mean adverse effects will occur. Though prudent public health practice calls for limiting exposure doses at or near the MRL, it should be noted that estimated dose levels (0.0007 mg/kg/day) are below the levels shown to cause effects in human studies. In fact, they are below dose levels at which no effects at all are reported (0.0013 mg/kg/day).

mercury exposure by avoiding Putah Creek largemouth bass. Slotton et al.'s data also show mercury at levels above 0.56 ppm in one downstream sample of white crappie (0.63 ppm) and two downstream samples of squaw fish (0.72–0.73 ppm). If further analysis shows that white crappie or squaw fish are sought after for consumption or that mercury levels continue to exceed our screening level of 0.56 ppm, then further action protective of public health may be warranted.

V. Community Health Concerns

During ATSDR's site visits, some community members expressed concerns about the need to identify exposures to hazardous materials, identify practices leading to environmental contamination, identify locations and inventories of wastes produced by LEHR and UC Davis, and assess health impacts from exposure to contamination produced at UC Davis. Some individuals told ATSDR of health problems that they or their families or neighbors have experienced. ATSDR's responses to these concerns are summarized below.

- **Concern was raised about high levels of nitrate frequently detected in private well water, with particular concern for infants who drink this water.**

  ATSDR evaluated nitrate concentrations in private well water near LEHR and the possible dangers of methemoglobinemia. ATSDR's review suggested that nitrate-induced health effects may occur in infants after they ingest some of the highest nitrate concentrations detected in private wells near the LEHR site. ATSDR also searched hospital discharge records for cases of infant methemoglobinemia during a 13-year time period, 1983 to 1995, for the vicinity of LEHR (broadly defined by seven zip codes). No cases of infant methemoglobinemia were found.

  We presented our initial findings for the community in a public health consultation released in 1998. We also provided the following recommendations for private well users in Yolo/Solano County to help reduce their infant's exposure to potentially harmful levels of nitrate:

  - Have the well water tested regularly for nitrate/nitrite levels by a reliable water testing firm.
  - Avoid giving infants under 6 months of age private well water if nitrate levels (as nitrogen) approach 10,000 ppb (EPA's maximum contaminant level and ATSDR's health-based CV).
  - Avoid boiling private well if bacteriological contamination is a concern. Boiling water tends to concentrate nitrate/nitrite levels. Instead, obtain water from an alternate water source.

- **There is concern for people eating fish from Putah Creek that are potentially contaminated with mercury, PCBs, pesticides, or dioxins.**

People are known to eat fish and shellfish from the South Fork of Putah Creek, including areas potentially receiving releases from LEHR. Through the public health assessment process, ATSDR reviewed the available fish sampling data that were collected between 1996 and 1998 from Putah Creek near the LEHR site. ATSDR used these data to assess exposures to potentially contaminated fish that inhabit the creek. A summary of ATSDR's findings follows.

Mercury. As described in earlier sections, mercury is present in Putah Creek fish, with the highest concentrations occurring in largemouth bass. Concentrations in some largemouth bass exceeded screening levels (greater than 0.56 ppm) developed to adequately protect the fetus or nursing infant whose mother eats the largemouth bass from the creek. Data also indicate that the stretch of Putah Creek adjacent to UC Davis and downstream to a distance of at least 3 miles frequently contained among the lowest levels of mercury. Mining-derived mercury (together with some level of ongoing mercury transfer through Lake Berryessa, upstream of UC Davis) constituted the primary source of mercury contamination in the South Fork of Putah Creek. Other shellfish/fish samples, including crayfish, bluegill, carp, channel catfish, and black bullhead, did not contain mercury or other tested metals at levels of public health concern. As of December 2002, no fish consumption advisory for the area of Putah Creek near the LEHR site has been issued by the CDFG. (CDFG has issued a fish consumption advisory for Lake Berryessa about 25 miles upstream of LEHR because of concerns about mercury.) However, because of potential health concern from mercury exposure for fetuses and nursing children, ATSDR recommends that pregnant and nursing mothers refrain from eating largemouth bass from Putah Creek.

PCBs, pesticides, and dioxins. Data describing the concentration of organic substances in Putah Creek fish are limited. What data that are available come from the 1997 NAREL study that analyzed fish samples for contaminants that included PCBs and pesticides. The results indicated that PCBs and pesticides were below levels of health concern. These data, however, describe concentrations in composited samples of unlike species only, so conclusions about PCB or pesticide concentrations in individual fish species could not be reached.

- **A number of concerns were expressed about surface water/sediment quality of Putah Creek. These concerns include:**

Excessive chromium in Putah Creek exists at levels that could be toxic to zooplankton. Information collected by UC Davis Aquatic Toxicology Laboratory showed that none of

the samples collected at Putah Creek watershed in November and December 1998 exhibited toxicity to zooplankton (*Ceriodaphnia*) (Larsen et al. 1998). Sampling locations included areas adjacent to, downstream of, and upstream of the LEHR site. While information about zooplankton aids in our understanding of environmental conditions in Putah Creek, information about actual contaminant concentrations in surface water or in fish inhabiting the creek are most useful to our role in assessing possible human exposure to environmental contaminants.

Chloroform concentrations in Putah Creek surface water are high and could pollute groundwater through surface water recharges. Chloroform in the surface water of Putah Creek is unlikely to pollute local groundwater sources. During DOE and UC Davis sampling of Putah Creek over the past 10 years, only one surface water sample collected from the creek (at the PCD location) had a concentration (8.9 ppb) that exceeded ATSDR CV of 6 ppb for chloroform. Concentrations in the remaining 13 downstream samples were below ATSDR's CV. An even higher chloroform concentration (19 ppb) was detected in an upstream sample. These levels of chloroform may be due to chlorine treatment of waste from the WWTP. Considering the low levels of chloroform in the surface water and that chloroform tends to volatilize upon mixing with surface water, little, if any, chloroform should reach groundwater through surface water recharge. Furthermore, monitored chloroform levels in off-site monitoring wells have been decreasing since the implementation of the groundwater treatment system.

The analytical methods used to measure chlordane, mercury, and hexavalent chromium in storm water and surface water and to evaluate possible related impacts on Putah Creek are inadequate, based on EPA water quality criteria documents. The detection limits used in current analytical methods are reportedly often higher than concentrations known to be toxic and/or bioaccumulative to aquatic life. ATSDR studied the detection limits reported in available data sets by comparing them to ATSDR's health-based CVs for drinking water, which represent the values below which no harmful effects are expected should an individual drink 2 liters of water daily over the course of a lifetime. These differ from the EPA water quality criteria in that they focus on human health and look only at direct intake of water. They do not consider the toxicity to aquatic life, nor do they account for bioaccumulation in fish. Generally, the detection limits reported in annual water monitoring reports were at or below ATSDR CVs for drinking water; so ATSDR considered reported levels low enough to support the public health evaluation. ATSDR relied on actual fish tissue data for Putah Creek to assess concerns about bioaccumulation in aquatic life. ATSDR prefers to look at measured data at the point of contact—fish tissue in this case—when available. Values such as EPA water quality criteria are useful as a screening tool in the absence of measured data.

Constituents released from the WWTP at LEHR 1) directly to surface water (Putah Creek) and 2) to surface water through LEHR storm water (both direct storm water runoff and storm water) are not adequately known. The current WWTP at LEHR treats 2.8 million gallons of sanitary waste water, which empty into the South Fork of Putah Creek from an outfall located about 0.25 miles from the current WWTP. Treated water released from the facility to Putah Creek is subject to the conditions of its NPDES permit, granted by EPA and the CRWQCB. The NPDES is a permit program that controls water pollution by regulating sources that discharge into surface water. LEHR's NPDES permit limits what may be ultimately discharged into the creek and specifies acceptable levels of a pollutant in the discharge. According to provisions of the NPDES, UC Davis is required to routinely sample its storm water discharges and to notify CRWQCB of its results. Collectively, these provisions help to ensure that the discharges entering the creek are safe and that public health is being protected. For review, the maximum concentrations of contaminants detected in the treatment plant outfall and storm water releases at the site are listed in Tables 12 and 13 of this document. Most importantly, surface water measurements are available. These are the best measure of possible exposure point concentrations.

There is concern that current discharge requirements do not adequately protect the beneficial uses of Putah Creek. Landfill Unit 3 was cited as particularly problematic, because in the past it had storm water running through a ditch atop the landfill and entering Putah Creek. As mentioned above, all releases to Putah Creek are monitored under the NPDES permit. The NPDES establishes what levels of a substance are acceptable for discharge to the creek. UC Davis has collected storm water samples from Landfill 3 (and Landfill 1) since 1996–1997. (DOE currently collects storm water only from the lift station. Sample collection from the western part of the WDPs was stopped in 1996–1997.) Monitoring results indicates that contaminants, primarily metals and pesticides, were detected infrequently in the storm water samples. ATSDR believes that these detections do not pose a direct threat to public health. As part of their program, UC Davis and DOE also compared the storm water monitoring results against EPA's and California's freshwater aquatic life criteria. Metals and pesticides exceeded these criteria in one or more samples collected between 1996 and 2001. Most of the detected metals in the storm water samples are naturally occurring and likely have not originated from LEHR operations. Similarly, potential pesticide sources include non-LEHR activities, such as regional agricultural practices, in addition to former LEHR practices. Site investigators have suggested that information about flow at Putah Creek discharge points is needed to help put the storm water data in perspective and better assess the potential impact, if any, of these constituents on the Putah Creek habitat.

There is concern that some sources of potential contamination are not being reported by current monitoring methods. For example, chromium-contaminated groundwater from the pump-and-treat remediation system at the currently active landfill on the west campus is reportedly being sent to the campus WWTP and discharged to Putah Creek, and is not captured in monitoring results. As noted previously, all releases to Putah Creek are subject to the conditions of the NPDES permit, which set limits on what may be discharged into the creek and requires routine monitoring of discharges. Sampling of the waste water at the outfall has been conducted since 1992, and the samples are analyzed for metals (including total chromium and hexavalent chromium), VOCs, SVOCs, PCBs, pesticides, and radionuclides. Only a few analytes had one or more detections higher than ATSDR's corresponding CV. Hexavalent chromium was detected only one time at a level above the ATSDR CV for drinking water (30 ppb; the detected level was 45 ppb, in 1992). All other samples collected have been below ATSDR's CVs. As discussed in response to the previous comment, surface water measurements are available and are the best measure of exposure point concentrations.

- **There is concern that the full extent of groundwater and surface water pollution on site and off site is still not known, even though the LEHR site has been under investigation for approximately 10 years.** The comment suggests that the full extent of groundwater and surface water pollution associated with LEHR is not known. The data available for ATSDR's review consisted of a relatively large set of groundwater and surface water data. In fact, we considered the results of several hundred groundwater and surface water samples collected by DOE and UC Davis at and around LEHR over a 15-year period. Data collected from these investigations have served to sufficiently define the current extent of groundwater contamination plumes and type and amount of contamination in Putah Creek. Most importantly for our purposes, we have monitoring data for public and private drinking water supplies near LEHR.

  It is not uncommon for site characterization at NPL sites to continue for years after releases have first been suspected because of the changing conditions at a site and to ensure the public is being protected. UC Davis will continue to monitor both on- and off-site groundwater (quarterly) as well as surface and storm water (biannually) to evaluate and reduce public exposure to site related contaminants. ATSDR believes that the amount of valid monitoring data for this site is sufficient and provides a reasonable account of the groundwater and surface water exposures experienced by local residents.

- **There is concern that groundwater movement and groundwater contamination from the LEHR site were not completely characterized.**

  Groundwater movement at LEHR has been well documented by hydrogeologic studies that characterize groundwater movement in each HSU beneath the site and as it moves off

site. These studies give us sufficient data to say that groundwater flow in HSU-1 is generally toward the northeast, with local, temporary changes in flow. They also indicate that the flow in the HSU-2 and HSU-4 aquifers is toward the east/northeast. There has been no indication in ATSDR's review to suggest that this characterization is only preliminary or inadequate.

As noted in responses to concerns above, ATSDR believes that the groundwater monitoring conducted by DOE and UC Davis provides sufficient information to describe the nature and extent of groundwater contamination at and near LEHR. The data reviewed indicate that:

- The highest concentrations of contamination were generally detected in *HSU-1*, which is not used as a source of drinking water. The primary contaminants of concern detected in this HSU at levels above ATSDR's CVs include chloroform, chromium, nitrate, and H-3. Most of the chloroform and H-3 has decreased over time. Concentrations of nitrate and chromium have remained generally stable at concentrations above CVs from limited movement with groundwater. Nitrate has been reported as a regional groundwater problem due to area-wide agricultural practices.

- Generally lower levels of chromium and nitrate exist in *HSU-2,* which is the aquifer used by several local private well users. Still, some concentrations of nitrate and chromium exceeded ATSDR CVs. Chloroform has migrated in the HSU-2 aquifer to off-site locations, but the levels have generally decreased to levels below ATSDR's CV since 1999—primarily because of the Groundwater Program Interim Remedial Action to reduce the concentrations of chloroform and VOCs in the groundwater at and downgradient of the LEHR site.

- The lowest levels of contaminants were detected in *HSU-4*. As noted above, HSU-4 serves as the primary source domestic drinking water (e.g., UC Davis, the city of Davis, and some private wells). Even though some detects sporadically exceed the CVs, contaminants in this aquifer have generally decreased over time.

A "dual-density convection system" began operations in December 2000 to further remove VOCs from groundwater (Dames & Moore 2001). Current estimates suggest that cleanup of the chloroform plume will take from 10 to 20 years. Because groundwater conditions can change over time due to the dynamic processes that occur at a site (e.g., source removal, groundwater treatment), groundwater monitoring will continue for some time to capture changes that result from these processes.

- **It is felt that, instead of LEHR site monitoring data being compared to comparison values and/or background conditions to assess potential public health hazards, beneficial uses and nondegradation policies should be applied to surface waters. For example, if background concentrations of constituents in Putah Creek upstream of the LEHR site violate basin plan objectives, such as toxicity, then UC Davis might not be allowed to discharge any constituents that contribute to toxicity, such as hexavalent chromium, at concentrations above approximately 0.5 ppb.**

  The goal of the public health assessment process is to determine whether people are being exposed to elevated levels of environmental contaminants and, if so, whether the exposure may cause harm. Though important, the public health assessment process does not evaluate the overall health of the creek from an ecological perspective. ATSDR focuses on evaluating how *measured* surface water levels compare to health-based criteria (e.g., comparison values). ATSDR may consider background data to bring added perspective to site-specific exposures, but we do not make public health decisions based on whether exposure levels are comparable or below background levels. Programs, such as the NPDES permitting program, have specific requirements related to allowable discharges to surface water bodies. The agencies responsible for such programs would need to address concerns related to acceptable discharges.

- **It is felt that each waste management unit should be investigated as an individual unit to determine the full range of constituents released to groundwater, including both the source and the extent of contamination. Specific areas mentioned include Landfill Units 2 and 3 and potential off-site pollution associated with the shallower aquifers. It has also been recommended that a site groundwater model be developed, as previously requested by the EPA, to help develop a systematic assessment of groundwater contamination.**

  Either UC Davis or DOE has investigated environmental conditions at each potential source area at LEHR: the Southwest Trenches; the dog pens; the Sr-90 and Ra-226 Treatment Systems; the Domestic Septic System; the DOE Disposal Box; Landfills 1, 2 and 3; waste holes; and the UC Davis Disposal Trenches. These sites are in various stages of investigation and site cleanup. Each landfill unit has undergone subsurface and surface soil investigations as well as groundwater impact analyses. ATSDR reviewed the available data for the various potential source areas collectively. This PHA summarizes our findings. Groundwater continues to be investigated by UC Davis. UC Davis is addressing site-wide groundwater contamination as part of its Operable Unit 6.

VI. Conclusions

Conclusions regarding potential past, current, and future exposures to community members near the LEHR site are based on a thorough evaluation of site investigation data and observations made during site visits and are described below. Items 1 through 3 below present conclusions about off-site exposures (beyond the LEHR site fence line). Items 4 and 5 present conclusions about contamination on site (at or within the LEHR fence line). (The public health hazard conclusion categories are described in the glossary in Appendix A of this PHA.)

1. *Past exposure to nitrate and metals in off-site groundwater was possible by way of private drinking water wells and irrigation wells.* These contaminants are not believed to be related to the LEHR site. However, current and potential future exposures may also be possible for people still relying on contaminated private well water or unknowingly using contaminated private well water. Of the contaminants measured in available samples, ATSDR determined that the highest levels of nitrate in certain private drinking water wells near LEHR could pose a health concern to infants 6 months of age or younger who could ingest the private well water directly or mixed in formula; therefore, *ATSDR categorizes this pathway as posing a public health hazard for infants 6 months of age or younger.* ATSDR has made some recommendations for private well users in the area, including regular testing, use restrictions, and treatment recommendations. People who follow these recommendations can minimize or prevent their exposure to nitrate.

2. *Exposure to mercury is possible for people who consume Putah Creek fish.* Mercury has been detected in some species of fish, primarily largemouth bass, at levels that could be harmful to the fetus or nursing infant. This contaminant is not believed to be related to the LEHR site; however, *ATSDR categorizes consumption of Putah Creek largemouth bass as posing a public health hazard for the fetus and nursing infant.* ATSDR recommends that pregnant women and nursing mothers prevent exposure to mercury by refraining from eating Putah Creek largemouth bass.

3. *Current and potential future exposures to contaminants in Putah Creek surface water are possible for people who use the creek for recreational activities.* Monitoring data collected since 1992 identified relatively low levels of contaminants in the off-site surface water of the South Fork of Putah Creek, which is the closest surface water body to LEHR. Incidental contact with the surface water or sediment is not expected to be detrimental to one's health. ATSDR categorizes this pathway as posing *no apparent public health hazards* for current and future exposures. Because of the possibility of past exposure at the creek and in light of the lack of data to describe contaminants prior to 1992, when releases to the creek might have been the greatest, a conclusion about past exposure to

contaminants in Putah Creek surface water cannot be drawn. Thus, past exposure to contaminants in surface water is categorized as an *indeterminate public health hazard.*

4. *Minimal potential, if any, exists for exposure to contaminants in on-site surface soil, airborne contaminants, or ambient radiation.* ATSDR categorizes these pathways as posing *no apparent public health hazards* for past, current, or potential future exposures.

   - *Surface soil:* Surface soil at certain locations within LEHR contained contaminants associated with former DOE and university activities. Most often, exposure has been prevented because soil contamination occurs in restricted access areas, is covered by pavement or grass, or has been removed. Occasional contact with surface soil contaminants, even at the highest levels reported, is not expected to pose a health concern for adults or children. Successful cleanup or removal of contamination will continue to reduce potential future exposures.

   - *Air:* Certain airborne contaminants have been detected at elevated concentrations at the Southwest Trenches during excavation, but access restrictions prevented the public from entering on-site areas where the highest levels of airborne contamination had been detected. Additionally, concentrations were shown to be greatly reduced before reaching the LEHR boundaries and with the completion of the removal activities.

   - *Ambient radiation:* Ambient radiation was measured near the fence line of LEHR property in the past; however, no one would have been exposed to enough radiation to have experienced adverse health effects. Worker exposures were limited because workers were kept away from the area when the irradiator was in use. Radiation exposure levels drop off significantly with distance, such that residents at nearby farmhouses south of the cobalt-60 source and people who fished in Putah Creek would not have incurred harmful radiation doses. No current or future exposures are expected, since the cobalt-60 source was removed and shipped to an off-site facility between 1993 and 1995.

5. *The public is not coming in contact with contaminated groundwater beneath the LEHR site.* The shallow groundwater of HSU-1 beneath LEHR has been contaminated primarily with chloroform, chromium, nitrate, and hydrogen-3 (H-3). No exposure has occurred on site because no one uses the shallow groundwater as a source of drinking water. UC Davis has removed contaminated soil and other potential sources of groundwater contamination, and continues to track groundwater contaminant migration within the HSUs beneath the site and away from the site boundaries. Since 1998, an extraction well (part of the Groundwater Interim Removal Action Treatment System) has reduced the concentrations of chloroform and other VOCs in the groundwater beneath the site. H-3

concentrations have also decreased over time. *ATSDR categorizes this pathway as posing no public health hazard for past, current, or potential future exposures.*

VII. Recommendations

1. ATSDR recommends that private well users in the community surrounding LEHR: 1) regularly test their well water for nitrate/nitrite; 2) avoid giving infants under 6 months of age private well water if nitrate/nitrite levels exceed 10,000 ppb; 3) avoid boiling water, which tends to concentrate nitrate/nitrite levels. Rather, seek an alternative source of water.

2. ATSDR recommends that pregnant women and nursing mothers refrain from eating largemouth bass from Putah Creek to keep their fetuses or nursing infants from being exposed to the harmful effects of mercury. If future data show elevated levels of mercury in other species of fish, then ATSDR will expand this caution as needed.

3. ATSDR recommends that UC Davis continue to monitor groundwater, particularly in the HSU-4 aquifer, to ensure that site-related contaminants are not reaching groundwater sources used for local drinking water supplies.

VIII. Public Health Action Plan

The Public Health Action Plan (PHAP) for LEHR describes actions taken and to be taken by ATSDR, DOE, UC Davis, EPA, CRWQCB, the CDTSC, and CDHS in the vicinity of the facility after the completion of this public health assessment. The purpose of the PHAP is to ensure that the public health assessment not only identifies public health hazards, but also provides a plan of action designated to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The public health actions that are completed, being implemented, or planned are as follows.

Completed Actions

- The following sites have been identified as potential source areas and characterized through extensive sampling by DOE and UC Davis: Southwest Trench Area, Ra/Sr Treatment Areas, Western and Eastern Dog Pens, DOE Box, seven Domestic Septic Systems, 49 waste holes, UC Davis Waste Disposal Trenches, and UC Davis Landfill Units 1, 2, and 3.

- UC Davis and DOE have conducted on- and off-site groundwater, surface water, storm water, and soil sampling since 1989 to characterize the nature and extent of site-related contamination.

- In 1989, DOE supplied bottled drinking water to those households whose well water was shown to be contaminated.

- DOE has conducted removal actions in the following potential source areas:

  - DOE Box—Time-critical removal in 1996.

  - Southwest Trench Area—Soils removed and disposed of off site in 1998.

  - Ra/Sr Treatment Areas—Sludge removal in 1992, two phases of removal actions in 1999 and 2000 (including Domestic Septic Tank 2 and parts of Domestic Septic Systems 1 and 5).

  - Dog pen area—Demolition in 1975 and 1996, fence removal in 1999, and soil removal at the former Western Dog Pens in 2001.

  - Domestic Septic Systems 3 and 6—Removal actions completed in 2002.

- UC Davis began an interim remedial action (IRA) for the groundwater beneath the LEHR facility in May 1998. The purpose of the IRA was to limit the off-site migration of contaminants by extracting water downgradient of source areas, treating the water, and injecting treated water upgradient of the source areas. In December 2000, a new dual density convection system was added to the groundwater treatment system to improve the removal of VOCs. As of October 2003, an estimated 80 pounds of chloroform have reportedly been removed from the 212,000,000 gallons of water treated and extracted through the system.

- UC Davis has conducted removal actions at the 49 waste holes.

- ATSDR conducted two site visits (July 1995 and April 2000), prepared a site summary report, and published three health consultations in 1997 and 1998, focusing on fish contamination in Putah Creek and nitrate contamination in groundwater.

- DOE completed remedial investigation of the LEHR site and released its findings initially in a report dated March 2002. A final remedial investigation report was issued in September 2003.

- UC Davis completed a remedial investigation of all its potential source areas (Landfill Units 1, 2, and 3, Eastern and Southern Trenches, and Waste Burial Holes) and released its findings in a draft document dated February 2003.

Ongoing/Planned Actions

- UC Davis will continue to operate the groundwater treatment systems in order prevent further migration of contaminants off site.

- UC Davis will continue to monitor both on- and off-site groundwater (quarterly) as well as surface and storm water (biannually) to evaluate and prevent public exposure to site-related contaminants.

- UC Davis will conduct remedial actions for Landfill Units 1, 2, and 3, the Eastern Trenches, and the Southern Trenches.

- UC Davis will complete its site-wide risk assessment.

- Fencing and signs surrounding the Eastern Dog Pens area will be monitored and maintained until the area is remediated to ensure that the public will not be exposed to potentially impacted areas within the Eastern Dog Pens.

- ATSDR will reassess any new data when they become available and reevaluate, if necessary, our conclusions about potential public health hazards.

IX. Preparers of Report

Authors

Wayne Henry
Environmental Health Scientist, Lead Health Assessor
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

Carol Connell
Health Physicist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

Reviewers

Burt J. Cooper, M.S.
Supervisory Environmental Health Scientist
Energy Section Chief
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

Sandra G. Isaacs
Chief
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

X. References

Andelman BJ, Giardino JN, Marshall J, Borrazzo E, Davidson IC, et al. 1989. Exposure to volatile chemicals from indoor uses of water. In: Proceedings of total exposure methodology: A new horizon; 1989 Nov 27-30; Las Vegas, Nevada. 1989.

ATSDR. 1992a. Toxicological profile for antimony. Atlanta: US Department of Health and Human Services; September 1992.

ATSDR. 1992b. Toxicological profile for thallium. Atlanta: US Department of Health and Human Services; July 1992.

ATSDR. 1995. Laboratory for Energy-Related Health Research, Davis, California, site summary. Atlanta: US Department of Health and Human Services; October 12, 1995.

ATSDR. 1997. Health consultation, fish sampling in Putah Creek. Laboratory for Energy-Related Health Research, Davis, California. CERCLIS No. CA2890190000. Atlanta: US Department of Health and Human Services; April 4, 1997.

ATSDR. 1998a. Health consultation, nitrate in groundwater and methemoglobinemia, Laboratory for Energy-Related Health Research, Davis, Yolo County, California. Atlanta: US Department of Health and Human Services; December 31, 1998.

ATSDR. 1998b. Health consultation, fish sampling in Putah Creek (phase II), Laboratory for Energy-Related Health Research, Davis, Yolo County, California. Public Comment Release. CERCLIS No. CA2890190000. Atlanta: US Department of Health and Human Services; September 16, 1998.

ATSDR. 1998c. Health consultation, fish sampling in Putah Creek, 1997, Laboratory for Energy-Related Health Research, Davis, California. Atlanta: US Department of Health and Human Services; August 1998.

ATSDR. 1999. Toxicological profile for mercury. Atlanta: US Department of Health and Human Services; September 1999.

ATSDR. 2000a. Toxicological profile for arsenic (update). Atlanta: US Department of Health and Human Services; September 2000.

ATSDR. 2000b. Toxicological profile for chromium (update). Atlanta: US Department of Health and Human Services; September 2000.

ATSDR. 2001. Summary report for the ATSDR Expert Panel Meeting on Tribal Exposures to Environmental Contaminants in Plants. Atlanta: US Department of Health and Human Services; March 2001.

Bosch HM, Rosefield AB, Huston R, Shipman HR, et al. 1950. Methemoglobinemia and Minnesota wells supplies. J Am Water Works Assoc 42:161-170.

CDFA. 1998. California Department of Food and Agriculture (CDFA) fruit and nut research and education project, nitrogen fertilizer management to reduce groundwater degradation in almonds. Available at: http://www.cdfa.ca.gov/inspection/frep/projects/fruitandnut/fandnl.htm. Last accessed 2Apr1998.

City of Davis. 2003. City of Davis, California Water Information. Available at: http://www.city.davis.ca.us/pw/water/. Last accessed 2Jun2003.

CRWQCB 2000. Personal communication between ATSDR and Susan Timm, CRWQCB; April 2000.

Dames & Moore. 1990. Final Solid Waste Assessment Test (SWAT) report, old UCD landfill, University of California, Davis, Part I & II; July 1990.

Dames & Moore. 1998. 1997 Annual water monitoring report, LEHR/SCDS environmental restoration, Davis, California; August 3, 1998.

Dames & Moore. 2001. Office of Environmental Health and Safety, University of California Davis, California. 2000 annual groundwater treatment system and water monitoring report for Laboratory for Energy-Related Health Research and South Campus Disposal Site. April 2001.

DOE. 1988. U.S. Department of Energy (DOE) environmental survey preliminary report. LEHR; March 1988.

EPA. 1995a. A guide to the biosolids risk assessment for the EPA 503 Rule. U.S. Environmental Protection Agency (EPA), Office of Waste Water Management. Washington, DC; September 1995.

EPA. 1995b. National Forum on Mercury in Fish. Proceedings; September 27-29, 1995. New Orleans, Louisiana.

EPA. 2000a. Exposure factors handbook. Washington DC: U.S. Environmental Protection Agency. March 2000 (rev Dec 2002). Available at: http://www.epa.gov/ncea/pdfs/efh/front.pdf. Last accessed 10Jun2003.

EPA. 2000b. EPA's soil screening guidance for radionuclides. Available at: http://www.epa.gov/superfund/resources/radiation/radssg.htm. Last accessed 2Jun2003.

EPA. 2003. Water Discharge Permits (PCS) CA0077895, University of California Davis. Available at: http://oaspub.epa.gov/enviro/pcs_web.report?pgm_sys_id=CA0077895. Last accessed 2Jun2003.

IPCS. 1996. International Programme on Chemical Safety (IPCS) and Canadian Centre for Occupational Health and Safety (CCOH). Environmental Health Criteria 182. Thallium. Available at: http://www.inchem.org/documents/ehc/ehc/ehc182.htm. Last accessed 10Jun2003.

Lapin L. 1999. Wastewater plant is much bigger, cleaner. Dateline UC Davis, faculty and staff newspaper for the University of California, Davis. 1999 October 8. Available at: http://www.dateline.ucdavis.edu/100899/DL_wastewater.html. Last accessed 8Oct1999.

Larsen K. and Deanovic L. 1998. Cache Creek and Putah Creek Project quarterly report, November–December 1998. Aquatic Toxicology Laboratory, University of California, Davis; January 1998.

MWH (MWH Americas, Inc.) 2003. Draft remedial investigation report LEHR/SCDS Environmental Restoration, University of California, Davis; January 2003.

OEHS. 2001. University of California Davis Office of Environmental Health and Safety LEHR Newsletter. Summer 2001.

PNL (Pacific Northwest Laboratory). 1994. 1993 Annual water monitoring report, water monitoring program, LEHR Environmental Restoration, Davis, California; November 1994.

Slotton DG, Ayers SM, Reuter JE, Goldman CR. 1999. Lower Putah Creek, 1997–1998, mercury biological distribution study. Department of Environmental Science and Policy, University of California, Davis; February 1999.

Stratton JW, et al. 1987. Methyl mercury in northern coastal mountain lakes: Guidelines for sport fish consumption for Clear Lake (Lake County), Lake Berryessa (Napa County), and Lake Herman (Solano County). Hazard Evaluation Section and Epidemiological Studies and Surveillance Section, Office of Environmental Health Hazard Assessment, State of California

Department of Health Services; April 1987. Available at: http://www.oehha.ca.gov/fish/pdf/CLEARLAKEREPORT.pdf

UC Davis Water Management Plan Task Force. 1997. Draft UC Davis (University of California, Davis) water management plan; October 1999 .

UC Davis 2001. Transmittal from Brian Oatman (UC Davis Environmental Health & Safety) to Linda Stein (ERG): Laboratory reports for LEHR neighbor wells 1989–1991; complete set of LEHR neighbor quarterly tables 1992–2000; radionuclide sample results, 1989–1991 and 1990–1996.

UC Davis. 2002a. UC Davis News & Information: Facts and figures. Available at: http://www.news.ucdavis.edu/facts/.

UC Davis. 2002b. Letter from Christine Judal (UC Davis Environmental Health & Safety) to Jessica Graham (ERG). Maps and LEHR/SCDS neighbors' well results for 2001/2002. December 20, 2002.

U.S. Bureau of Census. 2000. Washington: US Department of Commerce. Available at: http://www.census.gov/.

Walton. 1951. Survey of literature relating to infant methemoglobinemia due to nitrate-contaminated water. Am J Public Health 41:986-996.

Weiss Associates. 1997a. DOE. Final site characterization summary report for the DOE areas at the Laboratory for Energy-Related Health Research (LEHR), University of California at Davis, California; November 1997.

Weiss Associates. 1997b. DOE. Draft final determination of risk-based action standards for DOE areas for the Laboratory for Energy-Related Health Research (LEHR), University of California at Davis, California. Vol. 1 and 2; August 4, 1997.

Weiss Associates. 1997c. DOE. Draft risk assessment protocol for the DOE areas at the Laboratory for Energy-Related Health Research (LEHR), University of California at Davis, California. Rev. B; March 1997.

Weiss Associates. 1998a. DOE final technical report: Results of Western Dog Pens, background, and off-site investigations at the Laboratory for Energy-Related Health Research (LEHR), University of California Davis, California; June 1998.

Weiss Associates. 1998b. Summary data report for the mixed waste storage facility at the Laboratory for Energy-Related Health Research, University of California, Davis; 1998.

Weiss Associates. 1999a. Final annual site environmental report, calendar year 1998, for the Laboratory for Energy-Related Health Research (LEHR), University of California Davis, California; September 1999.

Weiss Associates. 1999b. Technical memorandum: Investigation results for the former Eastern Dog Pens at the Laboratory for Energy-Related Health Research (LEHR), University of California Davis, California; September 24, 1999.

Weiss Associates. 1999c. Draft Southwest Trenches Area 1998 removal action confirmation report for the Laboratory for Energy-Related Health Research (LEHR), University of California Davis, California; June 25, 1999.

Weiss Associates. 2003. Draft DOE areas remedial investigation report for the Laboratory for Energy-Related Health Research (LEHR), University of California Davis, California; February 28, 2003.

WHO. 1996. Thallium and thallium compounds health and safety guide. IPCS International Programme on Chemical Safety. Health and Safety Guide No. 102.

Yolo County Department of Public Health, Environmental Health Division. 1995. Workplan for water quality and aquatic toxicity investigations in the Putah Creek and Cache Creek watersheds (Revised); July 1995 (revised October 1996).

Tables

Table 1. Evaluation of Potential Public Health Hazards Associated with Study Areas at LEHR

Site Area	Site Description/Waste Disposal History	Pre-Removal Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
Southwest Trenches (shallow pits and trenches/ disposal cells) (SWT)	During the late 1950s–1970s, wastes disposed of in trenches and pits included low-level radioactive waste, fecal material, gravel from on-site dog pens, and laboratory waste generated by LEHR site activities. Additionally, part of this area was used for treating dogs with chlordane.	**Soil:** Gross beta radiation (34,700 picocuries per gram [pCi/g]) and strontium-90 (16,700 pCi/g) were detected at elevated concentrations on site. The metals arsenic (9.7 part per million [ppm]), chromium (250 ppm), and iron (46,000 ppm), and the pesticides chlordane (2,000 ppm, likely the result of a spill) and dieldrin (0.07 ppm), were detected above ATSDR comparison values (CVs) at depth. Multiple semivolatile organic compounds were also detected above CVs in two subsurface solid waste samples. **Air:** Generally low levels at or slightly above ATSDR CVs were detected in air sampled at the Southwest Trenches. Some levels above CVs were reported during removal actions in 1998. Monitoring since removal indicates that levels are below those of health concern.	Over 870 cubic yards (cu yds) of buried waste, about 435 cu yds of overburden, and 450 cu yds of chlordane-impacted soil were removed in 1998. Soil containing elevated strontium-90 was also removed. A large amount of buried waste and soil contaminated with chlordane and strontium-90 was removed from the SWT area and stockpiled in the Western Dog Pens for further characterization and later disposed off site. Additionally, a fence was installed around the SWT and parts of the area were paved.	No apparent public health hazards are associated with the SWT area. The public had limited access to the contaminated surface soil and no access to the contaminated subsurface soils in the past, most of the contaminated soils have since been removed, and the area is currently partially paved and fenced.
Radium/ Strontium Treatment Areas (Ra/Sr)	The Ra/Sr treatment areas consisted of multiple septic tanks, dry wells, leach fields, and an ion exchange system used to treat waste water from the Sr-90 and Ra-226 studies.	**Soil:** Elevated levels of Ra-226 were detected in the soil (maximum concentration 14.7 pCi/g) and sediment (maximum concentration 106.2 pCi/g) within the treatment areas. Concentrations of Sr-90 were also elevated in sludge (18,600 pCi/g) and soil (1.82 pCi/g). **Air:** Air monitoring conducted before, during, and after remediation indicate that no contaminants were found at levels of health concern.	40,000 gallons of low-level radioactive waste were removed from the tanks, solidified, and shipped off site in 1992. The site was then divided into two areas. Area I remedial actions were completed from May to November 1999, when 1,716 cubic yards of material were removed for off-site disposal. Area II actions were completed in November 2000, when 1,500 cubic yards of material were removed for off-site disposal. Confirmation samples were taken and the area was backfilled with clean fill.	No apparent public health hazards are associated with the Ra/Sr area. The public had no access to the contaminated subsurface soil in the past and the contaminated soil has since been removed.

Site Area	Site Description/Waste Disposal History	Pre-Removal Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
Eastern Dog Pens (EDP)	The EDP were built in 1970 and housed research dogs until LEHR-related research ended in 1988.	**Groundwater:** Three pesticides—alpha chlordane (0.016 ppb), gamma chlordane (0.0071 ppb), and dieldrin (0.03 ppb)—are periodically found in one on-site well (UCD1-13) located downgradient of the EDP. **Soil:** During a 1999 investigation, soil samples were analyzed for 58 constituents. Dieldrin (0.223 ppm) and chromium (251 ppm) were detected above their CVs in surface soil samples.	In 1996, building structures of the 96 EDP were removed; fencing was removed in 1999. No significant RAs have been conducted to date. Currently a Memorandum of Agreement under development to address the EDP and Landfill Disposal Unit 2. In the meantime, the area is due to be posted, have its fences repaired and maintained to prevent public access, and undergo semi-annual monitoring inspections to determine if it has been disturbed or needs repair.	No apparent public health hazards are associated with the EDP. The public has had limited access to contaminated surface and subsurface soil associated with the EDP area; the area is currently fenced. Also, no one drinks water from the areas of affected groundwater.
Western Dog Pens (WDP)	Located in the center and south-center of the site, these areas were used to house the research dogs. Chlordane was sprayed in and around the dog pen areas.	**Groundwater:** Hexavalent chromium (up to 37.1 ppb) was detected above the CV in the well located immediately downgradient of the WDP. **Soil:** Ra-226 (5.11 pCi/g at 5.75 feet below ground surface [bgs] in 1994), Sr-90 (3.59 pCi/g surface gravel), and chlordane (15 ppm*) were detected at elevated levels above ATSDR CVs. Metals chromium (273 ppm) and iron (46,600 ppm) were also detected above their CVs. **Air:** Air monitoring conducted before, during, and after remediation indicate that no contaminants were found above levels of public health concern.	During the construction of the Cellular Biology Laboratory in 1975, 64 pens were removed. The remaining 256 pens were removed in 1996. In 1999, fencing from the area was removed to be recycled off site. In April 2001, WDP remedial action (RA) work began. Chlordane-contaminated soil from the SWT area that had been placed in the WDP during previous remedial activity in the SWT area was removed along with 3,220 cubic yards of gravel, asphalt, concrete curbing, and metal grating. Confirmation samples were taken. Waste material was later removed. Gravel and overburden soil remains and will be reused on site or at another DOE site.	No apparent public health hazards are associated with the WDP area. The public has had limited access to the contaminated surface and subsurface soil in the past and most contaminated material and pens have since been removed. Also, no one is obtaining drinking water from the contaminated groundwater found near the WDP.

Site Area	Site Description/Waste Disposal History	Pre-Removal Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
Domestic Septic Systems (DSS)	Seven known DSSs are located at LEHR. They serviced the LEHR offices and laboratories beginning in 1958. Each DSS typically consists of a domestic septic tank (DST), a leach field, and interconnected piping. DSSs 1–6 received liquid wastes and sewage until 1971, when they were reportedly backfilled with sand and connecting lines were cut and capped. DST 7 was never used.	**Groundwater:** Groundwater collected in areas proximal to the DSS areas was found to contain elevated levels of hexavalent chromium, lead, mercury, molybdenum, silver, and selenium, but investigators did no identify the DSSs as sources of groundwater contamination. **Soil:** Subsurface sampling in the vicinity of each of the seven DSS returned varying results. Contaminants found above CVs near at least one DSS include: mercury (3.5 ppm), chromium (319 ppm), benzo(a)pyrene (2.38 ppm), lead-210 (9 pCi/g), radium-226 (Ra-226) (0.78 pCi/g), thorium-234 (4.15 pCi/g), and uranium-235 (0.16 pCi/g).	Remedial actions have been completed at DSS 2 and parts of DSS 1 and 5 (removed during the radium/strontium RA). RAs were completed for DSS 3 and 6 in 2002, but none are planned for DSS 1, 4, or 7, because contaminants in soil at these locations were not found to be above action levels.	No apparent public health hazards are associated with the DSS areas. The public has no access to the contaminated subsurface soil in this area and no one is drinking the groundwater from beneath these sites.
DOE Disposal Box	Approximately 55 cubic yards of low-level radioactive waste (including syringes, bottles, vials, and gravel) were disposed of in this "trench" located between the two dog pen areas.	**Soil:** Prior to removal various metals, pesticides, PCBs, VOCs, and radionuclides were detected in this area. Toluene (100 ppm) and radium-226 (9.7 pCi/g) were detected above CV in samples collected at depth.	In 1996, a series of trenches were dug in order to determine the location of the DOE Box. While no physical box was located, a plywood-lined trench, filled with gravel and labware, was found. About 110 cubic yards of waste were removed and shipped off site for disposal. Confirmation sampling was conducted and the excavation was lined with a polyethylene liner and backfilled with clean soil. Confirmation sampling indicated that no contaminants were present above CV post remediation.	No apparent public health hazards are associated with the DOE Box area. The public had no access to the contaminated subsurface soil and the contaminated subsurface material has since been removed.

Site Area	Site Description/Waste Disposal History	Pre-Removal Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
UCD Landfill Units 1, 2, 3	These landfills received sanitary and limited chemical and radiological wastes from campus activities in the 1940s, 50s, and 60s and were capped with 0.5 to 3 feet of clean soil. Wastes included municipal waste, sewage sludge, animal parts, incinerator ash, and liquid chemicals.	**Groundwater:** Various metals, VOCs, pesticides, nitrates, and radionuclides have been detected in monitoring wells downgradient of Landfill Unit 2 and continue to be monitored under UC Davis's groundwater treatment system and monitoring program. **Soil:** Various metals, VOCs, pesticides, and radionuclides have been detected in each of the three landfill areas. The metals arsenic (9.4 ppm) and iron (57,300 ppm) have been detected above their CVs in the surface soil at these areas during 2002 sampling; these detections are generally comparable to reported background levels. A single high detection of lead (3,640 ppm) was found in a Landfill Unit 1 surface soil sample.	Several investigations employing exploratory trenching, soil boring, and ground-penetrating radar (GPR) have been conducted to characterize contamination. Waste has not yet been removed.	No apparent public health hazards are associated with the landfill areas. The metal concentrations detected in surface soils are not at harmful levels. The public had limited access to these surface soils and no contact with subsurface materials, and no one is drinking the groundwater from beneath these sites.
49 Waste Holes	These holes along the southern edge of the EDPs received radioactive wastes from UCD Campus laboratory activities. Each hole was capped with 1 to 4 feet of clean soil.	**Groundwater:** Tritium (H-3) and carbon-14 have historically been detected in a monitoring well located at and downgradient of the waste holes (UCD1-13). Pesticides were also detected periodically in the same well (see the EDP row). **Soil:** Metals and radioactive materials have been found in this area. Arsenic (8 ppm), iron (47,600 ppm), and radium-226 (0.878 +/- 0.152 pCi/g) have been measured above their CVs in surface soil samples.	During a 1999 IRA, 32 holes were identified and excavated to 12 ft bgs. Approximately 157 cubic yards of low-level radioactive waste excavated from the area were sent off-site for disposal.	No apparent public health hazards are associated with the waste holes. The public has had limited access to surface soils and no contact with subsurface soils, and no one is drinking the groundwater beneath the site.

Site Area	Site Description/Waste Disposal History	Pre-Removal Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Evaluation of Public Health Hazard
UC Davis Solid Waste Trenches (Southern and Eastern Solid Waste Trenches)	These trenches located south and east of the dog pen area received campus laboratory waste including chemical, biological, and radiological waste from 1957 to 1965. The trenches were capped with 1 to 2 feet of clean soil.	**Soil:** Various metals, pesticides, and VOCs were detected in these trenches. The metals arsenic (8.26 ppm), chromium (283 ppm), and iron (38,500 ppm) and the pesticide dieldrin (63 ppb) were detected above their CVs in the surface soil during 2002 sampling. The detected metal concentrations are comparable to reported background concentrations.	The nature and extent of waste buried in these areas has been assessed through geophysical investigations, exploratory trenching, and soil borings. The areas have not yet been remediated.	No apparent public health hazards are associated with these trenches. The public has had limited access to surface soils and no contact with subsurface materials.

Sources: Weiss Associates 1997a, 1997b, 1998, 1999b, 1999c, 2002; MWH 2003

* This concentration was collected during the non-CERCLA-certified 1996 WPD investigation. The next highest chlordane value measured prior to remediation was 2.12 ppm (see Table 6).

Table 2. Chronological Summary of Environmental Restoration Activities at LEHR

Date	Restoration Activity
1975	During construction of the Cellular Biology Laboratory, 64 pens were removed (Weiss Associates 2003).
1988	Memorandum of Agreement (MOA) between DOE and UC Davis ends DOE LEHR-related research; initiates decontamination and decommissioning (D&D) activities, prompting investigations of environmental impacts (Weiss Associates 1999a).
1989	DOE and UC Davis submit a Part A permit application to EPA to allow on-site storage of mixed waste generated during D&D activities; mixed waste storage facility (MWSF) constructed and operated until 1996 (Weiss Associates 1999a).
1990	Between June and September, 856 biological waste packages (primarily dog carcasses) removed from the two large freezers and shipped to DOE Hanford for disposal (Weiss Associates 1997a).
1992–1995	Four on-site buildings (Animal Hospital Number 1, Animal Hospital Number 2, the cobalt-60 building, and the Specimen Storage Room) successfully decontaminated and decommissioned; material that cannot be effectively decontaminated is removed and shipped to DOE Hanford for disposal; buildings released to UC Davis for unrestricted use (Weiss Associates 1997a).
1992	Contaminated liquid and sludge removed from underground tanks beneath and around the Imhoff Waste Water Treatment Facility (part of the Strontium-90 Treatment System); 40,000 gallons of low-level radioactive liquids and sludge waste solidified and shipped to the DOE Hanford site for disposal (Weiss Associates 1997a).
1993–1995	Radioactive sources, including the cobalt-60 device, strontium and radium standards, and thorium and uranium salts, were removed and shipped to various off-site facilities for reuse in industrial processes or scientific research (Weiss Associates 1997a).
1994	EPA placed the LEHR site on the National Priorities List (NPL) because contaminants were detected at levels above maximum contaminant levels (MCLs) in on-site groundwater monitoring wells (Weiss Associates 1999a).
1995	Streamlined Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) process put in place at LEHR. Final RCRA Site Treatment Plan approved and issued in October, after the completion of the California Environmental Quality Act Initial Study and public comment (Weiss Associates 1999a).
1995	Imhoff Waste Water Treatment Facility demolished; waste material shipped to the DOE Hanford site for disposal (Weiss Associates 1997a).
1995	Tanker trailer used for transporting low-level radioactive waste shipped off site, super-compacted, and sent to the DOE Hanford site for disposal (Weiss Associates 1997a).
1996	Excavation and disposal of approximately 3,000 cubic feet of low-level radioactive waste removed from the "DOE Box" as part of a Removal Action, performed under a CERCLA Time Critical Action Memorandum; waste shipped to the DOE Hanford site for disposal; post-removal sampling shows that cleanup objectives have been achieved (Weiss Associates 1997a).

Date	Restoration Activity
1996	352 outdoor dog pens, including barrels and concrete pedestals, removed and shipped to the DOE Hanford site for disposal (Weiss Associates 1997a).
1997	MOA signed, dividing the responsibility for environmental restoration between DOE and UC Davis (Weiss Associates 1999a).
1998	Groundwater Interim Removal Action (IRA) treatment system begins operation in May to limit off-site migration of VOCs (Dames & Moore 2001).
1998	Between May and November, a removal action for the Southwest Trenches (SWT) was performed; 450 yd^3 of chlordane-impacted soil excavated; 873 yd^3 of buried waste and 435 yd^3 of overburden soil removed from the Waste Disposal Cells; material stockpiled in the Western Dog Pens (WDPs) for further characterization; fence installed, parts of the area paved; more than 200 samples collected during removal activities (Weiss Associates 1999c).
1999	Closure plan for the MWSF submitted to California Department of Toxic Substances Control (CDTSC) April 27, 1999 (Weiss Associates 1999a).
1999	In October and November, interim removal action of the Waste Burial Holes located along the south side of the Eastern Dog Pens is completed.
1999	Fencing from Eastern and Western Dog Pens removed and recycled off site (Weiss 2003).
1999	Underground structures in the Radium and Strontium Treatment Systems area removed, including a waste distribution box, three 40-ft vertical leaching wells, approx. 300 ft of horizontal leach trench, and a concrete septic tank; approx. 700 yd^3 of concrete and soil contaminated with low-level radioactive material removed for off-site disposal (OEHS 2001). Domestic Septic Tank 2 and parts of Domestic Septic Systems 1 and 5 (dry wells A through E) also removed (Weiss 2003).
2000	Removal activities in the Radium and Strontium Treatment Systems area completed (OEHS 2001).
2000	In December, new dual density convection system added to the groundwater treatment system to improve removal of VOCs (OEHS 2001).
2001	Testing of modified Groundwater IRA-treatment system (new system mixes IRA effluent with low total dissolved solids [TDS] water to reduce the TDS and nitrate concentrations in reinjected water) delays treatment system restart (OEHS 2001).
2001	Chlordane-contaminated soil stockpiled in the WDP during 1998 remedial activity in the SWT was removed from the WPD area. In addition, 3,220 additional yd^3 of gravel, asphalt, concrete curbing, and metal grating are pulverized—they are now stored in stockpiles in the WDP (Weiss 2003).
2002	Removal actions for Domestic Septic Systems 3 and DSS 6 completed (Weiss 2003).

Table 3. Evaluation of Exposure Pathways at LEHR

Exposure Pathway Elements							
Pathway Name	**Source of Contamination**	**Environmental Medium**	**Point of Exposure**	**Route of Exposure**	**Time of Exposure**	**Exposed Population**	**Comments**
On-site groundwater	Past activities at LEHR	Groundwater	None	None	None	None	VOCs, metals, nitrate, and radionuclides have been detected in on-site wells, but groundwater beneath the site is not used.
Off-site groundwater	Contaminants leaching into groundwater from agricultural sources, septic systems, LEHR, and unknown sources	Groundwater	Off-site private drinking water and irrigation wells	• Ingestion • Dermal contact • Inhalation	Past Current Future	Residents downgradient of LEHR who use private wells as their source of drinking water Local agricultural workers and gardeners	Nitrates, VOCs, and metals have been detected in some private drinking wells near UC Davis. Bottled water has been provided to approximately 15 households since 1989, because nitrate concentrations are above acceptable levels for infants (though not for adults). No exposure occurs through UC Davis or the city of Davis water supply. VOCs, metals, and nitrates have been detected in irrigation wells within a 2-mile radius of LEHR. Agricultural workers and gardeners are not expected to come in contact with harmful levels of contaminants.
On-site surface soil	Past activities at LEHR	Surface soil	Surface soil	• Incidental ingestion • Dermal contact • Inhalation	Past Current Future	Former LEHR workers, UC Davis staff, and visitors to the site	Arsenic, chlordane, dieldrin, and iron were detected above ATSDR CVs. Infrequent contact, if any, by workers or authorized site visitors is not expected to be of health concern.

Exposure Pathway Elements							
Pathway Name	**Source of Contamination**	**Environmental Medium**	**Point of Exposure**	**Route of Exposure**	**Time of Exposure**	**Exposed Population**	**Comments**
Off-site surface soil	Storm water overflows from LEHR	Surface soil	Surface soil	• Incidental ingestion • Dermal contact • Inhalation	Past Current Future	Off-site residents	Sampling (1996) of a storm water ditch along Old Davis Road found no contaminants above ATSDR CVs.
Off-site surface water and sediment	Waste water treatment plant discharge and surface water run-off from LEHR and other sources	Surface water and storm water	Putah Creek	• Ingestion • Dermal contact • Inhalation	Past Current Future	Recreational users and fishers at Putah Creek	Biannual sampling upstream of LEHR, at the sewage treatment plant outfall, and downstream of LEHR has revealed metal, VOC, SVOC, and pesticide concentrations in surface water exceeding ATSDR's CVs at all three locations. However, contact with contaminants should not lead to adverse health effects.
Biota	Waste water treatment plant discharge and surface water runoff from LEHR and other sources	Edible plants grown in the area and fish and shellfish from the South Fork of Putah Creek	Crops, fish, and shellfish	• Ingestion	Past Current Future	People who eat locally grown foods or catch and eat fish and shellfish from the South Fork of Putah Creek	The extent of exposure and contaminant transfer to foods is not known with certainty, but is likely minimal. People eat fish and shellfish from Putah Creek; however, sampling (1996–1998) has shown levels of mercury above ATSDR's CV, at levels of potential concern for developing fetuses or nursing children.

Exposure Pathway Elements							
Pathway Name	**Source of Contamination**	**Environmental Medium**	**Point of Exposure**	**Route of Exposure**	**Time of Exposure**	**Exposed Population**	**Comments**
Ambient radiation	Cobalt-60 irradiator located in the southeast corner of the LEHR property	Ambient radiation	On site and fence line	• Whole-body exposure	Past	Possible past exposure for people on site or near the fence line	No current or future exposures are expected since the cobalt-60 source was removed and shipped to an off-site facility between 1993 and 1995. No one was likely present at the LEHR fence line constantly and workers were kept away from the area when the irradiator was in use. Radiation exposure levels drop off significantly with distance; therefore, ATSDR determined that residents at nearby farmhouses south of the cobalt-60 source and people fishing in Putah Creek would not have been exposed to enough radiation to cause adverse health effects.

Key: CV = Comparison Value; SVOC = semivolatile organic compound; UC = University of California; VOC = volatile organic compound

Table 4. Maximum Contaminant Concentrations Greater Than ATSDR Comparison Values in On-Site Groundwater Monitoring Wells

Chemical	Maximum Detected Concentration	Date of Maximum Detection	Well Location	ATSDR Comparison Value (CV)	
				Value	Type of CV
VOCs and SVOCs in ppb					
1,1,2-Trichloroethane	5.1	2000	UCD1-12	0.6	CREG
1,1-Dichloroethene	44	1992–93	UCD1-12	0.06	CREG
1,2-Dichloroethane	15	1992–93	UCD1-12	0.4	CREG
Benzene	59	1989–90	UCD1-12	0.6	CREG
Bromodichloromethane	8.3	2/18/97	UCD1-12	0.6	CREG
Carbon Tetrachloride	5	1992–93	UCD1-01	0.3	CREG
Chloroform	17,000	1989–90	UCD1-09, -12	6	CREG
Methylene chloride	33	1989–90	UCD1-11	5	CREG
Trichloroethylene	5	1992–93	UCD1-01	0.09	CREG
Bis(2-ethylhexyl)phthalate	37	1992-93	UCD1-24	3	CREG
Pesticides and PCBs in ppb					
4,4'-DDD	0.11	1992–93	UCD1-12	0.1	CREG
4,4'-DDT	0.11	1992–93	UCD1-12	0.1	CREG
Alpha-BHC	0.057	1992–93	UCD1-01	0.006	CREG
Beta-BHC	0.057	1992–93	UCD1-01	0.02	CREG
Dieldrin	0.11	1992–93	UCD1-12	0.002	CREG
Heptachlor	0.057	1992–93	UCD1-01	0.008	CREG
Metals and Nitrate in ppb					
Antimony	90	1989–90	UCD1-04	4	$RMEG_{Child}$
Arsenic	30	1989–90	UCD2-14	0.02	CREG
Boron	906	2000	UCD1-11	100	$EMEG_{Child}$
Cadmium	49	1989–90	UCD1-04,-11,-12	2	$EMEG_{Child}$
Chromium	450	1992–93	UCD1-11	100 50	EPA MCL CDHS MCL

Chemical	Maximum Detected Concentration	Date of Maximum Detection	Well Location	ATSDR Comparison Value (CV)	
				Value	Type of CV
Chromium, hexavalent	350	1993	UCD1-11	30	$RMEG_{Child}$
Lead	63	1992–93	UCD2-07	15	EPA/CDHS Action Level
Magnesium	300,000	1989–90	UCD1-12	51,000	RBC-n
Mercury	2.2	1992–93	UCD1-21	2	EPA/CDHS MCL
Molybdenum	270	1989–90	UCD1-12	40	LTHA
Nickel	390	1992–93	UCD1-23	100	LTHA
Silver	90	1989–90	UCD1-04	50	$RMEG_{Child}$
Thallium	600	1989–90	UCD1-08	0.5	LTHA
Vanadium	40	1992–93	UCD1-04	30	$EMEG_{Child}$
Nitrate (as N)	135,000	1989–90	UCD-02	10,000	EPA/CDHS MCL
Radioactive Contaminants in pCi/L (Bq/L)					
Gross alpha	40 +/- 10 (1.5 +/- 0.4)	1992–93	UCD1-20	15 (0.56)	EPA/CDHS MCL
Carbon-14 (C-14)	2,464 +/- 353 (91.3 +/- 13.1)	1992–93	UCD1-13	2,000 (74.1)	EPA MCL
Hydrogen-3 (H-3)	79,548 +/-1261* (2,946 +/- 47) 37,241 +/-945 (1,379 +/- 35)	1990 1989	UCD1-04 UCD1-08	20,000 (740.7)	EPA/CDHS MCL

Sources: Dames & Moore 1990, 1998, 2001; PNL 1994

* = The rerun of a distilled fraction of this sample yielded ND; the second value presented in the table is the next highest H-3 concentration measured.

Key: BHC = benzene hexachloride; Bq/L = becquerels per liter (1 becquerel/liter = 27 picocuries/liter); CDHS = California Department of Health Services Action Level; child = standard for a child; CREG = Cancer Risk Evaluation Guide; EPA = U.S. Environmental Protection Agency; LTHA = Lifetime Health Advisory; MCL = maximum contaminant level; PCBs = polychlorinated biphenyls; pCi/L = picocuries per liter; ppb = parts per billion; RBC-n = EPA's Risk-Based Concentrations (non-cancer); RMEG = Reference Dose Media Evaluation Guide; SVOCs = semivolatile organic compounds; VOCs = volatile organic compounds

Table 5. Maximum Contaminant Concentrations Greater Than ATSDR Comparison Values in Off-Site* Groundwater Monitoring Wells

Chemical	Maximum Detected Concentration	Date of Maximum Detection	Well Location	ATSDR Comparison Value (CV)	
				Value	CV
VOCs and SVOCs in ppb					
1,1-Dichloroethene	1	2000	UCD2-29	0.06	CREG
1,2-Dichloroethane	1.7	1997	UCD2-29 UCD2-32	0.4	CREG
Chloroform	280 D	2000	UCD2-29	6	CREG
Methylene chloride	32	1989–90	UCD1-10	5	CREG
Bis(2-ethylhexyl)phthalate	31.6	1992	UCD2-16	3	CREG
Pesticides in ppb					
Heptachlor	0.009 J	1997	UCD2-27Z4	0.008	CREG
Metals and Nitrate in ppb					
Antimony	70	1989–90	UCD1-10	4	$RMEG_{Child}$
Arsenic	9.3	1997	UCD1-19	0.02	CREG
Boron	1,280	2000	UCD1-28	100	$EMEG_{Child}$
Cadmium	49	1989–90	UCD1-10	2	$EMEG_{Child}$
Chromium	613	2000	UCD1-28	100 50	EPA MCL CDHS MCL
Chromium, hexavalent	560	2000	UCD1-28	30	$RMEG_{Child}$
Lead	32	1989–90	UCD1-10	15	EPA/CDHS Action Level
Magnesium	198,000	1997	UCD1-10	5,100	RBC-n
Molybdenum	170	1989–90	UCD1-10	40	LTHA
Nickel	218	1997	UCD1-27Z3	100	LTHA
Silver	30	1989–90	UCD1-10	50	$RMEG_{Child}$
Thallium	700	1989–90	UCD1-10	0.5	LTHA
Vanadium	30	1993–94	UCD1-10	30	$EMEG_{Child}$
Nitrate (as N)	53,400	2000	UCD1-28	10,000	EPA/CDHS MCL

Chemical	Maximum Detected Concentration	Date of Maximum Detection	Well Location	ATSDR Comparison Value (CV)	
				Value	CV
Radioactive Contaminants in pCi/L (Bq/L)					
Radium-226	5.82 +/- 1.52 (0.2 +/- 0.1)	2000	UCD4-44	5 (0.19)	EPA/CDHS MCL
Strontium-90	8.40 +/- 5.80 (0.3 +/- 0.2)	1992–93	UCD1-19	8 (0.30)	EPA/CDHS MCL

Source: Dames & Moore 1990, 1998, 2001; PNL 1994

* Off-site monitoring wells include those located outside the site boundaries (see Figures 2 and 7), downgradient of LEHR source areas on UC Davis property.

Key: Bq/L = becquerel per liter (1 becquerel/liter = 27 picocuries/liter); CDHS = California Department of Health Services Action Level; child = standard for a child; CREG = Cancer Risk Evaluation Guide; D = diluted sample; EMEG = Environmental Media Evaluation Guide; EPA = U.S. Environmental Protection Agency; J = estimated quantity; LTHA = Lifetime Health Advisory; MCL = maximum contaminant level; N = nitrogen; pCi/L = picocuries per liter; ppb = parts per billion; RBC-n = EPA's Risk Based Concentrations (non-cancer); RMEG = Reference Dose Media Evaluation Guide; SVOCs = semivolatile organic compounds; VOCs = volatile organic compounds

Table 6. Maximum Contaminant Concentrations Greater Than ATSDR Comparison Values in Off-Site Private Domestic Wells

Contaminant	Maximum Detected Concentration	Date of Maximum Detected	Well Location	ATSDR Comparison Value (CV)		# of Detects >CV/ # Samples
				Value	Type	
VOCs in ppb						
Vinyl chloride	0.19	20-May-91	DW8	0.03	CREG	1/23
Metals and Nitrate in ppb						
Antimony	10	19-Oct-89	DW1, DW3	4	$RMEG_{Child}$	8/23
Arsenic	3	19-Oct-89	DW2, DW5, DW6	0.02	CREG	4/26
Chromium, total	140	20-May-91	DW8	100 50	EPA MCL CDHS MCL	2/37 27/37
Chromium, hexavalent	180	3-Nov-93	DW8	30	$RMEG_{Child}$	182/228
Lead	36	20-May-91	DW4	15	EPA/CDHS Action Level	1/23
Mercury	3.2	14-Aug-90	DW5	2	EPA/CDHS MCL	1/23
Molybdenum	120	19-May-91	DW3	40	LTHA	10/23
Thallium	60	19-Oct-91	DW4	0.5	LTHA	9/23
Nitrate	53,900	1999	DW5	10,000	EPA/CDHS MCL	151/236
Radioactive Contaminant in pCi/L (Bq/L)						
Gross beta*	63.32 +/- 15.81 (2.4 +/- 0.6)	1990	DW-3	50 (1.9)	EPA/CDHS MCL	2/178

Sources: UC Davis 2001, 2002b

* Repeat sampling showed nondetectable quantities

Key: # = number; > = greater than; Bq/L = becquerels per liter (1 becquerel/liter = 27 picocuries/liter); CDHS = California Department of Health Services; child = standard for a child; CREG = Cancer Risk Evaluation Guide; DW = drinking water well; EPA = U.S. Environmental Protection Agency; LTHA = Lifetime Health Advisory; MCL = maximum contaminant level; pCi/L = picocuries per liter; ppb = parts per billion; RMEG = Reference Dose Media Evaluation Guide

Table 7. Maximum Chemical Concentrations Greater Than ATSDR Comparison Values in Off-Site Irrigation Wells

Contaminant	Maximum Detected Concentration	Date of Maximum Detected	Location of Maximum	ATSDR Comparison Value (CV)		# of Detects >CV/ # of Samples
				Value	Type	
VOCs in ppb						
Chloroform	38 D	1996	IW3	6	CREG	10/81
1,2-Dichloroethane	1.4	18-Oct-89	IW3	0.4	CREG	4/81
Metals and Nitrate in ppb						
Antimony	10	19-Oct-89	IW3	4	$RMEG_{Child}$	2/10
Arsenic	3	19-Oct-89	IW4	0.02	$RMEG_{Child}$	1/10
Chromium, hexavalent	63	29-May-93	IW2	30	$RMEG_{Child}$	39/74
Molybdenum	70	19-Oct-89 20-May-91	IW3 IW4	40	LTHA	3/8
Thallium	80	19-Oct-89	IW4	0.5	LTHA	3/8
Nitrate	39,000	14-Dec-98	IW 7	10,000	EPA/CDHS MCL	37/72
Radioactive Contaminant in pCi/L (Bq/L)						
Gross alpha	53 +/- 5 (2.0 +/- 0.2)	1990	IW2	15 (0.56)	EPA/CDHS MCL	1/33

Source: UC Davis 2001, 2002b

Key: #= number; > = greater than; Bq/L = becquerels per liter (1 becquerel/liter = 27 picocuries/liter); CDHS = California Department of Health Services; child = standard for a child; CREG = Cancer Risk Evaluation Guide; D = sample was diluted because constituent concentration exceeded the instrument calibration range; EPA = U.S. Environmental Protection Agency; IW = irrigation well; LTHA = Lifetime Health Advisory; MCL = maximum contaminant level; pCi/L = picocuries per liter; ppb = parts per billion; RMEG = Reference Dose Media Evaluation Guide

Table 8. Maximum Contaminant Concentrations Greater Than Comparison Values in U.S. Department of Energy (DOE) Source Areas Surface Soil

Contaminant	Pre-Removal Action			Post-Removal Action where available (1)				ATSDR Comparison Value (CV)	Type of CV
	Maximum	Location of Maximum	Date of Maximum	Maximum	Location of Maximum	Date of Maximum	Depth (ft bgs)		
Metals and Pesticides in ppm									
Arsenic	8.2 (2)	WDP	Dec-94	(3)				0.5	CREG
Chromium	251 (2)	EDP	Mar-99	(4)				200	RMEG
Iron	41,700 (2)	WDP	Dec-94	(3)				23,000	RBC-n
Chlordane Alpha + gamma chlordane	15 (5) 2.186	WDP	Jul-96 Oct-97	4.34	WDP	2001	0.5	2	CREG
Dieldrin	0.223	EDP	Mar-99	(4)				0.04	CREG
Radioactive Contaminants in pCi/g (Bq/kg)									
Radium-226	1.68 +/- 0.247 (62.2 +/- 9.1)	EDP	99	(4)				0.513 (19.2)	NCRP (CC)

Sources: Weiss Associates 1997a, 1997b, 1998a, 1999b, 1999c, 2003

Key: Bq/kg = becquerels per kilogram (1 becquerel/kilogram = 0.027 picocuries/gram); CREG = Cancer Risk Evaluation Guide; EDP = Eastern Dog Pens; ft bgs = feet below ground surface; NCRP (CC) = National Council on Radiation Protection and Measurements (construction/commercial); pCi/g = picocuries per gram; ppm = parts per million; RBC-n = EPA's risk-based concentration (non-cancer); RMEG = Reference Dose Media Evaluation Guide; WDP = Western Dog Pens

Notes:

- The maximum contaminant values after remediation listed are the maximum concentration measured from all confirmation sampling at the LEHR facility, regardless of specific location or whether the maximum concentration was greater than or less than the CV.
- Detected metal concentrations, although above CVs, were generally comparable to background (As = 8.14 ppm; Cr = 199/125 ppm; Fe = 44,000 ppm) (Weiss Associates 2003).
- Confirmation sampling is not available for this contaminant in surface soil because confirmation samples were analyzed only for the contaminants of concern: chlordane and radioactive contaminants.
- Confirmation sampling is not available for this contaminant because the EDP has not been remediated.
- The validity of the data collected during this study (July 1996 WDP investigation) is questionable. These samples were collected for health and safety purposes rather than environmental characterization. Due to the minimal amount of surface soil sampling data available, however, ATSDR still considered data from this sampling effort when evaluating the overall possible magnitude of pesticide contamination on site. Because the reported maximum value from the 1996 sampling effort is significantly higher than other chlordane sampling results, we have also recorded the second highest reported chlordane concentration (2.186 ppm). Note that the reported value represents alpha + gamma chlordane, which could make up only half of the total chlordane in the sample.

Table 9. Maximum Contaminant Concentrations Greater Than Comparison Values in University of California, Davis (UCD) Source Areas Surface Soil

Contaminant	Maximum (ppm)	Location of Maximum	Depth of Maximum (ft bgs)	Date of Maximum	ATSDR Comparison Value (CV)	Type of CV
Arsenic	11.2 *Jd (1)	Landfill Unit 2	0.5	5/7/02	0.5	CREG
Chromium	283 (1)	Eastern Trenches	0.5	5/7/02	200	RMEG child
Dieldrin	0.063	Eastern Trenches	0.5	5/7/02	0.04	CREG
Iron	57,300 (1)	Landfill Unit 3	0.3	6/5/95	2,300	RBC-n
Lead	3,640 (2)	Landfill Unit 1	0.5	5/6/02	400	EPA AL
Radioactive Contaminants in pCi/g (Bq/kg)						
Hydrogen-3	39,360 +/- 9,500 (1,457,778 +/- 351,852)	Waste Burial Holes	0.5	1995	18,000 (666,667)	EPA SSL
Radium-226	0.878 +/- 0.152 (32.5 +/- 5.6)	Waste Burial Holes	0	9/21/99	0.513 (19)	NCRP (CC)

Source: MWH 2003

Key: Bq/kg = becquerels per kilogram (1 becquerel/kilogram = 0.027 picocuries/gram); child = standard for a child; CREG = Cancer Risk Evaluation Guide; d = laboratory duplicate imprecision; EPA AL = U.S. Environmental Protection Agency Action Level; EPA SSL = EPA's Soil Screening Level (age-adjusted) (EPA 2000b); ft bgs = feet below ground surface; J = laboratory estimated quantity; NCRP (CC) = National Council on Radiation Protection and Measurements (construction/commercial); pCi/g = picocuries per gram; ppm = parts per million; RBC-n = EPA Region III risk-based concentration (non-cancer); RMEG = Reference Dose Media Evaluation Guide; * = QC data exceeded acceptance limits

Notes:

- Detected metal concentrations, although about CVs, were generally comparable to background (As = 8.14 ppm; Cr = 199/125 ppm; Fe = 44,000 ppm) (Weiss Associates 2003).
- The lead concentration listed (3,640 ppm) was an anomaly. All other values are below ATSDR's CVs. The next highest lead concentration in any UC Davis area was 316 ppm in Landfill Unit 3.

Table 10. Maximum Contaminant Concentrations Greater Than Comparison Values in On-Site Surface Soil Outside DOE and UCD Source Areas

Chemical	Maximum (ppm)	Location of Maximum	Depth of Maximum (ft bgs)	Date of Maximum	ATSDR Comparison Value (CV)	CV Reference
Arsenic	10.8	SBL-400	0.5	5/6/02	0.5	CREG
Benzo(a)pyrene	0.71 Ji	SBL-408	0.5	5/7/02	0.1	CREG
Benzo(b)fluoranthene	0.89 Ji	SBL-408	0.5	5/7/02	0.87	RBC-c
Chromium	227 *	SBL-350-0550	0	10/3/00	200	RMEG-child
Iron	35,700	SBL-400	0.5	5/6/02	23,000	RBC-n

Source: MWH 2003

Key: child = standard for a child; CREG = Cancer Risk Evaluation Guide; ft bgs = feet below ground surface; i = Internal Standard Failure; J = laboratory estimated quantity; ppm = parts per million; RBC-c = EPA Region III risk-based concentration (cancer); RBC-n = EPA Region III risk-based concentration (non-cancer); RMEG = Reference Dose Media Evaluation Guide; * = QC data exceeded acceptance limits

Note: Detected metal concentrations, although above CVs, were generally comparable to background (As = 8.14 ppm; Cr = 199/125 ppm; Fe = 44,000 ppm) (Weiss Associates 2003).

Table 11. Maximum Contaminant Concentration Greater Than Comparison Values in Off-Site Surface Soil Samples

Contaminant	Maximum Concentration (ppm)	Location	Date	Depth (ft bgs)	ATSDR Comparison Value (CV) in ppm	Type of CV
Arsenic (1)	9.7	Old Davis Road LEHR-SS-RA-0001	1997	0	0.5	CREG
Chromium	705	Old Davis Road	1997	0	200	RMEG child
Radioactive Contaminant in pCi/g (Bq/kg)						
Radium-226	1.73 +/- 0.36 (64.1 +/- 13.3)	Old Davis Road	1996		0.513 (19)	NCRP (CC)

Sources: Weiss Associates 1997a, 1997b, 1998

Key: Bq/kg = becquerels per kilogram (1 becquerel per kilogram = 0.027 picocuries per gram); child = standard for a child; CREG = Cancer Risk Evaluation Guide; ft bgs = feet below ground surface; NCRP (CC) = National Council on Radiation Protection and Measurements (construction/commercial); pCi/g = picocuries per gram; ppm = parts per million; RMEG = Reference Dose Media Evaluation Guide

Note: A complete (raw) data set of off-site sampling was not available to ATSDR at time of evaluation. Based on available data, detected arsenic concentrations, although above the arsenic CV, were generally comparable to reported background levels (8.14–9.6 ppm) (Weiss Associates 1997a, 2003).

Table 12. Maximum Contaminant Concentrations Greater Than ATSDR's Comparison Values in the Sewage Treatment Plant Outfall (STPO): 1990–2001

Contaminant	Maximum Detected Concentration	Date of Maximum	ATSDR Comparison Value (CV)		# of Detects Above CV/ # of Samples Analyzed
			Value	Type of CV	
VOCs in ppb					
Bromodichloromethane	19	Summer 1997	4	CREG	6/50
Chloroform	33	Spring 1992	6	CREG	15/50
Dibromochloromethane	18	Summer 1997	0.13	RBC-c	15/50
Formaldehyde	2,100	Spring 1993	1,000	LTHA	3/29
Methylene chloride	40	Summer 1995	5	CREG	15/50
SVOCs in ppb					
Bis(2-ethylhexyl)phthalate	21.0	Winter 1996	3	CREG	12/35
Pesticides in ppb					
Aldrin	0.015	Spring 1993	0.002	CREG	3/49
Alpha-BHC	0.042	Fall 1992	0.006	CREG	8/49
Dieldrin	0.027	Spring 1993	0.002	CREG	5/49
Metals in ppb					
Antimony	110	Winter 1990	4	$RMEG_{child}$	6/51
Arsenic	6.7	Summer 1998	0.02	CREG	26/51
Boron	1,030	Winter 2001	100	$EMEG_{child}$	3/3
Chromium, hexavalent	45	Summer 1992	30	$RMEG_{child}$	2/46
Molybdenum	110	Spring 1993	40	LTHA	8/51
Nickel	130	Spring 1993	100	LTHA	1/50
Thallium	100	Fall 1990	0.8	$RMEG_{child}$	5/51
Other inorganics in ppb					
Nitrate	11,900	Winter 1991	10,000	MCL	4/49

Sources: Dames & Moore 1998, 2001; PNL 1994; MWH 2003

Key: # = number; BHC = benzene hexachloride; child = standard for a child; CREG = Cancer Risk Evaluation Guide; EMEG = Environmental Media Evaluation Guide (intermediate); LTHA = Lifetime Health Advisory; MCL = EPA's maximum contaminant level; ppb = parts per billion; RBC-c = EPA Region III risk-based concentration (cancer); RMEG = Reference Dose Media Evaluation Guide; SVOCs = semivolatile organic compounds; VOCs = volatile organic compounds

Notes:

- Comparison values are for drinking water exposures.
- The health-based comparison value for thallium sulfate is used to screen concentrations of thallium.
- The data were collected from 1992 to 1993 and 1997 to 2000.
- Number of samples greater than health-based comparison values does not include sampling data for 1998 or 1999. ATSDR reviewed waste water discharge data for 1998 and 1999 for constituents of concern showing detections only: acetone, bromodichloromethane, bromoform, chloroform, dibromochloromethane, ethyl ether, methylene chloride, toluene, chromium, and hexavalent chromium.
- All the radioactive parameters were detected below ATSDR's CVs.
- The number of samples greater than health-based comparison values does not include sampling data for 1998 or 1999. ATSDR reviewed waste water discharge data for 1998 and 1999 for constituents of concern showing detections only: acetone, bromodichloromethane, bromoform, chloroform, dibromochloromethane, ethyl ether, methylene chloride, toluene, chromium, and hexavalent chromium.

Table 13. Maximum Contaminant Concentrations Greater Than ATSDR's Comparison Values at Storm Water Sampling Locations: 1996–2000

Contaminant	Maximum Detected Concentration	Date of Maximum	Location of Maximum Detection	ATSDR Comparison Value (CV)		# of Detects Above CV/ # of Samples Analyzed
				Value	CV Type	
VOCs in ppb						
1,1-dichloroethene	0.34	1998-1999	LF-1	0.06	CREG	1/20
Pesticides in ppb						
Beta-BHC	0.098	Fall 2000	LS-1	0.02	CREG	1/11
Dieldrin	0.016	1998–1999	LF-1	0.002	CREG	1/11
Heptachlor	0.08	Winter 2000	LS-1	0.008	CREG	1/11
Metals in ppb						
Antimony	29	Spring 1997	LS-1	4	$RMEG_{child}$	5/13
Arsenic	15.6	Fall 1996	LS-1	0.02	CREG	8/13
Boron	128	Fall 2000	LF-1	100	$EMEG_{child}$	1/2
Chromium	115	Fall 1996	LS-1	30	$RMEG_{child}$	2/13
Iron	39,000	Fall 1996	LS-1	11,000	RBC-n	2/13
Lead	23.5	Fall 1996	SD-1	15	EPA AL	1/13
Manganese	570	1998–1999	LS-1	500	$RMEG_{child}$	1/13
Nickel	247	Fall 1996	LS-1	100	LTHA	2/13
Thallium	5.5	Winter 2000	LS-1	0.8	$RMEG_{child}$	1/13
Vanadium	73.5	Fall 1996	LS-1	30	$EMEG_{child}$	2/13
Radioactive contaminants in pCi/L (Bq/L)						
Gross beta	62.3 +/- 6.8 (0.04 +/- 0.002)	12/10/1996	LS-1	50 (1.85)	MCL	1/11

Sources: Dames & Moore 1998, 2001

Key: # = number; BHC = benzene hexachloride; Bq/L = becquerels per liter (1 becquerel/liter = 27 picocuries/liter); child = standard for a child; CREG = Cancer Risk Evaluation Guide; EPA AL = EPA Action Level; EMEG = Environmental Media Evaluation Guide (intermediate); LTHA = Lifetime Health Advisory; MCL = EPA's maximum contaminant level; pCi/L = picocuries per liter; ppb = parts per billion; RBC-n = EPA Region III risk-based concentration (non-cancer); RMEG = Reference Dose Media Evaluation Guide; VOCs = volatile organic compounds

Notes:

- Comparison values are for drinking water exposures.
- The health-based comparison value for thallium sulfate is used to screen concentrations of thallium.
- All other radioactive parameters were below ATSDR's CVs.

Table 14. Maximum Contaminant Concentration Greater Than ATSDR's Comparison Values in Surface Water of Putah Creek, Downstream (PCD) Sampling Locations

Contaminant	Maximum Detected Concentration (ppb)	Date of Maximum	ATSDR Comparison Value (CV)		# of Detects Above CV/ # of Samples Analyzed
			Value (ppb)	Type of CV	
VOCs					
Chloroform	8.9	Summer 1992	6	CREG	1/14
Dibromochloromethane	1.1	Summer 1992	0.13	RBC-c	4/14
SVOCs					
Bis(2-ethylhexyl)phthalate	12.6	Fall 1992	3	CREG	3/10
Pesticides					
Aldrin	0.006	Winter 1992	0.002	CREG	1/13
Alpha-BHC	0.038	Fall 1992	0.006	CREG	5/15
Dieldrin	0.043	Fall 1992	0.002	CREG	1/13
Heptachlor	0.032	Fall 1992	0.008	CREG	1/13
Metals					
Antimony	10	Summer 1992	4	$RMEG_{child}$	2/19
Arsenic	4.88	Winter 2000	0.02	CREG	8/19
Boron	747	Fall 2000	100	$EMEG_{child}$	1/1
Chromium	80	Winter 1993	30	$RMEG_{child}$	1/19
Chromium, hexavalent	42	Summer 1992	30	$RMEG_{child}$	3/14
Nickel	310	Winter 1993	100	LTHA	1/19

Sources: ATSDR 1998b, 1998c; Dames & Moore 1998, 2001; PNL 1994

Key: # = number; BHC = benzene hexachloride; child = standard for a child; CREG = Cancer Risk Evaluation Guide; EMEG = Environmental Media Evaluation Guide (intermediate); LTHA = Lifetime Health Advisory; ppb = parts per billion; RBC-c = EPA Region III risk-based concentration (cancer); RMEG = Reference Dose Media Evaluation Guide; SVOCs = semivolatile organic compounds; VOCs = volatile organic compounds

Notes:

- Comparison values are for drinking water exposures.
- The data were collected from 1992 to 1993 and 1997 to 2000.
- The number of samples greater than health-based comparison values does not include sampling data for 1998 or 1999. ATSDR reviewed waste water discharge data for 1998 and 1999 for constituents of concern showing detections only: acetone, bromodichloromethane, bromoform, chloroform, dibromochloromethane, ethyl ether, methylene chloride, toluene, chromium, and hexavalent chromium.
- All the radioactive parameters were below ATSDR's CVs.

Table 15. Maximum Contaminant Concentrations Greater Than ATSDR's Comparison Values in Surface Water of Putah Creek, Upstream (PCU) Sampling Location

Contaminant	Maximum Concentration Detected (ppb)	Date of Maximum	ATSDR Comparison Value (CV)		# of Detects Above CV/ # of Samples Analyzed
			Value (ppb)	Type of CV	
VOCs					
Bromodichloromethane	7.1	Summer 1992	4	CREG	1/14
Chloroform	19	Summer 1992	6	CREG	1/14
Dibromochloromethane	2.7	Summer 1992	0.13	RBC-c	1/14
SVOCs					
Bis(2-ethylhexyl)phthalate	13	Summer 1993	3	CREG	4/10
Pesticides					
Aldrin	0.003	Summer 1997	0.002	CREG	1/13
Alpha-BHC	0.055	Summer 1992	0.006	CREG	1/13
Heptachlor	0.03	Fall 1992	0.008	CREG	1/13
Metals					
Antimony	10	Fall 1992	4	$RMEG_{child}$	3/14
Arsenic	3.39	Fall 2000	0.02	CREG	3/14
Boron	713	Fall 2000	100	$EMEG_{child}$	1/1
Cadmium	2	Summer 1992	2	$EMEG_{child}$	1/14
Chromium	30	Summer 1992	30	$RMEG_{child}$	2/14
Chromium, hexavalent	43	Summer 1992	30	$RMEG_{child}$	2/12
Thallium	50	Winter 1992	0.8	$RMEG_{child}$	1/14

Sources: ATSDR 1998b, 1998c; Dames & Moore 1998, 2001; Pacific Northwest Laboratory 1994

Key: # = number; BHC = benzene hexachloride; child = standard for a child; CREG = Cancer Risk Evaluation Guide; EMEG = Environmental Media Evaluation Guide (intermediate); ppb = parts per billion; RBC-c = EPA Region III risk-based concentration (cancer); RMEG = Reference Dose Media Evaluation Guide; SVOCs = semivolatile organic compounds; VOCs = volatile organic compounds

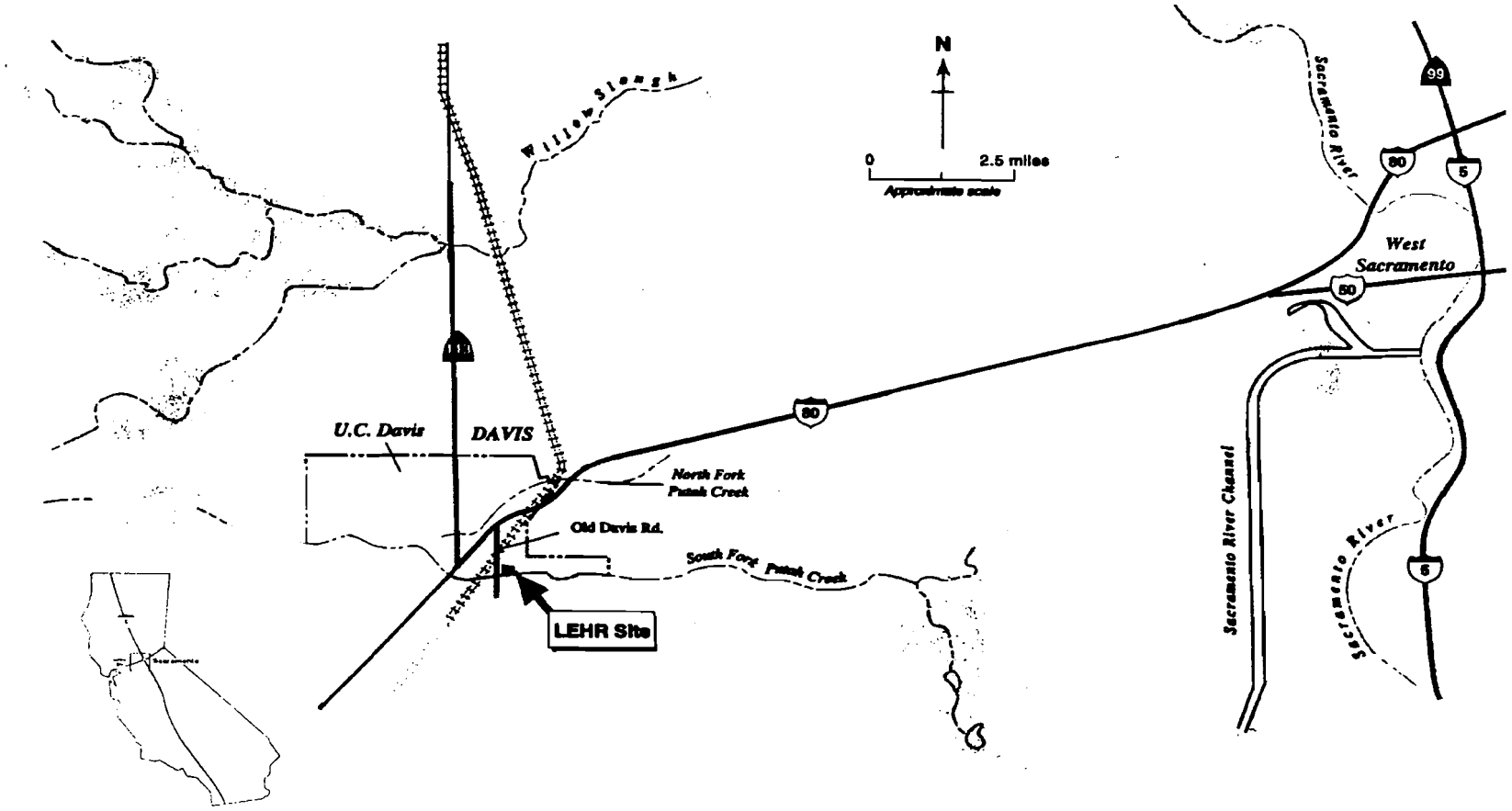
Notes:

- Comparison values are for drinking water exposures.
- The health-based comparison value for for thallium sulfate is used to screen concentrations of thallium.

- Data come from 1992 through 1993, 1997 through 2000, and (for Fishing Location 4) 1998.
- Only metals data area are available for fishing location 4 (ATSDR 1998b, 1998c).
- For 1998 and 1999 samples collected at PCU, ATSDR reviewed data for constituents of concern showing detections only: acetone, bromodichloromethane, bromoform, chloroform, dibromochloromethane, ethyl ether, methylene chloride, toluene, chromium, and hexavalent chromium.

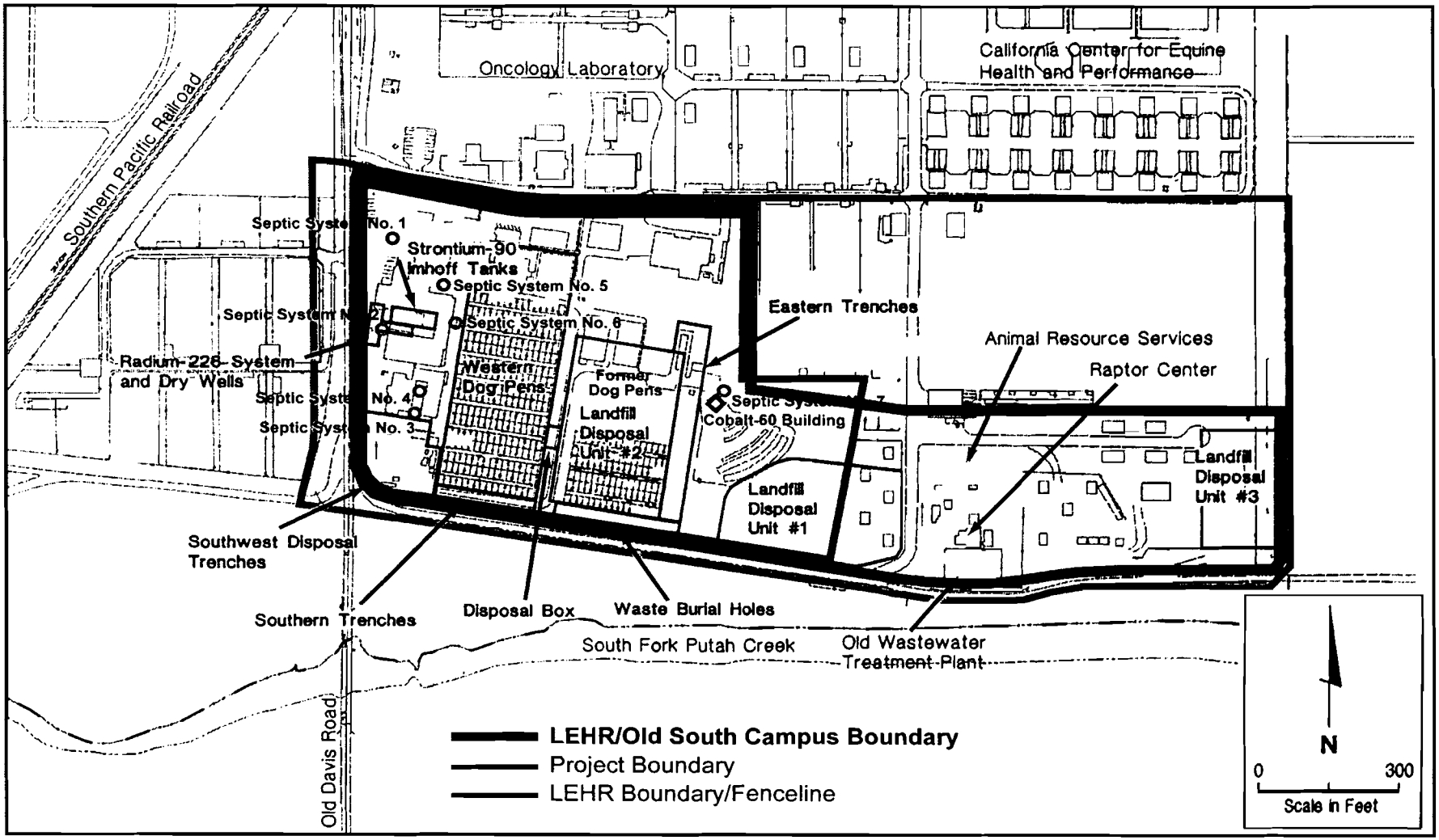
Figures

Figure 1. Area Map



Source: Weiss Associates 1999a.

Figure 2. Site Location Map



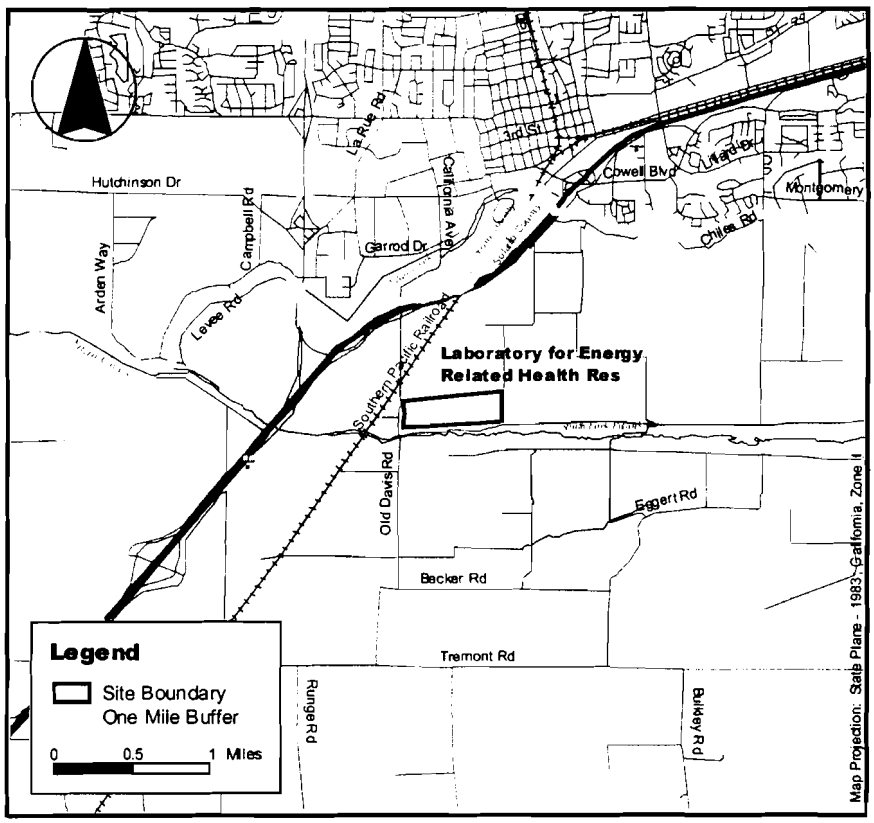
Source: Weiss Associates 1999a.

Laboratory for Energy Related Health Res

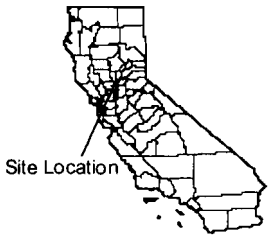
INTRO MAP

Davis, California

EPA Facility ID CA2890190000



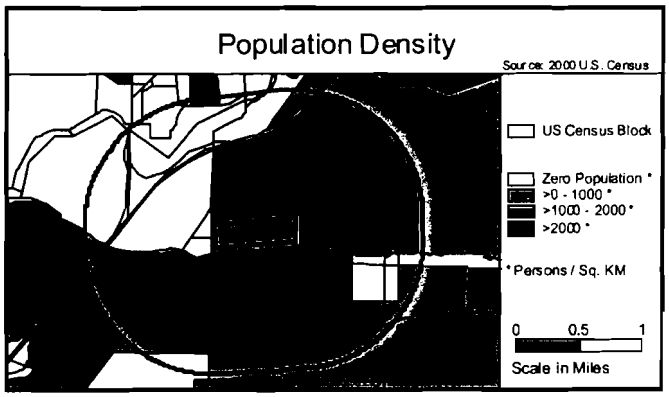
Base Map Source: 1995 TIGER/Line Files

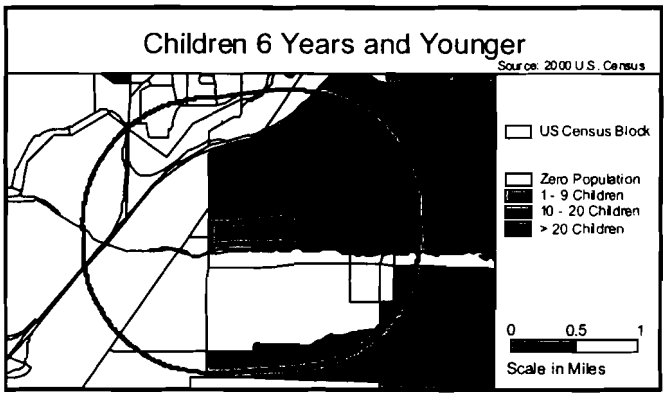


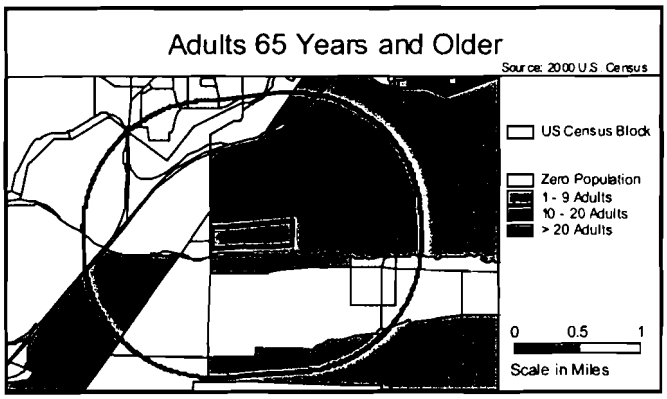
Solano County, California

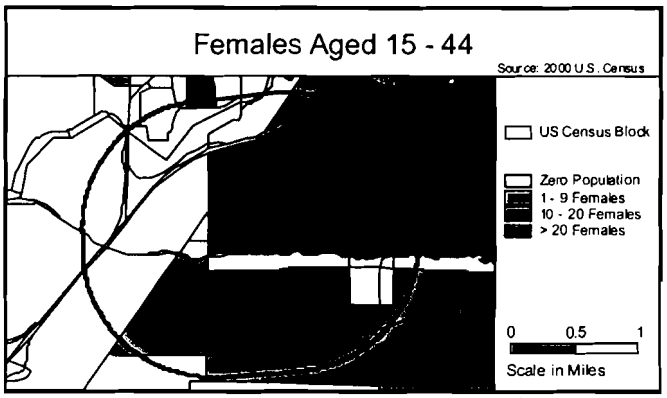
Demographic Statistics Within Area of Concern*	
Total Population	274
White alone	175
Black alone	7
Am. Indian and Alaska Native alone	0
Asian alone	46
Native Hawaiian and Other Pacific Islander alone	0
Some other race alone	24
Two or More races	22
Hispanic or Latino	38
Children Aged 6 and Younger	5
Adults Aged 65 and Older	3
Females Aged 15 - 44	141
Total Housing Units	22

Demographics Statistics Source: 2000 US Census
*Calculated using an area-proportion spatial analysis technique









JVA12 2002

AISDR GIS SAIDS

Figure 4: ATSDR Exposure Evaluation Process

REMEMBER: For a public health threat to exist, the following three conditions must all be met:

- Contaminants must exist in the environment
- People must come into contact with areas that have potential contamination
- The amount of contamination must be sufficient to affect people's health

Are the Environmental Media Contaminated?

ATSDR considers:

Soil
Ground water
Surface water and sediment
Air
Food sources

Are People Exposed To Areas With Potentially Contaminated Media?

For exposure to occur, contaminants must be in locations where people can contact them.

People may contact contaminants by any of the following three exposure routes:

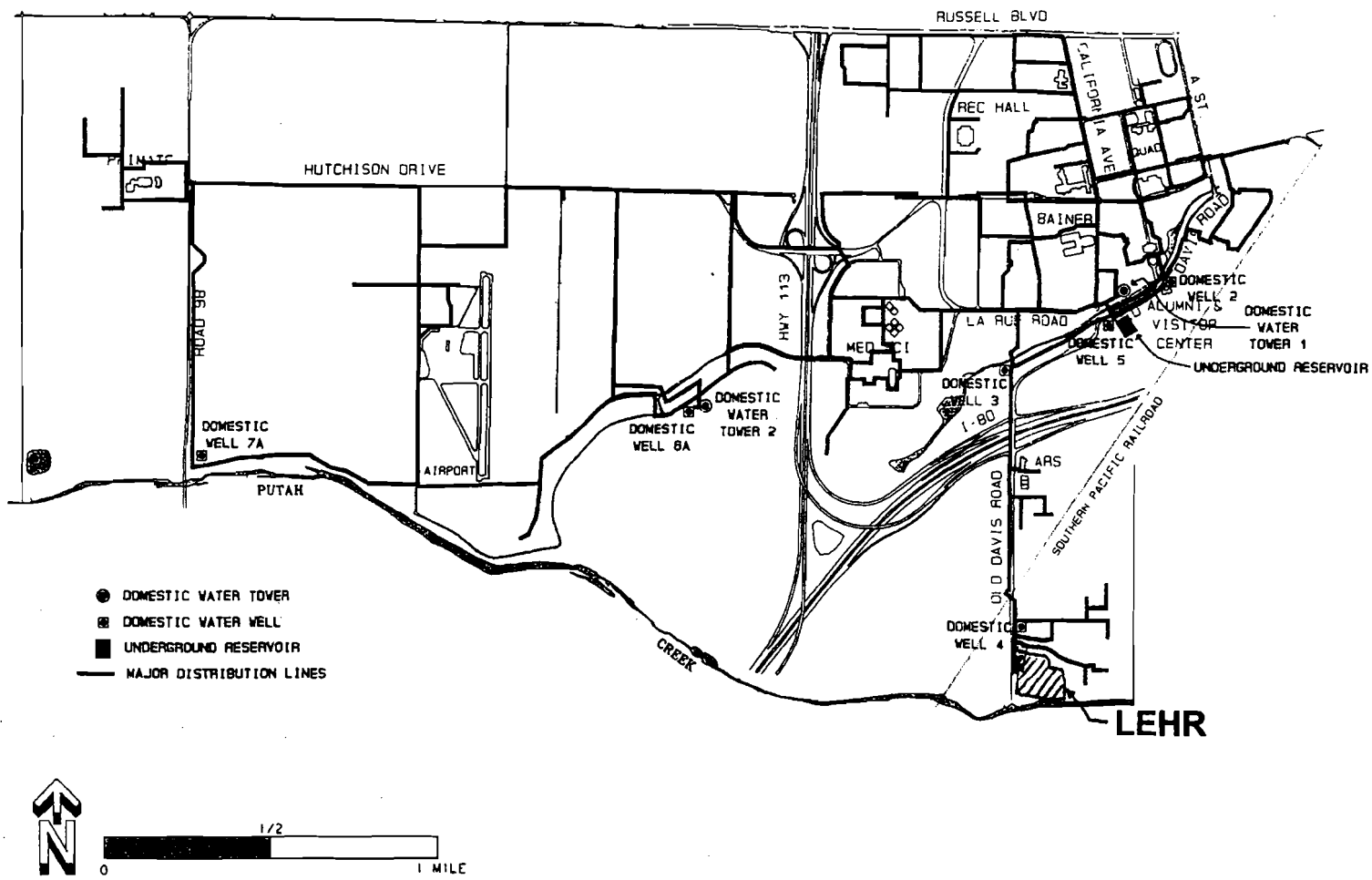
Inhalation
Ingestion
Dermal absorption

For Each Completed Exposure Pathway, Will the Contamination Affect Public Health?

ATSDR will evaluate existing data on contaminant concentration and exposure duration and frequency.

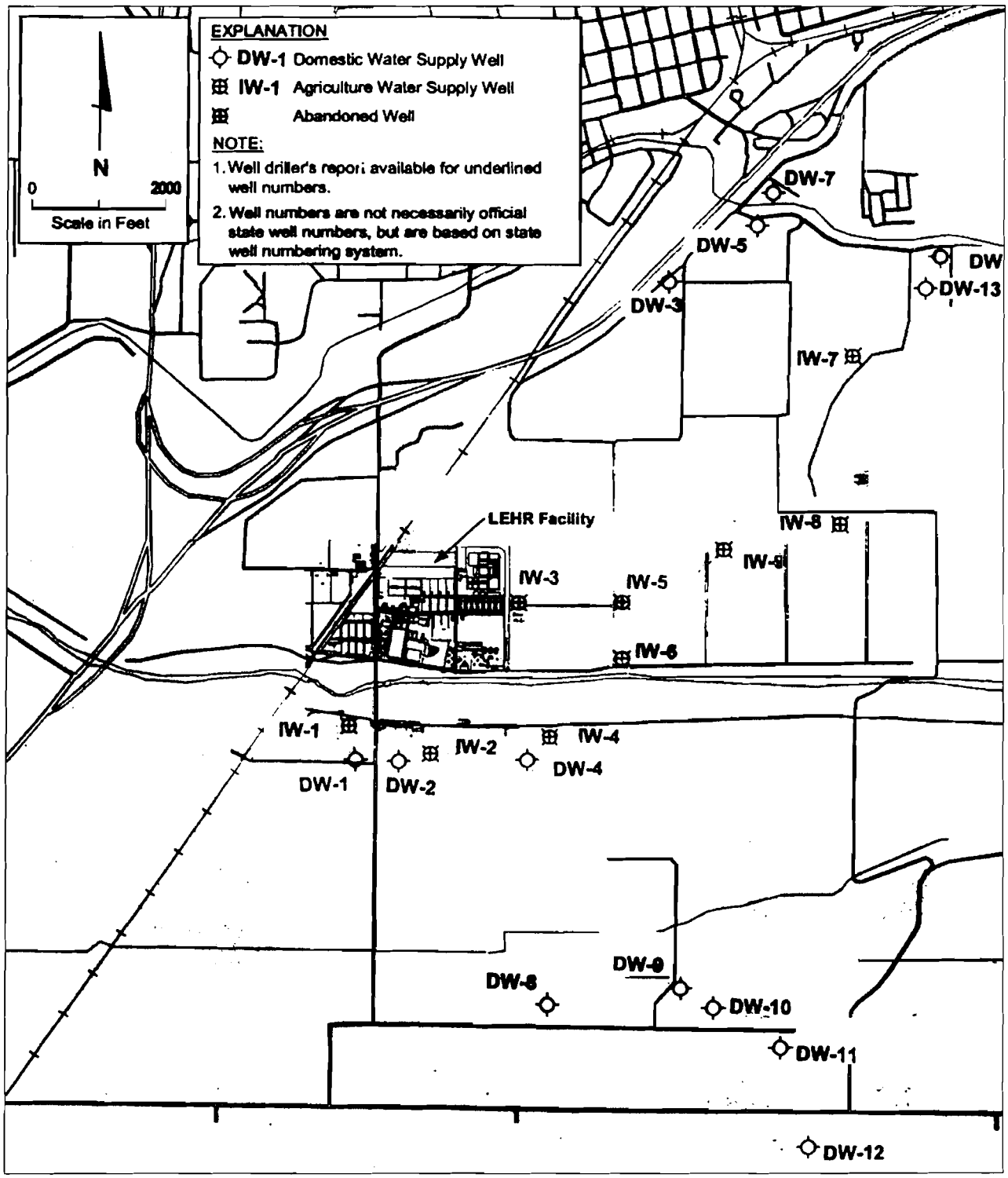
ATSDR will also consider individual characteristics (such as age, gender, and lifestyle) of the exposed population that may influence the public health effects of contamination.

Figure 5. UC Davis Domestic Supply Wells



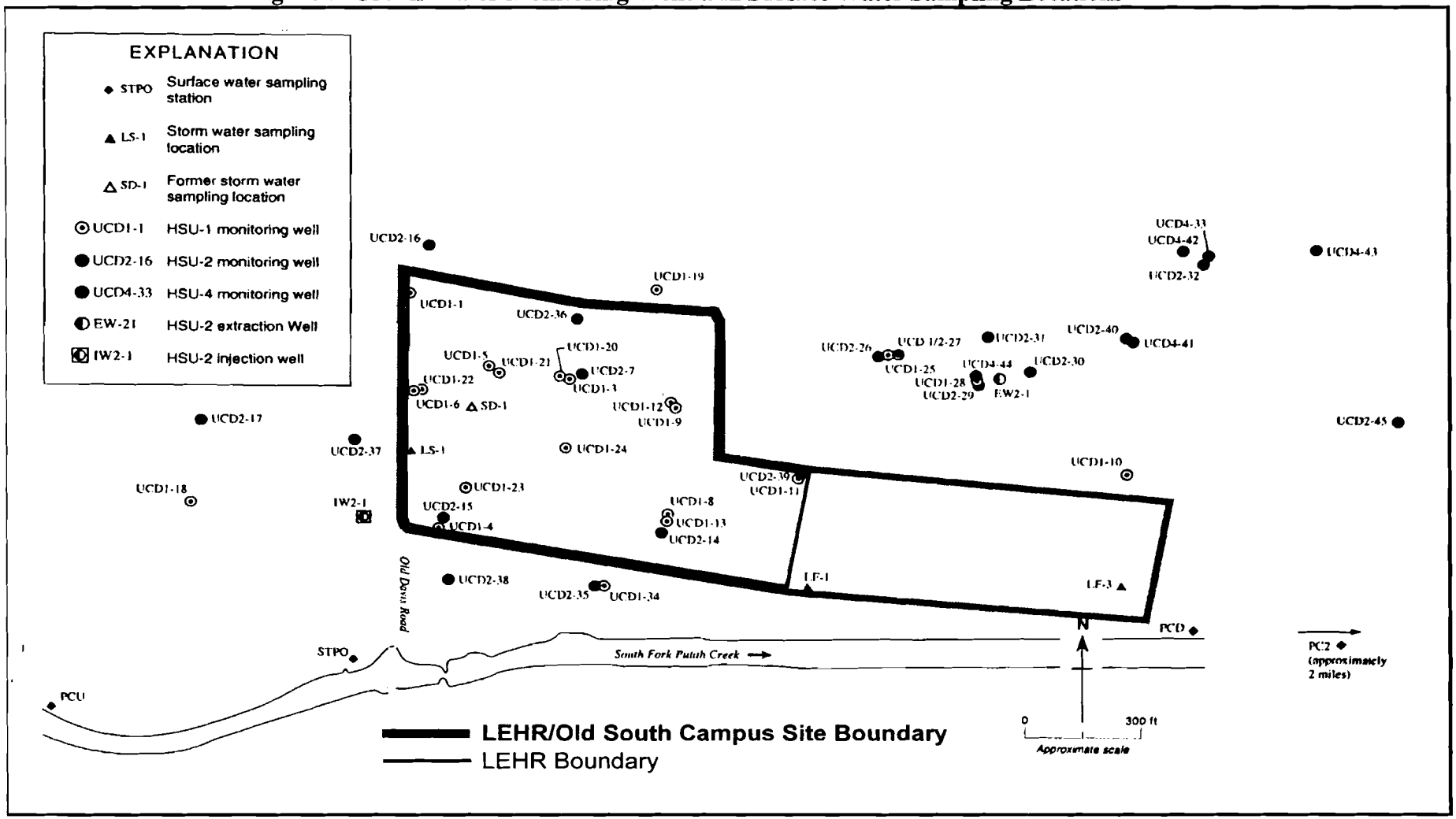
Source: UC Davis 1997.

Figure 6. Private Irrigation and Drinking Water Well Locations



Source: Adapted from URS 2002.

Figure 7. Groundwater Monitoring Wells and Surface Water Sampling Locations



Source: Weiss Associates 2003

Appendices

Appendix A
Glossary

Acute Exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with **intermediate duration exposure** and **chronic exposure**].

Adverse Health Effect
A change in body function or cell structure that might lead to disease or health problems.

Aquifer (Groundwater Aquifer)
A deposit of rock, such as sandstone or fractured limestone, containing water that can be used to supply wells.

- *unconfined* aquifer - an aquifer under atmospheric pressure which is partially filled with water (The top of the saturated area is known as the water table.)
- *confined* aquifer - an aquifer in which groundwater is held under pressure greater than atmospheric pressure by upper and lower confining layers, forcing water to rise in wells above the top of the aquifer.

Aquitard
A layer of rock having low permeability that stores groundwater but delays its flow.

Background Level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Cancer
Any one of a group of diseases that occurs when cells in the body become abnormal and grow or multiply out of control.

Carcinogen
A substance that causes cancer.

Chronic
Occurring over a long time (more than 1 year) [compare with **acute**].

Chronic Exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with **acute exposure** and **intermediate duration exposure**].

Comparison Value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed Exposure Pathway [see **exposure pathway**].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as **Superfund**, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances.

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal Contact
Contact with (touching) the skin [see **route of exposure**].

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response Relationship
The relationship between the amount of exposure [**dose**] to a substance and the resulting changes in body function or health (response).

Environmental Media
Soil, water, air, **biota** (plants and animals), or any other parts of the environment that can contain contaminants.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].

Exposure Assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure Pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a **source of contamination** (such as an abandoned business); an **environmental media and transport mechanism** (such as movement through groundwater); a **point of exposure** (such as a private well); a **route of exposure** (eating, drinking, breathing, or touching), and a **receptor population** (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a **completed exposure pathway**.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with **surface water**].

Hazardous Waste
Potentially harmful substances that have been released or discarded into the environment.

Hydrostratigraphic Unit (HSU)
A geologic unit with the same hydrogeologic properties. An aquifer is an HSU, but an HSU is not an aquifer unless it contains water that can be used to supply wells.

Indeterminate Public Health Hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see **route of exposure**].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **reference dose**].

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see **exposure pathway**].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with **health consultation**].

Public Health Hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or **radionuclides** that could result in harmful health effects.

Public Health Hazard Categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are **no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard**, and **urgent public health hazard**.

Radionuclide
Any radioactive isotope (form) of any element.

Receptor Population
People who could come into contact with hazardous substances [see **exposure pathway**].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Remedial Investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Route of Exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [**inhalation**], eating or drinking [**ingestion**], or contact with the skin [**dermal contact**].

Safety Factor [see **uncertainty factor**]

SARA [see **Superfund Amendments and Reauthorization Act**]

Source of Contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an **exposure pathway**.

Substance
A chemical.

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface Water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].

Toxicological Profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a **safety factor**].

Appendix B
Comparison Values

ATSDR health assessors use comparison values (CVs) as screening tools to evaluate environmental data that are relevant to the exposure pathways. CVs represent media-specific contaminant concentrations that are much lower than exposure concentrations observed to cause adverse health effects. In that way, CVs are protective of public health in essentially all exposure situations. If the concentrations in the exposure medium are less than the CV, the exposures are not of health concern and no further analysis of the pathway is required. However, while concentrations below the CV are not expected to lead to any observable health effect, it should not be inferred that a concentration greater than the CV will necessarily lead to adverse effects. Depending on site-specific environmental exposure factors (for example, duration of exposure) and activities of people that result in exposure (time spent in area of contamination), exposure to levels above the CV may or may not lead to a health effect. Therefore, ATSDR's CVs are not used to predict the occurrence of adverse health effects. Rather, they are used by ATSDR to select contaminants for further evaluation to determine the possibility of adverse health effects.

CVs used in this PHA include:

Cancer Risk Evaluation Guide (CREG)
Estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed over a 70-year life span. ATSDR's CREGs are calculated from EPA's cancer slope factors (CSFs).

Environmental Media Evaluation Guide (EMEG)
EMEGs are based on ATSDR minimal risk levels (MRLs) and factor in body weight and ingestion rates. An EMEG is an estimate of daily human exposure to a chemical (in mg/kg/day) that is likely to be without non-carcinogenic health effects over a specified duration of exposure to include acute, intermediate, and chronic exposures.

Reference Media Evaluation Guides (RMEG)
ATSDR derives RMEGs from EPA's oral reference doses (RfDs_. The RMEG represents the concentration in water or soil at which daily human exposure is unlikely to result in adverse non-carcinogenic effects.

EPA's Region III Risk-Based Concentration (RBC)
The U.S. Environmental Protection Agency (EPA) combines RfDs and CSF with "standard" exposure scenarios to calculate risk-based concentrations (RBCs), which are chemical concentrations corresponding to fixed levels of risk (i.e., a hazard quotient of 1, or lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration) in water, air, fish tissue, and soil.

EPA Maximum Contaminant Level (MCL)

The MCL is the drinking water standard established by the EPA. It is the maximum permissible level of a contaminant in water that is delivered to a free-flowing outlet. MCLs are considered protective of human health over a lifetime (70 years) for individuals consuming 2 liters of water per day.

CDHS Maximum Contaminant Level (MCL)

The California Department of Health Services (CDHS) also establishes drinking water standards. CDHS MCLs are enforceable regulatory standards under the Safe Drinking Water Act and must be met by all public drinking water systems for which they apply.

CVs are derived from available health guidelines, such as ATSDR's MRLs and EPA's RfDs, and EPA's CSFs. These guidelines are based on the no-observed adverse effect levels (NOAEL), lowest-observed adverse effect levels (LOAELs), or the cancer effect levels (CELs) reported for a contaminant in the toxicologic literature. A description of these terms is provided:

Minimal Risk Levels (MRL)

MRLs are estimates of daily human exposure to a chemical (i.e., doses expressed in mg/kg/day) that are unlikely to be associated with any appreciable risk of deleterious noncancer effects over a specified duration of exposure. MRLs are calculated using data from human and animal studies and are reported for acute ($\leq$ 14 days), intermediate (15-364 days), and chronic ($\geq$ 365 days) exposures.

Reference Dose (RfD)

The RfD is an estimate, with safety factors built in, of the daily, life-time exposure of human populations to a possible hazard that is <u>not</u> likely to cause harm to the person.

Cancer Slope Factor (CSF)

Usually derived from dose-response models and expressed in mg/kg/day, CSFs describe the inherent potency of carcinogens and estimate an upper limit on the likelihood that lifetime exposure to a particular chemical could lead to excess cancer deaths.

Lowest Observed Adverse Effect Level (LOAEL)

The lowest dose of a chemical that produced an adverse effect when it was administered to animals in a toxicity study or following human exposure.

No Observed Adverse Effect Level (NOAEL)

The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

Cancer Effect Level (CEL)

The CEL is the lowest dose of a chemical in a study, or group of studies, that was found to produce increased incidences of cancer (or tumors).

For radioactive contaminants, ATSDR uses information on radiation exposure and its effects, as related to environmental levels. This information comes from federal agencies, including EPA, the U.S. Department of Energy (DOE), and the U.S. Nuclear Regulatory Commission (NRC). ATSDR also uses other publicly available data sources and recommendations on radiation dose limits. The National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) develop these sources. The comparison values (CVs) used for the initial screening vary somewhat depending upon the site and potential exposure scenarios. For comparison values (CVs) in this document for LEHR, ATSDR used the following screening levels (CVs) for the different media:

Groundwater (on and off site)
US EPA's and CDHS's Maximum Contaminant Levels (MCLs) for drinking water

Surface Soil
NCRP Report No. 123I for the construction/commercial (CC) scenario since there are no dwellings on site and the present and future site activities include earth moving of potentially contaminated soils.

Surface Water, Sewage Treatment Plant Outfall, and Storm Water
US EPA's and CDHS's Maximum Contaminant Levels (MCLs) for drinking water

Ambient Radiation
NRC's and ICRP's limits to the general public, assuming 24 hours/day, 365 days/year exposure duration

Appendix C
ATSDR's Health Effects Evaluation

Estimates of Human Exposure Doses and Determination of Health Effects

Deriving Exposures Doses

After identifying contaminants in site media above comparison values and identifying potential pathways of exposure, ATSDR further evaluates exposures to detected contaminants considering information about exposures combined with scientific information from the toxicologic and epidemiologic literature. If necessary, ATSDR estimates exposure doses, which are estimates of how much contaminant a person is exposed to on a daily basis. Variables considered when estimating exposure doses include the contaminant concentration, the exposure amount (how much), the exposure frequency (how often), and the exposure duration (how long).

The estimated exposure doses can be used to evaluate potential noncancer and cancer effects associated with contaminants detected in site media. When evaluating ***noncancer*** effects, ATSDR compares the estimated exposure dose to standard toxicity values, including ATSDR's minimal risk levels (MRLs) and the U.S. Environmental Protection Agency's reference doses (RfDs), to evaluate whether adverse effects may occur. The chronic MRLs and RfDs are estimates of daily human exposure to a substance that is likely to be without appreciable risk of adverse noncancer effects over a specified duration. The chronic MRLs and RfDs are conservative values, based on the levels of exposure reported in the literature that represent no-observed-adverse-effects levels (NOAEL) or lowest-observed-adverse-effects-levels (LOAEL) for the most sensitive outcome for a given route of exposure (e.g., dermal contact, ingestion). Uncertainty (safety) factors are applied to NOAELs or LOAELs to account for variation in the human population and uncertainty involved in extrapolating human health effects from animal studies. ATSDR also reviews the toxicologic literature and epidemiology studies to further evaluate the weight of evidence for adverse effects.

ATSDR also evaluates the likelihood that site-related contaminants will cause ***cancer*** in people who would not otherwise develop it. As an initial screen, ATSDR calculates a theoretical increase of cancer cases in a population over a lifetime of exposure using EPA's cancer slope factors (CSFs), which represent the relative potency of carcinogens. This is accomplished by multiplying the calculated exposure dose by a chemical-specific CSF. CSFs are developed using data from studies of animal or human exposed to doses. Because they are derived using mathematical models which apply a number of uncertainties and conservative assumptions, risk estimates generated by using CSFs tend to be overestimated. Although no risk of cancer is considered acceptable, it is impossible to achieve a zero cancer risk. Consequently, ATSDR often uses a range of 10^{-4} to 10^{-6} estimated lifetime cancer risk (1 new case in 10,000 to 1,000,000 exposed

persons), based on conservative assumptions about exposure, to determine the likelihood of excess cancer resulting from this exposure.

ATSDR also compared an estimated lifetime exposure dose to available cancer effects levels (CELs), which are doses that produce significant increases in the incidence of cancer or tumors, and reviews genotoxicity studies to understand further the extent to which a chemical might be associated with cancer outcomes. This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

Estimating Exposure Doses from Ingesting Drinking Water from Private Domestic Wells

Nitrate and metals have been detected in private domestic wells near LEHR at concentrations greater than ATSDR comparison values for drinking water. The primary exposure pathway of concern is through consumption of the private well water. Because nearby residents possibly used or continue to use private well water containing elevated levels of nitrate and metals for drinking water, ATSDR evaluated the health effects that could possibly result from drinking water containing these constituents. Nitrate and metals are not readily absorbed through the skin or volatilized to indoor air. As such, exposure via skin contact and inhalation are not expected to be minimal and not of health concern.

In estimating to what extent people might be exposed to contaminants, ATSDR used protective assumptions about how long people were exposed to contaminants and how much contaminated water they ingested each day. Because some uncertainty exists regarding how long the contaminants have been in the private wells—no sampling data prior to 1989—ATSDR conservatively assumed that an adult was exposed to a contaminant for 30 years. In all likelihood, people may not have resided in the area for that long and the wells may have not been contaminated 30 years. Adults were assumed to drink about 2 quarts (2 liters) of tap water each day and to weigh (on average for male and female) about 150 pounds (or 70 kilograms). Children were assumed to drink about one quart (1 liter) of tap water each day and to weigh roughly 35 pounds (16 kg). ATSDR assumed that private well owners obtained all their daily fluids from their private wells. Again, this is a protective assumption because individuals tend to get some of their liquid requirements from sources such as milk, juice, soda, and a variety of foods. Furthermore, ATSDR assumed that private well owners were exposed to the most contaminated water; therefore, ATSDR used the highest (or maximum) measured concentrations of contaminants in the private well. These assumptions create a protective estimate of exposure, and together, allow ATSDR to safely evaluate the likelihood, if any, that contaminants in private well water could cause harm to its users.

Tables C-1 and C-2 summarize the estimated exposure doses to contaminants in the private well water and the following presents the equation and assumptions used to estimate the exposure doses:

$$\textit{Estimated exposure dose} = \frac{\text{Conc. x CF x IR x EF x ED}}{\text{BW x AT}}$$

where:

Conc.:	Maximum concentration in the well water (ppb)
CF:	Conversion factor to convert ppb to parts per million (1/1,000)
IR:	Ingestion rate: adult=2 liters per day; child=1 liter per day
EF:	Exposure frequency or number of exposure events per year of exposure: 365 days/year
ED:	Exposure duration or the duration over which exposure occurs: adult=30 years; child=6 years
BW:	Body weight: adult=70 kg (154 pounds); child=16 kg (34 pounds)
AT:	Averaging time or the period over which cumulative exposures are averaged (6 or 30 years x 365 days/year for noncancer effects or 70 years for cancer)

When dealing with exposure to lead, ATSDR uses another approach to the traditional methodology described above. A substantial part of human health effects data for lead are expressed in terms of blood lead level rather than exposure dose. Thus, ATSDR developed a secondary approach to utilize regression analysis with media-specific uptake parameters to estimate what cumulative blood lead level might result from exposure to a given level of contamination. To assess potential increase in blood lead levels for a child drinking private well water containing the maximum detected level of lead, ATSDR multiplied the detected concentration by the media-specific slope factor for water of 0.03 micrograms per deciliter (μg/dL) per microgram per liter (μg/L) of lead ingested in drinking water (ATSDR 1999a). The Centers for Disease Control and Prevention (CDC) have determined that health effects are more likely to be observed if blood lead levels are at or above 10 μg/dL.

Noncancer Effects

As an initial screen, ATSDR compared the estimated doses to the MRL or RfD for each contaminant. Doses estimated for a child exceeded the MRL or RfD for antimony, hexavalent chromium, molybdenum, and thallium. The estimated dose for an adult exceeded the RfD for hexavalent chromium. ATSDR estimated contribution to blood lead levels for a child drinking the private well water is 1 μg/dL, which is 10 times lower than CDC's recommended action level of 10 μg/dL. ATSDR then reviewed the scientific literature for contaminants exceeding their MRL or RfD to further evaluate potential health noncancer effects associated with exposure to the these

contaminants at the detected concentrations in private well water. Much of the toxicologic and health effects information reviewed by ATSDR came from experimental animal studies or from epidemiologic investigations of persons exposed in the workplace (human data). Less information is available that directly examines the relationship between exposure via drinking water and human health effects.

Antimony

Antimony is a metal that occurs naturally at low levels in the earth's crust. It can also be used in industrial applications when mixed with other metals to form alloys or produce antimony oxide. Some of the uses of the alloys include lead storage batteries, solder, sheet and pipe metal, bearings, castings, ammunition, and pewter. Antimony was detected in water collected from private wells near LEHR at levels up to 10 ppb. The highest concentration was found at wells located more than 400 feet south-southwest and more than 800 feet northeast of LEHR site boundaries.

ATSDR derived exposure doses to antimony in the well water for an adult and child. The highest estimated exposure dose was 0.0006 milligrams of antimony per kilogram of body weight per day (mg/kg/day) for a child. ATSDR reviewed the toxicologic literature to assess whether health effects were likely to occur at this dose. ATSDR found that estimated dose is just slightly higher than EPA's health guideline, called a reference dose (RfD), for chronic oral exposure to antimony of 0.0004 mg/kg/day. As noted earlier, an RfD is an estimate of the amount of a chemical that a person can be exposed to, on a daily basis, that is not anticipated to cause noncancer adverse health effects over a person's lifetime. The RfD is based on the lowest level at which adverse effects (decreased nonfasting serum glucose) have been reported in laboratory animals (rats) administered chronic oral doses of antimony is 0.262 mg/kg/day. (Scientist often rely on data from animals studies to provide some insight into possible effects from human exposure in the absence of sufficient human data.) ATSDR found that the estimated dose based on exposure to the highest detected concentration in private well water is approximately 400 times lower than the lowest observed effect levels for chronic, oral doses of antimony in animal studies (ATSDR 1992a).

ATSDR's estimated doses are considerably *lower* than the lowest level reported to cause adverse health effects. Information on the human health effects from chronic ingestion to antimony is limited, however. Available information on acute oral exposure suggests that the toxic potential of antimony in humans is relatively low, but has included abdominal distress. Amounts as low as 0.539 mg/kg/day have resulted in vomiting in a worker exposed to antimony-tainted lemonade. Even so, the dose shown to cause illness in the workers is 846 times higher than the dose estimated for exposure to antimony levels measured in private wells near LEHR.

Hexavalent Chromium

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and volcanic gases. Chromium occurs in the environment in several forms depending on the valence state of the chromium metal, primarily as trivalent (III) chromium or hexavalent (VI) chromium. While most chromium in the environment (e.g., soil, water) and the body is more commonly trivalent than hexavalent, chromium at LEHR is thought to occur primarily in the hexavalent form. Hexavalent chromium is used in chrome plating, dye manufacturing, leather tanning, and wood preservation. Hexavalent chromium is also considerably more toxic to humans than trivalent chromium. However, hexavalent is believed to be reduced to trivalent chromium in the stomach, limiting the "bioavailability" of chromium after ingestion and accounting for the relatively low oral toxicity of hexavalent chromium (ATSDR 2000a).

Hexavalent chromium was detected in private wells at levels up to 180 ppb and above ATSDR's CV of 30 ppb for children and 100 ppb for adults. Assuming daily exposure to the maximum detected concentration, the estimated doses for ingestion of hexavalent chromium in private wells were 0.005 mg/kg/day for an adult and 0.01 mg/kg/day for a child. Though these doses exceed EPA's RfD for chronic oral exposure to hexavalent chromium of 0.003 mg/kg/day, these doses fall well below effect levels reported in the scientific literature. Specifically, EPA's RfD is based on animal studies in which no observed adverse health effects were reported in rats administered hexavalent chromium at 2.5 mg/kg/day in drinking water (EPA 2002). This dose, called a no-observed effect level (NOAEL), is 250 to 500 times higher than the estimated doses from exposure to hexavalent chromium in the private wells. Other animal studies, that looked at developmental and reproductive toxicity revealed similar NOAELs and offer added perspective.

Relatively few human studies have been identified that address the oral toxicity of hexavalent chromium. One drinking water study suggests that gastrointestinal effects may be associated with hexavalent chromium concentrations of 20 ppm (20,000 ppb) in drinking water, but the study fails to detail exact exposure concentrations, possible confounding factors, or what effects might be seen at lower levels (Zhang and Li 1987, as cited in EPA 1998). It is interesting to note, however, that these effects were seen at drinking water concentrations more than 100 times those detected in private wells tested near LEHR. Investigators note some possible high per capita rates of some cancers, but do not draw any inferences.

Based on these observations, ATSDR scientists conclude that ingestion of hexavalent chromium at detected levels in off-site private wells is not expected to result in adverse human health effects.

Molybdenum

Molybdenum is an essential dietary nutrient. Molybdenum is also used in certain nickel-based alloys, nuclear energy applications and for missile and aircraft parts, and as a catalyst in the

refining of petroleum. Very little information exist in the toxicologic literature regarding health effects from molybdenum exposure. EPA has derived an RfD of 0.005 mg/kg/day for molybdenum based on a study in which humans were exposed for 6 or more years to a diet containing molybdenum (Koval'skuy et al. 1991). The RfD was derived from the LOAEL of 0.14 mg/kg/day, which was resulted in increases in uric acid levels. The LOAEL based on this human study is about 18 times higher than the estimated doses for exposure to molybdenum levels detected in private wells.

A 1979 study evaluated potential effects of what was considered low (2–50 ppb) and high (≥200 ppb) human exposures to molybdenum in two Colorado drinking water supplies. (The highest detected molybdenum concentration in tested private wells near LEHR was 120 ppb.) Measured blood (plasma) molybdenum levels in subjects consuming up to 50 ppb were reported within normal ranges. No adverse health effects were observed in this group. Decreased levels of serum uric acid and increases in serum ceruloplasmin were observed in the higher exposure group. The NOAEL for all subjects (also taking dietary exposures into account) ranged from 0.004–0.008 mg/kg/day. Generally, compared to the results of this particular study, estimated site-specific doses fall between those shown not to cause any effects and those that show some changes in blood chemistry, but no observable signs of illness (EPA 1979).

Further, the Food and Nutrition Board of the Subcommittee on the Tenth Edition of the Recommended Daily Allowances has established the following Estimated Safe and Adequate Daily Intake (ESAADI) values for molybdenum (NRC 1989): 0.00195–0.00536 mg/kg/day (for children) and 0.0015–0.0036 mg/kg/day (for adults). Site-specific doses fall within the recommended range for adults and are just slightly higher for the estimated child dose.

Considered collectively, available data indicate that exposures to molybdenum at detected levels are unlikely to be of public health concern. Site doses fall within the range of doses considered to be safe.

Nitrate

Nitrate is a naturally occurring compound, part of the nitrogen cycle, and is the primary source of nitrogen for plants. Agricultural and residential use of nitrogen-based fertilizers, nitrogenous wastes from livestock and poultry production, and urban sewage treatment systems are sources of nitrate in soil and water. Nitrate-containing compounds are water soluble, which means that they can be carried in water. Thus, nitrate can enter drinking water supplies through surface water runoff, home sewage systems, agricultural fields, and groundwater recharge.

Nitrate was detected in off-site private wells at levels up to 53,900 ppb. ATSDR estimated exposure doses for an adult and child exposed to the maximum concentration (53,900 ppb) of nitrate measured in the wells of 1.5 mg/kg/day and 3.3 mg/kg/day, respectively. The estimated

dose for a child exceeds EPA's chronic oral RfD for nitrate of 1.6 mg/kg/day. EPA's RfD on the NOAEL of 1.6 mg/kg/day from studies in cases of infant methemoglobinemia associated with exposure to nitrate-contaminated water (Bosh et al., 1950; Walton, 1951). Methemoglobinemia is caused because nitrate is converted into nitrite by bacteria in the infant's stomach. This poses a particular concern for infants because the infant's gastrointestinal tract normally has high pH levels (i.e., less acidic than the levels found in adults) that favor the growth of nitrate-reducing bacteria. Nitrite present in infant's body then interferes with the oxygen carrying capacity of the blood. The lack of oxygen causes shortness of breath and blueness of the skin. Although the condition can be serious, it is easily reversed with treatment. The studies suggest that nitrate-induced health effects occur in infants after ingestion of formula containing nitrate greater than 20,000 ppb. Cases reported at levels of 11,000 to 20,000 ppb are usually associated with co-exposure to bacteriological-contaminated water or other sources of excess nitrate. No health effects have been associated with levels less than 10,000 ppb (Bosch et al. 1950 , Walton 1951, Simon et al. 1964, ECETOC 1988).

ATSDR believes that adults and children would not have experienced adverse health effects from exposure through drinking water, even if they consumed the maximum detected concentration in their private wells. Most tested wells had nitrate at levels below those associated with adverse health effects in infants (20,000 ppb) and well below the CV used for adults of 60,000 ppb. Additionally, we do not know if people were actually exposed to the highest levels, as estimated, for long periods of time. As a precaution, however, if wells are found to contain high nitrate levels in the future, families with infants should use an alternate water supply for infant drinking water and when preparing infant formula.

Thallium

Thallium is a naturally occurring metal found in the environment as ore deposits. It can be found in a pure form, mixed with other metals, or combined with other substances to form salts. When ingested via drinking water, thallium is believed to be absorbed rapidly and distributed to various parts of the body. About half of the ingested dose will leave the body in urine or feces within 3 days. The systems or organs shown to be affected by high or poisonous doses include the cardiac, nervous, liver, and kidney (ATSDR 1992b).

Much of what we know about thallium is from human poisoning cases reports and a relatively sparse animal data set that describe effects associated with various thallium compounds (e.g., thallic oxide, thallium sulfate, or thallium chloride). Only a limited amount of data are available regarding dose-response relationships. A review of the literature suggest the lowest reported LOAEL (performance deficit) to be 0.08 mg/kg/day in a study in which rats were exposed to thallium sulfate via gavage (i.e., administered directly into their guts). The critical study on which EPA's bases its RfD is based on a NOAEL in rats exposed to thallium sulfate via gavage at 0.25 mg/kg/day. These exposure situations are not very analogous to possible human exposure

situations but they offer some perspective on the doses associated with harmful effects. The estimated doses (child and adult) associated with continuous exposure to the highest detected thallium concentration in tested private wells are approximately 20–100 times lower than those shown to cause no or very subtle effects in available studies.

Cancer Effects

Not all contaminants in the environment have the potential to cause cancer. Several of the chemical contaminants detected in private well water have been classified by EPA as possible carcinogens via the oral route of exposure. These include vinyl chloride, arsenic, lead, and mercury. ATSDR found, however, that the levels of these contaminants in the private wells do not pose a risk for excess cancer cases in the community based on our estimated theoretical excess cancer risk. For further evaluation, ATSDR compared the estimated lifetime dose to the lowest CEL reported in the scientific literature for oral exposure to that contaminant. In all cases, the estimated doses from a lifetime of exposure was 366–67,000 times than the lowest levels at which cancer was reported in available studies of these contaminants. Considering this information, ATSDR does not expect people who came in contact with the detected levels of contaminant via drinking water to be at an increased risk of developing cancer.

Estimated Exposure Doses for Incidental Ingestion of Putah Creek Surface Water

Volatile organic compounds, semivolatile organic compounds, pesticides, and metals were detected in surface water of Putah Creek at levels above ATSDR CVs. The primary exposure pathway of concern is through incidental exposure of water while swimming or otherwise using the creek for other recreational activities. ATSDR evaluated the health effects that could possibly result from incidental ingestion of surface water containing these constituents. Most of the contaminants are not readily absorbed through the skin, therefore, posing minimal, if any, health risk from dermal contact.

In deriving the exposure doses, ATSDR assumed that people ingested about 0.15 liters (about ½ to 3/4 cup) of surface water while swimming in Putah Creek every day (EPA 2000a). This is likely a conservative assumption because people are not likely to visit the creek each day or consistently ingest that much surface water while swimming. Uncertainty exists about how long the contaminants have been in the Putah Creek surface because no sampling data prior to 1989 exist. Further, it is uncertain whether detected levels of contaminants may have been higher in the past ATSDR, therefore, assumed that an adult was exposed to the detected contaminant levels collected in more recent years (1992-2000) for 30 years and a child for 6 years. These assumptions enable ATSDR to evaluate the likelihood, if any, that contaminants in surface water could cause harm to its current recreational users of Putah Creek.

Tables C-3 and C-4 summarize the estimated exposure doses to contaminants in the private well water and the following presents the equation and assumptions used to estimate the exposure dose:

$$\textit{Estimated exposure dose} = \frac{\text{Conc. x CF x IR x EF x ED}}{\text{BW x AT}}$$

where:

Conc.:	Maximum concentration in Putah Creek surface water (ppb)
CF:	Conversion factor to convert ppb to parts per million (1/1,000)
IR:	Ingestion rate: 0.15 liters per day
EF:	Exposure frequency or number of exposure events per year of exposure: 365 days/year
ED:	Exposure duration or the duration over which exposure occurs: adult=30 years; child=6 years
BW:	Body weight: adult=70 kg (154 pounds); child=16 kg (34 pounds)
AT:	Averaging time or the period over which cumulative exposures are averaged (6 or 30 years x 365 days/year for noncancer effects or 70 years for cancer)

Noncancer Effects

ATSDR compared the estimated doses for chloroform, dibromomethane, bis-ethylhexyl)phthlate, aldrin, alpha-BHC, dieldren, heptachlor, antimony, arsenic, boron, chromium (total and hexavalent), and nickel to their MRL or RfD. In all cases, the estimated dose to an adult and child for a contaminant was below its corresponding MRL or RfD. Based on this comparison, exposures to contaminants in the surface water are unlikely to be of public health concern.

Cancer Effects

EPA has classified chloroform, bis(2-ethylhexyl)phthlate, aldrin, dieldrin, heptachlor, and arsenic as human or probable human carcinogens via the oral route of exposure. ATSDR estimated theoretical cancer risk from drinking water for each of the contaminants at the detected level. All cancer risk levels (10^{-6} to 10^{-8}) are safely below the range considered to pose excess cancer risk. ATSDR also compared the estimated cancer dose for a contaminant to the lowest CEL reported in the toxicologic literature to further assess the potential for cancer effects to occur. The estimated doses were more than 275 times lower the levels at which cancer has been observed in human or animal studies. With this information, ATSDR concludes that people who incidentally ingest surface water from Putah Creek while swimming or during other recreational activities are not at increased likelihood of developing cancer.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1992a. Toxicological Profile for Antimony. September 1992.

Agency for Toxic Substances and Disease Registry (ATSDR). 1992b. Toxicological Profile for Thallium. July 1992.

Agency for Toxic Substances and Disease Registry (ATSDR). 1993. Toxicological Profile for Heptachlor/Heptachlor Epoxide. April 1993.

Agency for Toxic Substances and Disease Registry (ATSDR).1997a. Toxicological Profile for Vinyl Chloride(Update). September 1997.

Agency for Toxic Substances and Disease Registry (ATSDR).1997b. Toxicological Profile for Chloroform (Update). September 1997.

Agency for Toxic Substances and Disease Registry (ATSDR).1999a. Toxicological Profile for Lead (Update). July 1999.

Agency for Toxic Substances and Disease Registry (ATSDR).1999b. Toxicological Profile for Arsenic (Update). July 1999.

Agency for Toxic Substances and Disease Registry (ATSDR).1999c. Toxicological Profile for Mercury (Update). March 1999.

Agency for Toxic Substances and Disease Registry (ATSDR). 2000a. Toxicological Profile for Chromium. September 2000.

Agency for Toxic Substances and Disease Registry (ATSDR). 2000b. Toxicological Profile for Mercury (Update). September 2000.

Agency for Toxic Substances and Disease Registry (ATSDR). 2002a. Toxicological Profile for Aldrin/Dieldin. September 2002.

Agency for Toxic Substances and Disease Registry (ATSDR). 2002b. Toxicological Profile for Di(2-ethylhexyl)phthlate. September 2002.

Bosch HM, AB Rosefield, R Huston, HR Shipman, FL Woodward. 1950. Methemoglobinemia and Minnesota well supplies. J. Am. Water Works Assoc. 42:1561-170.

ECETOC (European Chemical Industry Ecology and Toxicology Center) 1988. Nitrate and drinking water. Technical Report No. 27. Nitrate and drinking water,. Brussels, Belgium. 1988.

EPA. 1979. Human health effects of molybdenum in drinking water. Cincinnati, OH. EPA-600A-79-006, as cited in IRIS.

EPA.1997. Exposure Factors Handbook. 1997 August. Available from: URL: http://www.epa.gov/ncea/exposfac.htm.

EPA. 1998. Toxicological review of hexavalent chromium (CAS No. 18540-29-9). In support of summary information on the Integrated Risk Information System (IRIS). August 1998.

EPA. 2002. U.S. Environmental Protection Agency. Integrated Risk Information System.

NRC (National Research Council). 1989. National Academy of Sciences. Recommended Dietary Allowances, 10th Ed., National Academy Press, Washington, DC, as cited in IRIS.

Simon C, H Manxzke, H Kay, and G Mrowetz. 1964. Occurrence, pathogenesis, and possible prophylaxis of nitrate induced methemoglobinemia. Zeitscxhr. Kinderheilk. 91:124-138.

Walton G. 1951 Survey of literature relating to infant methemoglobinemia due to nitrate-contaminated water. AM. J. Public Health. 41:986-996.

Zhang L, Li X. 1987. Chromium pollution of soil and water in Jinzhou. J Chin Prevent Med. 21:262-64, as cited in EPA 1998.

Table C-1. Estimated Exposure Doses—Noncancer Effects (Ingestion of Private Well Water)

Contaminant	Maximum Detected Contaminant Concentration (ppb)	Estimated Exposure Dose (mg/kg/day)[a]		Health Guideline (mg/kg/day)	Basis for Health Guideline
		Adult	Child		
Vinyl Chloride	0.19	0.00004	0.0001	0.002	chronic oral RfD
Antimony	10	0.0002	0.0006	0.0004	chronic oral RfD
Arsenic	3	0.00008	0.0001	0.003	chronic oral MRL
Chromium, total	140	0.004	0.008	1.5	chronic oral RfD
Chromium, hexavalent	180	0.005	0.01	0.003	chronic oral RfD
Lead	36	0.001	0.002	no value	
Mercury	3.2	0.00009	0.0002	0.0005	chronic oral MRL (proposed 1999)
Molybdenum	120	0.003	0.007	0.005	chronic oral RfD
Thallium	60	0.002	0.004	0.00009	chronic oral RfD
Nitrate	53,900	1.5	3.3 (8.9 for infants)	1.6	chronic oral RfD

[a] *Estimated Exposure Dose*=$\frac{\text{Conc. x CF x IR x EF x ED}}{\text{BW x AT}}$

Conc. = Maximum contaminant concentration detected in the private wells (ppb)
CF = Conversion factor to convert ppb to ppm (1/1000)
IR = Ingestion rate: adult = 2 liters per day; child/infant = 1 liter per day
EF = Exposure frequency or the number of exposure events 365 days per years
ED = Exposure duration or the duration over which exposure occurs: adults = 30 years; child = 6 years; infant = 1 year.
BW = Body weight (kg): adult = 70 kg (154 pounds); child = 16 kg (34 pounds); infant = 6 kg (14 pounds).
AT = Average time or the period over which cumulative exposures are averaged (1 or 6 or 30 years x 365 days)

Key: ppb = parts per billion; mg/kg/day=milligrams contaminant per kilogram body weight per day; MRL = ATSDR's minimal risk level; RfD= EPA's reference dose.

Table C-2. Estimated Exposure Doses—Cancer Effects Ingestion of Private Well Water

Contaminant	Maximum Detected Contaminant Concentration (ppb)	Estimated Exposure Dose (mg/kg/day)[a] (Adult)	CSF	Theoretical Excess Cancer Risk	CEL for Oral[a] Exposure (mg/kg/day)	Source of CEL
Vinyl Chloride	0.19	0.0001	1.4	3×10^{-6}	0.3	Maltonio et al. 1981
Arsenic	3.	0.00003	1.5	5×10^{-5}	0.0011	Ferriccio et al. 1998
Lead	36	0.0004	no value	no value	27	Azar et al. 1973
Mercury	3.2	0.00003	no value	no value	0.69	Mitsumori et al. 1990

[a] *Estimated Exposure Dose-Cancer* $= \frac{\text{Conc.} \times \text{CF} \times \text{IR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$

Conc. = Maximum contaminant concentration detected in the private wells (ppb)
CF = Conversion factor to convert ppb to ppm (1/1000)
IR = Ingestion rate: 2 liters per day
EF = Exposure frequency, or the number of exposure events (365 days per year)
ED = Exposure duration, or the duration over which exposure occurs = 30 years
BW = Body weight (kg): 70 kg (154 pounds)
AT = Average time or the time over which cumulative exposures are averaged (70 years x 365 days)

[b] CELs are reported in ATSDR 1997a, 1999a, 1999b, 1999.

Key: ppb = parts per billion; mg/kg/day=milligrams contaminant per kilogram body weight per day; CEL=cancer effect level; CSF= cancer slope factor.

Table C-3. Estimated Exposure Doses—Noncancer Effects Incidental Ingestion of Putah Creek Surface Water

Contaminant	Maximum Detected Contaminant Concentration (ppb)	Estimated Exposure Dose (mg/kg/day)[a]		Health Guideline (mg/kg/day)	Basis for Health Guideline
		Adult	Child		
Chloroform	8.9	0.00001	0.00008	0.01	chronic oral MRL
Dibromochloromethane	1.1	0.000002	0.00001	0.02	chronic oral RfD
bis(2-ethylhexyl)phthalate	12.6	0.00002	0.0001	0.02	chronic oral RfD
Aldrin	0.006	0.00000001	0.00000005	0.00003	chronic oral MRL
Alpha-BHC	0.03	0.00000008	0.0000003	no value	
Dieldrin	0.04	0.00000008	0.0000003	0.00005	chronic oral MRL
Heptachlor	0.03	0.00000006	0.0000003	0.0005	chronic oral RfD
Antimony	10	0.00002	0.00009	0.0004	chronic oral RfD
Arsenic	4.8	0.00001	0.00004	0.0003	chronic oral MRL
Boron	747	0.001	0.007	0.01	intermediate oral MRL
Chromium, total	80	0.0001	0.0007	1.5	chronic oral RfD
Chromium, hexavalent	42	0.00009	0.0004	0.003	chronic oral RfD
Nickel	310	0.0006	0.002	0.0002	chronic oral RfD

[a] *Estimated Exposure Dose*= $\frac{\text{Conc. x CF x IR x EF x ED}}{\text{BW x AT}}$

Conc. = Maximum contaminant concentration in Putah Creek surface water (ppb=parts per billion)
CF = Conversion factor to convert ppb to ppm (1/1000)
IR = Ingestion rate: 0.15 liters per day
EF = Exposure frequency or the number of exposure events (365 days)
ED = Exposure duration or the duration over which exposure occurs: adults = 30 years; child = 6 years
BW = Body weight (kg): adult = 70 kg (154 pounds); child = 16 kg (34 pounds)
AT = Average time or the period over which cumulative exposures are averaged (6 or 30 years x 365 days)

Key: BHC=benzene hexachloride; mg/kg/day=milligrams contaminant per kilogram body weight per day; MRL = ATSDR's minimal risk level; RfD= EPA's reference dose.

Table C-4. Estimated Exposure Doses—Cancer Effects Incidental Ingestion of Putah Creek Surface Water

Contaminant	Maximum Detected Contaminant	Estimated Exposure Dose (mg/kg/day)[a] (Adult)	CSF	Theoretical Excess Cancer Risk	CEL for Oral[b] Exposure (mg/kg/day)	Source of CEL
Chloroform	8.9	0.000008	0.0061	4×10^{-8}	90	Dunnick and Melnick 1993
bis(2-ethylhexyl)phthalate	12.6	0.00001	0.014	1×10^{-7}	147	David et al. 1999
Aldrin	0.006	0.00000005	17	8×10^{-7}	1.3	Davis and Fitzhugh 1962
Dieldrin	0.04	0.00000003	16	4×10^{-7}	0.33	Walker et al. 1972
Heptachlor	0.03	0.00000002	4.5	9×10^{-8}	1.8	NCI 1977
Arsenic	4.4	0.000004	1.5	6×10^{-6}	0.0011	Ferreccio et al. 1998

[a] *Estimated Exposure Dose-Cancer* $= \frac{\text{Conc. x CF x IR x EF x ED}}{\text{BW x AT}}$

Conc. = Maximum contaminant concentration detected in Putah Creek surface water (ppb)
CF = Conversion factor to convert ppb to ppm (1/1000)
IR = Ingestion rate: 0.15 liters per day
EF = Exposure frequency, or the number of exposure events (365 days per year)
ED = Exposure duration, or the duration over which exposure occurs =30 years
BW = Body weight (kg): 70 kg (154 pounds)
AT = Average time or the time over which cumulative exposures are averaged (70 years x 365 days)

[b] CELs are reported in ATSDR 1993, 1997b, 1999b, 2002a, 2002b.

Key: ppb = parts per billion; mg/kg/day=milligrams contaminant per kilogram body weight per day; CEL=cancer effect level.

Appendix D
Responses to Public Comment on the LEHR/Old Campus Landfill Public Health Assessment

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments from the public and local organizations during the public comment period (July 11, 2003 to October 31, 2003) for the LEHR/Old Campus Landfill Public Health Assessment (July 2003). For comments that questioned the validity of statements made in the PHA, ATSDR verified or corrected the statements. The list of comments does not include editorial comments, such as word spelling or sentence syntax.

No.	Comment	ATSDR Response
	General	
1	Foreword page, second paragraph, states that the assessment objective is "to find out if people are being exposed to hazardous...," but the report also addresses past exposure (e.g., Co-60 source). The assessment text should be consistent with the objective or the objective should be reworded to include past exposures.	ATSDR's public health assessment process examines *past*, *current*, and *potential future* exposures. A key element of ATSDR's public health assessment process is the exposure assessment, from which ATSDR determines what off-site populations may have contacted or may come in contact with site contaminants (who), the route or pathway of exposure (breathing, eating, drinking, or skin contact), the exposure concentration (how much), the frequency and duration of exposure (*when/how long*), and the multiplicity of exposure (combination of contaminants). All of these factors help us determine whether the public has or could be harmed by site-related exposures. Understanding the overall timing of identified exposures is an integral part of the evaluation and guides our recommendations for public health actions. As described in more detail in the main text of the document, ATSDR identified populations near the LEHR site who may have been exposed to hazardous substances at levels of health concern. Throughout, we explicitly state that ATSDR has considered past, current, and potential future exposure situations (e.g., Pages 2, 13, 15, Table 3). The foreword provides a general overview of the public health assessment process, touching upon the central elements of the process. For added clarity, ATSDR has modified the language in the foreword. The sentence in question now reads: "The aim of these evaluations is to find out if people could be exposed (past, current, future) to hazardous substances..."

No.	Comment	ATSDR Response
	General	
2	The name of the site on the cover page is misleading and is not the same as the header used in the document. There should be no a/k/a because the official EPA name for the site includes both portions. The Department of Energy (DOE) should be listed as responsible for LEHR and the University of California listed as responsible for the Old Campus Landfill.	ATSDR agrees. This has been corrected. The cover page now reads: "Laboratory for Energy-Related Health Research (U.S. Department of Energy)/Old Campus Landfill Site (University of California Davis)." Section II.B of the public health assessment (PHA) clearly lays out the division of responsibility across the site.
3	There are several places in the document that reference the distance to Putah Creek as 125 feet and others that use 250 feet. The document needs to be consistent.	ATSDR has revised the text to more accurately and consistently describe the distance between the site boundary and Putah Creek. The distance between the site and the creek actually ranges from approximately 125 to 250 feet, depending on where along the southern fence line one measures. The closest distance is at the eastern portion of the site, toward Landfill Disposal Unit 3.
4	The overall assessment of the draft ATSDR public health assessment for the LEHR site is that ATSDR has, in general, properly assessed the public health issues associated with this site. There are, however, some significant deficiencies that need to be addressed. These are detailed in subsequent comments.	ATSDR acknowledges this comment and addresses specific concerns voiced by this commenter below.
5	One of the principles of public health practice that is not being adequately/reliably addressed in the LEHR site investigation thus far is that of erring on the side of public health protection in situations when there is inadequate information to define the public health risk associated with a situation. This is known as the "precautionary principle." The ATSDR draft report is deficient in not adequately following this approach.	ATSDR adheres to the basic principle of prevention, which is considered the cornerstone of public health practice. Throughout our assessment of potential health hazards associated with the LEHR/Old Campus Landfill site, we make reasonable worst-case assumptions to err on the side of caution and conservatism. For example, when making our public health calls, we generally assumed that people could be exposed to the highest levels of contamination detected in a particular environmental medium. We provided perspective by explaining that exposures could and are very likely lower, but consistently recommended reducing or eliminating exposure to media where exposure levels even suggested the potential for harm (e.g., nitrates in water, mercury in fish).
6	Yolo County agrees with the general conclusion of the PHA, but suggests further study of the fish and nitrate issues.	ATSDR acknowledges this comment. The PHA includes recommendations regarding nitrates in drinking water (i.e., regular testing and general precautions). We also indicate the limitations of the fish testing data (Sections II.F.2). Based on our review of available data and site-related releases our conclusions and recommendations remain the same.

No.	Comment	ATSDR Response
	Reliability/adequacy of site environmental data	
7	ATSDR has relied almost exclusively on the PRPs' (UC Davis and DOE consultants) reports as being adequate to describe the situation at the LEHR site. The issue of greatest concern is the failure to adequately present and discuss the deficiencies that have taken place thus far in the site investigation with respect to defining the potential range of constituents of concern that are a threat to public health and the environment. ATSDR has not adequately incorporated the detailed information provided by the community on the significant deficiencies in the DOE and UCD reports, in properly characterizing the adequacy of the site investigation and proposed remediation. Pages 37 and 38 are devoted to storm water runoff issues. ATSDR has failed to discuss the documented fact that the storm water runoff monitoring has been and continues to be significantly deficient, compared to a monitoring program that would properly assess the potential for LEHR site constituents to lead to public health and environmental problems in Putah Creek. This situation reflects a significant deficiency in how ATSDR approached the development of this draft report. It appears that the agency has relied almost exclusively on DOE and UC Davis reports for information, without considering the repeated comments made by the community on the deficiencies in many of these reports. This problem is particularly severe with respect to storm water runoff issues.	ATSDR feels that the PHA adequately addresses this issue. As stated in the PHA, ATSDR believes that the amount of valid monitoring data for this site is sufficient and provides a reasonable account of the groundwater and surface water exposures experienced by local residents. ATSDR routinely relies on third-party environmental data when evaluating sites. As part of our data review process, we critically examine the overall quality and representativeness of the available data. We ask if site data are of sufficient quality and quantity to evaluate the exposure pathways of interest. We also examine any limitations or data gaps identified by the PRPs and/or the regulatory agency(ies) overseeing the PRPs' efforts. For the LEHR site, we also reviewed comments received by local scientists. ATSDR seeks to identify any *critical* data gaps that would prevent us from drawing public health conclusions, either because sampling is inadequate to evaluate exposure point concentrations or the data are of insufficient quality to serve as reliable estimates of exposure. Section II.E of the PHA outlines data quality factors that ATSDR evaluated as part of the health assessment process. Throughout the document, we clearly note any questions or uncertainties about the data being used to support our conclusions. Further, in Section V (Community Health Concerns), we address the specific data concerns voiced by community members in the context of ATSDR's public health assessment process. Specific issues are discussed in more detail in the comments and responses that follow.

No.	Comment	ATSDR Response
8	Page 62, last paragraph, that states that data meeting CERCLA requirements provide "ATSDR with assurance that the data are reliable and therefore adequate for our goal of assessing environmental exposures and making decisions protective of human health" fails to recognize deficiencies in available data sets. ATSDR has ignored or does not understand the significant problems that have existed at the LEHR site in properly conducting studies of storm water runoff from the LEHR site, with respect to the potential for excessive bioaccumulation of LEHR site-derived chemicals in Putah Creek fish or other edible aquatic life.	ATSDR modified the text on page 62 to respond more directly to the issue of detection limits raised by this community concern. In doing so, ATSDR deleted its reference to CERCLA program generated data. Note, however, that ATSDR's discussion of CERCLA data in the public comment release PHA was not meant to imply blind acceptance of such data. ATSDR does not simply rely on the fact that investigations are conducted as part of the CERCLA process to determine data quality and usability. ATSDR looks upon overall conformance with CERCLA requirements as adding credibility to the results, whereas sampling and analytical procedures are explicit and laboratory quality assurance/control requirements and data validation requirements are prescribed. As stated in previous responses, ATSDR independently examined the overall quality and representativeness of available data. We systematically review the procedures and findings before judging data usability for public health assessment purposes.
9	The quality of the data generated from the studies conducted under CERCLA, with respect to detection limits, is very much dependent on the remediation program managers requiring that adequate analytical methods be used. The public health and environmental literature is replete with problems of this type. There is a chronic problem with inadequate detection limits being used for monitoring certain parameters at the LEHR site. It was only after repeated efforts by community groups that the RPMs finally required that UC Davis improve the analytical methods for mercury. Even there, the improved method was only used for a short period, and UC Davis has been allowed to revert back to an inadequate analytical method to detect mercury in storm water runoff from LEHR at concentrations that could bioaccumulate in Putah Creek fish.	For the purposes of evaluating public health implications, ATSDR reviewed reported detection limits for surface and storm water samples against our health-based drinking screening or "comparison" values to determine whether harmful levels could be missed. We acknowledge that our drinking water comparison values do not account for bioaccumulation into fish. However, the comparison values are set relatively low to ensure that the tested water could be safely ingested on a daily basis over the course of a lifetime. Further, measured mercury in fish tissue were available to help us evaluate the health implications of mercury levels in fish. Fish tissue data are preferred over surface water or sediment data in determining the extent to which contaminants have or have not bioaccumulated.

No.	Comment	ATSDR Response
10	UCD's research activities have resulted in deposition of a wide variety of hazardous and deleterious chemicals in shallow pits at the LEHR site. Today there are in excess of 85,000 chemicals in commerce, with 1,000 new chemicals added per year. While the number of chemicals that could have reached the LEHR site in UCD's waste is somewhat less than that number, there still may be tens of thousands of chemicals that could be present in LEHR site wastes that were deposited in shallow, unlined pits, as part of campus waste disposal. Further, monitoring of groundwater and surface water at the LEHR site has shown that there is appreciable total organic carbon content in these waters, which could readily contain uncharacterized hazardous or deleterious chemicals.	ATSDR acknowledges that environmental samples collected for the purposes of evaluating LEHR site conditions were not analyzed for each and every chemical that could have been released. This is not technologically nor economically feasible. Can we say with certainty that nothing has been missed? No. However, the rationale behind the subset of chemicals that are routinely analyzed for at hazardous waste sites provides some assurance that the most important chemicals are being identified. A brief overview of this rationale and standard laboratory procedures in analyzing environmental samples is presented below. The analytical parameters tested as part of site investigations appear to cover the major classes and types of constituents known to be handled and disposed of at the LEHR site. Most environmental samples collected at LEHR were sampled for organic and inorganic constituents required under EPA's Contract Laboratory Program (CLP), specifically substances on EPA's Target Compound and Target Analyte lists (TCL and TAL, respectively). Samples were also analyzed for radiological parameters. EPA's TCL/TAL is an outgrowth of EPA's Priority Pollutant list, which refers a list of 126 specific pollutants that include heavy metals and specific organic compounds. These pollutants were assigned a high priority in developing water quality criteria and effluent limitation guidelines. The list is based on knowledge of contaminants that find their way into drinking water sources from industrial waste releases, agricultural runoff, atmospheric deposition, and other pollution sources and contaminants formed during the treatment of waters supplies; substance-specific toxicity; and available technology (i.e., the ability to identify and measure the substance) (EPA 1997). Laboratories recognize that constituents other than those on the TCL/TAL might be in a sample. When studying the chromatograms for individual samples, for example, laboratories match the "peaks" on these graphs with compounds on the method target list. Because the target list might not account for all peaks, laboratories will examine the most intense peaks that have not been accounted for and "tentatively" identify those compounds. In cases where specific knowledge exists that identifies site-specific or more obscure constituents, specialized analysis may be requested.

No.	Comment	ATSDR Response
10	(continued)	ATSDR agrees that the detected levels of total organic carbon (TOC) indicates the presence of uncharacterized (i.e., non-chemical specific) organic material in some tested samples. However, it is not unusual to find straight-chained hydrocarbons, for example, in environmental samples; these generally tend not to be outstandingly toxic. These hydrocarbons may not be on the method target list, but could contribute significantly to the TOC level. Again, could something have been missed of public health significance or masked by the presence of these uncharacterized materials? While possible, site investigators rely on standard methods to provide what is considered a reasonable account of environmental contaminants of potential concern.
11	The bottom of page 65 to the top of page 66 fails to address the issue of limiting the constituents of concern to only a few of the many thousands of chemicals that have been deposited in the waste material at the LEHR site.	The intent of the discussion on the bottom of page 65 and the top of 66 was to highlight the most prevalent and toxic constituents reported in site data sets. ATSDR does not believe discussion of the broader list of detected constituents is appropriate in this context.
12	An issue of concern is that there are ponds and wetland areas at the terminus of Putah Creek that have not been properly sampled with respect to human health and ecological effects, which receive Putah Creek discharges during most of the year, except during high flow periods when the discharges occur to Yolo Bypass. These areas could be contributing to a public health and environmental hazard.	As part of the public health assessment process, ATSDR reviews the availability of sampling data in areas possibly impacted by site activities. At the LEHR site, we believe that data collected at the WWTP outfall, along with sampling locations up and downstream from the site, serve the purpose of evaluating human health effects.

No.	Comment	ATSDR Response
	Groundwater conclusions	
13	The discussion of groundwater contamination, which begins on page 19 and continues through page 26, gives somewhat of an incorrect impression with respect to the pollution of the lower aquifers, particularly HSU-4. This write-up needs to be expanded to include the situation where an agricultural well was developed through HSU-2 into HSU-4. This well served as a conduit for pollutants in HSU-2 to enter HSU-4. This has led to the development of a substantial plume of polluted groundwater in HSU-4. These issues should be discussed in the ATSDR write-up.	ATSDR agrees that elevated concentrations of some substances were detected in the HSU-4 aquifer. Section III.B.3 (Nature and Extent of Groundwater Contamination) states this observation and forms the basis for our recommendation that UC Davis continue to monitor HSU-4 groundwater quality. ATSDR repeats this discussion in Section V (Community Health Concerns). Based on data available to ATSDR, however, we do not necessarily agree that a "substantial plume of polluted groundwater" is present in HSU-4 at the LEHR site. ATSDR is not familiar with the specific well installation to which the commenter refers, but we have made minor revisions to the PHA to more fully address this concern in the groundwater discussion section. Specifically, we added text to Section III.B.1 (Site Hydrogeology and Groundwater Use) indicating that the "confining layer" can be compromised should a situation like that described in this comment occur.
14	On the bottom of page 64, the draft ATSDR report states that "data collected from these investigations have served to sufficiently define the current extent of groundwater contamination plumes and the type and amount of contamination in Putah Creek." While ATSDR states that the definition of the current extent of groundwater contamination plumes is adequate for their purposes, the full extent of groundwater pollution by LEHR is still not known.	Again, a critical first step in the public health assessment process is our exposure assessment (environmental data and exposure pathway evaluations). As part of the exposure assessment, we evaluated the vertical and horizontal extent of groundwater contamination and the site hydrogeology and studied whether contamination was reaching drinking water supplies. Review of the available data (the network of monitoring wells and water supply well data) enabled us to achieve this objective.

No.	Comment	ATSDR Response
15	Another issue that should be discussed, associated with groundwater pollution near the LEHR site, is the fact that UCD discharge of its campus waste water to Putah Creek has led to pollution of the groundwater underlying the creek by VOCs. At this time, there are no known problems with this pollution; however, it has not been adequately investigated to see whether there is a potential problem in the future with VOC-polluted groundwater due to inadequate treatment of the campus waste water. It is important to note that, since Putah reek recharges to groundwater, pollutants in the creek can pollute groundwater that could be used for domestic purposes. On page 62, second paragraph, the statement that the chloroform from the waste water treatment plant is not likely leading to groundwater pollution is not in accord with the data that were collected, which showed that groundwater taken near Putah Creek, which could be influenced by the creek's recharge, showed elevated concentrations, compared to away from that location.	ATSDR acknowledges that Putah Creek is a losing stream and as such recharges area groundwater. However, it does not seem likely that the VOCs at the levels detected in the creek would have a significant impact on underlying groundwater. VOCs released to the creek, especially at reported concentrations, would be expected to be diluted and to volatilize to the atmosphere. Available data support this general premise. While some VOCs have been detected in surface water at the WWTP outfall above drinking water comparison values, few VOCs have been reported in other portions of the creek based on UCD data (Tables 12, 13, and 14) at frequencies or levels of concern. Further, private well sampling show no elevated levels of VOCs in nearby supply wells. It should be noted, however, that trace levels (< 1 part per billion) of VOCs (chloromethane, dichloroethene, and chloroform) were detected in monitoring wells just north of the creek (UCD2-35 and UCD2-38). The highest detected concentrations reported in Putah Creek samples were reported prior to 1997, most in the early 1990s. It is not known whether historical releases might have had a notable impact on area groundwater in the past.
16	The statement that neither nitrate nor chromium detected in private wells appears to have been derived by the LEHR site is appropriate. The nitrate in these wells is derived primarily from agricultural use of fertilizers that are polluting the groundwater in this area. The chromium is derived from naturally occurring chromium in the aquifer system. A statement needs to be added that this situation needs to be understood, in that this does not mean that there has not been more pollution of groundwater at the LEHR site by nitrate and chromium for UCD wastes. It appears that this pollution has occurred; however, it has not affected domestic water supply wells.	ATSDR agrees with the comment and believes the PHA currently reflects these thoughts. Section III.B.3 (Nature and Extent of Groundwater Contamination) clearly states that elevated nitrate and chromium concentrations were detected in the groundwater beneath the site, primarily in the HSU-1 aquifer, and particularly along the eastern boundary of the LEHR fence line. Because private drinking wells are not located in the flow of groundwater (immediately "down gradient" of the site), the presence of these same contaminants in private wells cannot be attributed to the LEHR site. No change or clarification in the PHA is necessary.

No.	Comment	ATSDR Response
17	On the bottom of page 4, the report states, "as such, ATSDR categorizes the on-site groundwater pathway as posing no public health hazard for past, current, and potential future exposures." ATSDR has neglected to discuss an important public health issue—namely, the significant unknowns associated with chemical constituents that were not analyzed for at the LEHR site. There could readily be hazardous chemicals in the soils, stormwater runoff and groundwater that have not been identified as a public health threat. These issues should be discussed in the final report.	ATSDR does not agree with this comment. Site environmental media have been analyzed for the full suite of organic and inorganic constituents required for CERCLA investigations. ATSDR looked at all of these data before drawing public health conclusions. As part of its review process, ATSDR reviewed the contaminants being analyzed, detection limits used, quality assurance and control measures, and overall temporal and spatial trends observed. For example, Tables 4 and 5 summarize contaminants detected above health-based comparison values. Even though nobody is drinking the water beneath the site, ATSDR carefully examined the nature and extent (vertical and horizontal) of the groundwater contamination to understand whether any of the detected contaminants could be reaching nearby populations. We also reviewed remediation plans to identify measures in place to prevent the off-site migration of groundwater contaminants and recommended continued monitoring of the HSU-4 aquifer in downgadient areas. Further, we reviewed sampling data collected from wells actually being used for drinking and other household purposes to guide our public health conclusions. See also our response to Comment #10.
	Conclusions and recommendations regarding fish in Putah Creek	
18	On page 4, under paragraph III Consumption of Fish from Putah Creek, ATSDR has failed to reliably report on the two different data sets on mercury in fish that were collected. The first, in 1997, showed that when Putah Creek was at low flow and there was no upstream flow, the University of California, Davis, waste water treatment plant was a source of mercury and conditions that promoted mercury bioaccumulation in fish. Since radioactive mercury was found in fish, there is no doubt that UCD's waste water contributes to the mercury problem. Further, recently Lower Putah Creek has been listed as a Clean Water Act 303(d) impaired water body because of excessive mercury bioaccumulation. It is now known, through other studies, that any source of mercury, such as storm water runoff from the LEHR site, is a potential contributor to excessive mercury in fish.	Detailed analysis of source attribution is not the purpose of ATSDR's public health assessment process. ATSDR's primary goal is to evaluate what contaminants could be reaching people, and, through the examination of sampling data evaluate the possible impact of measured (and sometimes modeled) exposure point concentrations. ATSDR did review soil and storm water data, which generally revealed very few contaminants at concentrations above ATSDR health-based comparison values (based on direct contact exposures). We focused on evaluating the measured mercury data in fish samples collected from Putah Creek, again, the most reliable measure of exposure potential. We agree that available data show slightly elevated mercury concentrations in tested fish tissue collected both up-gradient, near, and down-gradient of the LEHR site. Also, when describing Slotton et al. data (1999), we acknowledge that reduced flow conditions might be favorable for mercury uptake in fish at and near the LEHR site (page 50).

No.	Comment	ATSDR Response
18	(continued)	In responding to this comment, ATSDR re-visited the original data sets. As noted in our previous health consultations, available sampling data indicated that location where fish were caught had no significant bearing on the accumulation of mercury. At the same time, we acknowledged some limitations and uncertainties in the sampling efforts. For example, fish from each size range at each location would have helped to further evaluate possible effects of location on mercury accumulation. Further, fish sampling data were not sufficient in quantity to evaluate contaminant levels in some fish species (e.g., black bullhead, channel catfish) (ATSDR 1998). Follow-on studies by Slotton et al. (1999) confirmed the presence of mercury in edible fish tissue at levels generally comparable to those measured in previous samples. Because the PHA focus is on examining possible health concerns, we do not feel that additional discussion regarding source attribution is needed in the main text of the PHA.
19	ATSDR's statement that the mercury in Putah Creek fish does not appear to have come from LEHR is not technically valid. The LEHR site has been contributing mercury to Putah Creek, and some of the mercury in the fish is likely from LEHR. The discussion of the contamination of the soil, from page 27 through page 35 does not mention the fact that mercury has been found in the soils at LEHR at concentrations above background for the area. Further, these concentrations are sufficient so that mercury has been found to be present in stormwater runoff from the LEHR site and thereby contributes to the excessive mercury that is present in Putah Creek fish. Page 68, paragraph 2, states that mercury is not believed to be related to the LEHR site. Again, this is a mistake made by ATSDR which reflects a lack of review of the data that have been collected over the past year or so, which shows that mercury in soils and in storm water runoff from LEHR is at sufficient concentrations to lead to excessive bioaccumulation of mercury in fish.	ATSDR's statement was based on the relatively consistent findings in mercury in fish tissue in different reaches of the creek. ATSDR recognizes the limitations in the available data. These are highlighted in our health consultations and in the PHA. We further note that the mercury levels detected in storm water and waste water are below ATSDR's health-based comparison values for drinking water. See also previous response.

No.	Comment	ATSDR Response
20	Page 49, devoted to fish monitoring data, fails to mention the significant differences between the two years of monitoring. The first monitoring period, 1996-1997, was during a low flow period for Putah Creek, when there was not upstream discharge of water to Putah Creek in the vicinity of the LEHR site during the summer. The only waters near that site during the time of fish sampling were waters derived from the UC Davis campus domestic waste water treatment plant. The subsequent sampling, in 1998, was during a period of elevated Putah Creek flow. The results of the sampling from the two different hydrologic situations showed that there could be local sources of mercury or conditions that lead to mercury methylation in Putah Creek near LEHR and the waste water treatment plan discharge.	When reviewing the available data, ATSDR evaluated temporal and spatial trends, but again focused on evaluating the measured levels of mercury in fish tissue. Further, when describing the Slotton et al. (1999) findings, we acknowledge that reduced flow conditions might be favorable for mercury uptake in fish at and near the LEHR site. See also previous responses.
21	The ATSDR report discussing fish monitoring data also fails to discuss the fact that the US EPA failed to properly analyze fish taken from Putah Creek during both sampling events for organochlorine pesticides and PCBs. Since chlordane has been found at measurable concentrations in storm water runoff from the LEHR site and would be expected to be present in many of the storm water runoff samples at concentrations that could lead to excessive bioaccumulation, LEHR could readily be contributing to an excessive chlordane situation in Putah Creek fish. UC Davis/DOE never properly conducted organochlorine pesticide and PCB tissue analyses for fish taken from the vicinity of the LEHR site. This is a significant information gap that still exists, which is part of the potential human health threat that has not been adequately addressed thus far.	As stated in this public health assessment and in ATSDR's 1997 and 1998 health consultations, ATSDR agrees that data gaps exist related to fish in Putah Creek. ATSDR acknowledged that we do not know for certain (1) whether the species and size of fish evaluated are fully representative of fish caught and eaten by people in the area, and (2) whether organic compounds are at elevated or harmful levels in fish. Recognizing this, ATSDR drew conclusions based on a clear understanding of what is known and not known about contaminant levels in Putah Creek fish. Though limited, none of the information that we do have for pesticide and PCBs (1996 composite data) indicates the fish in Putah Creek pose a health hazard to people who eat them. None of the information we have—except mercury in largemouth bass—indicates the fish in Putah Creek pose a health hazard to people who eat them. We have made some slight revisions to the section of the public health assessment discussing the EPA Region IX sampling effort (Section III.F.2) to more explicitly state the limitations of the available data sets.

No.	Comment	ATSDR Response
22	On page 70, ATSDR should have included in Item 4 under recommendations properly assessing whether the fish in Putah Creek contain excessive organochlorine pesticides and PCBs, and whether the LEHR site is a contributor to these excessive concentrations.	As stated in the previous response, ATSDR acknowledges that the data we have do not fully address whether toxic organic substances are at levels of health concern in fish. This is clearly stated in the PHA, as well as in our 1997 and 1998 health consultations. ATSDR did not include a recommendation for the further assessment of Putah Creek fish because we believe that the mercury poses the greatest threat—in terms of both historical and current releases throughout the watershed and bioaccumulation potential—and available mercury fish tissue data are sufficient to support ATSDR public health conclusions and recommendations. In addition, while extensive sediment data are not available for Putah Creek, sediment samples collected during the 2002 data gaps investigation revealed very low levels of alpha- and gamma-chlordane (below the highest reported detection limit of 1.6 part per billion [ppb]). As a point of reference, ATSDR's most conservative soil comparison value for chlordane is 2,000 ppb. Further, ATSDR believes that the potential for accumulation of chemicals associated with past LEHR activities (the focus of our assessment) has been greatly reduced with the removal or containment of contaminant source areas.
	Worker health issues	
23	Some past workers at LEHR have reportedly experienced ill health effects, believed to be linked with chemical exposures (e.g., working at/near the incinerator, handling liquid and other waste materials).	The evaluation of worker health issues is not generally part of ATSDR's mandate, as this falls under the purview of agencies such as the Occupational Safety and Health Administration (OSHA). As part of the public health assessment process, ATSDR may evaluate exposures that are incidental to exposures directly linked to work activities (e.g., drinking contaminated water, incidental exposure to contaminated soils). Therefore, the PHA does not include any specific discussion on worker health issues.

No.	Comment	ATSDR Response
24	Page 41 states, in the last paragraph, that it is unlikely that workers at the LEHR site could come in contact with storm water runoff, because much of the captured storm water runoff flows underground or in drainage ditches. This statement is incorrect since there is storm water runoff from the LEHR site that is on the surface, and therefore, people could have been exposed.	ATSDR was referring to possible public exposures. The text has been modified to reflect this.
	Miscellaneous page-specific comments	
25	On page 1, under Summary, last paragraph, the current wording could lead to the conclusion that DSCSOC was not involved until April 2000. In the discussion about 1995, the following should be added: It was at that time that DSCSOC informed ATSDR that one of the primary deficiencies in the LEHR Superfund site investigation was the failure to determine if the fish in Putah Creek contained excessive concentrations of constituents that could be a threat to human health.	The purpose of the *Summary* is to provide a clear and concise overview of the site issues, findings, and recommended public health actions. ATSDR has modified the text to make it clear that ATSDR met with DSCSOC in 1995 as well as in 2000. However, the summary already presents an overview of community concerns, including the concern regarding possible impacts on people who eat fish from the creek. No further detail is warranted in the *Summary*. The fish pathway is discussed in detail in Section III.F.2 and IV.E. ATSDR also presents the specific concerns voiced by DSCSOC and other community members in Section V (Community Health Concerns).

No.	Comment	ATSDR Response
26	On page 3, under item 1, this statement needs to be reworded to make it clear that the so-called metal mentioned refers specifically to chromium. Some private shallow-water wells in the vicinity of the LEHR site at times contain excessive chromium. Some of the private domestic water supply wells in the vicinity of LEHR, at times are a threat to the health of those who use the water for domestic consumption purposes.	ATSDR does not believe any change to this summary statement is appropriate. While private well sampling focused on the metal chromium and nitrates in more recent years, ATSDR also reviewed and evaluated data for other metals reported in private wells (see Section III.B.3–*Off-site Private Wells*; Section IV.C; Tables 6 and 7; and Appendix C). Based on our review of detected levels of metals, ATSDR concluded that harmful exposures to metals were not occurring. Specific to hexavalent chromium, ATSDR recognizes that elevated levels (up to 180 parts per billion [ppb]) were detected in some wells. Some detections exceeded ATSDR's health-based comparison value of 30 ppb and state (50 ppb) and federal (100 ppb) drinking water standards. However, upon closer examination of the possible daily exposure doses and the toxicity literature regarding oral exposure to hexavalent chromium, ATSDR concluded that ingestion of hexavalent chromium at detected levels is not expected to result in adverse health effects.

No.	Comment	ATSDR Response
26	(continued)	As described in Appendix C, estimated doses assuming daily exposure to the highest detected concentration are 250 to 500 times *lower* than doses shown to cause *no* adverse effects in animal studies. Further, the few human studies available to assess the oral toxicity of chromium report adverse effects (gastrointestinal), but at concentrations more than 100 times those detected in private wells tested near LEHR. Though exposure in these human studies are not well-defined and only a small range of concentrations was studied, such data offer some added perspective. Lastly, hexavalent chromium has been shown to be reduced to the less toxic trivalent chromium in the stomach, accounting to the relatively low oral toxicity of hexavalent chromium. Scientists at ATSDR, the U.S. Environmental Protection Agency, the California Department of Health Services, among others, continue to examine oral chromium toxicity data, including possible carcinogenic effects.
27	Page 4, first paragraph discusses recreational use of Putah Creek. Only sources of water to Putah Creek should be included in this paragraph. The sentence that addresses historical waste water discharges (i.e., 3 million gallons of low-level radioactive waste discharged to dry wells) should be deleted since it is not a source of water to Putah Creek. The public could easily misread this sentence and believe the low-level waste was discharged to the creek. A good write-up on Waste Water Releases is provided on pages 36 and 37.	ATSDR agrees that this paragraph could be misinterpreted and has deleted the last sentence.
28	Page 6, third line from bottom indicates that dog feces and gravel were disposed of in "landfill," Based on process knowledge and past operations record, landfills did not receive any dog feces or gravel generated during the DOE funded research.	ATSDR re-examined site documents and found no record of dog feces or gravel being disposed of in the landfill, though research-related wastes were disposed of south of the Eastern Dog Pens, which overlies Landfill Disposal Unit 2. ATSDR has removed the word "landfill" from this sentence.
29	Page 8, first bullet includes 49 waste holes, Southern Solid Waste Trenches, and Eastern Solid Waste Trenches. These disposal areas have there own bullets and should not be listed twice. The first bullet could be called DOE Disposal Trenches.	ATSDR agrees and has consolidated this presentation. We no longer include the 49 waste holes, and the southern and eastern solid waste trenches, under the first bullet now entitled DOE Disposal Areas.
30	Page 8, last paragraph lists the 1997 MOA as the second one between DOE and UC Davis. This is actually the third MOA. The first was related to the closure of the facility in 1988 and the second was issued in 1990 at the commencement of environmental restoration activities.	ATSDR appreciates this clarification and has reworded the text of this paragraph to read: "In 1997, *another* MOA between DOE and UC Davis divided the responsibility..."

No.	Comment	ATSDR Response
31	Page 21, second paragraph refers to an area on the eastern side of the Eastern Dog pens as a possible source of the H-3 detected in on-site wells. To prevent any misunderstanding by the public regarding the source of H-3 concentrations in wells UCD1-13 and 2-14, it should be stated that these wells are down gradient of the UC Davis 49 holes that contained elevated levels of H-3.	ATSDR reexamined this paragraph. The document does not state that a possible source of H-3 detected on-site is an area on the eastern side of the Eastern Dog Pens. This area is identified as the location where H-3 groundwater concentrations exceeded ATSDR's CV. In this section, ATSDR is not attempting to identify the original source of contamination, just the location and the concentration; therefore, ATSDR has not changed this paragraph.
32	Page 27, third paragraph, 6th line. replace "most" by "all" since all DOE contamination sources have been removed at present.	ATSDR now has documentation of all DOE removal actions and has modified the text to read: "...all of these three source areas [the DOE disposal box, Radium and Strontium Treatment Systems, and the Domestic Septic Systems] have been removed." Tables 1 and 2 have also been modified to reflect the current status of remedial/restoration activities.
33	Page 28- DOE Source Area section indicates that the only detection above CVs values were two pesticides and three metals at the dog pen areas. Please specify which dog pens area (western or eastern).	The introductory paragraph to the DOE Source Areas section refers the reader to Table 8 for more detail regarding the detected levels of contaminants in the dog pen areas. This table indicates where the elevated detections were found (i.e., eastern or western dog pen). As such, no changes were made to the text on page 28.
34	Page 28 and Table 1 (page 81) - Southwest Trench Area (SWT) should indicate that the chlordane-contaminated soil has been disposed rather than stockpiled in the WDP area. Disposal occurred in 1999. (Please note that Table 1, page 83, WDP status already indicates that this waste was removed.) The fence described in these two sections and page 71 was installed on the northern perimeter only. The pavement was installed in the parking lot on the north side of the SWT. This supplemental information concerning pavement is provided to ensure ATSDR and readers of the report understand that the SWT area is not paved.	ATSDR has modified the text to reflect this comment. On page 28, the text relating to the SWT area now reads: "As much as 450 cubic yards of chlordane-contaminated surface soil (0-1 ft bgs) was removed, initially stockpiled in the Western Dog Pens, and properly disposed of off site in 1999." ATSDR also has revised the text on pages 29 and 71 to more accurately reflect the extent of fencing and pavement installed in the SWT area.
35	Page 30, second paragraph, the following sentence is inaccurate and should be removed from the text: "Ra-226 concentrations exceeded background and ATSDR's CV in about 25% of the surface soil samples." All of the soil samples collected from 0 to 0.5 ft bgs are below Ra-226 background concentration of 0.75 pCi/g. Only sample SSDP033 at 0.545 pCi/g, had Ra-226 concentration that exceeded the ATSDR CV of 0.513 pCi/g.	ATSDR reexamined the data set described in this paragraph (Weiss Associates. 1999. Technical Memorandum: Investigation Results for the Former Eastern Dog Pens. September 24, 1999). We agree that Ra-226 was reported below background concentrations in all surface soil samples collected as part of this March 1999 investigation. Our original tally erroneously counted gravel test results and results from earlier sampling rounds. Therefore, the sentence in question is inaccurate and has been removed from the public health assessment.

No.	Comment	ATSDR Response
36	Page 30, beginning of third paragraph, internal fencing of dog pens areas was removed in 1996 not in 1999.	The draft DOE Areas Remedial Investigation Report (Weiss 2003) indicates that the internal fencing from the Western and Eastern Dog Pens was removed in 1996 and "released" off site for recycling in 1999 (Sections 6.4.3 and 6.5.2, respectively). ATSDR has modified the text to more accurately reflect the date of the actual removal action.
37	Page 31, first paragraph addresses possible remedial solutions for the EDP. The draft Site Wide Risk Assessment indicates there is no significant risk (i.e., HI<1 and cancer risk < 10^{-6}) at the EDP for industrial/researcher use of the site so a removal action is unlikely. UC Davis may cap their Landfill #2, along with the EDP, but this is not likely to occur prior to 2006. This paragraph should be re-written to reflect this new information. (DOE #14)	It is ATSDR's understanding that the remedial plan for EDP has not yet been determined, pending finalization of the site-wide risk assessment. ATSDR has modified the text to indicate that the plan for EDP soils is still under study and will be based largely on the final findings of the site wide risk assessment, with capping of EDP along with Landfill #2 being a likely outcome.
38	Page 36 mentions waste water releases. There is no discussion, however, about the fact that some of the storm water runoff for the LEHR site is still, at times, discharged to the campus sewerage system and, therefore, is part of the waste water releases from the treatment plant.	After researching this issue, ATSDR learned that surface drains in the vicinity of the former Cobalt-60 area discharge to the sanitary sewer. With the effective elimination of surface contamination at the LEHR site, storm water should not be contaminated. Therefore, ATSDR does not believe that adding this detail to the text is necessary.
39	On page 40, in the second paragraph (and elsewhere), ATSDR has used the term "EPA." Since there is a California EPA, whenever EPA is mentioned it should be designated "US EPA."	ATSDR defines "EPA" as representing the U.S. Environmental Protection Agency when it is first referenced in the document (page 7). It is also defined as such in the list of abbreviations on page vi. ATSDR does not reference the California EPA in this document. Therefore, no change has been made to the document.

No.	Comment	ATSDR Response
40	Beginning on page 46 is a discussion of the uptake of LEHR pollutants in various types of biota. While there is mention of a "fruitless Mulberry tree" not having measurable radioactivity, no mention is made of the tree that was cut down on the LEHR site, which had greatly elevated concentrations of tritium. Efforts have been made to get the RPJs and PRPs for the LEHR site to conduct a comprehensive study of the uptake of pollutants from the LEHR site into vegetation. Thus far, the PRPs have refused to do these studies, and the RPMs have not required that they be done, even though there is direct evidence that uptake of tritium did, in fact, occur into one tree where measurement were made.	In the referenced section of the public health assessment (biota), ATSDR's evaluation focuses on potential exposures to *off-site* populations from edible plants, fish, and shellfish. ATSDR agrees, however, that if trees or other plant life are cut down on site in areas where there is known soil, surface water, or groundwater contamination, those items leaving the site (whether edible or not) should be monitored to prevent the spread of potential contaminants. This appears to be the course of action taken during past removal actions of the waste burial hole area. Trees growing in tritium contaminated areas and removed during excavation activities were tested for tritium. According to UC Davis, tritium was detected at elevated levels (1,900 to 19,000 pCi/g). Background levels were reported at concentrations up to 84.7 pCi/g. Contaminated materials have been held on site pending determination of proper disposal. Because no off-site exposure concerns have been identified, no changes have been made to the PHA.
41	On the bottom of page 48, mention should be made that the Central Valley Regional Water Quality Control Board, in 2002, recommended that Lower Putah Creek be placed on the Clean Water Act 303(d) list of impaired water bodies because of excessive mercury bioaccumulation in fish. In July 2003, the US EPA approved this recommendation. As a result, Lower Putah Creek is now an impaired water body because of excessive mercury in fish. This will require that mercury from all sources, including storm water runoff from LEHR, be controlled to prevent further bioaccumulation.	ATSDR agrees that the designation of Lower Putah Creek as a Clean Water Act 303(d) impaired water body because of excessive mercury bioaccumulation in fish is relevant to the discussions in Section III.F.2 and has added this information to the second paragraph.
42	Page 51, Ambient Radiation Section. This section discusses the potential dose from exposure to the CO-60 irradiator which was located on top of CO-60 building. It appears that ATSDR is not aware of the Dose Reconstruction Study conducted by PNNL for DOE in 1991. This study is contained in a report entitled "Reconstruction of Dose Equivalents to the Public on University of California, Davis Property from the CO-60 Irradiator Facility." ATSDR could benefit from reviewing this report as it contained calculated potential doses for certain public receptors including on-site students and site neighbors. As a footnote, the source was removed in 1993 and not between 1993 and 1995 as the report indicated.	ATSDR reviewed the 1991 Dose Reconstruction Study. No information contradicts the outcome of ATSDR's evaluation. ATSDR calculated potential doses for off-site persons using the maximum ambient radiation levels measured at the fence line and at locations closest to the Co-60 Irradiator Facility on North Levee Road and information gathered from documentation and interviews with personnel during ATSDR's site visit. The date that the Co-60 source was removed from the site has been changed to 1993 instead of "between 1993 and 1995."

No.	Comment	ATSDR Response
43	On page 51, the first paragraph mentions that the irradiator consisted of a cobalt-60 source mounted on the roof of a concrete building located in the southeast corner of the LEHR site. It is my understanding that the irradiator was located close to the center of the LEHR site.	As depicted on Figure 2 in the PHA and stated in the text, the irradiator was located in the southeast corner of the LEHR *property boundary*. The location could be considered to be in the center of the project boundary shown in Figure 2, but the PHA is correct as written.
44	In the last two paragraphs on page 66, ATSDR has gone outside of its area of expertise when it comments that the NPDES permit issued by the CVRWQCB will be protective of aquatic life and other resources of Putah Creek from discharges by the UC Davis waste water treatment plant and other sources. Those familiar with how NPDES permits are developed know that they are often significantly deficient with respect to properly protecting public health and the environment.	ATSDR agrees that the statements regarding the NPDES permits are perhaps overly broad. Our intent was not to judge or evaluate the adequacy of the NPDES permitting process. Instead, our intent was to draw the distinction between ATSDR's public health focus (evaluating whether harmful exposures to people are possible) and other programs that focus more specifically on the overall protection of water resources. We have revised the text in these paragraphs slightly to make this point more clear.
45	Page 72, fourth bullet should indicate DOE's draft RI report was issued March 2002, not 2001. The report was finalized and issued September 2003.	The reference to the March 2001 date is incorrect and has been corrected. The date of the final RI was added. Note that ATSDR reviewed various versions of DOE's RI report during the preparation of the PHA. At the writing of the public comment release version of this PHA, ATSDR had reviewed and extracted relevant information from Revision E of the draft RI (dated February 2003).
46	Page 83 – The current status of the WDP (last sentence) should indicate that the stockpiles are material only, and there is no more waste in this area. Approximately 1,725 cubic yards of gravel and 370 cubic yards of overburden soil from the SWT area remains. This material will be reused on site or at another DOE site.	ATSDR revised the text to reflect this point.
47	Page 84 – The Domestic Septic Systems (DSS) discussion of groundwater needs to remove the statement that more sampling is scheduled at DSS-4 and 5 because all sampling has been completed. The discussion on impacts from the DSS areas is too generalized and inconsistent with ground water impact discussions for other site areas included in Table 1. For example, for other site areas ATSDR used valid ground water monitoring data to assess ground water impacts. The DOE Areas RI (Weiss 2003) does not identify the DSS as a source for contaminants present in site monitoring wells. ATSDR appears to be using modeling results to assess ground water impacts for some of the DSS areas. Additionally, Table 1 does not identify the UC Davis Landfill No. 2 or the 49 waste holes, two areas with known significant ground water impacts, as having ground water monitoring results.	ATSDR has modified the tables as needed to reflect the most up-to-date status of site investigations and planned activities. We have also provided clarification regarding the data associated with DSS-4 and DSS-5. Lastly, we have added information regarding groundwater conditions at/near UC Davis Landfill No. 2 and the 49 waste holes.

References

EPA (U.S. Environmental Protection Agency). 1997. Announcement of the Draft Drinking Water Contaminant Candidate List. Federal Register. October 6, 1997.

MWH (MWH Americas, Inc.) 2003. Draft Remedial Investigation Report LEHR/SCDS Environmental Restoration, University of California, Davis; January 2003.

Slotton DG, Ayers SM, Reuter JE, Goldman CR. 1999. Lower Putah Creek, 1997-1998, Mercury Biological Distribution Study. Department of Environmental Science and Policy, University of California, Davis; February 1999.

Weiss Associates. 2003. DOE. Draft Areas Remedial Investigation Report for the Laboratory for Energy-Related Health Research (LEHR) University of California Davis, California; February 28, 2003.