

# 1. Introduction

Lawrence Livermore National Laboratory (LLNL) has prepared this Site-Wide Feasibility Study (SWFS) for the Site 300 experimental test facility near Tracy, California, in accordance with the terms outlined in a Federal Facility Agreement (FFA). This SWFS provides the basis for a Proposed Plan, in preparation for an Interim Record of Decision (ROD). The Site 300 FFA was negotiated between the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), California Department of Toxic Substances Control (DTSC), and California Regional Water Quality Control Board (RWQCB). The FFA provides the framework for the conduct of the site cleanup and preparation of necessary regulatory documents. This SWFS is prepared in compliance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). The SWFS, along with the previously conducted Site-Wide Remedial Investigation (SWRI) (Webster-Scholten, 1994) and subsequent site characterizations at Building 850/Pits 3 and 5, Building 854, and Building 832 Canyon Operable Units (OUs), form the basis for evaluating and selecting alternative technologies for remediation of contaminants at Site 300. The Feasibility Study process involves:

- Identifying remedial action objectives (RAOs) based on Applicable or Relevant and Appropriate Requirements (ARARs).
- Identifying general response actions.
- Identifying potential remedial technologies and associated process options.
- Screening various technologies and process options based on their applicability, effectiveness, implementability, and cost.
- Assembling the selected technologies into alternatives for contaminant remediation at Site 300.
- Analyzing the alternatives using the U.S. EPA evaluation criteria.

## 1.1. Purpose of Report

The purpose of this SWFS is to develop and evaluate alternatives for remedial action at Site 300 in accordance with CERCLA/SARA. The SWFS process begins with the selection of cost-effective remediation technologies or modules that can provide protection of human health and the environment. The modules are then assembled into alternative remedies and evaluated. The SWFS does not identify preferred remedies. The Draft Site-Wide Proposed Plan (DSWPP, which will follow the SWFS), will further propose, describe, and justify a preferred alternative remedy for each OU or release site, as the proposed remedy for selection at each OU.

After public and regulatory review and comment on the DSWPP, DOE will present the selected remedies in an Interim ROD. The Interim ROD will not set cleanup standards; they will be set in the Final ROD. An interim ROD is intended to allow remediation to commence as soon as possible, while collecting additional information. Data on the effectiveness of remediation technologies relevant to decisions of final cleanup concentrations can be developed without delaying the decisions to begin the cleanup processes. Information developed through more

detailed source characterization and observation of how aquifers react to the interim response actions will be considered in choosing the final cleanup standards, which are set in the Final ROD, scheduled about six years after the Interim ROD. The Schedule of Activities in the LLNL Site 300 Federal Facility Agreement also calls out for the submittal of a Site-Wide Compliance Monitoring Plan/Contingency Plan, in the year 2002, which will be based on information in the SWFS and data collected prior to its preparation.

The SWFS is based on the remedial investigations of Site 300 conducted from 1982 to 1998. This chapter provides a summary of the information presented in the SWRI report, the Building 850 SWRI Addendum (Taffet et al., 1996), the Building 832 Canyon Characterization Summary report (DOE, 1997), and the Building 854 Characterization Summary report (DOE, 1998a). Chapters 2 through 5 present the determination of ARARs and RAOs, an evaluation of technologies, a description of remediation modules, and an analysis of the modules. Chapter 6 assembles the modules described into Chapters 4 and 5 into alternative remedies. The evaluation of each alternative against the EPA criteria is presented in Chapter 7. Chapter 8 discusses environmental considerations to fulfill the requirements of the National Environmental Policy Act (NEPA).

## **1.2. Site Background and Summary of Remedial Investigations**

LLNL Site 300 is a DOE experimental test facility operated by the University of California. The facility is located in the eastern Altamont Hills about 13 miles southeast of the main Laboratory site in Livermore and 8.5 miles southwest of Tracy (Fig. 1-1). Site 300 is primarily a high-explosives (HE) test facility that supports the LLNL weapons program in research, development, and testing associated with weapons components. This work includes explosives processing; preparation of new explosives; and pressing, machining, and assembly of explosives components. Site 300 activities also include hydrodynamic testing for verifying computer simulation results, obtaining equation-of-state data for weapons materials, evaluating material behavior at assembly joints and welds, evaluating the quality and uniformity of implosion, and evaluating the performance of post-nuclear test design modifications (LLNL, 1991). Some experiments performed at Site 300 do not involve high explosives. These experiments may require more space or isolation or may have other requirements that cannot be met at the Livermore Site (U.S. DOE, 1982). Access to Site 300 is restricted.

Prior to August 1990, investigations of potential chemical contamination at Site 300 were conducted under the oversight of the California RWQCB-Central Valley Region. In August 1990, Site 300 was placed on the National Priorities List (NPL). Since then, all investigations, including the preparation of the SWRI report, have been conducted in accordance with CERCLA under the oversight of the three supervising regulatory agencies: EPA, RWQCB, and DTSC.

### **1.2.1. Description of Site 300**

Site 300 is located in the southeastern Altamont Hills of the Diablo Range, about 30 miles east of San Francisco Bay. The site covers 11 square miles (mi<sup>2</sup>), most of which is in San Joaquin County (Fig. 1-2). The western one-sixth of the site is located in Alameda County.

The topography of Site 300 consists of a series of steep hills and canyons generally oriented northwest to southeast. Elevation ranges from about 500 feet (ft) in the southeast corner to about

1,750 ft in the northwestern area. Grassland cover grows seasonally. The climate of Site 300 is semiarid and windy. The average annual rainfall for the 32-year period from 1965 through 1997 was 10.44 inches (in). During the same 38-year period the annual (July through June) total rainfall ranged from 3.82 to 23.64 inches. The most rain for one day (midnight through midnight) in the last 8 years (1992 through 1999) was 1.64 inches on 3 February 1998. The wind is predominantly from the west-southwest; the temperature extremes in 1997 ranged from 99 degrees Fahrenheit (°F) in July to 27°F in January. The estimated potential evapotranspiration (defined by the U.S. Department of Agriculture as the amount of moisture a plant could use if it had all the moisture it needed) at Site 300 is about 30.6 in. (USDA, 1966).

The seven major plant habitats occurring at Site 300, four upland habitats and three less extensive wetland habitats, consist of 14 plant communities containing 343 plant taxa. The upland habitats are introduced grassland, native grassland, coastal sage scrub, and oak woodland. The rare wetland habitats consist of northern riparian woodland, vernal pool, and the most frequently encountered, herbaceous wetlands. Fauna observed at Site 300 include 20 species of reptiles and amphibians, 70 species of birds, and 25 species of mammals. Mammal species include mice, hares, squirrels, skunks, foxes, and black-tailed deer. Detailed ecological information, including an assessment of endangered species at Site 300, is included in the SWRI report.

Site 300 has been divided into eight OUs based on the nature and extent of contamination originating at release sites identified in the site-wide remedial investigation (Fig. 1-3). The eight OUs, as well as a brief description of each, are listed below:

- General Services Area (GSA), OU 1. Contamination resulted from past solvent disposal, causing volatile organic compound (VOC) contamination of soil, bedrock and ground water. A Record of Decision (ROD) for the GSA OU was signed in 1997. Ground water and vadose zone remediation is ongoing as described in the Remedial Design report for the GSA (Rueth et al., 1998). The GSA OU CERCLA documents are incorporated into this SWFS by reference. Since the GSA OU has completed the CERCLA document pathway, this OU is not discussed further in this SWFS.
- Building 834, OU 2. Past spills of trichloroethylene (TCE) and other VOCs from release sites at the core of the Building 834 complex, have resulted in contamination of the vadose zone and a perched water-bearing unit. The deeper regional aquifer has not been affected. Dense Non-Aqueous Phase Liquids (DNAPLs) and Light Non-aqueous Phase Liquids (LNAPLs) are believed to be present in ground water. Other contaminants of concern (COCs) in ground water include nitrate and tetra-butyl-orthosilicate/tetra-kis-2-ethylbutylorthosilicate (TBOS/TKEBS). An interim ROD was signed in 1995. Ground water and vadose zone remediation is ongoing, as is innovative technology development.
- Pit 6 Landfill, OU 3. From 1964 to 1973, approximately 1,900 cubic yards of waste was placed in nine unlined debris trenches and animal pits at the Pit 6 Landfill. The material buried included laboratory and shop debris, and biomedical waste. Plumes of VOCs and tritium in ground water originated from the landfill. VOC concentrations in ground water has been declining since 1989. Perchlorate and nitrate have also been detected in ground water. The landfill was capped as a removal action in 1997 to prevent the further leaching of contaminants from the buried waste.

- HE Process Area, OU 4. Surface spills at the drum storage and dispensing area for the former Building 815 steam plant, where TCE was used to clean pipelines, resulted in the release of TCE and other VOCs to the ground surface and contamination of the ground water and the vadose zone. Ground water extraction will be initiated in 1999 as a removal action to control offsite VOC migration from Building 815. HE compounds, nitrate, and perchlorate have also been detected in ground water and are believed to be the result of wastewater discharges to former unlined rinsewater lagoons. HE compounds have also been detected in surface soil and the vadose zone. The lagoons were closed in 1989. In addition, VOCs, nitrate, and perchlorate have been detected in ground water in the vicinity of the former HE Burn Pits. The HE Burn Pits were capped under RCRA in 1998. Carbon disulfide was reported sporadically in the early 1990's and has not yet been ruled out as a contaminant of concern.
- Building 850/Pits 3 & 5, OU 5. Contamination in this OU emanates from the Building 850 firing table, and from landfill Pits 3, 5, and 7. Tritium is the primary contaminant in ground water. TCE and 1,1-DCE have been detected downgradient of Pit 5. Uranium isotope signatures characteristic of depleted uranium (uranium with the 235 isotope extracted, leaving almost entirely uranium-238) have also been identified downgradient of Pits 5 and 7 and Building 850. Other ground water contaminants include nitrate and perchlorate. Pits 1, 4, 7, and a portion of Pit 3 were capped and closed under RCRA in 1992. Polychlorinated biphenyl (PCB)-bearing shrapnel from explosive experiments was identified in surface soil in the vicinity of the Building 850 firing table and was removed in October 1998. PCBs, chlorinated dibenzodioxins and dibenzofurans, high melting explosives (HMX), metals, and uranium-238 have been detected in soil in the vicinity of this firing table. Landfill Pit 2 operated from 1956 to 1960 and incorporated firing table waste from Buildings 801 and 802. No contaminants have been found leaking from the landfill. Tritium measured in ground water in the vicinity of Pit 2 appears to originate upgradient, at the Building 850 area.
- Building 854, OU 6. TCE was used at Building 854 as a heat exchange fluid and site characterization indicates vadose zone and ground water contamination. Nitrate, perchlorate, tritium, and uranium-238 have also been detected in ground water. PCBs, metals, HMX, and tritium have been detected in surface soil. TCE-contaminated soil was excavated in 1983 in the vicinity of the Building 854H drain cutfall. Contaminated surface soil was removed at the northeast corner of Building 854F. The TCE brine systems were removed in 1989.
- Building 832 Canyon, OU 7. Facilities in this OU were used to test the stability of weapons and weapons components under various environmental conditions. Contaminants released to the subsurface are primarily VOCs, although nitrate and perchlorate have also been detected in ground water. Vadose zone and ground water contamination was identified emanating from the Building 830 and Building 832 release sites. Nitrate and HMX have been detected in the subsurface soil. HMX has also been detected in surface soil. A treatability study is underway to evaluate ground water and soil vapor extraction.
- Other Site 300 Release Sites, OU 8. This OU covers all other release sites not covered in individual OUs. These release sites are as follows:

- Building 801 firing table: This firing table was used for explosives testing. Dispersal of firing debris resulted in metal and uranium-238 contamination of surface soil. No contaminants from the firing table have been detected in ground water. Gravel and surface soil beneath the firing table was removed in 1988. Use of this firing table was discontinued in 1998. Firing table gravels and surface soil in the vicinity were removed under RWQCB oversight. Landfill Pit 8, located adjacent to the Building 801 firing table, received firing table debris prior to 1974, when a final cover was installed. As of our most recent characterization, it appears that Pit 8 landfill materials have not contaminated either the vadose zone or ground water.
- 1. Building 801 dry well: Low-concentrations of VOCs in ground water and the vadose zone resulted from waste fluid discharges to a dry well beneath Building 801D. This dry well was decommissioned and filled with concrete in 1981.
- Building 802 firing table: This firing table was used for explosives testing between 1959 and 1979. Dispersal of firing table debris resulted in tritium contamination in surface soil. Leaching of contaminants from the firing table gravel resulted in the contamination of subsurface soil with tritium. However, tritium is not considered to be a COC as there is no risk or hazard associated with tritium in soil or rock and no potential impact to ground water. No contaminants from the firing table have been detected in ground water. As a result, the Building 802 firing table was not addressed as a release site in the SWFS. Gravel from the firing table was removed in 1988.
- Building 833 disposal lagoon, test cell and settling basin, and area north of Building 833: TCE was used as a heat-exchange fluid in the Building 833 area. Surface discharge of waste fluids containing TCE occurred through spills, building washdown, rinsewater from the test cell and settling basin, and rinsewater disposal in a disposal lagoon adjacent to Building 833. As a result, VOCs have been detected in subsurface soil and ephemeral perched ground water. A monitoring-only remedy was accepted by the regulatory agencies at a December 8, 1993 Remedial Project Managers' meeting.
- Building 845 firing table: This firing table was used until 1963 to conduct explosives experiments that may have occasionally contained tritium and uranium. The Pit 9 Landfill was used prior to 1968 for the disposal of debris generated at the Building 845 firing table. As a result, subsurface soil is contaminated with uranium-238 and HMX. In 1988, firing table gravel and soil from the firing table berm were removed.
- Building 851 firing table: This firing table is used to conduct experimental high explosives research. These experiments resulted in the release of uranium-238, RDX, and metals to surface soil and VOCs and uranium-238 to subsurface soil and rock. VOC contamination has been identified in ground water. Uranium-238 with anthropogenic isotope ratios have been detected in ground water in four wells in the vicinity of the firing table. Firing table gravels were removed in 1988 and are replaced periodically.

A brief description of each OU including release sites, contaminants and media of concern, release mechanisms, and status of the OU is presented in Table 1-1. Figure 1-4 shows the decision process used to evaluate which release sites require remedial actions to be considered in

the SWFS. Sites where a remedy has been previously agreed upon or completed as a Removal Action are presented in Table 1-2. In addition, the SWRI (Chapter 11) identified four sites: Building 812 firing table, Building 812 dry well, Building 865 Advanced Test Accelerator, and the Sandia Test Site that need further characterization to determine if contaminant releases have occurred. These are scheduled for further investigation work and are not addressed in this SWFS. These sites were identified as potential contaminant release sites in the SWRI. Following characterization of these areas, a summary report will be issued and a remediation strategy proposed, if necessary.

Offsite land use in close proximity to the Site 300 boundary (Fig. 1-2) includes:

- Gallo ranch to the south, and Connolly ranch to the south and east, primarily used for cattle grazing.
- California Department of Fish and Game ecological preserve to the east.
- Carnegie State Vehicular Recreation Area (SVRA) to the southwest; an outdoor recreational facility for private and commercial off-road motorcycle riding, testing, and racing.
- Physics International, Inc., to the northeast; a privately owned HE testing facility.
- Vieira ranch land to the northeast (proposed Tracy Hills Development) and west.
- Yroz ranch land and Mulqueeny ranch land to the north and northwest, respectively.

### **1.2.2. Site 300 History**

LLNL, operated by the University of California for the U.S. DOE, began weapons research operations at the Livermore Site in 1952. At that time, LLNL was a part of what was then the University of California Radiation Laboratory (UCRL). In July 1953, UCRL proposed the Site 300 location for an HE test site along Corral Hollow between Livermore and Tracy. Experiments with HE began at Site 300 in 1955. The size of the original site was approximately 3 mi<sup>2</sup>. In 1957, the site was enlarged to 10.4 mi<sup>2</sup> (U.S. DOE, 1982). In 1971, the Livermore site and Site 300 portion of UCRL became LLNL. Prior to acquisition by UCRL, land use in the area of Site 300 was limited to sheep and cattle grazing.

In 1977, the U.S. Navy transferred ownership of a 7.44 acre parcel on the eastern edge of Site 300 to LLNL to be used as a pistol range, subsequent to its use by the U.S. Navy as a fire-fighting experimentation area. Currently, this parcel is unused (Graham, 1990). In February 1991, LLNL acquired 11.6 acres of the adjoining Connolly Ranch at the southeastern edge of Site 300. The parcel had been in the Connolly family since the 1890s and had been used for seasonal cattle grazing.

### **1.2.3. Site 300 Geology**

Regional geologic maps and stratigraphic columns for Site 300, based on studies prior to 1981, have been modified by more recent investigations conducted by LLNL during and subsequent to the preparation of the SWRI report. Detailed geologic logs have been prepared for most boreholes and monitor wells at Site 300. A more detailed discussion of Site 300 geology is presented in Chapter 3 of the SWRI report (Webster-Scholten, 1994).

### **1.2.3.1. Stratigraphy**

Bedrock strata exposed within Site 300 have been correlated with five mappable geologic units (Webster-Scholten, 1994). The units are the late Cretaceous Great Valley sequence (Kgv), the late Paleocene to mid-Eocene Tesla Formation (Tts), the mid-Miocene Cierbo Formation (Tmss), the late Miocene Neroly Formation (Tn), and the Pliocene nonmarine unit (Tps) of Dibblee (1980). The bedrock units are locally overlain by mid- to late-Pleistocene terrace deposits and late Pleistocene to Holocene floodplain, ravine fill, landslide and colluvial deposits (Carpenter et al., 1991; Dibblee, 1980). A schematic stratigraphic column for Site 300 is presented as Figure 1-5. Summary lithologic descriptions of these geologic units are provided in Table 1-3. Distributions of the various units are shown on the Site 300 geologic map (Fig. 1-6).

### **1.2.3.2. Structure**

Site 300 is located in an area of historical seismicity and Quaternary folding (Eaton, 1986; Namson and Davis, 1988; Wentworth and Zoback, 1989). Structural features within Site 300 are shown on Figure 1-7.

**1.2.3.2.1. Folds.** The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds (Fig. 1-7). These folds include:

- Patterson Anticline, controls bedding attitudes throughout much of Site 300; the southern limb of the structure strikes nearly east-west and dips toward the south at 5 to 25 degrees; the northern limb strikes toward the northwest and dips northeast, typically 5 to 15 degrees.
- East Firing Area (EFA) syncline, informally named the EFA syncline, is a very broad, open, gently northeast-plunging fold with a wide, nearly flat axial trough (Taffet and Oberdorfer, 1991).
- HE Process Area syncline, a southeast-plunging syncline, underlies the HE Process Area in the southerly portion of Site 300 (Fig. 1-7).

**1.2.3.2.2. Faults.** Three general types of faults have been identified at Site 300:

1. West-northwest trending, high-angle, presumably strike-slip faults.
2. Discontinuous, north-northeast-trending, normal faults mapped chiefly in the east-central portion of Site 300 (Webster-Scholten, 1994).
3. West-northwest-trending, high-angle reverse and thrust faults that are mainly present on the south flank of the Patterson anticline (Webster-Scholten, 1994).

Locations of principal faults within Site 300 are listed below and shown on Figure 1-7.

- Corral Hollow, Carnegie Fault Zone, interpreted as a right lateral strike-slip fault that crosses the southwestern portion of Site 300 and extends southeast and west beyond the limits of the site (Raymond, 1973; Dibblee, 1980). This fault system is regarded as active and is judged capable of generating an earthquake in the range of  $M_s = 6.3$  to 7.1 (Carpenter et al., 1992).
- Elk Ravine Fault, a complex structure composed of pre-Holocene strike-slip faults, reverse faults, normal faults, and local folds. Two branches of the Elk Ravine Fault have

been mapped as extending across Site 300 from northwest to southeast (Dibblee, 1980) (Fig. 1-7).

- Possible Midway Fault extension (Dibblee, 1980), a possible southeasterly extension of the Midway Fault mapped north of Site 300 across the northeastern corner of Site 300 (Fig. 1-6). The fault is classified as potentially active based on geomorphic criteria and possible associated microseismicity (CDWR, 1979).
- Terrace Fault (informal name), a high-angle reverse fault or fault zone within the southern portion of Site 300 (Fig. 1-7). Farther east, the projection of the Terrace Fault enters the southern HE Process Area.
- Unnamed Fault (informal name), a well-defined, north-south trending fault located in the southeastern portion of Site 300 (Fig. 1-7). Approximately 50 ft of pre-Holocene normal offset occurs along this near vertical fault.

**1.2.3.2.3. Joint and Fracture Systems.** Rocks within Site 300 are pervasively fractured. Fractures include joint sets, fractures subparallel to bedding planes, and shear zones. Frequently, thin-bedded claystones are intensively and randomly fractured.

Joint sets are observed most often in the well indurated rocks present within Site 300. These rocks include the Great Valley sequence, Tesla Formation, and Neroly Formation. Joint sets are locally observed in more indurated portions of the Pliocene nonmarine unit, but well-defined joints are uncommon in these sediments and in the poorly indurated Cierbo Formation strata.

In general, the intensity of jointing and fracturing increases in the vicinity of fault zones. Claystone beds, in particular, may be intensely fractured and sheared; however there are exceptions. Ground water flow through fractured rock at Site 300 is discussed in Section 1.2.4.2. of this document and Chapter 3, Section 3.6.5 of the SWRI.

**1.2.3.2.4. Seismic Setting.** Site 300 is located near the eastern margin of the seismically active San Francisco Bay region and is also within about four miles of the seismically active Coast Ranges-Central Valley boundary (Eaton, 1986; Namson and Davis, 1988). Seismic monitoring by LLNL (Hauk, 1990) confirms microseismic activity within the Altamont Hills in the region surrounding Site 300.

Facilities at Site 300 may experience earthquake shaking from three seismic sources. These sources are:

- A major earthquake on a principal Bay Region fault.
- A strong earthquake generated by a local fault within the Altamont Hills.
- A major earthquake on a regional fault along the Coast Ranges-Central Valley boundary or possibly beneath the western portion of the San Joaquin Valley.

## **1.2.4. Site 300 Hydrogeology**

This section describes the general framework of the hydrogeologic model of Site 300, including the occurrence of surface water and ground water.

### **1.2.4.1. Surface Water**

There are no perennial streams at Site 300. Surface water at the site consists of intermittent runoff, springs, and natural and man-made ponds. Figure 1-8 shows the surface water drainage basins at Site 300. Surface water sometimes occurs locally as a result of discharge from cooling towers.

**1.2.4.1.1. Springs.** There are 24 springs at Site 300 (Fig. 1-9). Most of the springs have very low flow rates and are recognized only by small marshy areas, pools of water, or vegetation. Vegetation surrounding the springs includes cattails, nettles, willows, and grass. Only three of the springs have flow rates greater than one gallon per minute (gpm) (Springs 6, 12 and GEOCRK).

**1.2.4.1.2. Other Surface Water.** Site 300 contains three man-made surface water bodies (Fig. 1-9). A sewage treatment pond is located in the southeast corner of the site in the GSA and two, lined HE rinse-water impoundments are located in the HE Process Area OU. The Carnegie SVRA residence pond is located off site just east of the Pit 6 Landfill at the mouth of Middle Canyon. In addition, there are four small, offsite stock watering ponds in the area north and west of Site 300. As mentioned above, other surface water at Site 300 results from blowdown water from cooling towers.

There is a natural pool in the northwest corner of Site 300 within the EFA/West Firing Area (WFA). It is an ephemeral (vernal) pool created by ponding of water in a natural depression.

**1.2.4.1.3. Drainage.** The major drainages at Site 300 are Elk Ravine in the EFA/WFA; Draney Canyon and Davis Canyon to the west of the Building 854 area; Drop Tower Canyon in the Building 854 area; Firing Range Canyon in the Pit 6 Landfill area; Middle Canyon and Paper Canyon in the south-central portion of the site; Long Canyon in the HE Process Area; and Building 832 Canyon (Fig. 1-8). Water flows in these drainages only after heavy storms. The occasional runoff from these drainages that does not infiltrate the ground eventually flows into Corral Hollow Creek. This creek is an intermittent stream that flows eastward along the southern boundary of Site 300 toward the San Joaquin Valley.

LLNL's field technicians regularly inspect four locations for potential runoff into Corral Hollow Creek: Elk Ravine; Firing Range Canyon near Pit 6; Long Canyon; and the drainage in the GSA near Building 883.

Flow from effluent discharge into the Elk Ravine has only been observed three times in the past 4 years. At Pit 6, due to the construction of improved drainage channels as part of the Pit 6 capping, flow now runs into a settling basin, but seems to remain on Site 300 property. It has not been seen to flow off site in the past two (wet) years. Long Canyon has not had an observed offsite flow in many years. The only time that surface water in the canyon was observed flowing, there was a small trickle that had no potential to reach Corral Hollow Creek. Drainage from the improved parking areas near Building 883 (GSA) frequently flows into the offsite drainage system towards Corral Hollow Creek, but that area was covered in the GSA documentation and is not part of the present SWFS. Surface water flows in the Building 832 Canyon during storm events, and enters a culvert in the lowermost portion of the canyon and discharges into the alluvial channel on the south side of Corral Hollow Road.

### 1.2.4.2. Ground Water

Site 300 is a large and hydrogeologically diverse site. Due to the steep topography, and structural complexity, the stratigraphic units described in Section 1.2.3. and Table 1-3 are discontinuous across the site. Consequently, unique hydrogeologic conditions govern the occurrence and flow of ground water and the fate and transport of contaminants beneath each OU. We have defined individual hydrogeologic units consisting of one or more stratigraphic intervals that comprise a single hydraulic system within each OU. These hydrogeologic units and their stratigraphic components are shown in Figure 1-10 and are described in Table 1-4. Site-wide stratigraphic relationships are depicted in cross-sections A-A' and B-B' (Fig. 1-11). The hydraulic relationships between the northwest and southeast portion of the site, however, have not been well established due to sparse well control in the center of the site. Separate potentiometric surface contours for the five hydrogeologic units at Site 300 are shown in Figure 1-12.

In the northeast part of Site 300, ground water occurs under unconfined to confined conditions primarily within the Neroly Formation Lower Blue Sandstone (Tnbs<sub>1</sub>) and the Cierbo Formation (Tmss) stratigraphic units, which are part of the Qal-Tmss hydrogeologic unit. General ground water flow in the EFA/WFA is to the east (Fig. 1-12), and is controlled primarily by the dip of the bedding planes. Perched water-bearing zones also occur within the Quaternary alluvial sands and gravels, and fractured siltstones and claystones of the Tnbs<sub>1</sub> and Tmss stratigraphic units. These perched zones are highly discontinuous and of variable character.

Throughout most of the southeastern part of Site 300, the Tnbs<sub>1</sub> hydrogeologic unit is a continuous, regional water bearing zone (Fig. 1-12). Ground water in the Tnbs<sub>1</sub> hydrogeologic unit occurs within sandstones of the Tnbs<sub>1</sub> stratigraphic unit under confined to flowing artesian conditions. As indicated by the potentiometric surface contours, ground water generally flows to the south and southeast (i.e., in the direction of dip) in the southeastern and southern parts of Site 300 (Fig. 1-12).

Other water-bearing zones that exist in the southeastern part of the site include the Neroly Formation Upper Blue Sandstone (Tnbs<sub>2</sub>) and Tps hydrogeologic units. Ground water occurs under unconfined to artesian conditions in the Tnbs<sub>2</sub> hydrogeologic unit beneath the HE Process Area OU. The ground water flow direction in this unit is also dip-controlled and sub-parallel the flow direction in the underlying Tnbs<sub>1</sub>. Perched ground water occurs primarily in gravel channels within the Tps hydrogeologic unit beneath the Building 834 and HE Process Area OUs. The ground water flow direction within these shallow, perched zones is controlled by the channel geometry of the water-bearing unit and the dip direction.

The claystone and siltstone of the Neroly Formation Lower Siltstone/Claystone (Tnsc<sub>1</sub>) unit are present throughout significant portions of Site 300. Hydraulic test data indicate that this low permeability unit acts as a confining layer where present. In the Building 832 Canyon area, sandy units within the Tnsc<sub>1</sub> are important water-bearing zones, which are contaminated.

Ground water supply wells within Site 300 and within 0.5 miles of the site are shown in Figure 1-13. Site 300 ground water level concentrations of total dissolved solids (TDS) generally range from 300 to 2,000 milligrams per liter (mg/L), specific conductivity ranges from 770 to 2,400 mhos/cm, and pH generally ranges from 7 to 9. The ground water in this area

commonly contains naturally occurring selenium and arsenic above drinking water Maximum Contaminant Levels (MCLs) (Webster-Scholten, 1994).

The two primary hydrogeologic units where most contaminant transport occurs at Site 300 are the alluvial-shallow bedrock and bedrock water-bearing zones within the Neroly Formation. In the alluvium, which is poorly indurated, fracturing is considered insignificant. In addition, mass transport within the alluvium is much more significant than the influence of a fracture in the shallow bedrock underlying the alluvium. This is because the alluvium is capable of transporting a much higher volume of water per unit time.

Hydraulic test data from the Neroly Formation are interpreted as representing a porous medium. Observed anisotropy is not significant enough to indicate a fracture-dominated system. Rather, the effects of fracturing are seen together with the effects of porous media. In addition, the contaminant plumes at Site 300 generally appear to have the characteristics associated with flow through a porous media, although exceptions have been observed at Elk Ravine where the tritium plume follows bedrock shear zones, and at Pit 6, where the Carnegie fault influences ground water flow.

Claystone in the Neroly Formation exhibits near-horizontal, bedding-parallel shear planes that are probably closed in the subsurface and incapable of transmitting significant volumes of subsurface fluids.

### **1.3. Nature and Extent of Contamination**

Environmental investigations at Site 300 began in 1981 and are ongoing. A number of specific release sites within Site 300 have been the focus of many of these environmental investigations. The determination of the nature and extent of contamination at Site 300 is based on a detailed screening process performed in accordance with EPA guidelines. Briefly summarized, this screening process included: records searches, interviews with operating personnel and retirees, examination of aerial photographs, site visits, and, in most cases, subsurface investigations which have included soil vapor surveys, and soil, rock, ground water, and surface water analyses. At some locations, the release characterization process is ongoing.

#### **1.3.1. Sources of Contamination**

Historic information and analytic data have been used to identify the nature and extent of anthropogenic contamination in environmental media. These data were also used to identify chemicals of potential concern at Site 300 and within each OU for contaminant fate and transport modeling and baseline risk analyses.

As a result of detailed site-wide and OU-specific environmental investigations, a number of locations where contaminants have been released to the environment were identified. Because of the complex nature and history of Site 300, a variety of contaminant sources exist at the site. These sources include: surface spills; leakage from transfer pumps, piping, and tanks, landfills and pits, and underground fuel tanks; disposal lagoon discharges; disposal dry well discharges; leaching from contaminated gravel; and septic tank discharges.

Figure 1-14 provides a summary of release site locations and types of anthropogenic contamination at Site 300 by OU. Tables 1-5 and 1-6 present information on contaminants identified in environmental media in each OU.

### 1.3.2. Nature and Extent of Contamination in Soil and Rock

Many of the borehole soil, rock, and surface soil samples collected at Site 300 have been analyzed for semivolatile and volatile organic compounds, California and EPA-listed metals, pesticides, and herbicides, HE compounds, tritium, and other radionuclides [e.g., uranium-234 ( $^{234}\text{U}$ ),  $^{235}\text{U}$ , and  $^{238}\text{U}$ ]. Although a number of these substances that have been detected in soil and rock are attributed to Site 300 operations, some are attributed to natural background concentrations. Background concentrations for naturally occurring substances (i.e., some metals, and radionuclides) were established in Chapter 4, Section 4.2.2 of the SWRI. Appendix A discusses the subsequent re-evaluation of background concentrations made using additional data collected since the SWRI.

In general, the highest concentrations and greatest extent of soil and rock contamination coincide with areas of known surface or near surface releases. The compounds most frequently found in release areas in soil and rock at Site 300 are TCE, tetrachloroethylene (PCE), certain HE compounds, and tritium. Analytic and historic data indicate that solvents containing VOCs were released to the environment via surface spills, discharges to some disposal lagoons, leachate from landfills, pits, and debris burial trenches, dry wells, and pipe leaks from facility equipment. VOCs have been detected in subsurface soil/rock in the Building 834, HE Process Area, Building 854 and Building 832 Canyon OUs, as well as at the Building 801 dry well, Building 833, and Building 851 firing table release sites.

Prior to 1990, tritium was used during explosives testing in the EFA/WFA, and became entrained in gravel used to cover the firing tables. The firing table gravels were periodically disposed of in several disposal pits in the northern portion of the site. Surface soil was contaminated with tritium in the vicinity of the Building 850/Pits 3 & 5 OU and the Building 854 OU, and the Building 851 firing table release site. Tritium above background has also been detected in the vadose zone in the Building 850/Pits 3 & 5 OU, Building 832 Canyon OU, and the Building 801, Building 802, and Building 845 firing table release sites.

The HE compounds HMX and Research Department Explosive (RDX) have been found primarily at decommissioned rinsewater lagoons in the HE Process Area, but have also been reported sporadically in samples collected in other portions of the site. HE compounds have been detected in surface soil in the HE Process Area, Building 850/Pits 3 & 5, Building 854, and Building 832 Canyon OUs as well as at the Building 851 firing table area. HE compounds have also been found in the vadose zone at the HE Process Area OU, Building 832 Canyon OU, and the Building 845 firing table release site.

Other less frequently detected contaminants in surface and/or subsurface soil/rock include uranium-238, metals, PCBs, chlorinated dibenzo-p-dioxins (CDDs), chlorinated dibenzofurans (CDFs), and nitrate. Uranium-238 with an anthropogenic isotope signature has been detected in surface and/or subsurface soil/rock in the vicinity of the Building 850/Pits 3 & 5 OU, and the Building 845 and Building 851 firing tables.

Metals have been detected in surface soil near Building 854, and in the vicinity of the Building 850, and Building 851 firing tables. Surface soil in the vicinity of the Building 850 firing table and Building 854 is contaminated with PCBs. CDDs and CDFs have also been detected in surface soil near Building 850. Nitrate has been detected in the vadose zone in the

Building 832 Canyon OU, however it is not certain whether the nitrate is anthropogenic or naturally occurring.

Table 1-7 presents estimates of area, volume, and mass of the primary contaminants found in the vadose zone at each OU or release site at Site 300. The estimates presented in Table 1-7 are gross, conservative estimates with varying degrees of confidence in the data used to generate these numbers. The intent of generating these estimates was to: (1) give a very general idea of the extent of contamination and (2) produce rough estimates to be used by engineers in developing and costing the remedial alternatives. These numbers should not be used for comparison with mass removal estimates.

Detailed discussions of the nature and extent of contamination in soil and rock in each OU is presented in Section 4 of Chapters 9 through 14 of the SWRI.

### **1.3.3. Nature and Extent of Contamination in Ground Water**

Much of the contaminated ground water at Site 300 occurs in isolated or perched water-bearing zones, and does not communicate with regional aquifers. Except for the GSA area, which is undergoing remediation not covered in this document, no contaminated ground water has migrated offsite. A private well directly offsite from the distal portion of the HE Process area plume has occasionally been shown to have low concentrations of TCE (<1 µg/L). Also one private well near Pit 6 occasionally reported low concentrations of chloroform (maximum 4.9 µg/L, in 1990), but that seems unrelated to a Pit 6 release.

Tracy, located northeast of Site 300, uses ground water only from alluvial aquifers in the San Joaquin Valley, which are isolated from the contamination onsite by thick claystone layers and a horizontal distance of more than five miles. Modeling suggests that any contaminants from Site 300 will not impact ground water used in the Tracy area.

Ground water has been encountered in one or more hydrogeologic units beneath each of the eight OUs. LLNL has installed more than 500 ground water monitor wells throughout Site 300 since environmental investigations began in 1981. Analytic data from sampling of these wells have been used to assess the nature and extent of ground water contamination. Ground water samples from these wells have been analyzed for metals regulated by drinking water standards, regulated inorganic compounds, organic compounds [including VOCs, benzene, toluene, ethylbenzene, and total xylenes (BTEX)], HE compounds, ions (including general minerals), radiologic substances (including uranium and tritium), PCBs and pesticides, phenols and phenolics, and perchlorate.

Although a variety of compounds have been detected in ground water, various metals, radionuclides, inorganic compounds, and ions occur naturally in ground water. To determine whether these substances are present at background levels or as contamination, data on background concentrations from Site 300 and from a ground water quality database maintained by the United States Geological Survey (USGS) (1992) were evaluated in the SWRI. Site 300 ground water concentration and/or activity data were also analyzed, as appropriate, on a well-by-well basis for the presence of a statistically significant positive trend. A detailed discussion of the statistical analysis, screening methodology, and the evaluation of background levels is presented in Chapter 4, Section 4.9, of the SWRI report and Appendix A of this document.

Because VOCs and HE compounds detected at Site 300 are known to be anthropogenic in origin, no background concentrations have been identified for these substances. Carbon disulfide, perchlorate, and TBOS/TKEBS have also been identified as anthropogenic contaminants in ground water at Site 300. As a result, these compounds are classified as chemicals of potential concern if their frequency of detection is  $\geq 2\%$  unless data provided sufficient evidence that the detection of a compound was not related to a release or that the contaminant is no longer present in ground water.

VOCs, including chloroform, 1,1-dichloroethylene (DCE), 1,2-DCE, 1,2-dichloroethane (DCA), 1,1,1-trichloroethane (TCA), TCE, and PCE are routinely detected in ground water at several locations throughout the site (i.e., at process and test complexes, maintenance facilities, and a few disposal pits) (Fig. 1-15). Generally, TCE constitutes the major VOC component in ground water; comprising up to 98% of the total VOCs in some areas. The highest VOC concentration detected was 800,000  $\mu\text{g/L}$  of TCE beneath the Building 834 Complex in the southeastern portion of the site.

Tritium has been detected in ground water beneath and downgradient from several disposal pits and firing tables located in the northern portion of Site 300 (Fig. 1-15). The highest tritium activity detected in ground water was 2,660,000 pCi/L at the Pit 3 Landfill.

Other contaminants frequently detected in ground water at numerous locations throughout the site include nitrate in the HE Process Area, Pit 6 Landfill area, and at Buildings 834, 850, 854, 830, and 832; and perchlorate in the HE Process Area, the Pit 6 Landfill, and at Buildings 850, 854, 830, and 832.

Contaminants detected less frequently in ground water at Site 300 include isotopically significant uranium-238 at Pits 3, 5, and 7, Building 854 and the Building 851 firing table; HE compounds (RDX, HMX, and 4-amino-2,6-dinitrotoluene [DNT] and) in the HE Process Area; and TBOS/TKEBS at Building 834. Carbon disulfide has been infrequently reported in ground water. Nitrite has also been reported on occasion in wells containing nitrate. Because nitrite is a transient daughter product of nitrate, we have not included nitrite as a separate contaminant of concern. Nonetheless, we continue to analyze for nitrite and will continue to monitor concentrations.

Isoconcentration maps of the primary contaminants in ground water at the Site 300 OUs are presented in the following figures:

- Building 834 OU: Distribution of TCE (Fig. 1-16) and nitrate (Fig. 1-17) in ground water. Contamination is restricted to a perched zone of limited extent, in the Qt-Tp<sub>sg</sub> and Tps-Tnsc<sub>2</sub> units. There has been no impact on the underlying Tnbs<sub>1</sub> regional aquifer.
- Pit 6 Landfill OU: Distribution of TCE (Fig. 1-18), and tritium, nitrate, and perchlorate (Fig. 1-19) in ground water. Shallow ground water and the regional aquifer are contaminated and may communicate. The contamination is of limited extent, with concentrations near and below MCLs. Guard wells demonstrate that there is no contamination off-site.
- HE Process Area OU: Distribution of TCE [Figs. 1-20 (Tnbs<sub>2</sub> aquifer) and 1-21 (Tps aquifer)], RDX (Fig. 1-22), nitrate (Fig. 1-23), and perchlorate (Fig. 1-24) in ground water; distribution of TCE (Fig. 1-25), nitrate (Fig. 1-26), and perchlorate (Fig. 1-27) in

ground water in the vicinity of the HE Burn Pit portion of the HE Process Area. The highest concentrations are in Tps, which exists as discontinuous perched zones and of limited extent. Concentrations near the site boundary are below MCLs. TCE contamination also exists in the Tnbs<sub>2</sub> aquifer, which is artesian near the site boundary, but off-site wells indicate no significant contamination. Tnbs<sub>2</sub> is used offsite for agricultural purposes. Actions are underway to contain contamination on site. Contamination at the Burn Pit involves isolated water-bearing zones in the Tnsc<sub>1</sub>, which are locally perched and of limited extent.

- Building 850/Pits 3 & 5 OU: Distribution of TCE (Fig. 1-28), nitrate (Fig. 1-29), perchlorate (Fig. 1-30), and uranium-238 (Fig. 1-31) in ground water in the Pits 3 & 5 area; distribution of uranium-238 and nitrate in the Building 850 area (Fig. 1-32); and distribution of tritium and perchlorate in the first water-bearing zone (Fig. 1-33) in the Building 850/Pits 3 & 5 area. Tritium contamination in the shallow alluvial/bedrock water-bearing zone in the vicinity of Building 850 is separated from the underlying deep aquifer in the Cierbo Formation by a thick claystone confining layer. Guard wells indicate that elevated tritium activities are not within 2,000 feet of the site boundary along any viable flow path. To the east of Pit 2, the previous guard wells have recently shown the advance of the leading edge of the plume. New guard wells are being added further to the east to define the extent of the plume in that area.
- Building 854 OU: Distribution of TCE (Fig. 1-34) and nitrate and perchlorate (Fig. 1-35) in ground water. Contamination occurs in a perched water-bearing zone within the Neroly bedrock, and is separated from the underlying deep aquifer in the Cierbo Formation by a thick claystone confining layer.
- Building 832 Canyon OU: Distribution of TCE (Fig. 1-36), nitrate (Fig. 1-37), and perchlorate (Fig. 1-38) in ground water. Contamination is primarily in Qal, Tnbs<sub>2</sub>, and Tnsc<sub>1</sub> – whereas Tnbs<sub>1</sub> is the regional aquifer. Concentrations approaching the site boundary are below MCLs.
- Site 300 OU:
  - Building 801/Pit 8 Landfill: TCE (Fig. 1-39) and nitrate (Fig. 1-40) occur in ground water in the Tnbs<sub>1</sub> regional aquifer one-half mile from the site boundary. TCE concentrations are below MCLs.
  - Building 833: Distribution of TCE (Fig. 1-41) in ground water. TCE exists in a very limited, shallow, perched water-bearing zone (Qt, Tps, Tnsc<sub>2</sub>), which is isolated from Tnbs<sub>1</sub>, the underlying regional aquifer.
  - Building 851 firing table: Distribution of uranium-238 (Fig. 1-42) in ground water. A small amount of depleted uranium exists in ground water in the Qal-Tmss hydrogeologic unit, which is only saturated for 5-10 feet. It is over a mile to the site boundary along any possible flow path.

Table 1-8 presents estimates of area, volume, and mass of the primary contaminants in ground water at each OU or release site at Site 300. The estimates presented in Table 1-8 are gross, conservative estimates with varying degrees of confidence in the data used to generate these numbers. The intent of generating these estimates was to: (1) give a very general idea of

the extent of contamination and (2) produce rough estimates to be used by engineers in developing and costing the remedial alternatives. These numbers should not be used for comparison with mass removal estimates. Detailed discussions of the nature and extent of contamination in ground water in each OU is presented in Section 4 of Chapters 9 through 14 of the SWRI.

#### **1.3.4. Nature and Extent of Contamination in Surface Water**

No perennial streams exist on or near Site 300. Runoff occurs within ravines and intermittent stream channels during and following heavy rains. Except for small areas in the northeastern and northwestern portions of Site 300, runoff that does not infiltrate the ground eventually discharges into Corral Hollow Creek, an intermittent stream which flows west to east near the southern perimeter of the site. Such discharges, however, are rare. Only on three occasions have offsite discharges been observed outside the B832 Canyon and GSA in the last 2 (wet) years.

Other surface water bodies and discharges at Site 300 include 24 seeps and springs located throughout the site; two double-lined, State-regulated Class II surface-water impoundments at the HE process area, which are used to evaporate HE process rinsewater; cooling tower discharge locations; and a lined sewage pond located in the southeast corner of the site. The lined sewage pond accepts sewage from the GSA for bio-treatment and evaporation. Septic tanks and leach fields provide for sewage discharge from other facilities at the site. The HE process rinse water surface impoundments; the sewage treatment pond, sewer lagoons, septic tanks and leach fields; and cooling tower discharges are all regulated under existing Waste Discharge Orders and therefore, are not discussed in this document, which is concerned only with past releases.

Surface water samples have been collected and analyzed from Corral Hollow Creek, drainages and other ephemeral surface water runoff sources in the vicinity of Site 300 facilities, and from several springs across the site. VOCs and tritium have been detected periodically in springs in several OUs throughout the site. VOCs have been detected in surface water in the Pit 6 OU (Spring 7, sampled at well BC6-13), Building 832 Canyon OU (Spring 3), the HE Process Area OU (Spring 5, sampled at W-817-03A), and the Building 854 OU (Springs 10 and 11). Of these, only Spring 3 in the Building 832 Canyon has any potential for off-site flow. The B832 Canyon OU Characterization Summary report (August 1997; p. A-2-14) provided sampling results from five sampling events in the Building 832 Canyon during the rainy seasons of 1996 and 1997. All five samples reported below the detection limit for VOCs. These results provide evidence that no measurable pollution is flowing off-site from Spring 3. Tritium has activities have been monitored in Well 8 Spring in the Building 850/Pits 3 & 5 OU, since 1971, with a generally decreasing trend. Flow from Well 8 Spring is less than 200 gal/day, with no potential for off-site flow.

#### **1.3.5. Contaminants of Potential Concern**

In the SWRI, compounds detected in soil, rock, ground water and/or surface water were evaluated by a screening process to determine which compounds were contaminants of potential concern. These contaminants of potential concern were then used in the baseline risk assessment to determine risk to human health or the environment presented by the presence of these

compounds in environmental media at Site 300. For the SWFS, we conducted new database queries to ensure that no new contaminants and media of potential concern were overlooked.

### **1.3.5.1. Evaluation of Contaminants of Potential Concern in the SWRI Report**

In the SWRI, contaminants of potential concern were identified for each study area and media. The principal criterion used to evaluate the exposure potential of substances detected at Site 300 was the frequency with which each substance has been detected. This criterion was selected because it reflects the fact that for a substance to have been detected frequently, it must be both persistent in the environment and relatively widespread. The potential for human exposure is directly related to these parameters as well as the tendency of the contaminant to migrate within and between environmental media. The use of 2% frequency of detection as a basic criterion for inclusion or exclusion of substances of potential concern was stipulated by staff of the U.S. EPA, Region IX (Seraydarian, 1992).

The SWRI identified six individual study areas as the basic units used to define sets of data. These areas were the Building 833, Building 834, EFA/WFA, Pit 6 Landfill, HE Process Area and the GSA study areas. The Building 850/Pits 3, 5 OU, Building 854 OU, and the Building 801 firing, Building 802 firing and dry well, and the Building 845 and Building 851 firing release sites were evaluated as part of the EFA/WFA study area in the SWRI. The Building 832 Canyon OU was evaluated as part of the Building 834 and Building 833 study areas.

Sampling data for each study area were separated by environmental medium (i.e., ground water, subsurface soil, surface soil, and surface water). The frequency of detection was then determined for ground water and surface soil by dividing the number of times a substance was detected by the number of times it was sampled for. Those compounds that were detected at a greater than 2% frequency of detection in ground water and surface soil were considered to be contaminants of potential concern in the SWRI.

Contaminants of potential concern were then evaluated with respect to available quality control data. Contaminants of potential concern with only poor quality control data (such as evidence that contaminants were laboratory contaminants through their presence in method blanks and not validated with good quality data) were eliminated as contaminants of potential concern. In addition, the ranges of natural background concentration for metals, ions, and radiological parameters in ground water and surface soil were determined as part of the contaminant screening process in the SWRI. Since metals, ions, and radiological constituents occur naturally in environmental media, it is important to distinguish between measured concentrations or activities of metals, ions, and radiologic parameters that are representative of background levels and those that are indicative of contamination. Metals, ions, and radiologic constituents that were detected within the background concentration range established for that constituent at Site 300 were not considered to be contaminants of potential concern. A detailed discussion of the determination of background levels for these constituents in various environmental media at Site 300 is presented in Chapter 4, Sections 4.2.2, 4.4.2, and 4.9.2.4 of the SWRI.

Data on contaminants of potential concern (COPCs) in surface water (i.e., springs) and subsurface soil were not subjected to a frequency-of-detection screening process to identify the

most frequently occurring substances. Instead, we identified those springs located in areas of the site where human exposure could occur. We then reviewed sampling data from each spring for evidence of (or lack thereof) contamination with compounds that could volatilize (e.g., VOCs) or evaporate (tritium) from springs, thereby leading to human exposure (springs are not used at Site 300 as drinking water for humans). If such contaminants were present, we incorporated the data for these compounds into our estimates of exposure and risk, regardless of the frequency of detection. The approach for determining COPCs in subsurface soil was similar to that described for surface water. For example, subsurface soil data were reviewed to determine if VOCs or tritium were present in soil within 12 ft of the surface, which could volatilize and lead to human exposure. The depth of 12 ft. below ground surface (bgs) for evaluating subsurface soil was established for the SWRI evaluation in conjunction with State and Federal Remedial Program Managers and the EPA toxicologist on the project. In addition, further evaluation of substances detected in surface water and subsurface soil was conducted to identify potential contaminants of ecological concern due to ingestion or inhalation risk or hazard to animals. A detailed discussion of screening process and criteria, and the evaluation of contaminants of potential concern is presented in Chapter 4, Section 4.9 of the SWRI.

In the SWRI, a baseline risk assessment was conducted subsequent to the determination of contaminants of potential concern. Section 1.5 discusses the risk assessment process. This risk assessment was used to determine if these contaminants of potential concern presented a risk to human health and the environment. The results of this risk assessment are used herein to assist in determining actual COCs as discussed in Section 1.6.

### **1.3.5.2. Evaluation of Recent Data**

New soil and water data have been collected since the SWRI report was issued. We conducted two database queries to ensure that no new contaminants of concern were overlooked. In these queries, all media were screened using the 2% frequency of detection criteria (this was not the case for surface water and subsurface soil in the SWRI, as described above). This data evaluation also included the determination of contaminants of potential concern for new OUs established after the SWRI.

The first query identified any compounds detected after December 31, 1991 (SWRI data cutoff date) at greater than a 2% frequency of detection that were not detected above the method detection limit or were not analyzed for prior to this date. The 2% frequency of detection was based on all data (before and after December 21, 1991) collected for the compound in a given OU through October 22, 1999 (the SWFS data cutoff date). The results of this query are summarized in Tables 1-9 through 1-12.

The second query was conducted on a selected group of compounds known to be of potential concern at Site 300 (volatile and semi-volatile compounds, uranium isotopes, tritium, HMX, RDX, phenolics, silver, nitrate/nitrite, TBOS/TKEBS and perchlorate). This query was conducted to identify compounds that are currently detected at greater than 2% frequency of detection, which may have been detected before 1992 but at less than 2% frequency of detection. This query was conducted on surface soil, subsurface soil to all depths, and ground water. Surface water and subsurface soil between the depth of 0.5 and 12 ft. were evaluated for volatile compounds only, as inhalation is the only pathway that could potentially expose an adult working on site. The 12 ft. depth for evaluating subsurface soil is consistent with that used in the

SWRI evaluation. Although there is currently no consensus in the scientific community regarding the depth from which volatile compounds in the subsurface can be expected to reach the surface in any significant quantity, a depth of 10 ft. is typically used for such evaluations. We selected 12 ft. to ensure results from at least two subsurface soil analyses (typically conducted on cores collected every 5 ft.) were available for evaluation. The results of this query are summarized in Tables 1-13 through 1-17.

## 1.4. Contaminant Fate and Transport

As part of the SWRI, contaminant release screening and fate analysis for Site 300 was conducted using methods described in the EPA Superfund Exposure Assessment Manual (U.S. EPA, 1988). The contaminant release screening analysis was initiated by identifying each potential contaminant release. The environmental media of concern (ground water, subsurface soil/rock, surface soil, surface water) were then determined by evaluating laboratory analytic data and the transport potential for chemicals at the release sites. Each conceptual migration process was presented in the context of an exposure pathway to define the boundaries of contaminant migration/transport.

On the basis of this evaluation, conceptual models were developed to identify the probable migration processes of the chemicals of potential concern from OUs and release sites to selected potential exposure points. These conceptual models provided the basis for selecting the quantitative models used to generate estimates of contaminant migration rates and exposure-point concentrations.

The models used to estimate the release rates and exposure point concentrations at Site 300 include:

- Estimation of the concentration of contaminants bound to resuspended soil particles,
- Estimation of the concentration of contaminants that volatilize from subsurface soil to the atmosphere,
- Air dispersion modeling,
- Estimation of the concentration of contaminants that flux from subsurface soil and diffuse through a concrete slab into building air,
- Modeling of volatilization of tritium-bearing soil moisture,
- Modeling of VOC volatilization from surface water,
- Modeling of tritium evaporating from surface water to the atmosphere,
- Vadose zone modeling, and
- Ground water flow and transport modeling.

A detailed discussion of the Site 300 modeling is contained in Chapter 5 of the SWRI.

These models generated exposure-point concentrations, which were then used to estimate the magnitude of exposure to contaminants in the baseline public health and ecological assessments presented in Chapter 6 of the SWRI report and summarized in Section 1.5 of this document.

Since the completion of the SWRI report, LLNL conducted additional field studies to better characterize VOC vapor flux from soil and better define the release rates of VOC vapor from soil in selected OUs (i.e., Building 832 Canyon, Building 854). These models replace those presented in Chapter 5 of the SWRI report, which used VOC concentration data obtained from subsurface soil samples to estimate VOC flux into indoor and outdoor air rather than direct flux measurements.

We conducted modeling as part of this SWFS in order to determine which COCs in surface and subsurface soil are present at concentrations that could present a threat to ground water and therefore might require an active remediation alternative. A discussion of this modeling effort is included in Appendix B.

## **1.5. Baseline Risk Assessment Summary**

The baseline risk assessment provides the basis for taking action and identifies the potential exposure pathways that need to be addressed by the remedial alternatives. It serves as the baseline to indicate what potential risks might exist if no action were taken at the site. This section of the SWFS summarizes the results of the baseline risk assessment conducted for Site 300. Additional details may be found in Chapter 6 of the Site 300 SWRI report (Webster-Scholten, 1994), the Building 850 SWRI Addendum (Taffet et al., 1996), the Building 832 Canyon Characterization Summary report (U.S. DOE, 1997), and the Building 854 Characterization Summary report (U.S. DOE, 1998a).

The baseline risk assessment evaluated potential present and future public health and ecological risks associated with environmental contamination at Site 300, using the assumption that no cleanup or remediation activities would take place at the site. Selection of a specific remediation strategy will be based in part on the extent to which it can reduce potential public health and ecological risks.

The human health baseline risk assessment presented in the SWRI report consists of six components:

- Identification of chemicals of potential concern.
- Identification of the contaminated environmental media and exposure pathways.
- Estimation of potential exposure-point concentrations of contaminants.
- Human exposure and dose assessment.
- Toxicity assessment.
- Risk characterization.

Section 1.5.1 summarizes the baseline human health risk assessment as presented in the SWRI and other previous documents. Section 1.5.2 presents the re-evaluation of the baseline risk assessment for the SWFS using data collected since the publication of the previous documents.

The ecological assessment for Site 300 presented in the SWRI included the following components:

- Determination of the presence or potential presence of threatened or endangered species at Site 300.
- Determination of the significant ecological exposure pathways to the ecological contaminants of potential concern at Site 300.
- Selection of ecological assessment and measurement endpoints.
- Final estimation of ecological impact and hazard on the selected assessment endpoints.

Section 1.5.3 summarizes the baseline ecological assessment.

### **1.5.1. Baseline Human Health Risk Assessment**

Sections 1.3 and 1.4 above summarize the methodology used in the SWRI and previous assessments to identify contaminants of potential concern and estimate potential exposure point concentrations, respectively.

#### **1.5.1.1. Toxicity Assessment**

For each location with environmental contamination, we began by identifying those contaminants of potential concern that are classified by the U.S. EPA (U.S. EPA, 1992a) or by the State of California EPA (1992) as carcinogens. EPA bases this classification on data from epidemiological studies, animal bioassays, and in vivo and in vitro tests of genotoxicity.

**1.5.1.1.1. Cancer Potency Factors.** The Cancer Potency Factors (CPFs) used in our estimations of cancer risk were obtained from values published in either the Integrated Risk Information System (IRIS) (U.S. EPA, 1992b), the Health Effects Assessment Summary Tables (U.S. EPA, 1992a,c), or by the State of California EPA (1992). CPFs for TCE and PCE were also provided by Region IX of the U.S. EPA (1993). All CPFs were derived using versions of the linearized, multistage dose-response model (U.S. EPA, 1989a,b); generally, the dose- and tumor-incidence data used in the model are from animal bioassays. For contaminants of potential concern at Site 300, the exceptions are cadmium, benzene, and beryllium, where human tumor data are available. The model calculates the potential increased cancer risk, where increased risk is assumed to be linearly related to dose for low-dose levels typical of environmental exposure. Use of animal bioassay data to predict human tumorigenic response assumes that animals are appropriate models of human carcinogenic response, and that the dose-response relationships observed in high-dose animal bioassays can be extrapolated linearly to the low doses generally associated with human exposure to environmental contaminants. When CPFs were available for a particular contaminant from both a U.S. EPA source and the State of California, the higher potency factors were used. Chapter 6 of the SWRI report lists reference documents for CPFs (slope factors) used to calculate cancer risks in our evaluation.

**1.5.1.1.2. Reference Dose.** The reference doses (RfDs) used to evaluate potential noncarcinogenic adverse health effects were based, when possible, on long-term (i.e., chronic) exposures and were derived by dividing an experimentally-determined no-observed-adverse-effect-level or lowest-observed-adverse-effect-level (each has units of mg/[kg • d]) by one or more uncertainty factors (U.S. EPA, 1992a,b,c). Each of these uncertainty factors has a value that ranges from 1 to 10 (U.S. EPA, 1992a,b,c). We used pathway-specific RfDs, when available (U.S. EPA, 1992a,b,c; Cal-EPA, 1992), to calculate a corresponding Hazard Quotient (HQ). If

pathway-specific RfDs were not available, the published RfDs (typically developed for oral exposures) were used to calculate an HQ for all exposure pathways. Reference documents and reference doses used to calculate noncancer hazard indices in our evaluation are listed in Chapter 6 of the SWRI.

### **1.5.1.2. Risk Characterization**

LLNL performed the risk assessment in accordance with Risk Assessment Guidance for Superfund (U.S. EPA, 1989a,b). Carcinogenic risks, an evaluation of potential noncarcinogenic exposure health hazards, and the additivity of response are described below.

1.5.1.2.1. **Carcinogenic Risks.** For carcinogens, we calculated the potential incremental cancer risk associated with long-term exposure to chemicals in surface soil, subsurface soil, and ground water. For each chemical at each exposure location, the total risk attributable to that chemical was estimated by multiplying each pathway-specific intake (e.g., the dose due to ingestion of water or to inhalation of contaminants that volatilize from water to indoor air) by the corresponding pathway-specific CPF. The products of each pathway-specific intake and pathway-specific CPF were summed to obtain the potential incremental cancer risk for a specific chemical. Parallel sets of calculations were completed for all chemicals at each exposure location, then values of chemical-specific risk from all chemicals were summed to yield an estimate of total incremental risk for exposures associated with a given location.

1.5.1.2.2. **Evaluation of Hazard from Exposure to Chemicals that Cause Noncancer Health Effects.** For chemicals of potential concern that are not classified as carcinogens, and for those carcinogens known to cause adverse health effects other than cancer, the potential for exposure to result in noncarcinogenic adverse health effects was evaluated by comparing the chronic daily intake (CDI) with an RfD. When calculated for a single chemical, this comparison yields a hazard quotient (HQ). For each chemical at each location, pathway-specific HQs were summed (where applicable) to obtain an HQ estimate for a given chemical. We then summed all HQs from all chemicals to yield a hazard index (HI) estimate for exposures associated with a given location.

1.5.1.2.3. **Additivity of Response.** In every location at or near each OU where cancer risk and noncancer HQs were calculated, CDIs were estimated for exposures attributable to multiple pathways for each of several contaminants. As noted previously, we estimated the total potential cancer risk and/or total HI by summing risk or HQs for all contaminants at a given location, where each chemical-specific estimate of risk or hazard represents an estimated exposure from multiple pathways. Implicit in the summation of risk and hazard is the assumption that the effects of exposure to more than one chemical are additive. This simplifying assumption does not consider similarities or differences in target organ toxicity, mechanism(s) of action, or the possibility of synergistic or antagonistic effects of different chemicals in the mixture.

### **1.5.1.3. Summary of Human Health Baseline Risks and Hazards Associated with Contaminants**

Estimated baseline human health risks and hazards for the Site 300 OUs were evaluated for adults onsite exposure and residential exposure, as well as additive potential risk. These are presented in Table 1-18 and described below. Chapter 6 of the SWRI presents detailed discussions of the baseline human health risk and hazard evaluated. Since the completion of the

SWRI, LLNL has collected and evaluated additional data to further define human health risk and hazard at Site 300. Details of these additional risk evaluations are contained in the Building 850 SWRI Addendum, and the Characterization Summary Reports for Building 854 and Building 832 Canyon OUs.

**1.5.1.3.1. Adult Onsite Exposures.** The adult onsite (AOS) exposure scenario addresses potential health risk attributable to contaminants in surface soil, subsurface soil, and surface water (springs) where an adult is presumed to work in the immediate vicinity of the contamination over a 30-year period of employment at the site.

We evaluated potential AOS exposure to contamination by calculating the associated risk and hazard for two scenarios. The first of these scenarios pertains to potential AOS exposure to contaminated subsurface soil through inhalation of VOCs and/or tritium from subsurface soil to air. The second scenario pertains to potential AOS exposure to contaminated surface soil from inhalation of resuspended particulates, dermal absorption of contaminants following direct contact with contaminated soil, and incidental ingestion.

Risk and hazard were also evaluated for AOS inhalation exposure to VOCs volatilizing from contaminated subsurface soil underneath Buildings 834, 854F, 854A, 830, 832, and 833, and diffusing into the building. Where VOCs and/or tritium contamination was identified in surface water (springs), we evaluated risk and hazard for AOS inhalation exposure to contaminants volatilizing from contaminated surface water (Springs 3, 5, 7, 6, and Well 8 spring).

We based our estimates of risk and hazard for adults onsite on conservative exposure scenarios (e.g., an individual was assumed to be exposed at a single location every working day over their entire career at LLNL) and conservative model parameters were used. Consequently, we may have overestimated the true risk and hazard associated with adult onsite exposure to environmental contamination at the site. For example, the evaluation of AOS inhalation exposure to VOCs volatilizing from contaminated subsurface soil and diffusing into various buildings at Site 300 assumed that an individual worker would be exposed 8 hrs/day, 5 days/week for 30 years. In reality, few of the buildings evaluated are utilized to the extent that an onsite worker would be exposed to contaminants at this frequency for a 30-year period. Most of these buildings are used only sporadically during experiments and the actual exposure to contaminants is expected to be far less than the estimates assumed in the risk assessment. In addition, the current concentration or activity of contaminants may be much lower than the maximum concentration/activity used to calculate risk and hazard due to natural attenuation or active remediation.

**1.5.1.3.2. Additive Risk and Hazards for Adults Onsite.** Adults working outdoors at Site 300 could be exposed simultaneously to contaminants in surface soil (by inhalation of resuspended particulates, and ingestion and dermal absorption of surface soil contaminants) as well as by inhalation of VOCs and/or tritium that volatilized from subsurface soil or surface water. Table 1-24 presents the potential additive individual excess lifetime cancer risk and HI estimates for baseline AOS exposures in Site 300 OUs.

**1.5.1.3.3. Residential Exposures.** In previous reports, we evaluated risk and hazard for potential residential exposure (RES) through the use of contaminated water from hypothetical and existing water-supply wells located at Site 300 boundaries. The residential exposure

scenario was developed in consideration of the fact that lands in the vicinity of Site 300 have been subject to encroaching urbanization.

We also evaluated RES risk and hazard associated with inhalation of VOCs and/or tritium that volatilizes from surface water bodies located offsite (Carnegie Residence Pond). Estimates of baseline cancer risk and hazard index for potential residential exposure are summarized by OU in Table 1-18.

**1.5.1.3.4. Uncertainty in the SWRI Baseline Public Health Assessment.** Uncertainties are associated with all estimates of potential carcinogenic risk and noncarcinogenic hazard. For example, the exposure parameters recommended by the U.S. EPA (1990; 1991) are typically obtained from the 90th or 95th percentile of a distribution; they are not necessarily representative of an average individual or of average exposure conditions. Consequently, use of multiple upper-bound parameters may contribute to overly conservative estimates of potential exposure, risk, and hazard.

In addition, the total cancer risk and/or total HI was calculated by summing risk of HQs for all contaminants at a given location, where each chemical-specific estimate of risk or hazard represents exposures from multiple pathways. Implicit in the summation of risk and hazard, is the assumption that the effects of exposure to more than one chemical are additive. This simplifying assumption does not consider similarities or differences in target organ toxicity, mechanism(s) of action, or the possibility of synergistic or antagonistic effects of different chemicals in the mixture.

Other uncertainties associated with the estimates of risk and hazard are OU-specific and are related to the generally conservative assumptions made in the modeling conducted to provide exposure-point concentrations, which were subsequently used to calculate risk and hazard. These risks calculations are also predicated on the assumption of DOE continued control over the land at Site 300, hence the use of industrial assumptions for occupancy and exposure. If the lands were ever to become privately controlled and residential scenarios become appropriate, new assessments would be warranted.

**1.5.1.3.5. Evaluation of Data Subsequent to the SWRI Related to Human Health Risk.** Subsequent to completion of the SWRI report, LLNL has collected and evaluated additional data to determine human health risks. In 1995, surface soil samples were collected in the vicinity of the Building 850 firing table and analyzed for PCBs, CDDs, and CDFs. At the recommendation of the U.S. EPA, we used the Toxicity Equivalence Factor approach to evaluate the potential risks associated with exposure to CDDs and CDFs in the vicinity of the Building 850 firing table. As part of this post-SWRI risk assessment for the Building 850/Pits 3 & 5 OU, we made calculations of potential exposure, risk, and hazard arising from metals, uranium, and thorium in surface soil in this OU. A detailed discussion of that risk assessment is contained in the Building 850/Pit 7 Complex SWRI Addendum (Taffet et al., 1996).

In 1996, measurements of VOCs were made in the Building 854 OU and the Building 832 Canyon OU by collecting samples of soil vapor flux and ambient air in order to calculate cancer risks in these OUs. A detailed discussion of these effort is presented in the Characterization Summary reports for Building 832 Canyon and Building 854 OUs (U.S. DOE, 1997 and 1998, respectively).

The results of these post-SWRI risk assessments are also included in Table 1-18.

### 1.5.2. Re-evaluation of the Baseline Risk Assessment

The purpose of this re-evaluation of the baseline risk assessment is to evaluate the risk associated with chemicals of potential concern identified subsequent to the baseline evaluations presented in previous documents. Therefore, we examined the compounds which were detected at a greater than 2% frequency (Tables 1-9 through 1-17) for potential comparison to the U.S. EPA PRGs (for both cancer risk and noncancer hazard). If the chemical had the potential to occur naturally, the maximum concentration of the chemical was first compared to background concentrations. Only chemicals exceeding background concentrations were compared to PRGs. Appendix A presents the Site 300 background concentrations, which were re-evaluated using data collected subsequent to the SWRI evaluation. Appendix A also contains an evaluation of the occurrence of uranium at Site 300. Table 1-19 lists those chemicals above background concentrations that had not been evaluated for potential health effects. Rather than simply compare these new chemicals to PRGs, we elected to re-evaluate the entire data set presented in Tables 1-9 through 1-17 using the PRG approach to provide information on cumulative risk in similar metrics. We did not, however, change the concentration basis for the analysis if current concentrations were lower than the maximum historical values. Discussion of current concentrations is provided in Chapter 6, where appropriate.

When a PRG comparison was appropriate, the maximum concentration of the compound was compared to the appropriate PRG. If the maximum concentration exceeded the PRG for cancer risk, we calculated the expected risk for that single data point by taking the ratio of the maximum concentration to the PRG then multiplying by  $10^{-6}$ . We similarly calculated the expected hazard quotient for that single data point by taking the ratio of the maximum concentration to the hazard PRG, then multiplying by one. Risk and hazard quotients were then summed for the respective media.

For surface soil (Tables 1-9 and 1-13), the maximum concentration of the compound was compared to the industrial PRGs for soil. These PRGs incorporate the inhalation, dermal absorption, and incidental ingestion pathways. These are the same pathways considered in the SWRI evaluation, and incorporate similar default assumptions. For PCBs and dioxins, we did not include PRGs in Table 1-9 or 1-13, as there are no PRGs for many of the dioxin/PCB compounds. However, in both the Building 850 SWRI Addendum and the Building 854 Characterization Summary Report, these compounds were evaluated using the Toxicity Equivalent approach. This is analogous to a PRG approach, and thus we include the results of these evaluations in Table 1-20, which summarizes the PRG evaluations.

Compounds detected in subsurface soil at all depths greater than 0.5 ft. at a frequency greater than 2% are presented in Tables 1-10 and 1-14. These compounds were evaluated for their potential to impact ground water resources. This evaluation is presented in Appendix B. The maximum concentration of volatile compounds in subsurface soil detected between 0.5 and 12 feet were also compared to the PRGs for industrial soils. The results of this comparison are presented in Table 1-15. In the Building 832 and Building 854 Characterization Summary reports, concentrations of contaminants of potential concern in ambient air (determined either through direct measurement or estimated from flux chamber measurements) were compared to the PRGs for ambient air. As the presence of these contaminants were presumed to have been from the volatilization of contaminants in subsurface soil, these PRGs evaluations are also presented in Table 1-20.

Compounds detected in ground water at a frequency greater than 2% are presented in Tables 1-11 and 1-16. Maximum concentrations were compared to the PRGs for tap water. These are residential PRGs and incorporate ingestion, dermal absorption, and inhalation pathways. This is very different from what was conducted in the SWRI evaluation, in which chemicals in ground water were modeled to the site boundary, and a residential exposure developed. This current PRG evaluation implies that persons onsite will be consuming ground water at the points of highest chemical concentration. Note, however, that ground water on-site is not used as a drinking water source, nor can it be, under current administrative controls.

Compounds detected in surface water at a frequency greater than 2% are presented in Tables 1-12 and 1-17. Only volatile compounds were compared to PRGs (Table 1-16), as the inhalation pathway represents the only true exposure pathway for adults working onsite. This is the same assumption used in the SWRI evaluation. However, the only PRGs available for comparison are the PRGs for tap water. Again, these are residential PRGs and incorporate ingestion, dermal absorption, and inhalation pathways. The previous risk assessment conducted in the SWRI only included the inhalation pathway. Therefore, the risk and hazard numbers presented in Table 1-16 greatly overestimate the true risk and hazard associated with these chemicals to adults working onsite, provided these springs are not used for drinking.

Table 1-20 summarizes the results of the PRG evaluations. In this table, the additive risks for outdoor exposure to adults onsite from contaminated surface soil and subsurface soil is presented. These are realistic exposure pathways, and in general are similar to what was estimated in previous evaluations. Indoor air PRG evaluations were conducted using the results of ambient air samples collected in Buildings 830, 832 and 854A. However, an indoor air PRG evaluation was not conducted for Building 834. Therefore, the results of the indoor air evaluation presented in the SWRI are presented in Table 1-20 for comparison purposes.

We did not include the risks associated with ground water and surface water in the additive risks. For ground water, these are associated with the use of ground water as a drinking water source for persons onsite. However, the actual exposure pathway for ground water is from a private well near the site boundary. Even so, we elected not to develop a site-specific onsite adult exposure scenario, as cleanup goals for this media will not be based on risk. The concentrations of COCs in ground water were compared to MCLs, or Water Quality Objectives (WQOs) where applicable, from Chapter 2 to address the RAO for human consumption of ground water. Residential exposure scenarios for ground water were evaluated in the SWRI, and are presented in Table 1-20 for comparison purposes. In addition, all contaminants detected in ground water at greater than 2% frequency of detection and above background levels are considered as COCs and remedial alternatives are developed to address all COCs. The only exception were those contaminants for which data provided sufficient evidence that the detection of the compound was not related to a release or that the contaminant is no longer present in ground water.

For surface water, the only realistic exposure pathway to adults onsite is from contaminants volatilizing from the surface water. However, the only PRGs available are for tap water. Again, surface water will not be used as a drinking water source at Site 300. Again, we elected not to develop a site-specific onsite adult exposure scenario, as contaminants in surface water essentially reflect those found in ground water, and will be addressed accordingly. Adult onsite inhalation exposure scenarios for surface water were evaluated in the SWRI, and are presented in

Table 1-20 for comparison purposes. The only contaminants not addressed in the modeling presented in the SWRI were 1,2-DCE in Spring 3, PCE and TCE in Spring 6, methylene chloride and toluene in Spring 7, and TCE in Springs 10 and 11.

The risk and hazard values presented here were calculated from the maximum historical concentration or activity. Concentrations and activities for many constituents have decreased over time and some others are suspected to be outliers not reflecting true environmental conditions. Therefore, the risk and hazard values presented in Tables 1-9 through 1-17 and summarized in Table 1-20 are conservative.

### **1.5.3. Summary of the Baseline Ecological Assessment**

The baseline ecological assessment is presented in Chapter 6 of the SWRI report. Since its completion, additional data have been collected and evaluated to further define the potential for ecological hazard by contaminants present at Site 300. An evaluation of these data is also presented below.

#### **1.5.3.1. Baseline Ecological Assessment**

The baseline ecological assessment was conducted to determine the potential for ecological damage as a result of contaminant releases to the Site 300 environment. The assessment includes the following:

- Brief description of the ecological setting.
- Determination of the presence of threatened or endangered species.
- Comprehensive exposure pathway and food web analysis.
- Selection of contaminants of potential concern, and an evaluation of their ecological significance.
- Selection of assessment endpoints.
- Selection of measurement endpoints and estimation of reference doses for each contaminant of potential concern.
- Final estimation of ecological impact and hazard on the selected assessment endpoints.

Assessment endpoints are explicit expressions of the specific environmental values that are to be protected. The assessment endpoints were selected using the exposure pathway/food web analysis; the threatened and endangered species analysis; and the evaluation of contaminants of potential concern. The assessment endpoints selected for the Site 300 baseline ecological assessment include:

- Changes in species composition in native grassland communities.
- Reduction in the abundance of aquatic and/or amphibian populations.
- Reduction in the abundance of California ground squirrel populations.
- Reduction in the abundance of black-tailed deer populations.
- Mortality or reduction in reproductive potential of individual San Joaquin kit fox.

Measurement endpoints were selected for each assessment endpoint. HIs were calculated for individual terrestrial animals and plants, species diversity indices were calculated for plant communities, toxicity quotients (TQs) were calculated for aquatic communities, and changes in abundance (both spatially and temporally) were evaluated for the ground squirrel population. An HI or TQ greater than 1 indicates that an elevated ecological hazard potentially exists to individuals of the selected species, although this may not be reflective of hazard to the overall population. Table 1-21 presents a summary of risk or hazard to ecological receptors for each OU at Site 300 from the SWRI.

The results of the measurement endpoints for the native grassland communities indicate a low potential for radionuclides in the EFA/WFA to significantly alter the composition of this community. Species diversity indices calculated for the location containing elevated levels of tritium and uranium are not significantly different than species diversity indices calculated for the reference location. In addition, all calculated hazard indices for the native grassland are well below one.

The results of the measurement endpoints for aquatic populations indicate that the calculated TQ for radionuclides in Well 8 Spring and for predicted activities of tritium in Spring 6 are well below one. However, a potential hazard existed from copper and zinc in Springs 4, 5, and GEOCRK. Section 1.5.3.2 summarizes post-SWRI bioassay test results.

Hazard indices for individual ground squirrels exceed one for TCE and PCE in the Building 834 OU and the Pit 6 OU. In addition, HIs for cadmium exceed one for adult animals in the Building 834, HE Process Area, and Building 850/Pits 3 & 5 OUs, as well as in the Building 801 area. Although the HIs for individual ground squirrels exceed one in several areas, an evaluation of the percentage of the population thus affected, as well as the distribution of the ground squirrel population (both spatially and temporally), provides evidence that the Site 300 ground squirrel population has not been adversely impacted by the COCs at Site 300.

Hazard indices for individual deer exceed one for cadmium in the Building 834, HE Process Area, and the Building 850/Pits 3 & 5 OUs, as well as in the Building 801 area. Qualitative evidence suggests that the deer population is not at risk from these COCs. A subsequent evaluation of risk to the deer population at Site 300 was conducted in 1994. Section 1.5.3.2 discusses the results of this evaluation.

Based on maximum historic concentrations, hazard indices for individual kit fox exceed one for TCE, PCE, and cadmium in the Building 834 OU, for TCE and PCE in the Pit 6 OU, and for cadmium in the EFA/WFA. While there is no evidence that kit fox currently use these areas, individual kit fox denning in these areas in the future are potentially at risk. The Building 834 area was further evaluated with respect to TCE and PCE hazard to ground dwelling species in 1994. Section 1.5.3.2 discusses the results of this evaluation.

### **1.5.3.2. Evaluation of Recent Ecological Data**

Since the completion of the SWRI report, additional ecological data have been collected. During the summer of 1994, two bioassays were conducted using water from those springs with at least one TQ exceeding one. The bioassays selected were the *Ceriodaphnia dubia* (water flea) chronic seven-day toxicity test (EPA Method 1002) and the *Selenastrum capricornutum* (algae) four-day growth test (EPA Method 1003). These tests were selected as being representative of

the types of species expected to occur in these springs. In order to examine the effect sampling a spring through a well might have on the results of the bioassay (such as in the case of Spring 5), we also conducted the two bioassays on water obtained from well NC2-23. This well samples water from Spring 6 just prior to the location where the spring water surfaces.

No significant effects on reproduction, survival, or growth were observed in the bioassays from the two springs which had available surface water (GEOCRK and Spring 6). Water assumed to be representative of Spring 5, which was obtained from well W-817-03A, exhibited statistically significant toxicity at the higher concentrations in both bioassays. However, this was also observed in water obtained from NC2-23, which was assumed to be representative of Spring 6. As water obtained from the surface of Spring 6 failed to show toxicity, we assume that ground water is not biologically equivalent to the actual surface water. Thus, it is reasonable to conclude that the presence of low concentrations of copper and zinc in these springs do not present an ecological hazard. Table 1-22 presents a summary of bioassay results for the spring samples collected in the summer of 1994.

We also conducted additional evaluations of ecological risk posed by cadmium, PCBs, and CDDs in surface soil in the Building 850/Pits 3 & 5 OU in 1995. These evaluations are described in detail in the Building 850/Pit 7 Complex SWRI Addendum (Taffet et al., 1996).

In 1994, additional soil samples were collected throughout the site to further define areas of elevated cadmium levels. In addition, the location of deer sightings were recorded throughout the year. These sightings were made by ERD and Site 300 personnel working in the field. Figure 1-43 shows the results of the soil sampling as well as the locations of the deer sightings. The majority of the deer sightings are associated with springs located in the southern half of the site. Areas with deer sightings in general had soil cadmium concentrations below 1 mg/kg, with most of the areas below the detection limit of 0.1 mg/kg. Thus, it is reasonable to conclude the localized presence of elevated cadmium levels in the surface soil at Site 300 does not pose a significant threat to the deer populations, as their primary habitat is outside of these areas.

During the summer 1994, we conducted a PETREX passive soil vapor survey in animal burrows located in the vicinity of Building 834 to determine if VOC vapors were indeed migrating into the animal burrows as suggested by the SWRI ecological assessment. PETREX tubes were manually placed as far back into burrows as could be done without disturbing the burrows. Tubes were left in the burrows for approximately two weeks, retrieved, and sent to the lab for analysis. The results were reported qualitatively as total ion counts (TICs), and are summarized in Figure 1-44. Elevated TICs were observed in burrows in the Building 834 complex, and were of a similar magnitude to those observed from PETREX surveys conducted using standard tube installation. Although this type of survey does not quantify VOC concentrations in the animal burrows, it does indicate that significant amounts of VOCs can be present in the air of subsurface burrows.

One Swainson's hawk (*Buteo swainsoni*, threatened) and two peregrine falcons (*Falco mexicanus*, endangered) have been observed at Site 300 since the EIS/EIR surveys described in the SWRI. The Swainson's hawk was sighted along Corral Hollow Creek in the California Department of Fish and Game Ecoreserve. The Swainson's preferred habitats and distribution occur in the Central Valley and not the Coastal Range where Site 300 is located. In the winter, these birds migrate to South America (i.e., Argentina). Their preferred diet in the Central Valley includes insects (commonly found in cropland areas) and California voles. In 1989, the entire

Central Valley population was estimated at 550 pairs. A female Swainson's requires a territory of about 2200 acres and the male a territory four or five times that size.

The peregrine is also a rare visitor at Site 300; we've had a couple of fly-by sightings and the birds appeared transient. No nesting pairs have been discovered onsite and they are considered unlikely residents. Peregrines hunt bird species (i.e., doves, pigeons, waterfowl). Site 300 landscape features (lack of cliffs) do not provide much suitable habitat for the birds. It has been estimated that there are roughly 130 pairs currently breeding in the entire State.

In conclusion, because of the low probability of these raptors occurring at Site 300 and the nature of their diets, we do not include them as a noted species of concern likely to be adversely affected by contamination at Site 300.

The diamond petaled poppy (*Eschscholzia rhombipetala*, candidate) and big tar plant (*Blepharizonia plumosa* ssp *plumosa*, CNPS list 1B) have been found to occur at Site 300 since the EIS/EIR surveys described in the SWRI. A small population of the diamond petaled poppy (less than 30 plants) was discovered in the very southwest corner of the site, near the bottom of Draney Canyon. Annual monitoring of this species has been initiated. As it occurs well outside the areas of contamination, this species is not expected to be adversely affected by contamination at Site 300.

The big tar plant is quite widespread throughout Site 300, with significant populations in the Building 850 and Building 834 OUs. Monitoring of populations in these two OUs as well as outside areas of contamination is currently underway, as well as investigations into the population biology of the species. These investigations have shown the populations in both OUs to be robust, with no apparent adverse impacts from the contamination. Comparisons between various populations show that the occurrence of controlled burns is the best predictor of this species success.

### **1.5.3.3. Evaluation of Chemicals of Potential Concern**

In areas where ecological risk assessments have not been conducted, contaminants were evaluated against the existing ecological assessments to determine the potential for additional risk. For contaminants that were not evaluated in the ecological risk assessment, available literature was reviewed to evaluate their potential to pose ecological harm.

Tables 1-9, 1-10, and 1-12 summarize the substances that have been detected in surface soil, subsurface soil, and surface water since December 1991. With the exception of arsenic and selenium, substances found in surface water are all below available Ambient Water Quality Criteria (AWQC). Arsenic and selenium occur naturally above AWQC in the surface water at Site 300. A variety of dioxin and PCB compounds have been detected in surface soil in the vicinity of Buildings 850 and 854. The occurrences and ecological impact of these compounds are discussed in more detail in the Building 850 OU SWRI Addendum (Taffet et al., 1996) and the Building 854 Characterization Summary report (U.S. DOE, 1998). This localized contamination is not expected to pose a significant threat to the Site 300 biota. The additional radiological substances detected in surface and subsurface soil are also not expected to pose an ecological threat, as comparison of these activities with those evaluated in detail in the SWRI suggest they are far below the levels that could cause an ecological impact. All other substances

detected since December 1991 are similar to those evaluated in the SWRI report, and are thus not expected to pose an additional ecological threat.

## 1.6. Identification of Contaminants of Concern

As part of this SWFS, a screening and evaluation process was conducted for the contaminants of potential concern identified in the SWRI or earlier in this document. The objective of this evaluation process was to determine which contaminants of potential concern were actual COCs based on the:

- Frequency with which each substance has been detected.
- Concentration of the compound relative to background concentrations.
- Risk or hazard presented by the compound.
- Potential for a compound present in soil or rock to affect ground water.

The criteria used in this evaluation process were as follows:

1. The frequency with which each substance has been detected. This criterion was selected because it reflects the fact that for a substance to have been detected frequently, it is likely to be both persistent in the environment and relatively widespread. The potential for human exposure is directly related to these parameters as well as to the tendency of the contaminant to migrate within and between environmental media. Contaminants in ground water and surface soil detected at less than 2% frequency of detection were not considered as COCs in the SWRI. For the additional data base queries conducted as part of this SWFS, the 2% frequency of detection criteria was applied to all environmental media (i.e., ground water, surface soil, subsurface soil, and surface water).
2. Concentration of the constituent relative to background concentrations. If a compound was detected in an environmental media at Site 300 but was reported at concentrations within the range of natural background concentrations, it is not considered to be a COC. Appendix A discusses a re-evaluation of background levels for naturally-occurring substances (i.e., metals, ions and radionuclides). Constituents detected as part of either a Pit/Landfill Post-Closure Plan or Waste Discharge Requirements (WDR) monitoring program that do not exceed the established background and/or statistical limit are not considered as COCs.
3. Risk or hazard presented by the constituent. Constituents in surface and subsurface soil and VOCs in surface water are not considered COCs if the calculated risk was less than  $10^{-6}$  and the hazard index was less than one. This criteria was not used to determine COCs in ground water. Contaminants previously identified in ground and surface water, but not detected for an extended period of time (at least two years) have been screened out as not indicating a degradation in water quality, and thus not presenting a cause for remediation.
4. Potential for a constituent in soil or rock to affect ground water. Constituents in surface soil and subsurface soil or rock are not considered COCs if the modeling results, as presented in Appendix B, indicate the constituent does not present a threat to ground water. However, if a constituent in soil or rock did not present a threat to ground water

but the calculated risk was greater than  $10^{-6}$  or the hazard index was greater than one, it is still considered to be a COC.

Furthermore if the presence of a constituent may be attributable to a source other than an OU release at Site 300, it was screened out. Possible indicators include:

- Low absolute number of detections out of the total sample population (e.g., 1 detection out of 46 samples), and
- Other likely sources of sample contamination exist that may have contributed contaminants to the sample (i.e., compound is a common laboratory contaminant, compound is present in pipe glue used to construct monitor well, etc.),
- Contaminant detected in well upgradient from source area. Such contaminants may become COCs for a different OU or study area.

Also, naturally occurring compounds or radioisotopes that were not considered to be constituents of concern in the Compliance Monitoring Program for waste disposal units were not considered as contaminants of concern in the SWFS. Constituents of concern in the Compliance Monitoring Program for waste disposal units are defined by CCR Chapter 15 as waste constituents, reaction products, and hazardous constituents that are reasonably expected to be in or derived from waste buried in the disposal units. The constituents of concern selected for a specific waste disposal unit are based on one or more of the following criteria:

- Records specifically identify the constituent of concern as being disposed of in the waste disposal or potentially associated with the buried waste.
- The constituent of concern has been detected above background concentrations in soil, ground water and/or surface water in the immediate vicinity of the waste disposal unit, indicating a previous release.
- The constituent of concern is a contaminant or breakdown product that can be reasonably expected to be associated with the type of waste disposed of in the waste disposal unit.

In a few cases, data are so limited we can neither determine if the constituent detected represents contamination nor can we discern the source of the contamination (e.g., 1 detection out of 1 sample collected for the entire OU). In the absence of other corroborating evidence that the constituent is not related to anthropogenic contamination, additional sampling and analysis for the constituent will be conducted.

#### COC Summary

Any constituent detected in surface soil at greater than 2% frequency and above background concentrations is considered to be a contaminant of concern if (1) a risk above  $10^{-6}$  or hazard quotient above one was calculated for complete exposure pathways for the contaminant and media, and/or (2) the contaminant presents a potential threat to ground water as determined by modeling.

Any constituent detected in subsurface soil above background concentrations is considered to be a contaminant of concern if (1) a risk above  $10^{-6}$  or hazard quotient above one was calculated for complete exposure pathways for the contaminant and media, and/or (2) the contaminant presents a potential threat to ground water as determined by modeling.

Any constituent detected in ground water at greater than 2% frequency and above background concentrations and not screened out by one of the above criteria is considered to be a contaminant of concern.

VOCs detected in surface water are considered to be COCs if a risk greater than  $10^{-6}$  or hazard quotient greater than one was calculated for an inhalation pathway. Non-VOC constituents detected at greater than 2% frequency were compared to COCs in ground water in the same OU. All surface water bodies (springs) in which contaminants were detected at Site 300 are fed by ground water. If a non-VOC constituent detected in surface water is present as a COC in ground water, we consider that contaminant to be addressed in ground water remedial alternatives. We do not consider the contaminant to be a COC in surface water as no complete exposure pathway exists for non-VOC contaminants.

Tables 1-23 and 1-24 contain a list of compounds that were detected at greater than 2% frequency of detection and above background concentrations for ground/surface water and soil/rock respectively, but are not considered to be COCs, and the justification for the decision.

The lists of COCs for each media from SWRI were modified based on the results of the new data evaluation, risk assessment, and vadose zone modeling, and are presented in Tables 1-25 through 1-28.

## **1.7. Corrective Actions and Facility Upgrades**

Concurrent with the remedial investigation of Site 300, LLNL has conducted several corrective actions, removal actions, and facility upgrades to address environmental contamination. These actions have included landfill cappings; closures of HE rinsewater lagoons, HE open burn treatment facility, and dry wells; removal and replacement of firing table gravels; well sealing and abandonments; and ground water and vadose zone remediation. A summary of these actions is contained in Table 1-29.

## **1.8. Summary of Operable Units and Release Sites at Site 300**

Environmental investigations at Site 300 began in 1981 and are ongoing. To-date, DOE/LLNL have drilled over 500 monitor wells and boreholes and have collected and analyzed thousands of samples of ground water, soil, rock, soil vapor, and surface water to define the geology and hydrogeology, identify release sites and contaminants of concern, and determine the nature and extent of contamination at Site 300. In addition, DOE/LLNL have conducted extensive contaminant fate and transport modeling and risk assessment to evaluate the risks associated with Site 300 contaminants. Although characterization work at Site 300 is ongoing, the conceptual model for the site is fairly well understood.

The results of site investigations, evaluations of the nature and extent of contamination, fate and transport modeling, and risk assessments conducted in each OU were used to (1) develop RAOs and ARARs for the site, (2) screen and evaluate general response actions and technologies, (3) develop and evaluate the remediation modules applicable to each OU, and (4) ultimately combine the modules into alternative remedies and evaluate them against EPA criteria. Table 1-29 presents a summary of conditions and problems present at each OU at Site 300 including:

- An OU summary.
- Release sites.
- Media of concern.
- Geologic/hydrologic units affected by contamination.
- Contaminants of concern and highest contaminant concentration detected in each media.
- Estimated volume of contaminated media and contaminant volume based on the most recent data.
- Vadose zone modeling results.
- Baseline human health risk assessment summary (exposure pathways, COCs, risk, and hazard quotient).
- Ecological risk assessment summary.
- Corrective action(s) performed at the OU to-date.
- References for documents related to remedial investigations and remedial actions at the OU.

## 1.9. References

- Berry, T. R. (1996), *Addendum to the Pit 6 Engineering Evaluation/Cost Analysis for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.
- Berry, T. R. (1997), *Action Memorandum for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.
- California Department of Water Resources (CDWR) (1979), *Re-evaluation of Seismic Hazards for Clifton Court Forebay, Bethany Dams and Reservoir, Patterson Reservoir, Del Valle Dam and Lake Del Valle*, State of California, Department of Water Resources, Sacramento, Calif.
- California Environmental Protection Agency (Cal-EPA) (1992), Memorandum from Standards and Criteria Work Group to California EPA Departments, Boards, and Offices regarding California Cancer Potency Factors, dated June 18, 1992.
- Carpenter, D. W., A. L. Lamarre, N. B. Crow, and P. M. Swearingen, (1988), *Closure Plan for the Decommissioned High Explosives Rinse-Water Lagoons at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCID-21369).
- Carpenter, D. W., J. R. Copland, A. L. Lamarre, R. S. Mateik, M. J. Taffet, and W. M. Wade (1991), *Investigation of Holocene Faulting Near Closed Landfill Pit 6, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-ID-106316).

- Carpenter, D. W., M. J. Taffet, J. R. Copland, R. S. Mateik, and W. M. Wade (1992), "Holocene Faulting Near Lawrence Livermore National Laboratory, Site 300," in *Proceedings of the Second Conference on Earthquake Hazards in the Eastern San Francisco Bay Area*, G. Borchardt, Chief Ed., California Department of Conservation, Division of Mines and Geology, Special Publication 113, pp. 333–338.
- Corey, R. (1988), *The Resource Conservation and Recovery Act (RCRA) Closure and Post-Closure Plans for the Landfill Pits 1 and 7, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (EPA ID Number CA2890090002).
- Devany, R., R. Landgraf, and T. Berry (1994), *Draft Final Feasibility Study for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-113861).
- Dibblee, T. W., Jr. (1980), Preliminary Geologic Map of the Midway Quadrangle, Alameda and San Joaquin Counties, California, USGS Open-File Report 80–535.
- Eaton, J. (1986), *Tectonic Environment of the 1892 Vacaville/Winters Earthquake, and the Potential for Large Earthquakes along the Western Edge of the Sacramento Valley, California*, USGS Open-File Report 86–370.
- Ferry, L. S., T. Berry, D. MacQueen (1998), *Post-Closure Plan for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-128638).
- Graham, K. (1990), Lawrence Livermore National Laboratory, personal communication with L. Glick, Weiss Associates, Emeryville, Calif., February 27.
- Hauk, T. (1990), physicist, Earth Sciences Department, Lawrence Livermore National Laboratory, "Seismicity and Location Resolution with LLSN near Site 300," personal communication with D. W. Carpenter, geologist, Earth Sciences Department, Lawrence Livermore National Laboratory.
- Jakub, B. J. (1998a), *Action Memorandum for the Building 815 Operable Unit Removal Action Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.
- Jakub, B. J. (1998b), *Removal Action Design Workplan for the Building 815 Operable Unit Removal Action Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.
- Lamarre, A. L., T. L. Phillips, and N. B. Crow (1989), *Remedial Investigation of Dry Wells Facilities Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCID-21774) with addenda dated January 29, 1990 and November 15, 1990.
- Lamarre, A. L. and M. J. Taffet (1989), *Firing Gravel Cleanup at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCAR-10282).

- Landgraf, R. K., E. Miner, T. Berry (1994), *Feasibility Study for the Building 834 Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-113863).
- LLNL (1991), *Site 300—Site Development Plan*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-106744).
- Madrid, V. M. and B. J. Jakub (1998), *Engineering Evaluation/Cost Analysis for the Building 815 Operable Unit Removal Action Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-126639).
- Namson, J. S., and T. L. Davis (1988), “Seismically Active Fold and Thrust Belt in the San Joaquin Valley, Central California,” *Geol. Soc. Am. Bull.* **100**, pp. 257–273.
- Olsen, J. L. (1982), LLNL, memorandum to E. Keheley concerning Site 300 trichloroethylene sample results.
- Raymond, L. A. (1969), *The Stratigraphy and Structural Geology of the Northern Lone Tree Creek and Southern Tracy Quadrangles, California*, M.S. Thesis, San Jose State College, San Jose, Calif., 143 p.
- Raymond, L. A. (1973), “Tesla—Ortogonalita Fault, Coast Range Thrust Fault and Franciscan Metamorphism, Northwestern Diablo Range, California,” *Geol. Soc. Am. Bull.* **84**, pp. 3547-3562.
- Rueth, L. S., R. A. Ferry, L. K. Green-Horner, and T. DeLorenzo (1998), *Remedial Design Document for the General Services Area Operable Unit Treatment Facilities Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-1274645).
- Sator, F. (1992), personal communication with Michael Wade, project geologist, Weiss Associates.
- Seraydarian, R. (1992), Remedial Project Manager, U.S. EPA, Region IX, San Francisco, Calif., personal communication to L. C. Hall, Environmental Scientist, Environmental Sciences Division, LLNL, regarding use of a 2% frequency of detection criterion for the inclusion or exclusion of contaminants of potential concern in certain environmental media at Lawrence Livermore National Laboratory Site 300, Livermore, Calif., January 27, 1992.
- Stupfel, D. S. (1992), former LLNL TCE-brine system operator and Engineering Technical Associate, personal communication with J. R. Copland, Senior Hydrogeologist, SAIC.
- Taffet, M. J. (1989), *Remedial Investigation of Landfill Pit 8, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, California (UCID-21764).
- Taffet, M. J., and A. L. Lamarre (1989), *Remedial Investigation of Landfill Pit 9, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, California (UCID-21688).
- Taffet, M. J., and J. A. Oberdorfer (1991), *Draft Feasibility Study of the Building 850/East Firing Area, Lawrence Livermore National Laboratory Site 300, April 1991*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-107033).

- Taffet, M. J., L. K. Green-Horner, L. C. Hall, T. M. Carlsen, J. A. Oberdorfer (1996), *Addendum to Site-Wide Remedial Investigation Report Lawrence Livermore National Laboratory Site 300; Building 850/Pit 7 Complex Operable Unit*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-108131 Add 1).
- Taffet, M. J., L. K. Green-Horner, R. J. Woodward, and J. A. Oberdorfer (1997), *Draft Engineering Evaluation/Cost Analysis for the Building 850/Pits 3 and 5 Operable Unit, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-126368DR).
- USDA (1966), *Soil Survey—Alameda Area, California*, by L. E. Welch et al., U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Series 1961, No. 41, 95 pp. plus plates.
- U.S. Department of Energy (DOE) (1982), *Final Environmental Impact Statement, Lawrence Livermore National Laboratory and Sandia National Laboratories—Livermore Sites, Livermore, California*, U.S. Department of Energy, Washington, D.C. (DOE/EIS-0028).
- U.S. DOE (1995a), *Proposed Plan for Remedial Action at the Building 834 Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-118086).
- U.S. DOE (1995b), *Interim Record of Decision for the Building 834 Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-119791).
- U.S. DOE (1997), *Building 832 Canyon Operable Unit Characterization Summary Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.
- U.S. DOE, (1997) *Final Closure Plan for the High Explosives Open Burn Treatment Facility at Lawrence Livermore National Laboratory Site 300*, Livermore, Calif., (UCRL-ID-111753 Rev. 1).
- U.S. DOE (1998a), *Building 854 Operable Unit Characterization Summary Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.
- U.S. DOE (1998b), *Submittal of the Ground Water Tritium Plume Characterization Summary Report for the Building 850/Pits 3 and 5 Operable Unit*, Lawrence Livermore National Laboratory Site 300, U.S. Department of Energy, Oakland Operations Office, Oakland, Calif.
- U.S. Environmental Protection Agency (EPA) (1988), *Superfund Exposure Assessment Manual*, EPA/540/1-88/001, OSWER Directive 9355.3-01, U.S. Environmental Protection Agency, Office of Remedial Response, Washington, D.C.
- U.S. EPA (1989a), *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual, Interim Final*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (EPA/540/1-89/002).
- U.S. EPA (1989b), *Risk Assessment Guidance for Superfund, Vol. II: Human Health Evaluation Manual, Interim Final*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (EPA/540/1-89/001).

- U.S. EPA (1990), *Exposure Factors Handbook*, Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, D.C. (EPA 600-8-89-043).
- U.S. EPA (1991), *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual, Supplemental Guidance—“Standard Default Exposure Factors,”* Interim Final, Office of Emergency and Remedial Response, Toxics Integration Branch, U.S. Environmental Protection Agency, Washington, D.C. (OSWER Directive: 9285.6-03).
- U.S. EPA (1992a), *Health Effects Summary Tables*, Supplement No. 2 to the March 1992 Annual Update, Office of Research and Development, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (OERR 9200.6-303 [92-3]).
- U.S. EPA (1992b), *Integrated Risk Information System (IRIS)*, an electronic database maintained by the U.S. Environmental Protection Agency, Office of Research and Development, Environmental Criteria and Assessment Office, Cincinnati, Ohio.
- U.S. EPA (1992c), *Health Effects Assessment Summary Tables, FY-1992 Annual*, Office of Research and Development, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (OHEA ECAO-CIN-821).
- U.S. EPA (1993), Memorandum from D. Stralka, Ph.D., U.S. Environmental Protection Agency Region IX, to L. Tan, Remedial Project Manager, U.S. Environmental Protection Agency Region IX, regarding a “Technical request from Linda Hall at Lawrence Livermore National Laboratory” for toxicity values for PCE, TCE, and tetrahydrofuran, dated February 25, 1993.
- USGS (1992), “WATSTORE” *a computerized database of ground water quality data, selected data obtained for the Central Valley of California*, United States Geological Survey, Water Resources Division, Sacramento, Calif.
- Webster-Scholten, C. P., Ed. (1994), *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-108131).
- Wentworth, C. M., and M. D. Zoback (1989), “The Style of Late Cenozoic Deformation at the Eastern Front of the California Coast Ranges,” *Tectonics* **8**, pp. 237–246.
- Ziagos, J. and E. Reber-Cox (1998), *Ground Water Tritium Plume Characterization Summary Report for the Building 850/Pits 3 & 5 Operable Unit*, Lawrence Livermore National Laboratory Site 300, Lawrence Livermore National Laboratory, Livermore, Calif.