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Remedial Design Report No. 3 for Treatment Facilities D and E Lawrence Livermore National Laboratory Livermore Site

March 1, 1994

Technical Editors

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Environmental Protection Department

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Summary

This is the third of six reports that describe plans for implementing ground water and soil cleanup at the Lawrence Livermore National Laboratory (LLNL) Livermore Site. The sixth report, for the Building 518 Area in the southeastern part of the Livermore Site, was added in December 1993 in consultation with the regulatory agencies.

The cleanup has been divided into six geographic areas. The U.S. Department of Energy (DOE) and LLNL are preparing these reports, called Remedial Design reports, over a 3-year period. The cleanup plans described in each report are designed to optimize the overall site cleanup and be consistent with projected funding levels. The overall cleanup approach for the LLNL Livermore Site is explained in the Remedial Action Implementation Plan (Dresen *et al.*, 1993), which can be found in the Information Repositories located at the LLNL Visitors Center and at the Livermore Public Library.

This Remedial Design report is for Treatment Facilities D and E in the central part of the Livermore Site. This report discusses the treatment facility equipment, and the associated extraction wells and piezometers. The extraction wells are used to pump ground water to the treatment facility, and piezometers are used to measure water levels at various depths and horizontal distances from the extraction wells. Monitoring the water levels in piezometers provides information about the size of the area being affected by the extraction wells.

In addition, this Remedial Design report discusses the results of a soil-vapor extraction test at Building 518 in southeastern LLNL.

Treatment Facility D

Treatment Facility D will treat ground water in the northeast part of the Livermore Site. The main ground water contaminants in that area are the volatile organic compounds trichloroethylene, trichlorofluoromethane, perchloroethylene, chloroform, 1,1-dichloroethylene, carbon tetrachloride, 1,2-dichloroethane, and trichlorotrifluoroethane. Chromium is also locally present in ground water in the area.

Treatment Facility D will consist of an air stripper and an ion-exchange unit. Ground water will be pumped from the extraction wells to the air stripper tank. As the water passes through the tank, a large blower aerates the water and strips the volatile compounds from it. The volatile organic compounds are released into the air inside the tank, and are collected by filtering the air through granular activated carbon. The air stripper will remove all of the above-described compounds from the ground water except for chromium, which will be removed by an ion-exchange unit. In ion exchange, water is pumped through a fixed bed of ion-exchange resin, where the chromium ions are removed by exchanging them for nonhazardous ions in the resin.

Treatment Facility D will be designed to remediate up to 70 gallons per minute of ground water. As many as 13 ground water extraction wells and associated piezometers are planned to supply water to this facility. The extraction wells will be placed to remove the highest concentrations and stop further migration of concentrations above about 100 parts per billion. Treated ground water from this facility will be discharged to the Drainage Retention Basin in the central part of the Livermore Site. Any contaminants that remain in the treated water will be at or below the limits set by the California Regional Water Quality Control Board, as specified in Waste Discharge Requirement Order No. 91-091. This order is included in Appendix A of this report.

Treatment Facility D is scheduled to begin operating in September 1994. The estimated total design and construction cost of the facility is about $1,600,000.

Treatment Facility E

Treatment Facility E will treat ground water in the southeast part of the Livermore Site. The main ground water contaminants are trichloroethylene, perchloroethylene, chromium, chloroform, 1,1-dichloroethylene, carbon tetrachloride, 1,2-dichloroethane, and trichlorotrifluoroethane. Treatment Facility E will treat ground water using an ultraviolet/hydrogen peroxide treatment system, followed by air stripping. The ultraviolet/hydrogen peroxide treatment involves the destruction of organic compounds using ultraviolet light and a strong oxidizer, such as hydrogen peroxide, to break chemical bonds. The ultraviolet/hydrogen peroxide system reduces most volatile organic compounds to concentrations below discharge limits. The air stripping unit further reduces the remaining volatile organic compounds to concentrations below discharge limits. Granular activated carbon will be used to remove volatile organic compounds from the air stripper vapors. The ultraviolet/hydrogen peroxide unit and the air stripper will remove all of the above-described contaminants from the ground water except for chromium, which will be removed by an ion-exchange unit.

Treatment Facility E will be initially designed to remediate up to 70 gallons per minute of ground water. As many as 17 ground water extraction wells and associated piezometers are planned to supply water to this facility. The extraction wells will be placed to remove the highest concentrations and stop further migration of concentrations above about 100 parts per billion. Treated ground water from this facility will be discharged to the Drainage Retention Basin in the central part of the Livermore Site. Any contaminants that remain in the treated water will be at or below the limits set by the California Regional Water Quality Control Board, as described in Waste Discharge Requirement Order No. 91-091.

Treatment Facility E is scheduled to begin operating in September 1994. The estimated total design and construction cost of the facility is about $1,500,000.

Elements Common to Both Facilities

If it is shown that hexavalent chromium in the ground water is naturally occurring, and the regulatory agencies concur that treated water from Treatment Facilities D and E can be reinjected, ion-exchange treatment may be bypassed. Reinjection will comply with the California Non-Degradation Policy (State Water Resources Control Board Resolution No. 68-16). All injected fluids must also be within hydraulic control of an extraction well.

DOE/LLNL will sample for volatile organic compounds and chromium and monitor water levels in the wells and piezometers around Treatment Facilities D and E. This information will be used to monitor the progress of the cleanup and determine the size and shape of the area being affected by the extraction wells. Results of all treatment system, extraction well, and piezometer monitoring will be included in the LLNL Monthly, Quarterly, and/or Annual Reports.

DOE/LLNL will manage the extraction wellfield by varying the rates and locations of ground water extraction. The goal is to maximize the rate of volatile organic compound mass removal, and ensure remediation in all portions of the plume that exceed drinking water standards. In addition, DOE/LLNL are evaluating reinjection of the treated water, possibly in conjunction with the use of heat, surfactants and/or microbes, and cyclic pumping, to accelerate the cleanup.

Appendices to this report contain the Quality Assurance and Health and Safety Plans for the operation and maintenance of Treatment Facilities D and E. The appendices also contain the effluent discharge permits and sampling procedures for Treatment Facilities D and E. The Quality Assurance/Quality Control and Health and Safety Plans for construction were presented in Remedial Design Report No. 1 (Boegel *et al.*, 1993).

Building 518 Soil-Vapor Treatability Test

A test was conducted in June 1993 to collect data for designing a soil-vapor extraction and treatment system to clean up volatile organic compounds in a localized area above the water table in the Building 518 Area in the southeastern part of the Livermore Site. Trichloroethylene is the primary compound of concern in this area. Soil-vapor extraction is somewhat similar to ground water extraction discussed above, in that the contaminants are removed from the subsurface and treated prior to discharge. For the extraction test, a vacuum was applied to remove vapors from the soil using a well completed above the water table, and the vapor was treated by filtering it through granular activated carbon. This test indicates that vapor extraction can effectively remove trichloroethylene vapor and that granular activated carbon can successfully treat the extracted vapor. The data from the test will be used to design a soil-vapor extraction and treatment system for the Building 518 Area.

1. Introduction

This report is the third of six Remedial Design (RD) reports for the Lawrence Livermore National Laboratory (LLNL) Livermore Site, which is located about 40 miles east of San Francisco, California (Fig. 1). The sixth report, for the Building 518 Area in the southeastern part of the Livermore Site, was added in December 1993 in consultation with the regulatory agencies. This RD report is for Treatment Facility D (TFD) and Treatment Facility E (TFE) and their respective extraction wells and piezometer networks. A brief discussion of the extraction wells and piezometers added to the Treatment Facility C (TFC) area is also included. As required by the Remedial Action Implementation Plan (RAIP) (Dresen *et al.*, 1993), this RD report also describes the Building 518 Area vapor extraction treatability test. Subsequent RD reports will cover the remaining planned treatment facilities and their extraction well and piezometer networks. The six RD reports are being prepared over a 3-year period according to the schedule in the RAIP for the Livermore Site. As described in the RAIP, the remedial actions presented in the Record of Decision (ROD) for the Livermore Site (DOE, 1992) will be phased-in over a 3-year period to be consistent with projected funding levels, and to enable determination of the actual, rather than predicted, effectiveness of the planned extraction and treatment systems before proceeding with subsequent phases.

The Livermore Site was placed on the U.S. Environmental Protection Agency's (EPA's) National Priorities List in 1987. In November 1988, the U.S. Department of Energy (DOE), EPA, the California Department of Toxic Substances Control (DTSC), and the California Regional Water Quality Control Board (RWQCB) signed a Federal Facility Agreement (FFA) to facilitate compliance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended. As part of the CERCLA process, the LLNL Environmental Restoration Division (ERD) has prepared a series of documents: the Remedial Investigation (RI) (Thorpe *et al.*, 1990) characterized the site hydrogeology and contaminant distribution; the Feasibility Study (FS) (Isherwood *et al*., 1990) screened and evaluated possible remedial alternatives; the Proposed Remedial Action Plan (Dresen *et al*., 1991) further evaluated conceptual remedial alternatives and recommended particular alternatives for ground water and soil cleanup; the ROD (DOE, 1992) codified and bound DOE and EPA to a cleanup approach for ground water and soil; and the RAIP (Dresen *et al*., 1993) presented the cleanup approach and a schedule for the remaining remedial actions.

As discussed in the ROD, the contaminants of concern at the Livermore Site are volatile organic compounds (VOCs), primarily trichloroethylene (TCE) and perchloroethylene (PCE); fuel hydrocarbons (FHCs), including benzene; tritium; and perhaps chromium and lead. VOCs and, possibly, chromium are the only chemicals of concern at TFD and TFE. The Applicable or Relevant and Appropriate Requirements (ARARs) for the Livermore Site are detailed in the FS (Isherwood *et al.*, 1990) and the ROD (DOE, 1992).

The scope and format of this report are based on EPA guidance documents (EPA, 1989; 1990), an outline provided by the EPA (Gill, 1993), and subsequent discussions with EPA. As specified by EPA, each RD report contains engineering design specifications for the ground water extraction and treatment systems, including piping and instrument diagrams (P&IDs),

Figure 1. Location of the LLNL Livermore Site

system descriptions, monitoring and construction schedules, and cost estimates. The RD reports also include a Remedial Action Work Plan that contains Quality Assurance/Quality Control (QA/QC) Plans and Health and Safety Plans for operation and maintenance, and the requirements for offsite shipment of hazardous waste and for project closeout. The QA/QC and Health and Safety Plans for construction are the same for all RD reports. Therefore, these documents were submitted only with Remedial Design Report No. 1 (RD1) (Boegel *et al*., 1993).

This document was prepared by LLNL for DOE with oversight from the EPA, the DTSC, and the RWQCB. The six RD reports are primary documents under the FFA for the Livermore Site.

Sections 2 and 3 of this report are the remedial designs for TFD and TFE, respectively. Section 4 is the Remedial Action Work Plan for TFD and TFE. Section 5 presents the results of the Building 518 Area vapor extraction treatability test. Appendices A through D present the waste discharge permits, the Operations and Maintenance (O&M) QA/QC and Health and Safety Plans, and sampling procedures for TFD and TFE, respectively.

2. Remedial Design for Treatment Facility D

2.1. TFD Design Summary

TFD will be a ground water treatment facility located in the northeastern quadrant of the Livermore Site (Fig. 2). Ground water in the TFD vicinity will be extracted to remove VOCs near the East Traffic Circle Area (Fig. 2). The principal compounds of concern are, in order of highest average concentration (see Table 3, Section 2.2.2.1), TCE, trichlorofluoromethane (Freon 11), PCE, 1,2-dichloroethane (1,2-DCA), carbon tetrachloride, 1,1-dichloroethylene (1,1-DCE), hexavalent chromium, chloroform, 1,1-DCA, Freon 113, and 1,2-DCE. Six VOCs exceed their respective Maximum Contaminant Levels (MCLs): TCE, PCE, 1,2-DCA, carbon tetrachloride, 1,1-DCE, and Freon 11. TFD will consist of a commercially available air stripper to treat VOCs and a commercially available ion-exchange unit to remove chromium. The ion-exchange unit may be bypassed if the regulatory agencies concur that hexavalent chromium is naturally occurring, and if reinjection complies with the State Water Resources Control Board (SWRCB) Resolution No. 68-16 (the Non-Degradation Policy). All reinjected fluids must also be within hydraulic control of an extraction well. The air stripper effluent air stream will be passed through granular activated carbon (GAC) to remove VOCs from the air. The treated ground water will be either discharged through a pipeline to the Drainage Retention Basin, located approximately 200 ft south of the treatment facility (Fig. 2); reinjected; and/or used at LLNL for landscape irrigation. TFD will meet the discharge requirements specified in RWQCB Waste Discharge Requirement (WDR) Order No. 91-091 [National Pollutant Discharge Elimination System (NPDES) Permit No. CA 0029289] (Appendix A).

Figure 2. Planned ground water extraction locations for TFD and TFE

2.2. Design Specifications

Design specifications for the TFD extraction wells and piezometers and for the treatment facility are described in Sections 2.2.1 and 2.2.2, respectively.

2.2.1. Extraction Wells and Piezometers

The hydrostratigraphic analyses for the TFD and TFE areas are presented in Section 2.2.1.1. Extraction well and piezometer locations and design are discussed in Sections 2.2.1.2 through 2.2.1.4.

2.2.1.1. Hydrostratigraphic Analyses

2.2.1.1.1. Basis for Defining Hydrostratigraphic Units

For this Remedial Design report, hydrostratigraphic units were defined and used to design the TFD and TFE wellfields. In previous RD reports, water-bearing zones were used to assist in the wellfield design. The use of hydrostratigraphic units reflects ongoing work to interpret and synthesize the Livermore Site hydrogeology on a site-wide scale, and is a natural progression from the use of borehole-specific water-bearing zones to more regional interpretations. The progression from use of water-bearing zones to hydrostratigraphic units is discussed further below.

A water-bearing zone is defined as saturated permeable sediment greater than about 3 ft thick, separated from other permeable sediments above and below by at least 5 ft of low-permeability sediment. The water-bearing zones are numbered consecutively downward from the ground surface at each borehole. During the hydrogeologic investigation conducted for this report, it was determined based on pumping tests, chemical data, and geologic correlations, that several of the water-bearing zones in the TFD and TFE areas are interconnected hydraulically. Therefore, hydrostratigraphic units are defined by grouping sediments together on the basis of their hydraulic properties.

Six hydrostratigraphic units have been defined in the TFD and TFE areas (Fig. 3). Aquifer test analyses, soil and ground water chemical data, geologic core descriptions, and geophysical borehole logs were analyzed to define the six hydrostratigraphic units. VOC distribution and aquifer properties within these units were analyzed to select the best preliminary extraction well and piezometer locations. The primary purpose of TFD and TFE extraction wells was to expedite cleanup by maximizing VOC mass removal.

Twelve cross sections showing hydrogeologic descriptions, geophysical logs, and soil and ground water chemical concentrations were constructed across the TFD and TFE areas to correlate the hydrostratigraphic units. Hydraulic communication data from pumping tests were also incorporated into the cross sections. Maps showing geologic structure, unit thickness, hydraulic communication, VOC and/or tritium concentrations, and the potentiometric surface were then constructed for each individual hydrostratigraphic unit. The location and screened interval of each extraction well and piezometer in the TFD and TFE area were determined by synthesizing data on these maps as described in Sections 2.2.1.2 and 3.2.1.1.

Figure 3. Planned TFD area extraction well and piezometer locations

Subsequent RD reports will also utilize the hydrostratigraphic unit approach to describe the hydrogeology on a more regional, rather than borehole-specific, basis. DOE/LLNL will make available project files containing this hydrogeologic information upon request to Bert Heffner, the LLNL Area Relations Manager. After completion of all RD reports, a report is planned that will summarize the detailed analysis on which the hydrostratigraphy is based. Preliminary wellfield designs presented in RD reports may be modified based on new information or interpretations presented by DOE/LLNL staff or regulatory agencies.

2.2.1.1.2. Hydrostratigraphic Units in the TFD and TFE Areas

Figure 3 is a conceptual model of the hydrostratigraphic units defined for the TFD and TFE areas (Fig. 4 in Section 2, and Fig. 7 in Section 3 show the TFD and TFE areas). The first hydrostratigraphic unit (Unit 1) is a 30- to 50-ft thick interval of interbedded sand, silt, and gravel. The top of this unit ranges from about 60-ft depth in the east to 100 ft in the west, reflecting the general westward dip of the sediments in the TFD and TFE areas. High resistivity geophysical log response and generally low gamma ray response is typical for this unit. Good hydraulic communication is seen in long-term aquifer tests that show about 0.5 ft of drawdown between the sandy interbeds of this unit over distances of about 400 ft. However, this unit is unsaturated over a large portion of the TFE area.

The second hydrostratigraphic unit (Unit 2) occurs between depths of about 80 and 140 ft. Unit 2 consists predominantly of low-permeability clayey silt, silty clay, and clayey sand with laterally discontinuous interbeds of sand and sandy gravel. Sandy interbeds are more prevalent in the TFE area where Unit 2 is usually the first saturated zone. The contact between Units 1 and 2 is marked by a change to predominantly fine grained sediments in Unit 2. The geophysical logs reflect this change as an increased gamma ray response and a reduced resistivity log response compared to Unit 1. Aquifer tests indicate limited lateral and vertical communication between wells screened within Unit 2, and with wells screened in the units above or below. However, localized coarser grained interbeds show about 0.1- to 0.2-ft drawdown over distances of 400 ft during pumping tests. The dissimilarity of VOC concentrations and distributions in Units 1 and 2 further indicates these intervals are discrete hydrostratigraphic units.

The third hydrostratigraphic unit (Unit 3) is a 1- to 15-ft-thick sequence of silt, sand, and sandy gravel found only in the TFE area. Based on geologic, VOC concentration, and aquifer test data, the characteristics of this unit vary from east to west. In the eastern part of the TFE area, the coarse-grained deposits within this unit are laterally separated by finer grained sediments (Fig. 3). Toward the west, 48-h pumping tests show about 0.5 ft of drawdown over distances of 500 ft, indicating greater lateral continuity for the coarser grained sediments. In addition, pumping tests in the western TFE area show localized areas of hydraulic communication with Unit 4, thus indicating that coarse-grained sediments of Units 3 and 4 communicate hydraulically as shown in Figure 3.

The fourth hydrostratigraphic unit (Unit 4) is a laterally continuous, high-permeability, sand and gravel unit that occurs on top of the Lower Member of the Livermore Formation. Unit 4 ranges in thickness from about 2 to 25 ft. The top of Unit 4 is typically found at depths ranging from 130 to 150 ft. Geophysical logs and geologic core descriptions indicate this unit is thickest along a north-south trend in the western TFD and TFE areas. Pumping tests demonstrate a high degree of lateral hydraulic continuity within Unit 4 across the entire TFD and TFE areas, particularly in a north-south direction. Over 1- to 3-ft of drawdown has been observed in wells over 1,000 ft from the pumping well. High flow rates [>30 gallons per minute (gpm)] have also been observed in wells completed in this unit during long-term aquifer tests. Unit 4 thins toward the east where higher VOC concentrations occur.

The fifth hydrostratigraphic unit (Unit 5) is the uppermost part of the Lower Member of the Livermore Formation. This unit is equivalent to the transition zone (Tpl-t) between the Upper and Lower Members of the Livermore Formation as described in the RI (Thorpe *et al.*, 1990). Unit 5 is about 20- to 50-ft thick, and its top occurs between the 150- to 180-ft depth. Unit 5 consists predominantly of fine-grained, mottled greenish-gray to yellow-brown silt and clay with interbeds of silty to clayey gravel and sand. A laterally continuous sand layer forms the base of this unit over much of the TFD and TFE areas. Elevated gamma ray response accompanied by a subdued resistivity response are typical of Unit 5 fine sediments. The basal sand layer exhibits a low gamma ray response and a high resistivity response. Pumping tests from wells completed in the basal sand layer indicate about 0.5 ft of drawdown over distances of 500 ft.

The upper portion of the sixth hydrostratigraphic unit (Unit 6) consists of a light-green silty clay to clayey silt, with minor interbeds of clayey sand and gravel. The silty clay and clayey silt form a regional confining layer in the LLNL area. This unit is equivalent to the green unit (Tpl-g) in the Lower Member of the Livermore Formation as described in the RI (Thorpe *et al.*, 1990). Elevated gamma ray response reflects the higher clay content within this unit. Based on field descriptions and laboratory tests, the clay unit exhibits very low permeability, on the order of 10^{-7} to 10^{-8} centimeters per second. Limited data indicate that laterally continuous, high-permeability gravel lenses occur below this clay layer.

In the TFD area, three of the six hydrostratigraphic units contain VOCs in concentrations exceeding MCLs. Unit 3 does not occur in the TFD area, and the fifth and sixth Units do not contain VOCs in concentrations above an MCL. In several portions of the TFD area, units 1, 2, and 4 contain total VOC concentrations greater than 100 parts per billion (ppb). Ground water in the TFE area contains over 6,000 ppb total VOCs, consisting primarily of TCE. Although the highest VOC concentrations occur in the second and fourth hydrostratigraphic units, VOC concentrations above MCLs occur locally in all the saturated units in the TFE area. As described below, the primary purpose of extraction wells planned in the TFD and TFE areas is to maximize VOC mass removal.

2.2.1.2. Extraction Well Location and Design

To estimate the hydraulic capture areas of the 24 ground water extraction locations shown in the RAIP, ground water flow paths were calculated using the numerical model CFEST (Coupled Fluid, Energy, and Solute Transport; Gupta *et al.,* 1987). Ground water extraction at the 24 extraction locations, and recharge at 2 injection locations, the TFA Recharge Basin and the TFB and TFC drainage ditches, were simulated using the two-dimensional numerical flow model. The results of the simulation are shown in Figure 4.

Previous estimates of ground water capture zones presented in the ROD (DOE, 1992) and the RAIP (Dresen *et al.,* 1993) were calculated using the two-dimensional analytical flow model CAPTURE (McEdwards, 1986). Unlike the previous CAPTURE model, the CFEST results shown in Figure 4 incorporate the effects of aquifer recharge and heterogeneities such as varying

Figure 4. Extraction well hydraulic capture zones and recharge well locations for the 24 initial extraction wells

permeability and aquifer thickness. The development and results of the CFEST model are discussed in more detail in Tompson *et al.* (1994, in press).

As stated in the RAIP (Dresen *et al.,* 1993), extraction locations 11 and 12 will supply ground water to TFD (Fig. 2). In addition, further analysis conducted since the RAIP for this RD indicated that it would be more cost-effective for TFD, rather than TFE, to treat ground water from extraction location 20 because of the shorter pipeline distance. In the RAIP, water from extraction locations 10 and 21 was shown piped to either TFD or TFC. However, due to relatively higher concentrations of chromium, water from these extraction locations will be piped to TFC.

A total of 12 extraction wells are planned at locations 11, 12, and 20. This total is higher than initially estimated because additional analysis indicates that more wells are necessary to efficiently remove VOC mass and capture VOC concentrations above 100 ppb. Four of these wells are currently installed, and the remaining eight wells are tentatively planned for phased installation in the future. The phased-in approach will help to determine the actual effectiveness, compared to the predicted effectiveness, of the initial planned extraction wells and treatment systems before proceeding with subsequent phases. Design specifications for the TFD extraction wells are shown in Table 1, and proposed TFD extraction well and piezometer locations are shown in Figure 5. The construction of the extraction wells will follow the design principles specified in the RAIP.

TFD area extraction well locations are based on ground water modeling results [Chapter 3 and Appendix B in Isherwood *et al.* (1990); Tompson (1990); Tompson *et al.* (1991), and Tompson *et al.* (1994, in press)]; local hydrogeology (Thorpe *et al.* 1990; Isherwood *et al.* 1990); and isopach (thickness), structure contour, and isoconcentration maps prepared for this RD. Because the TFD area is located in the interior of the Livermore Site and extraction wellfields for Treatment Facilities B and C are downgradient of the TFD area VOC plumes, the remedial strategy for TFD differs from that described in previous RD reports. Rather than position extraction wells to capture plume margins, the primary purpose of TFD extraction wells is to enhance mass removal by extracting ground water from areas where VOC concentrations exceed 100 ppb. The areas where one or more VOCs exceed an MCL, 100 ppb total VOCs and 1,000 ppb total VOCs, are shown on Figure 5.

Extraction location 11, as shown in Figure 5, is different from that shown in the RAIP (Dresen *et al*., 1993). Two additional extraction wells are planned for installation in phases at this location (Fig. 5). EW-11-1A (MW-423), located west of Building 482, will capture a Freon 11 plume in the first hydrostratigraphic unit where concentrations exceed 1,000 ppb. EW-11-1B is located near the downgradient side of the 100 ppb total VOC contour of a first hydrostratigraphic unit VOC plume originating northwest of the Drainage Retention Basin. EW-11-1B is positioned to hydraulically control the leading edge of the 100 ppb contour. Total VOC concentrations are expected to range between 100 and 200 ppb in EW-11-1B.

Five extraction wells are planned for the portion of extraction location 11 located north of the Drainage Retention Basin (Figs. 2 and 5), consisting of four new wells and one existing well. This area contains the highest VOC concentrations in the TFD area (up to 7,000 ppb total VOCs). TCE and carbon tetrachloride are the principal constituents comprising the ground water plume located north of the Drainage Retention Basin. Total VOCs over 1,000 ppb are detected

Table 1. TFD extraction well specifications.

Well name	Extraction well name[a]	Well design[b]	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval (ft)	Sand-pack interval (ft)	Hydro-stratigraphic unit[c]	Estimated maximum long-term steady state yield (gpm)[d]	Pump type[e]	Pump intake depth (ft)	Activation priority[f]
Extraction Location 10[g]												
TBI	EW-10-1	Single	—	(112)	(111)	(95-110)	(93-111)	First	20	—	103	14
Extraction Location 11												
MW-423	EW-11-1A	Single	9-Sep-88	308.0	118.0	106-118	103-122	First	20	25S20-11	112	12
TBI	EW-11-1B	Single	—	(142)	(141)	(130-140)	(128-141)	First	(15)	—	(135)	11
TBI	EW-11-1C	Multiple w/ seal	—	(107)	(106)	(65-105)	(63-106)	First	(6)	—	(90)	4
TBI	EW-11-1D	Multiple w/ seal	—	(107)	(106)	(65-105)	(63-106)	First	(6)	—	(90)	5
MW-906	EW-11-1/2	Single	27-Jul-93	200.0	132.0	58-132	47.5-132	First & Second	10	—	(125)	2
MW-351	EW-11-4A	Single	17-Oct-86	191.0	151.0	(146-152)	145-152	Fourth	5	10S05-9	148	1
MW-907	EW-11-4/5	Multiple w/ seal	30-Aug-93	239.0	220.0	172.7-186.8 204.5-215.0	165-195 200-222	Fourth & Fifth	25	—	(210)	4
Extraction Location 12												
TBI	EW-12-1	Single	—	(87)	(86)	(65-85)	(63-86)	First	(10)	—	(75)	9
TBI	EW-12-2	Single	—	(122)	(121)	(100-120)	(98-121)	Second	(5)	—	(110)	10
Extraction Location 20												
MW-119	EW-20-1	Single	2-Aug-85	139.0	102.5	87.5-102.5	86-103	First	(5)	10S05-9	95	6
TBI	EW-20-2	Single	—	(142)	(141)	(125-140)	(123-141)	Second	(5)	—	(133)	7
TBI	EW-20-4	Single	—	(157)	(156)	(145-155)	(143-156)	Fourth	(15)	—	(150)	8
Extraction Location 21[g]												
MW-317	EW-21-1	Single	20-Apr-87	100.0	95.0	88-95	87-96	First	8	10S05-9	92	13

Notes:

TBI = To be installed.

Estimates are shown in parentheses.

[a] Extraction well name indicates location as shown in Figure 4 (i.e., EW-11-1A is at extraction location 11), and the hydrostratigraphic unit monitored (i.e., EW-11-1A is screened in the first unit). When multiple extraction wells are screened in the same hydrostratigraphic unit, a letter follows the unit designation (i.e., EW-11-1A, EW-11-1B, etc.). Figure 5 shows planned extraction well locations.

[b] The two extraction well designs are:

single = a well screened and sand-packed in only one water-bearing zone.
multiple w/seal = a well screened and sand-packed in more than one water-bearing zone with annular grout seals between screened zones. If cross contamination in any multiple-screened well becomes a concern, packers can be placed between the screened intervals during periods of inactivity.
Additional information regarding these well designs and their applications is presented in the RAIP (Dresen *et al.*, 1993).

Table 1. (Continued.)

[c] Numbered consecutively downward from ground surface at each extraction location. A hydrostratigraphic unit is defined as a sequence of sediments grouped together on the basis of hydraulic properties, geologic data, and/or chemical data.

[d] Estimated yield based on pumping test results. Actual long-term pumping rates will generally be lower. Where an extraction well is not yet installed, estimates of sustainable flow rates are shown in parentheses. These rates are based on the flow rates from nearby wells screened in similar zones and/or thickness and estimated permeability of sediments in the area.

[e] Pump type currently installed. All are Grundfos stainless steel submersible pumps. Nominal pump flow rates are 25S20-11 = 2 horsepower (hp), 20 gpm at 250-ft head; 10S05-9 = 0.5 hp, 8 gpm at 200-ft head.

[f] Activation priority is the estimated order in which extraction wells will be connected to the treatment facility. Activation priority is based on whether the well currently exists, engineering design and cost, and the known or anticipated VOC concentrations in ground water at the extraction locations.

[g] The extraction wells at locations 10 and 21 will supply water to Treatment Facility C, as discussed in Section 2.2.1.2.

Figure 5. Conceptual TFD and TFE area hydrostratigraphy

in the first, second, and fourth hydrostratigraphic units, and concentrations have generally increased with time. Extraction wells EW-11-1A, EW-11-1B, EW-11-2, and EW-11-4B are located to maximize VOC mass removal from their respective hydrostratigraphic units. Concentrations exceeding 1,000 ppb are anticipated in all four of the planned extraction wells. EW-11-C, EW-11-D, and EW-11-4B will be multiple screened wells, completed within a single hydrostratigraphic unit, with grout seals between the screens. Consistent with the RAIP, these multiple screened wells will be constructed only where total VOC concentrations are within about one order of magnitude. Finer grained intervals will not be screened in these three wells to mitigate introducing fine-grained sediments into the treatment system.

TCE and carbon tetrachloride concentrations of 20 and 3.3 ppb, respectively, exceed their respective MCLs in nearby monitor well MW-370. Because these concentrations are below the 100-ppb guideline used to site VOC source control wells, this well will be monitored to determine whether the currently planned extraction wells are effectively remediating this interval in this area. If not, MW-370 may be used as an extraction well in the future.

Two new extraction wells are planned for installation in phases at extraction location 12. Extraction wells EW-12-1 and EW-12-2 are located to maximize VOC mass removal in the first and second hydrostratigraphic units west of the East Traffic Circle (Figs. 2 and 5). Lithologic and chemical data from monitor wells and source investigation boreholes were used to site these wells downgradient of the areas of highest VOC concentrations. The primary VOCs of concern in this area are PCE, TCE, 1,1-DCE, and 1,2-DCA, which comprise the plume originating from the East Traffic Circle Area. In this area, total VOC concentrations in the first two hydrostratigraphic units range from 100 to 500 ppb; however, total VOC concentrations have previously been about 2,000 ppb.

One existing and two planned extraction wells located immediately south of the Drainage Retention Basin are proposed for extraction location 20. Extraction well locations EW-20-1 (MW-119), EW-20-2, and EW-20-4 are positioned to maximize VOC mass removal in the first, second, and fourth hydrostratigraphic units. VOC concentrations have increased in monitor wells in this area over the past few years. For example, total VOC concentrations in MW-361 have increased from about 1,000 ppb in 1987 to about 4,000 ppb in 1992. The primary VOCs near extraction location 20 are TCE, carbon tetrachloride, 1,1-DCE, PCE, and 1,2-DCA. This chemical signature is a combination of VOCs present at extraction locations 11 and 12, suggesting that VOCs originating from the East Traffic Circle may commingle with VOCs north of the Drainage Retention Basin at this location. Total VOC concentrations over 1,000 ppb are expected in EW-20-2, and concentrations between 500 and 1,000 ppb are expected in EW-20-1 and EW-20-4 based on VOC concentrations in nearby monitor wells.

In the RAIP (Dresen *et al.*, 1993), the influent flow rate for TFD was estimated at 70 gpm as shown in Figure 2. The more detailed analyses conducted for this RD report indicate that sustainable extraction flow rates may be higher. Higher flow rates may result from installing more extraction wells than originally estimated, as discussed above. In addition, a properly designed extraction well will have a higher well efficiency and perhaps a longer screened interval than most of the existing monitor wells. Therefore, flow rates higher than those observed from hydraulic tests conducted on the existing monitor wells may be expected. Table 1 shows estimates of the maximum sustainable yields from each TFD extraction well that are based on the most recent hydraulic and hydrogeologic data. Because long-term pumping data are relatively limited, the estimates in Table 1 probably represent upper bounds for steady-state yields. These upper bounds are shown on Table 1 so that pumps with adequate capacity can be installed. The estimated maximum long-term steady-state yields of the TFD area wells in Table 1 total 133 gpm. In most cases, as long-term ground water extraction progresses, flow rates will decline as shallow sediments dewater, distant hydraulic boundaries are encountered, pumping of other wells in the vicinity begins, and/or local gradients decrease. Based on long-term pumping from extraction well EW-415 in southwestern LLNL, the long-term yield of these wells may actually be about 63 to 84 gpm. As discussed in Section 2.2.2, TFD will be designed to treat an initial flow of 70 gpm, with the flexibility to expand to accommodate larger flows, if needed.

Pumping in the TFD area will begin at EW-11-4A as soon as piping to TFD is completed. Additional wells will begin pumping as funding allows. Extraction flow rates and ground water elevation and chemistry data will be collected to determine if the planned extraction scenario is capturing the 100 ppb total VOC contour. If actual flow rates are substantially lower and result in incomplete capture of water within the 100 ppb contour, additional extraction wells may be installed. The locations of any new wells would be based on field water level data and recalibrated modeling results.

2.2.1.3. Piezometer Location and Design

Piezometers near the extraction wells will be monitored to determine the extents of hydraulic capture zones and identify potential areas of little or no ground water flow. The primary objective of the TFD remedial wellfield design is to maximize VOC mass removal. Therefore, the TFD area piezometer configuration has been designed to monitor the cumulative drawdowns for each TFD area hydrostratigraphic unit, rather than the drawdown achieved by each individual extraction well. Thus, some piezometers monitor multiple extraction wells, including some of the TFE extraction wells.

TFD area piezometer locations, shown in Figure 5, were based primarily on information from hydraulic test data. In areas where low sustainable yields are anticipated, additional piezometers are planned within about 100 ft of the extraction wells. Whenever possible, existing monitor wells were incorporated into the piezometer network. Up to 36 piezometers are planned for installation in phases at the TFD area. Preliminary design specifications for the additional piezometers, along with the design specifications of the existing piezometers, are shown in Table 2. The planned piezometers include 25 existing and 11 new piezometers. These new piezometers will be installed in phases in the future. A discussion of the ground water chemistry monitoring plan for the TFD monitoring network is presented in Section 4.2.2.

2.2.1.4. Additional Treatment Facility C Extraction Wells and Piezometers

As discussed in Section 2.2.1.1, extraction locations 10 and 21 will be connected to TFC rather than TFD. The TFC design was presented in Remedial Design Report No. 2 (Berg *et al.*, 1993). One extraction well is planned for the first hydrostratigraphic unit at both extraction locations 10 and 21. Data from deeper intervals indicate that VOC concentrations are below MCLs. The primary VOCs in ground water in this area are TCE, 1,1-DCE, and chloroform, a

Table 2. TFD piezometer specifications.

Well name	Piezometer name [a]	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval[b] (ft)	Sand-pack interval (ft)	Approximate flow rate (gpm)	Activation priority[c]
Extraction Location 10[d]								
MW-320	P-10-1A	11-May-87	106.0	99.0	94-99	91-99	3	40
MW-319	P-10-1B	5-May-87	198.0	125.0	119-125	118-125	25	41
MW-568	P-10-1C	5-Jun-89	156.0	101.0	97-101	94-101	20	42
TBI	P-10-1D	—	(102)	(101)	(90-100)	(88-101)	—	43
Extraction Location 11								
MW-7	P-11-1A	3-Oct-80	110.5	100.5	76-81, 88-98	67.5-103	NA	36
TBI	P-11-1B	—	(92)	(91)	(70-90)	(68-91)	—	35
MW-424	P-11-1C	4-Oct-88	208.0	144.0	137-144	135-144	3	34
MW-316	P-11-1D	15-Apr-87	196.0	71.0	66-72	66-72	3	33
MW-273	P-11-1E	11-Aug-86	203.0	84.0	64-84	62-84	3	32
SIP-HPA-003	P-11-1F	19-Apr-90	91.5	66.0	61-66	57-66	NA	31
MW-313	P-11-1G	12-Mar-87	99.0	85.0	80-85	79-85	5.5	13
MW-412	P-11-1H	18-Apr-88	104.0	74.0	67-74	65-74	2.5	30
MW-411	P-11-1I	12-Apr-88	192.0	138.0	131-138	129-138	16	29
MW-355	P-11-1J	5-Dec-86	202.0	107.0	102-107	100-108	2	6
SIP-HPA-001	P-11-1K	20-Apr-90	92.75	75.0	65-75	61-75	NA	7
TBI	P-11-1L	—	(92)	(91)	(80-90)	(78-91)	—	8
MW-653	P-11-2A	27-Mar-90	225.0	128.0	122-128	121-128	0.5	9
TBI	P-11-2B	—	(132)	(131)	(120-130)	(118-131)	—	10
TBI	P-11-2C	—	(132)	(131)	(120-130)	(118-131)	—	11
MW-311	P-11-2D	20-Feb-87	226.5	147.5	134.5-147.5	132-148	5	12
MW-450	P-11-4A	21-Mar-88	300.0	200.0	193-200	190-200	2	1
MW-312	P-11-4B	5-Mar-87	224.5	168.0	160-168	159-169	25	2
MW-370	P-11-4C	29-May-87	286.0	208.0	196.5-208	191-208	5	3
P-908	P-11-4D	18-Aug-93	239.0	197.0	180-197	177-201	<0.5	4
TBI	P-11-4E	—	(157)	(156)	(145-155)	(143-156)	—	5
Extraction Location 12								
MW-222	P-12-1A	17-Jul-86	197.0	83.0	63-83	61-83	5	24
MW-142	P-12-1B	29-Mar-85	74.2	72.0	62-72	59-72	0.8	25
SIP-EGD-001	P-12-1C	16-Oct-90	101.5	85.0	75-85	73-85	NA	26
TBI	P-12-2A	—	(102)	(101)	(90-100)	(88-101)	—	27

Table 2. Continued.

Well name	Piezometer name [a]	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval[b] (ft)	Sand-pack interval (ft)	Approximate flow rate (gpm)	Activation priority[c]
MW-220	P-12-2B	25-Jun-86	196.0	92.5	82.5-92.5	78-93	<0.5	28
MW-362	P-12-4A	13-Mar-87	151.0	145.0	131-145	129-145	12	21
MW-561	P-12-4B	23-Feb-89	180.0	152.0	143-152	141-152	4	22
TBI	P-12-4C	—	(142)	(141)	(120-140)	(118-141)	—	23
Extraction Location 20								
MW-10A	P-20-1A	8-Sep-80	110.7	110.0	85-95, 100-105	68-110	NA	14
MW-414	P-20-1B	20-May-88	179.0	74.0	69.5-74	67-74	0.5	15
TBI	P-20-1C	—	(102)	(101)	(90-100)	(88-101)	—	16
MW-361	P-20-2A	5-Mar-87	257.0	135.0	125-135	122-135	4	17
TBI	P-20-2B	—	(157)	(156)	(140-155)	(138-156)	—	18
TBI	P-20-2C	—	(132)	(131)	(120-130)	(118-131)	—	19
MW-360	P-20-4	24-Feb-87	260.0	204.5	181.5-204.5	180-205	30	20
Extraction Location 21[d]								
TBI	P-21-1A	—	(102)	(101)	(90-100)	(88-101)	—	37
MW-569	P-21-1B	16-May-89	215.0	138.0	101-109.5	129-138	4	38
TBI	P-21-1C	—	(102)	(101)	(90-100)	(88-101)	—	39

Notes:

NA = Not available.

TBI = To be installed.

Estimates are shown in parentheses.

[a] Piezometer names indicate their location (i.e., P-20-1A is at extraction location 20) and the hydrostratigraphic unit monitored (i.e., P-20-1A is screened in the first unit). Letters following the unit designation indicate that multiple piezometers are screened in that unit.

[b] The perforated interval listed for piezometers not yet installed is the perforated interval of the extraction well they are designed to monitor. These estimates are shown in parentheses. The actual perforated interval will be based on the hydrostratigraphy and chemistry encountered during drilling.

[c] Piezometers are prioritized according to the activation of their associated extraction wells.

[d] The extraction wells at locations 10 and 21 will supply water to Treatment Facility C, as discussed in Section 2.2.1.2.

See Figure 5 for piezometer and extraction well locations.

chemical signature distinct from the rest of the TFD area. EW-10-1 is located along the northeastern side of the West Traffic Circle to hydraulically control and remediate the areas north and east of the West Traffic Circle. EW-21-1 (MW-317) is located at the downgradient edge of the 100 ppb total VOC contour in this area. Initial total VOC concentrations of about 100 ppb are expected in ground water from both of these extraction wells. Extraction wells at locations 10 and 21 could contribute about 28 gpm of the 60 gpm total flow influent to TFC. However, pumping at the maximum flow rate at locations 10 and 21 is a lower priority than that for locations 8 and 9 to the west, which are key locations for achieving western plume margin capture. Therefore, the wells at locations 10 and 21 may be pumped below their maximum rate because achieving rapid plume margin control at the northwestern portion of the site is a higher priority than mass removal in the interior part of the LLNL site.

A total of seven piezometers are planned in the vicinity of extraction locations 10 and 21 in the TFC area. Of these, four are existing wells and three new piezometers are planned.

2.2.2. TFD Specifications, Design, Treatability Test, Controls, and Safeguards

The specifications, design, treatability test, controls, and safeguards for TFD and its associated piping are described in Sections 2.2.2.1 through 2.2.2.3.

2.2.2.1. Specifications and Design

TFD will be designed to treat up to 70 gpm of ground water. As discussed in Section 2.2.1.1., TFD will be designed to accommodate possible higher influent flows if additional extraction wells are necessary or if higher than predicted sustainable wells yields are obtained. TFD will operate during working hours until 24-hr/day operation is technically feasible. VOCs and possibly chromium are the constituents to be remediated at TFD. Design influent concentrations and effluent discharge requirements are shown in Table 3. The design VOC influent concentrations are based on recent data (January 1993) from wells in the newly defined extraction locations, and differ from the estimated total VOC influent concentrations presented in the RAIP (Dresen *et al.*, 1993) and FS (Isherwood *et al.,* 1990). Average influent concentrations were determined by calculating the mass of individual constituents per well, and then dividing the cumulative mass of each constituent from all wells by the combined estimated influent flow rate. Sitewide total chromium and hexavalent chromium data indicate that virtually all of the total chromium is hexavalent chromium, which may be naturally occurring.

The process equipment at TFD will be designed such that the inorganic ground water chemistry will not cause excessive system component degradation. Scaling will be controlled through routine maintenance. Table 4 presents average inorganic chemistry data for the TFD area using data collected since 1984.

RWQCB WDR Order No. 91-091 (Appendix A) limits the TFD effluent concentration to 5 ppb total VOCs and 11 ppb hexavalent chromium (Table 3). Bay Area Air Quality Management District's (BAAQMD) Best Available Control Technology (BACT) guidelines (BAAQMD, 1992) are met if VOC emissions to the atmosphere are less than 6 parts per million on a volume per volume basis ($ppm_{v/v}$). LLNL has applied for an air permit for TFD and is awaiting response from BAAQMD.

Table 3. TFD design influent concentrations (January 1993 data[a]).

	Concentration (ppb)	
Constituent	**Average influent**	**Effluent discharge requirements**
Perchloroethylene	**28**	**4**
Trichloroethylene	**875**	**5[b]**
1,1-Dichloroethylene	**11**	**5[b]**
1,2-Dichloroethylene (total)	**1**	**5[b]**
1,1-Dichloroethane	**1**	**5[b]**
1,2-Dichloroethane	**20**	**5[b]**
Carbon tetrachloride	**20**	**5[b]**
Chloroform	**5**	**5[b]**
Trichlorofluoromethane (Freon 11)	**148**	**5[b]**
Trichlorotrifluoroethane (Freon 113)	**1**	**5[b]**
Total VOCs	**1,110**	**5**
Hexavalent chromium	**11**	**11**

[a] **Hexavalent chromium concentrations are from June 1985 through July 1991.**

[b] **There are no individual discharge limits for these VOCs, but they are included in the 5-ppb total VOC limit.**

Table 4. TFD inorganic ground water chemistry influent concentrations since 1984.

Constituent/parameter	**Average influent concentration (ppm)**
pH	**7.8 (pH units)**
Sodium	**103**
Calcium	**98**
Magnesium	**19**
Bicarbonate	**271**
Chloride	**127**
Nitrate	**37**
Sulfate	**135**
Potassium	**2**
Carbonate	**<1**
Total dissolved solids	**697**
Iron	**0.085**
Manganese	**0.011**

The specifications and design for TFD are presented below. The equipment specifications are presented in Table 5. A location plan and a P&ID are presented as Plates 1 and 2[*], respectively.

Table 5. TFD equipment specifications.

Equipment	Specification
TFD Building	Prefabricated steel or wood frame, 35- × 37- ft inside dimensions
Extraction well pumps	Grundfos model numbers 5S05-9, 10S05-9, 16S10-10, 25S20-11, or equivalent. MW-423 has a Grundfos 25S20-11 stainless steel, 2 horsepower (hp) pump capable of 20 gpm at 250-ft head. MW-351, MW-119, and MW-317 have Grundfos 10S05-9 stainless steel 0.5-hp pumps capable of 4 gpm at 200-ft head
Influent pipeline from extraction wells to TFD	Schedule 80, 1- to 3-in. inside diameter, doubly contained pipe where visual access is not possible
Leak detection system for doubly contained underground piping to extraction wells	As required, Trace Tek 300 Longline system, Raychem Corporation, or equivalent
Particulate filter canister	Cuno Model No. 12 DC3, stainless steel, 100-gpm maximum, or equivalent
Particulate filter cartridges	Cellulose cartridges or equivalent, 100-gpm maximum flow rate, 125 maximum operating pressure, nominal 5-micron filter
Air stripping tanks	Aeromix System, Inc., Breeze Series 6, 300 gpm maximum 400 standard cubic feet per minute (scfm) max. inlet air diffusers, water baffles, outlet chamber not aerated, 80 × 30 × 32 in., or equivalent
Stripper tank level control sensor	MTS magnetic level sensor or equivalent
Discharge pump and motor	Bell and Gossett pump or equivalent, 10 to 70 gpm
Variable speed control unit	Fuji single loop PID controller, or equivalent, to control speed of pump from 10 to 70 gpm
Variable frequency drive	Baldor variable frequency drive inverter or equivalent
Supply and exhaust blowers	Fuji Model No. VFC 904A with a rating of 375 scfm at 80 in. water pressure, 20 hp, 200-230/460V, 48-44/22 amp, Universal silencer U5-3, or equivalent
Vapor phase GAC	Carbtrol Model No. G3, 140 1b carbon, 3.5 in. water at 400 cubic feet per minute (cfm), or equivalent, 30 lb/ft^3 apparent density
Ion-exchange unit	Purolite A-600, or equivalent ion-exchange resin with resin regeneration, or equivalent technology
pH adjustment and monitor	Acid or carbon dioxide system, to be determined
Programmable logic controller	Mitsubishi with MEDOC software or equivalent
Water flow meter	E-T-A Mass Flow Transmitter with a range of 5 to 90 gpm or equivalent
Air flow meter	E-T-A Mass Flow Transmitter to measure up to 1,050 cfm or equivalent
Submersible pressure transducers	Model PS9000, or equivalent, 4 to 20 milliamp output, 30 pounds per square in. gauge range

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[*] Plates 1 and 2 are located in a pocket inside the back cover of this report.

TFD will be enclosed in a building insulated and lined with painted gypsum wall board on the interior. The building will be constructed to Uniform Building Code (UBC) requirements, and/or DOE general design criteria 6430.1A, whichever is more stringent. The floor slab will consist of 6-in. reinforced concrete [3,000 pounds per square in. (psi) rating]. For maintenance access, there will be a 10- × 10-ft roll-up door on the side of the building.

Ground water containing VOCs will be extracted for treatment using Grundfos submersible pumps or equivalents. These centrifugal pumps are stainless steel with a variety of horsepower and flow ratings.

From the wellheads, the ground water will be pumped to TFD through 1- to 3-in. inside-diameter polyvinyl chloride (PVC) pipe. Pipeline that cannot be visually inspected will be doubly contained. Ground water then will enter a filtration system to filter out suspended particles in the ground water.

From the filtration system, ground water will flow to the air stripping tanks. Ground water will flow through two air stripping tanks in parallel and then through one additional air stripping tank. The aeration process will reduce VOCs in the water to less than or equal to the discharge limit of 5 ppb. The air strippers will be a commercially available Breeze Series-6 from Aeromix Corporation, or equivalent.

The supply air for the aeration will come from three parallel Fuji-type VFC 904A blowers or equivalent. These blowers are expected to have an output of approximately 375 standard cubic feet per minute (scfm) for a total of 1,125 scfm with an operating level of about two feet of water in the air stripping tanks.

Once removed from the water, the VOCs will be exhausted from the air strippers and pass through three GAC canisters in parallel where the residual VOCs will be adsorbed to the carbon. The GAC will adsorb volatilized VOCs so that no VOCs will be emitted to the atmosphere from TFD above the 6 $\text{ppm}_{\text{V/V}}$ BAAQMD limit. The GAC canisters contain 140 pounds of carbon each with a 3.5-in. pressure drop at 400 scfm flow. Effluent VOC concentrations from the GAC will be measured by a photoionization detector or flame ionization detector. GAC will be replaced as needed to remain in compliance with the 6 $\text{ppm}_{\text{V/V}}$ BAAQMD limit. The GAC will be delivered to the LLNL Hazardous Waste Management Division to be regenerated or disposed offsite at a Resource Conservation and Recovery Act (RCRA)-permitted facility.

The last cell of the final air stripping tank will contain the level controls for the stripping tanks (Plate 2). The level control system will consist of a level-sensing device in the tank which, in a closed-loop feedback system, controls the speed of the stripping tank discharge pump to keep the water level in the tank constant. The water will then be pumped directly into an ion-exchange unit.

The ion-exchange unit will be a commercially purchased Purolite A-600, or equivalent, macroporous anion-exchange resin unit and will remove chromate ions (the form that hexavalent chromium exists in ground water) from the ground water and exchange them for chloride ions. Hexavalent chromium will be removed to concentrations equal to or below the discharge limit of 11 ppb prior to surface discharge. If hexavalent chromium is shown to be naturally occurring, the treated ground water can be reinjected and the ion-exchange unit may be bypassed. If conducted, reinjection will comply with SWRCB Resolution No. 68-16. All reinjected fluids must also be within hydraulic control of an extraction well. Hexavalent chromium will be removed to a concentration equal to or less than its concentration in an injection well if injection is performed. The detection limit for hexavalent chromium is 10 ppb. The ion-exchange bed will be regenerated at TFD as needed.

Following the ion-exchange unit, a pH monitor will signal if discharge pH exceeds the WDR Order No. 91-091 discharge limit of 6.5–8.5. The pH monitor will consist of a probe and a transducer. It is not anticipated that the pH of the treated effluent from TFD will decrease below the lower discharge limit of 6.5. pH adjustment will either be by carbon dioxide or acid injection downstream of the ion-exchange unit.

The treated effluent from TFD will be discharged to the Drainage Retention Basin as shown on Figure 2. The treated effluent from TFD may also be reinjected or used for landscape irrigation.

TFD influent piping that cannot be visually monitored will be instrumented with a leak detection system. This system will be a Trace Tek 300 Long Line System, manufactured by Raychem Corporation, or equivalent, that is monitored and alarmed at TFD. This system will detect aqueous fluids at any point along the cable’s length, alarm the TFD system, and indicate the distance from TFD to the leak.

2.2.2.2. Treatability Test

To assist in the design of TFD, a treatability test was conducted with ground water from the TFD area. The test consisted of introducing about 190 gallons of ground water from MW-361 into a single Lowry P-12 air stripper tank and recirculating the water through the tank while aerating it with a Fuji-904A blower. The results of the treatability test are presented in Table 6. After 15 minutes, the total VOC concentration was reduced below the discharge limit of 5 ppb. TCE and 1,2-DCA effluent concentrations were plotted as a function of the amount of total blower air injected in cubic feet per minute of air per gpm of water [ft^3/gal or cubic feet per minute (cfm)/gpm] to determine the required air/water ratio for treating these constituents to concentrations below the detection limit of 0.5 ppb at a flow rate of 70 gpm (Fig. 6). TCE and

Table 6. TFD air stripper treatability test results[a].

	0 min	**5 min**	**10 min**	**15 min**	**20 min**
Constituent	**<--------------------------**		**Concentration (ppb)**		**----------------------------->**
Trichloroethylene	**1,780**	**21**	**1**	**0.5**	**0.4**
1,2-Dichloroethane	**132**	**34**	**8**	**1.2**	**<0.4**
1,1-Dichloroethylene	**176**	**<0.4**	**<0.4**	**<0.4**	**<0.4**
cis- 1,2-Dichloroethylene	**15**	**<0.4**	**<0.4**	**<0.4**	**<0.4**
Perchloroethylene	**208**	**0.6**	**<0.4**	**<0.4**	**<0.4**
1,1,1-Trichloroethane	**<0.4**	**<0.4**	**<0.4**	**<0.4**	**<0.4**
Chloroform	**10**	**<0.4**	**<0.4**	**<0.4**	**<0.4**
Carbon tetrachloride	**2.8**	**<0.4**	**<0.4**	**<0.4**	**<0.4**

[a] **Analyses performed using LLNL's onsite laboratory.**

Figure 6. Airflow design graph for TFD

1,2-DCA were chosen for the test because TCE occurs in the highest concentration in the TFD area, and 1,2-DCA is the constituent with the lowest Henry's constant (i.e., is the least volatile and is most difficult to remove by air stripping).

The detection limit of 0.5 ppb rather than the MCL was used as a design criterion to be conservative and provide a safety factor. The required air/water ratio was predicted using a 20-ppb average influent concentration for 1,2-DCA and the slope of the 1,2-DCA line because removal of 1,2-DCA requires more air than for TCE. The treatability test results indicate that a ratio of about 16 scfm/gpm is required to reduce VOC concentrations to the detection limit of 0.5 ppb or less. At an average influent flow rate of 70 gpm, the required air flow rate is 70 gpm multiplied by 16 scfm/gpm, or 1,120 scfm.

2.2.2.3. Controls and Safeguards

TFD will be designed to be fail-safe and will be equipped with an interlock control system (Plate 2). If one of the components listed below malfunctions, the entire system, including the associated extraction well pumps, will automatically shut down. The operator will be notified of a shutdown by a visual alarm. The operator must determine and correct the problem before the system can be manually restarted.

A system shutdown involves de-energizing the following equipment:

- Well pumps.
- Blowers.
- Discharge pump.
- Ion-exchange unit, if used.
- Chemical injection pump or CO_2 injection, if pH control is used.

A system-wide shutdown would be initiated by the following hard-wired interlocks:

- Low water level in the well.
- High water level in air stripper tanks.
- Low pressure at or downstream of the air stripper discharge pump.
- High water level in the ion-exchange unit tanks.
- High water level in holding tanks.
- Low air compressor pressure.
- High or low pressure downstream of the blowers.
- pH out-of-range as sensed by final effluent pH monitor.
- Loss of power to control and instrumentation.
- Leak detected within inaccessible pipelines.

In addition, all aboveground pipelines will be visually monitored for leaks on a daily basis. Underground pipelines will be doubly contained with a leak detection system installed inside the outer pipe.

2.2.3. Discharge of Treated Ground Water

Ground water treated at TFD will be discharged to the Drainage Retention Basin located south of TFD (Fig. 2), used for onsite irrigation, or reinjected. Reinjection will be conducted only if hexavalent chromium is shown to be naturally occurring, and only in accordance with SWRCB Resolution No. 68-16. All reinjected fluids must also be within hydraulic control of an extraction well. If overflow from the Drainage Retention Basin were to occur, the water would flow through an underground pipeline that discharges to Arroyo Las Positas (Fig. 2). Treated water may also be used for onsite irrigation and/or in LLNL cooling towers to reduce the amount of water imported to LLNL.

As discussed in Section 4.2, self-monitoring receiving water samples will be collected from the Drainage Retention Basin. Analyses of receiving water samples will be conducted according to the specifications outlined in WDR Order No. 91-091 (Appendix A).

2.3. Construction and Startup Schedule and Cost Estimates

2.3.1. Schedule

Technology evaluations and conceptual designs for TFD were conducted by ERD in July 1993 (Table 7). Following completion of the conceptual design, LLNL Plant Engineering will complete the final design that will be used for construction. Construction of TFD will begin March 1994, and TFD is scheduled to be operational by September 30, 1994 (Dresen *et al.*, 1993).

Table 7. TFD design and construction schedule.

	Design		**Construction**	
Item	**Start**	**End**	**Start**	**End**
TFD design and construction	**7/93**	**12/93**	**3/94**	**8/94**
TFD activation	**---**	**---**	**8/94**	**9/94**

2.3.2. Cost Estimates

The estimated costs for design, construction, and O&M of TFD are shown in Table 8. The cost associated with building construction in Table 8 includes design and construction for the initial influent and effluent pipelines, facility power, and power to the wellheads.

Table 8. TFD cost summary.

Item	Cost[a]	Annual O&M [a]	53-year cleanup O&M[a]
TFD building (including design, construction, piping, and power)	**$1,000,000**	—	—
Process equipment and associated equipment	**170,000**	—	—
Ion-exchange unit and associated equipment	**180,000**	—	—
Activation cost	**40,000**	—	—
9.7% MPC[b]	**16,500**	—	—
Subtotal	***1,406,500***	—	—
TFD Operations & Maintenance:			
Labor:			
ERD personnel[c]	—	**$516,000**	**$16,251,420**
HWM[d]	—	**30,000**	**1,590,000**
Plant support	—	**60,000**	**3,180,000**
Subtotal	—	***606,000***	***21,021,420***
Materials:			
Extraction wells	—	**2,400**	**127,200**
Ion-exchange unit	—	**12,900**	**683,700**
Air compressor	—	**600**	**31,800**
Pumps	—	**240**	**12,720**
Filters	—	**3,600**	**190,800**
Carbon housing	—	**9,600**	**508,800**
Blowers	—	**360**	**19,080**
Holding tanks	—	**13,200**	**699,600**
pH metering	—	**5,400**	**286,200**
Miscellaneous piping	—	**1,200**	**63,600**
Miscellaneous electronics	—	**600**	**31,800**
Sample analyses	—	**24,000**	**1,272,000**
HWM[d]	—	**132,720**	**7,034,160**
9.7% MPC[b]	—	**4,860**	**257,564**
Subtotal	—	***211,680***	***11,219,024***
13% G&A/LDRD[e] charge	**182,800**	**106,298**	**4,191,126**
Total	**$1,589,300**	**$923,978**	**$36,431,570**

[a] **Estimated cost is in Fiscal Year 93 dollars and does not include yearly escalation.**

[b] **Material Procurement Charge.**

[c] **ERD personnel labor estimates include hydrogeologist, chemist, engineer, technician, and analyst time to meet the requirements in the ROD and milestones in the RAIP. The 53-year cleanup cost reflects time for these staff to maintain and improve treatment systems, effectively manage the well field as conditions change over the life of the cleanup, and evaluate and potentially implement new cleanup technologies as they are developed in the future. The estimated cost for ERD personnel is based on a constant level of effort for the first 5 years of the cleanup, about 83% of that effort for years 6 through 10, about 67% of that effort for years 11 through 15, and half the initial effort for years 16 through 53.**

[d] **LLNL Hazardous Waste Management.**

[e] **General and Administrative/Laboratory Directed Research and Development cost.**

The cost associated with the air stripping equipment includes the air stripping tanks, blowers, in-line water filters, effluent GAC, air stripping tank discharge pump and control, and the pH adjustment metering pump and control.

The cost associated with the ion-exchange unit and associated equipment includes the commercially purchased ion-exchange unit, which includes all pumps, piping, tanks, and control hardware.

3. Remedial Design for Treatment Facility E

3.1. TFE Design Summary

TFE will be a ground water treatment facility located near the center of the southeastern quadrant of the Livermore Site (Fig. 2). The planned Trailer 5475 Treatment Facility, which will be discussed separately in Remedial Design Report No. 4, is within the TFE area. TFE will treat ground water containing VOCs and chromium. The compounds of concern in the TFE area are, in order of highest average concentration (see Table 11, Section 3.2.2.1), TCE, PCE, 1,1-DCE, Freon 113, chloroform, chromium, carbon tetrachloride, 1,2-DCA, 1,2-DCE (total), and 1,1,1-TCA. Of these, all but Freon 113, 1,2-DCA, 1,2-DCE, and 1,1,1-TCA exceed their respective MCL. TFE will consist of a commercially available ultraviolet/hydrogen-peroxide (UV/H_2O_2) ground water treatment unit to treat most of the VOCs dissolved in the water, and an air stripping system to treat VOCs that are not destroyed by the UV/H_2O_2 unit. The ion-exchange unit for chromium treatment may be bypassed if the regulatory agencies concur that hexavalent chromium is naturally occurring, and that reinjection complies with SWRCB Resolution No. 68-16. All reinjected fluids must also be within hydraulic control of an extraction well. Initially, ground water will be extracted from existing monitor well MW-566 (EW-19-5A), and the treated effluent will be discharged to the Drainage Retention Basin, or reinjected. TFE will meet the discharge requirements specified in WDR Order No. 91-091 (NPDES Permit No. CA 0029289) (Appendix A).

3.2. Design Specifications

Design specifications for the planned TFE area extraction wells and piezometers and for the treatment system are described in Sections 3.2.1 and 3.2.2, respectively.

3.2.1. Extraction Wells and Piezometers

3.2.1.1. Extraction Well Location and Design

As discussed in the RAIP (Dresen *et al.*, 1993), it was originally planned that extraction locations 13, 14, 19, and 20 would supply ground water to TFE (Fig. 2). Further analyses indicate that the water from extraction location 14 can be more efficiently treated at the planned Trailer 5475 Treatment Facility due to tritium in the ground water at this location. Therefore, the wellfield design for extraction location 14 will be presented in Remedial Design Report No. 4. As previously discussed in Section 2.2.1, ground water from extraction location 20 will be treated at TFD instead of TFE. Thus, only extraction locations 13 and 19 will supply ground water to TFE. However, extraction location 19 has been enlarged to address VOCs in ground water to the north, south, and west of extraction location 19.

A total of 17 extraction wells are currently planned for installation in phases at extraction locations 13 and 19. This total is higher than the original estimate because further analysis indicates that more wells are required to effectively remove VOC mass and capture VOC concentrations above 100 ppb. Seven of the 17 extraction wells are existing monitor wells, and the remaining wells are planned for installation in the future. Design specifications for the extraction wells are shown in Table 9, and proposed TFE extraction well and piezometer locations are shown in Figure 7.

Extraction well locations in Figure 7 are based on ground water modeling results [Chapter 3 and Appendix B in Isherwood *et al.* (1990); Tompson (1990); Tompson *et al.* (1991); and Tompson *et al.* (1993)]; local hydrogeology (Thorpe *et al.*, 1990; Isherwood *et al.*, 1990); and isopach, structure contour, and isoconcentration maps prepared for this RD. The primary purpose of the TFE extraction wells is to maximize mass removal from water-bearing zones where total VOC concentrations exceed 100 ppb. Some wells are also planned for zones where it is anticipated that VOC concentrations above MCLs will not be captured by downgradient extraction wells (e.g., extraction well EW-19-6). The areas where one or more VOCs in ground water exceed an MCL, 100 ppb total VOCs, and 1,000 ppb total VOCs are shown on Figure 7.

As described in Section 2.2.1.1.2, the TFE area is underlain by six hydrostratigraphic units (Fig. 3), including a permeable unit beneath the Lower Member of the Livermore Formation regional confining layer. The hydrostratigraphy of the TFD/TFE area was defined by constructing a series of detailed cross sections, and isopach, structure contour, and isoconcentration maps. The first hydrostratigraphic unit is unsaturated throughout most of the TFE area. After completion of all RD reports, a report is planned that will summarize the detailed analysis on which the hydrostratigraphy is based.

Ground water in the TFE area contains over 6,000 ppb total VOCs, consisting of primarily TCE. Although the highest VOC concentrations occur in the second and fourth hydrostratigraphic units, VOC concentrations above MCLs occur locally in all of the saturated units.

Extraction locations 13 and 19 are key locations for maximizing mass removal in the vicinity of the high VOC concentrations in the southeast portion of the Livermore Site. Three of the five extraction wells at extraction location 13 are near the downgradient side of the 100 ppb contour, and will also hydraulically control further westerly plume migration (Fig. 7). Analyses of geologic, chemical, and hydraulic data for this RD report indicate that VOCs occur above MCLs throughout most of the TFE area (Fig. 7). Therefore, additional extraction locations have been added to the north, south, and west of the initial extraction location 19 shown in the RAIP (Fig. 7). Due to the heterogeneous nature of the subsurface and generally low ground water yields, the extraction well locations shown in Figure 7 may be modified based on new chemical and hydrogeologic data obtained during extraction well and piezometer installation. Due to generally low permeability, low available drawdown in wells screened in the first and second units, and the

Table 9. TFE extraction well specifications.

Well name	Extraction well name[a]	Well design[b]	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval (ft)	Sand pack interval (ft)	Hydro-stratigraphic unit[c]	Estimated maximum long-term steady state yield (gpm)[d]	Pump type[e]	Pump intake depth (ft)	Activation priority[f]
Extraction Location 13												
TBI	EW-13-1	Single	—	(112)	(111)	(90-110)	(88-111)	First	(5)	—	(100)	9
MW-305	EW-13-2	Single	18-Nov-86	146	138	128-138	125-142.5	Second	20	25S20-11	133	6
MW-292	EW-13-3	Single	14-Aug-86	250	184.5	176-184.5	174-186	Third	5	5S05-9	180	7
TBI	EW-13-4	Single	—	(202)	(201)	(180-200)	(178-201)	Fourth	(20)	—	190	8
TBI	EW-13-5	Single	—	(282)	(281)	(250-280)	(248-281)	Fifth	(8)	—	(265)	10
Extraction Location 19												
TBI	EW-19-1/2	Multiple w/ seal	—	(112)	(111)	(60-110)	(58-111)	First and Second	(5)	—	(85)	17
MW-911	EW-19-2A	Single	20-Oct-93	178	113.5	73.5-108.5	65.5-112	Second	(3)	5S05-9	91	2
MW-271	EW-19-2B	Single	07-July-86	201	112	105-112	103-112	Second	4	5S05-9	180.5	4
TBI	EW-19-2C	Single	—	(112)	(111)	(95-110)	(93-111)	Second	(2)	—	(103)	12
TBI	EW-19-2D	Single	—	(127)	(126)	(100-125)	(98-126)	Second	(6)	—	(113)	11
MW-314	EW-19-4A	Single	20-Mar-87	228	142	134-142	129-142	Fourth	12	16S10-10	138	16
TBI	EW-19-4B[g]	Single	—	(161)	(160)	(150-160)	(148-160)	Fourth	(7)	—	(155)	3
MW-364	EW-19-4C	Single	31-Mar-87	195	165	155-165	153-165	Fourth	5	5S05-9	160	5
TBI	EW-19-4D	Single	—	(182)	(181)	(130-145)	(128-145)	Fourth	(15)	—	(155)	13
MW-566	EW-19-5A	Single	19-Apr-89	317	207	197-207	186-207.5	Fifth	15	25S20-11	203	1
TBI	EW-19-5B	Single	—	(192)	(191)	(180-190)	(178-191)	Fifth	(5)	—	(185)	14
TBI	EW-19-6	Single	—	(242)	(241)	(230-240)	(228-241)	Sixth	(10)	—	(235)	15

Notes:

TBI = To be installed.

Estimates are shown in parentheses.

[a] Extraction well name indicates location as shown in Figure 7 (i.e, EW-13-1 is at extraction location 13) and the hydrostratigraphic unit monitored (i.e., EW-13-1 is screened in the first unit). When multiple extraction wells are screened in the same hydrostratigraphic unit, a letter follows the unit designation (i.e., EW-19-2A, EW-19-2B, etc.). When a single extraction well is screened in more than one unit, the screened units are indicated (i.e., EW-19-1/2 is screened in the first and second hydrostratigraphic units). Figure 7 shows planned extraction well locations.

[b] The two extraction well designs are:

Single = a well screened and sand-packed in only one water-bearing zone.

Multiple w/ seal = a well screened and sand-packed in more than one water-bearing zone with annular grout seals between the screened zones. If cross contamination in any multiple-screened well becomes a concern, packers can be placed between the screened intervals during periods of inactivity.

Additional information regarding these well designs and their applications is presented in the RAIP (Dresen *et al*., 1993).

Table 9. (Continued.)

[c] Numbered consecutively downward from ground surface at each extraction location. A hydrostratigraphic unit is defined as a sequence of sediments grouped together on the basis of hydraulic properties, geologic data, and/or chemical data.

[d] Estimated yield based on pumping test results. Actual long-term pumping rates will generally be lower. Where an extraction well is not yet installed, estimates of sustainable flow rates are shown in parentheses. These rates are based on the flow rates from nearby wells screened in similar zones and/or thickness and estimated permeability of sediments in the area.

[e] Pump type currently installed. All are Grundfos stainless steel submersible pumps. Nominal pump flow rates are 16S10-10 = 0.5 horsepower (hp), 14 gpm at 200-ft head; 5S05-9 = 0.5 hp, 8 gpm at 200-ft head; and 25S20-11 = 2 hp, 20 gpm at 250-ft head.

[f] Activation priority is the estimated order in which extraction wells will be connected to the treatment facility. Activation priority is based on whether the well currently exists, engineering design and cost, and the known or anticipated VOC concentrations in ground water at the extraction locations.

Figure 7. Planned TFE area extraction well and piezometer locations

potential for dewatering, cyclic pumping may be necessary in wells completed in the first or second units. Cyclic pumping will be conducted if the water level in the well cannot be maintained above the pump intake with continuous pumping. Additional extraction wells may be installed to accelerate mass removal if a cost/benefit analysis is favorable.

Five extraction wells are planned for extraction location 13 (Fig. 7). Of these, EW-13-2, EW-13-3, and EW-13-5 are located to capture VOCs above 100 ppb to enhance VOC mass removal rates. Total VOC concentrations up to 500 ppb occur in this area. Although the VOC concentrations are not as high at this location as in other areas, the closest planned downgradient extraction wells are about 2,000 ft to the west in the Treatment Facility G area (Fig. 2). In addition, extraction at location 13 may mitigate formation of a stagnant zone if ground water is recharged on the west side of the TFE area.

EW-13-1 will be screened in the first hydrostratigraphic unit to capture about 300 ppb total VOCs in MW-353, as well as VOCs migrating southwestward from a former source area south of the East Traffic Circle. EW-13-1 will be located east of Southgate Drive to eliminate costly excavation for piping beneath the road, and will be where the permeable sediments are expected to be thicker and the flow rate is expected to be higher than MW-353. Because there is little available drawdown in existing wells in this area, cyclic pumping may be necessary at EW-13-1. EW-13-4, located adjacent to EW-13-1, is positioned to hydraulically capture VOCs migrating southwest along a high-permeability channel sequence in the fourth hydrostratigraphic unit. EW-13-3 is similarly positioned to hydraulically capture VOCs migrating south along a high permeability channel sequence in the third hydrostratigraphic unit. Hydraulic testing indicates that pumping EW-13-2 (MW-305) affects a large area (Thorpe *et al.*, 1990) and should effectively remove VOC mass and control plume migration in this area. While most of the VOCs are in the second and fourth hydrostratigraphic units, VOC concentrations above MCLs exist in the fifth unit in the extraction location 19 area upgradient of extraction location 13. Therefore, a pilot borehole is planned adjacent to EW-13-2 to determine whether VOCs exist in the fifth unit in this area (Fig. 7). If VOC analytic results indicate concentrations above MCLs may be in the ground water, the borehole will be completed as EW-13-5. Otherwise, the pilot borehole may be completed as a fifth-unit piezometer.

Twelve extraction wells are planned for extraction location 19, proximal to areas with high VOC concentrations to maximize VOC mass removal (Fig. 7). EW-19-1/2 is downgradient of a former VOC source area south of the East Traffic Circle, and will be screened to capture the VOCs detected in nearby MW-207, which is completed partially in both the first and second hydrostratigraphic units. MW-207 contained about 600 ppb total VOCs in January 1993. EW-19-1/2 will be located about 300 ft west of MW-207 because a greater thickness of higher permeability sediments is anticipated in this area. In addition, the units are inclined to the west, and an increase in available drawdown is also expected.

Currently, the water level in MW-207 is about 8 ft below the top of the screen. Thus, EW-19-1/2 will be a multiple-screened well, similar to MW-207, and MW-207 will be used as a piezometer. Because chemical data are limited in this area, EW-19-1/2 screen length will be based on chemical and lithologic data obtained during drilling. Because little drawdown is available in wells in the area, cyclic pumping of EW-19-1/2 may be necessary. Depending on the actual size of the EW-19-1/2 capture area, an additional second- or first-unit extraction well may be needed in this area to enhance VOC mass removal.

An additional extraction well may be drilled upgradient of EW-19-1/2 if there is no response in MW-207 (P-19-1/2A) during pumping of EW-19-1/2. Only one of these two extraction wells will likely be operating at a time due to low yields. Therefore, the well that is not operating can serve as a piezometer. Piezometers in the southern portion of the TFD area (Fig. 4) will also monitor extraction in the TFE area. Any VOCs not captured in this area will be extracted downgradient at extraction location 13. EW-19-4A (MW-314) will capture VOCs in the fourth hydrostratigraphic unit.

Relatively high total VOC concentrations occur in the eastern portion of extraction location 19 (Fig. 7) where bailed ground water samples from source investigation boreholes contained over 6,000 ppb total VOCs. Extraction wells EW-19-2A, EW-19-2B (MW-271), EW-19-4B, EW-19-4C (MW-364), and EW-19-5A (MW-566) are located to maximize VOC mass removal from specific hydrostratigraphic units and control further VOC migration in this area. Initial VOC concentrations exceeding 1,000 ppb are anticipated at EW-19-2A, EW-19-2B, and EW-19-4B. Ground water extraction will begin at EW-19-5A (MW-566) once piping to TFE is installed. Extraction well EW-19-5A is screened in the fifth hydrostratigraphic unit, and contains up to 400 ppb total VOCs.

A cluster of four extraction wells is planned for the area just north of South Outer Loop (Fig. 7): EW-19-2C, EW-19-4D, EW-19-5B, and EW-19-6. These wells are positioned to capture VOCs in intervals screened in nearby wells MW-275, MW-358, MW-354, MW-272, MW-259, and MW-356, and to avoid installing piping from TFE to wells located south of South Outer Loop, a major roadway.

MW-358 has contained 0.5 to 11 ppb TCE, and contained 3.7 ppb in the most recent analysis (April 1993). It is the only well screened in the sixth hydrostratigraphic unit in the TFE area. To date, no VOCs above MCLs have been detected beneath the top of the regional confining layer in hydrostratigraphic Unit 6 (Fig. 3) at any other location. VOCs may have migrated downward into the MW-358 screen through a possible conduit (i.e., leaky annular seal) within the well annulus. Because hydraulic tests on MW-358 may not be conclusive regarding the integrity of the annular seal, MW-358 will be sealed in Fiscal Year (FY) 94 according to SOP No. 1.7 (Rice *et al.*, 1990). MW-358 will be replaced as piezometer P-19-6C when the extraction wells and piezometers are installed for extraction location 19. If VOCs above MCLs are detected in P-19-6C, then EW-19-6 and associated piezometers will be installed.

EW-19-2D will be installed east of the four new extraction wells discussed above to remove the VOCs detected in MW-274, which is located just south of South Outer Loop. MW-274 contains only TCE at a concentration over 1,000 ppb. MW-259, located north of MW-274, also has only TCE in ground water in concentrations of about 300 ppb. Therefore, EW-19-2D is located upgradient of these two wells to remove VOCs from the former source of TCE in ground water in this area.

Figure 2 shows a 70-gpm influent flow rate to TFE. Additional analyses of hydrogeochemical data conducted for this RD report indicate that the original TFE area extraction locations needed to be expanded in order to maximize mass removal and plume control. Table 9 presents maximum sustainable yield estimates for each TFE extraction well based on the most recent hydraulic and hydrogeologic data. The maximum sustainable yield for the TFE area wells is 147 gpm. Because long-term pumping test data are relatively limited, the estimates in Table 9 probably represent upper bounds for steady-state yields. The estimates are shown as upper bounds in Table 9 so that pumps with adequate capacity can be installed for maximum initial flow rates and mass removal. In most cases, as long-term ground water extraction progresses, flow rates will decline as shallow sediments dewater, distant hydraulic boundaries are encountered, pumping of other wells in the vicinity begins, and/or local gradients decrease. In addition, pumps in extraction wells with little available drawdown will automatically be cycled on and off to mitigate potential pump damage and dewatering. Therefore, the combined long-term yield of these wells may actually be about 70 to 120 gpm. TFE will be designed to treat an initial flow of 70 gpm and will be expandable to accommodate higher flows, if needed.

In order to minimize the possibility of dewatering lower permeability hydrostratigraphic units during ground water extraction and to enhance plume control, a ground water reinjection well is being considered for the TFE area (Fig. 7). At least one reinjection well is planned between extraction location 14 (Fig. 2) and all TFE area extraction wells to mitigate tritium migration from the Trailer 5475 area toward TFE extraction wells. Reinjection is also being considered in the western TFE area to mitigate further westward migration of VOC plumes and enhance downgradient VOC capture. The actual location of the reinjection wells will be based on the Trailer 5475 extraction well field design, to be reported in Remedial Design Report No. 4, and the results of reinjection tests.

Pumping will begin at EW-19-5A (MW-566) as soon as piping to TFE is completed. Subsequent wells will be operational as they are installed and piping is completed. Initial flow rates will be maximized to accelerate mass removal.

Extraction flow rates and ground water elevation and chemistry data will be monitored to evaluate if the planned extraction scenario is effectively removing VOC mass. If actual flow rates are substantially lower than predicted, additional extraction wells may be added to increase VOC mass removal. The locations of any new wells will be based on field water level data and recalibrated modeling results.

3.2.1.2. Piezometer Location and Design

Piezometers near the extraction wells will be monitored to determine hydraulic capture zones and identify potential areas of little or no ground water flow. The primary objective of the TFE remedial well field design is to maximize VOC mass removal rather than achieve hydraulic plume margin capture. Therefore, the TFE area piezometer configuration has been designed to monitor the cumulative drawdowns for each TFE area hydrostratigraphic unit, rather than the drawdown achieved by each individual extraction well. Thus, some piezometers will monitor multiple extraction wells, including some of the TFD extraction wells.

Planned TFE area piezometer locations are shown in Figure 7. Where possible, existing monitor wells will be used as piezometers. To monitor drawdown in areas where low sustainable yields are anticipated (for example MW-271), the planned piezometers have been located within about 200 feet of the extraction wells. Up to 41 piezometers are planned for the TFE area.

Twenty-two of these piezometers are existing monitor wells, and 19 new piezometers may be installed in phases in the future. Preliminary design specifications for the additional piezometers, along with the design specifications of the existing piezometers, are shown in Table 10. A discussion of the ground water chemistry monitoring plan for the TFE monitoring network is presented in Section 4.2.2.

3.2.2. TFE Specifications, Design, Treatability Tests, Controls, and Safeguards

The specifications, design, performance, controls, and safeguards for TFE and its associated piping are described in Sections 3.2.2.1 through 3.2.2.3.

3.2.2.1. Specifications and Design

TFE will be designed to treat an initial flow of up to 70 gpm of extracted ground water using a UV/H_2O_2 system followed by air stripping and possibly ion exchange. The principal compounds of concern in ground water in the TFE area are VOCs, including TCE, PCE, and 1,1-DCE, and possibly hexavalent chromium. Design influent concentrations and effluent discharge requirements are shown in Table 11. The design VOC and chromium influent concentrations are based on recent data (January 1993) from wells at extraction locations added since the RAIP was issued, and differ from the estimated total VOC influent concentrations presented in the RAIP. Average influent concentrations were determined by calculating the mass of individual constituents per well, and then dividing the cumulative mass of each constituent from all wells by the combined estimated influent flow rate. As discussed in Section 2.2.1.1., TFE will be designed to accommodate possible higher influent flows if additional extraction wells are needed, or if higher than predicted sustainable wells yields are obtained.

The process equipment at TFE will be designed such that the inorganic ground water chemistry will not cause excessive system component degradation. Some carbonate scaling is expected to occur in the air stripper, which will be controlled through routine maintenance. Table 12 presents inorganic ground water chemistry data for the TFE area using data collected since 1984.

RWQCB WDR Order No. 91-091 (Appendix A) limits the effluent VOC concentration to 5 ppb total VOCs and 11 ppb hexavalent chromium. BAAQMD BACT guidelines (BAAQMD, 1992) are met if VOC emissions to the atmosphere are less than 6 $\text{ppm}_{\text{v/v}}$. LLNL has applied for an air permit for TFE and is awaiting response from the BAAQMD.

The specifications and design for TFE are presented below. The equipment specifications are presented in Table 13. A location plan and a P&ID are presented as Plates 3 and 4*, respectively.

TFE will be enclosed in a prefabricated building with outside dimensions of 35 × 40 ft. The structure will anchor to an 8-in. concrete (3,000 psi rating) pad with steel rebar, which also will be the foundation for the UV/H_2O_2 ground water treatment unit. The building will be constructed according to UBC requirements, and DOE general design criteria 6430.1A,

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* Plates 3 and 4 are located in a pocket inside the back cover of this report.

Table 10. TFE piezometer specifications.

Well name	Piezometer name[a]	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval[b] (ft)	Sand-pack interval (ft)	Approximate flow rate (gpm)	Activation priority[c]
Extraction Location 13								
MW-101	P-13-1A	25-Jan-85	77.0	72.0	62-72	59-72	1	39
MW-303	P-13-1B	28-Oct-86	197.0	128.0	124-128	123-130	15	40
TBI	P-13-1C	—	(112)	(111)	(90-110)	(88-111)	—	41
MW-353	P-13-1D	12-Nov-86	205.0	101.0	95.5-101	93.5-101	1	37
MW-148	P-13-1E	08-Aug-85	152.0	98.0	83-98	80-98	0.5	38
TBI	P-13-2A	—	(140)	(139)	(128-138)	(126-139)	—	14
TBI	P-13-2B	—	(140)	(139)	(128-138)	(126-139)	—	15
TBI	P-13-3A	—	(188)	(187)	(176-186)	(174-187)	—	16
TBI	P-13-3B	—	(188)	(187)	(176-186)	(174-187)	—	17
MW-276	P-13-3C	17-Sept-86	267.0	170.0	153.5-169.5	152.5-169.5	12	18
MW-352	P-13-4A	29-Oct-86	235.0	201.0	181-201	179-201	12.5	19
TBI	P-13-4B	—	(203)	(202)	(181-201)	(179-202)	—	21
MW-304	P-13-4C	12-Nov-86	207.0	200	195-200	188-205	1	20
Extraction Location 19								
MW-224	P-19-1A	26-Aug-86	199.0	88.0	78-88	76-88	3	36
MW-258	P-19-2A	31-Jan-86	157.0	121.5	116.5-121.5	114-121.5	0.5	10
TBI	P-19-2B	—	(102)	(101)	(80-100)	(78-101)	—	7
P-909	P-19-2C	4-Nov-93	252.0	113.5	88.5-108.5	70.0-113.5	2	5
MW-257	P-19-2D	15-Jan-86	197.0	96.5	82.5-96.5	79-96.5	<0.5	4
MW-204	P-19-2E	22-Nov-85	110.0	110.0	100-110	99-110	7	6
TBI	P-19-2F	—	(114)	(113)	(105-112)	(103-113)	—	8
MW-259	P-19-2G	07-Feb-86	200.0	99.0	93.5-99	92.5-99	<0.5	9
MW-272	P-19-2H	18-July-86	226.0	110.0	95-110	92-115	1	24
TBI	P-19-2I	—	(127)	(126)	(100-125)	(98-126)	—	22
MW-274	P-19-2J	21-Aug-86	217.0	95.0	90-95	87.5-95	<0.5	23

Table 10. (Continued.)

Well name	Piezometer name[a]	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval[b] (ft)	Sand-pack interval (ft)	Approximate flow rate (gpm)	Activation priority[c]
MW-12	P-19-2K	14-Aug-80	115.75	115.0	99-114	77-115	NA	25
TBI	P-19-2L	—	(112)	(111)	(95-110)	(93-111)	—	26
MW-207	P-19-1/2A	24-Jan-86	150.0	85.0	69-85	68-85	<0.5	35
TBI	P-19-4A	—	(144)	(143)	(132-142)	(130-143)	—	34
TBI	P-19-4B	—	(144)	(143)	(132-142)	(130-143)	—	33
P-912	P-19-4C	07-Oct-93	239.0	174.0	168-174	164-176	5	11
MW-356	P-19-4D	18-Dec-86	237.0	137.0	133-137	132-137	6	12
MW-354	P-19-4E	24-Nov-86	185.0	179.0	163-179	160-179	8	13
TBI	P-19-4F	—	(182)	(181)	(170-180)	(168-181)	—	27
TBI	P-19-4G	—	(182)	(181)	(170-180)	(168-181)	—	28
TBI	P-19-5A	—	(209)	(208)	(197-207)	(195-208)	—	2
MW-562	P-19-5B	08-Mar-89	263.0	158.0	145-158	141.5-159	2	1
TBI	P-19-5C	—	(209)	(208)	(197-207)	(195-208)	—	3
MW-275	P-19-5D	05-Sept-86	262.0	184.0	179-184	177-184	4	29
TBI	P-19-6A	—	(242)	(241)	(230-240)	(228-241)	—	31
TBI	P-19-6B	—	(242)	(241)	(230-240)	(228-241)	—	32
TBI	P-19-6C	—	(242)	(241)	(230-240)	(228-241)	—	30

Notes:

TBI = To be installed.

NA = Not available.

Estimates are shown in parentheses.

[a] Piezometer names indicate their location (i.e., P-13-1A is at extraction location 13) and the hydrostratigraphic unit monitored (i.e., P-13-1A is screened in the first unit). Letters following the unit designation indicate that multiple piezometers are screened in that unit.

[b] The perforated interval listed for piezometers not yet installed is the perforated interval of the extraction well they are designed to monitor. These estimates are shown in parentheses. The actual perforated interval will be based on the hydrostratigraphy and chemistry encountered during drilling.

[c] Piezometers are prioritized according to the activation of their associated extraction wells.

See Figure 7 for piezometer and extraction well locations.

Table 11. TFE design influent concentrations.

Constituent	Concentration (ppb) Average influent	Concentration (ppb) Effluent discharge requirements
Perchloroethylene	**60**	**4**
Trichloroethylene	**860**	**5**[a]
1,1-Dichloroethylene	**20**	**5**[a]
1,2-Dichloroethylene (total)	**1**	**5**[a]
1,1,1-Trichloroethane	**<1**	**5**[a]
1,2-Dichloroethane	**2**	**5**[a]
Carbon tetrachloride	**3**	**5**[a]
Chloroform	**9**	**5**[a]
Trichlorotrifluoroethane (Freon 113)	**8**	**5**[a]
Total VOCs	**963**	**5**
Hexavalent chromium	**4**	**11**

[a] There are no individual discharge limits for these VOCs, but the compounds are included in the 5 ppb total VOC limit.

Table 12. TFE inorganic ground water chemistry influent concentrations since 1984.

Constituent/parameter	Average influent concentration (ppm)
pH	**7 (pH units)**
Sodium	**74**
Calcium	**62**
Magnesium	**24**
Bicarbonate	**272**
Chloride	**94**
Nitrate	**18**
Sulfate	**42**
Potassium	**2**
Carbonate	**4**
Iron	**<0.03**
Manganese	**<0.01**
Total dissolved solids	**468**

Table 13. TFE equipment specifications.

Equipment	Specifications
TFE building	Prefabricated steel or wood frame 35 × 40 ft
Concrete pad and LVB-60 foundation	8 in. thick with rebar (3,000 psi rating)
Extraction well pumps	Grundfos models 5S05-9, 10S05-9, 16S10-10 and 25S20-11, or equivalent. MW-566 and MW-305 have Grundfos 25S20-11 stainless steel 2 horsepower (hp) pumps capable of 20 gpm at 250 ft head; MW-292, MW-271, and MW-364 have Grundfos 5S05-9 stainless steel 0.5 hp pumps capable of 8 gpm at 200-ft head; MW-314 has a Grundfos 16510-10 stainless steel 1 hp pump capable of 14 gpm at 250-ft head
Influent pipeline from extraction wells to TFE	1- to 3-in. inside diameter, doubly contained pipe where visual access is not possible
Leak detection system for doubly contained underground piping to extraction wells	As required, Trace Tek 300 Longline system, Raychem Corporation, or equivalent
Stripper tank level control sensor	MTS magnetic level sensor or equivalent
Particulate filter housings	Cuno model 12DC3; 100-gpm, stainless steel
Particulate filter cartridges	Cellulose cartridges or equivalent, 100-gpm maximum flow rate, 125 maximum operating pressure, nominal 5-micron filter
UV oxidation system	Peroxidation Systems, Inc. Perox-pure LVB-60; four 15-kilowatt medium pressure mercury vapor UV lamps, 480 volts (V), 3 phase, or equivalent
LVB-60 oxidation chamber	Type 316 stainless steel
H_2O_2 storage tank	500-gal polyethylene 0.25-in. single wall with 0.25-in. single-wall double-containment shell
H_2O_2 drip containment	Type 316 stainless steel
H_2O_2 feed pumps	Two Liquid Metronics Model A141-152 or A751-192SPX pumps; 24 gallons per day at 150 psi gauge max, 115 V, 1 amp (A), or equivalent
H_2O_2 injection tubing	Type 304 stainless steel, 0.035-in. wall thickness
Air stripping tanks	Two Aeromix Breeze Series-6, or equivalent, 300 gpm max, 400 scfm max, inlet air diffusers, water baffles, outlet chamber not aerated, 80 × 30 × 32 in.
Supply and exhaust blowers	Fuji VFC 804A; 330 scfm at 50-in. water gauge 200-230/460 V, 24-25/12.5 A, 3 phase, Universal silencer U5-3, or equivalent
Supply air manifolds	3-in. Schedule 80 PVC
Ion-exchange unit	Purolite A-600, or equivalent, ion-exchange resin, or equivalent technology
Vapor phase GAC	Carbtrol G-3, 140 lb carbon, 3.5 in. water at 400 cfm, 30 lb/ft^3 apparent density
Discharge pump and motor	Bell and Gossett pump or equivalent, 10 to 70 gpm
Variable speed control unit	Fuji single loop PID controller, or equivalent, to control speed of pump from 10 to 70 gpm
Variable frequency drive	Baldor variable frequency drive inverter or equivalent

whichever is more stringent. For maintenance access, a 10- × 10-ft roll-up door will be on the front side of the building.

Ground water will initially be extracted from monitor well MW-566 (EW-19-5A), which is equipped with a Grundfos 25S20-11 electrically powered stainless-steel centrifugal pump. From the wellhead, the ground water will be pumped above grade to TFE through 3-in. inside diameter PVC pipe. Pipelines that cannot be visually inspected will be doubly contained. The water will be pumped through a Cuno No. 12DC3 stainless steel 5-micron particulate filter canister to remove undissolved solids.

From the particulate filter canister, ground water will flow to a self-contained Peroxidation Systems, Inc., Model LVB-60 UV/H_2O_2 treatment system with four 15-kilowatt (kW) mercury-vapor UV lamps. UV light disassociates the H_2O_2 to form the hydroxyl radical ($OH^\bullet$). The hydroxyl radical oxidizes the VOCs to water, chloride ions, and carbon dioxide. The TFE UV/H_2O_2 treatment unit efficiently oxidizes TCE, PCE, and DCE. The double carbon-to-carbon bond of these compounds is readily oxidized under the influence of the hydroxyl radical. At a maximum influent flow rate of 70 gpm, the water residence time will be 69 seconds and the specific energy input to the ground water by the UV lamps will be 14.3 kilowatt hours (kWh)/1,000 gal. The LVB-60 can be drained of water for maintenance. The drain water will be pumped to a transfer tank to be treated by the facility after maintenance is complete.

H_2O_2 will be injected into the influent water to achieve a concentration of 60 to 150 ppm H_2O_2. The 50% H_2O_2 solution will be stored in a 500-gal doubly contained tank. The two H_2O_2 feed pumps will be LMI Model A151-192SPX positive-displacement diaphragm pumps with adjustable stroke length and frequency, or equivalent. Their maximum flow rate is 24 gal/day each, resulting in a maximum H_2O_2 concentration of 238 ppm when the treatment unit is processing 70 gpm.

Ground water in the TFE vicinity also contains less than about 30 ppb combined chloroform, 1,2-DCA, carbon tetrachloride, and 1,1,1-TCA, and 110 ppb Freon 113, which have single carbon-to-carbon bonds and are difficult to oxidize. Therefore, an aeration system will be used following the UV/H_2O_2 treatment unit to reduce the concentrations of these compounds to concentrations below the analytical detection limit of 0.5 ppb. The aeration system will consist of two Aeromix Breeze Series-6 air strippers in series or equivalent. Each air stripper will have a 80- × 30- × 32-in. tank containing 12 air diffusers. The water will be subjected to intense aeration using two Fuji VFC 804A centrifugal blowers in parallel that inject air at the rate of 330 scfm each for a total of 660 scfm.

Air vapor from the air stripper tanks will pass through demisters to remove moisture and then pass through two GAC canisters in parallel. The GAC will adsorb volatilized VOCs so that no VOCs will be emitted to the atmosphere from TFE above the 6 $ppm_{v/v}$ BAAQMD limit. The Carbtrol G-3 GAC canister contains 140 pounds of GAC each and can operate at up to 500 scfm. The GAC canisters will have a 3.5-in. water pressure drop at 400 scfm flow. Effluent VOC concentrations from the GAC will be measured by a photoionization or flame ionization detector. The GAC will be changed out as needed to remain in compliance with the 6 $ppm_{v/v}$ BAAQMD limit. The GAC will be replaced to the LLNL Hazardous Waste Management Division to be regenerated or disposed offsite at a RCRA-permitted facility.

The last cell of the air stripping tank will contain the level controls for the stripping tanks (Plate 4). The level control system will consist of a level-sensing device in the tank which, in a closed-loop feedback system, controls the speed of the stripping tank discharge pump to keep the water level in the tank constant. The water will then be pumped directly into an ion-exchange unit.

The ion-exchange unit will be a commercially purchased Purolite A-600, or equivalent, macroporous anion-exchange resin unit, and will remove chromate ions (the form that hexavalent chromium exists in ground water) from the ground water and exchange them for chloride ions. Hexavalent chromium will be reduced to concentrations at or below the discharge limit of 11 ppb prior to surface discharge. The detection limit for hexavalent chromium is 10 ppb. If hexavalent chromium is shown to be naturally occurring, treated ground water can be reinjected, and the ion-exchange unit may be bypassed. Reinjection will comply with SWRCB Resolution No. 68-16. All reinjected fluids must also be within hydraulic control of an extraction well. Hexavalent chromium will be reduced to a concentration equal to or less than the concentration in an injection well if injection is performed. The ion-exchange bed will be moved and regenerated at TFD.

Following the hexavalent chromium removal unit, a pH monitor will signal if discharge pH exceeds the WDR Order No. 91-091 discharge limit of 6.5 - 8.5. This pH monitor will consist of a probe and a transducer. It is not anticipated that the pH of the treated effluent from TFE will decrease below the lower discharge limit of 6.5. pH adjustment will either be by carbon dioxide or acid injection downstream of the hexavalent chromium removal unit.

The treated effluent from TFE will be discharged to the Drainage Retention Basin as shown on Figure 2. The treated effluent from TFE may also be reinjected or used for landscape irrigation.

TFE influent piping that cannot be visually monitored will be instrumented with a leak detection system. This system will be a Trace Tek 300 Long Line System, manufactured by Raychem Corporation, or equivalent, that is monitored and alarmed at TFE. This system will detect aqueous fluids at any point along the cable’s length, alarm the TFE system, and indicate the distance from TFE to the leak.

3.2.2.2. Treatability Tests

To assist in the design of TFE, a treatability test was performed using water extracted from MW-566 (EW-19-5A). The test was conducted at the UV/H_2O_2 system at Treatment Facility B (TFB) since the anticipated TFE design is very similar to TFB. Results of the test indicated that the UV/H_2O_2 system significantly reduced the VOC concentrations in the influent ground water after the first lamp (Table 14). After the fourth lamp, the concentration of all the VOCs, except chloroform and Freon 113, were reduced to less than the discharge limit of 5 ppb (Table 14). The TFE design will include an air stripper to remove those compounds remaining after passing through the UV/H_2O_2 system.

A second treatability test was conducted with ground water from monitor well MW-566 (EW-19-5A) to assist with the TFE air stripper design. The test consisted of introducing about 170 gallons of ground water from MW-566 into a single Aeromix Breeze Series-6 air stripper tank and recirculating the water through the tank while aerating the water with a Fuji-904A blower. The results of the air stripper treatability test are presented in Table 15. TCE and chloroform concentrations were plotted as a function of the amount of total blower air injected in cubic feet per minute of air per gpm of water (Fig. 8). These two constituents were chosen for plotting because TCE is the VOC with the highest concentration in the TFE area, and chloroform is the constituent with the lowest Henry's constant (i.e., is the least volatile, and is the most difficult to remove by air stripping).

Table 14. TFE UV/H_2O_2 system treatability test results[a].

Constituent	Initial	After lamp #1	After lamp #2	After lamp #3[b]	After lamp #4
	<-----------------------	Concentration (ppb)			------------------------->
Trichloroethylene	200	32	5.8	6.6	2.1
Perchloroethylene	10	3.7	1.3	1.3	0.4
1,1-Dichloroethylene	6	0.4	<0.2	<0.2	<0.2
Chloroform	12	11	11	11	9.2
Trichlorotrifluoroethane (Freon 113)	14[c]	9.2	8.6	8	8.4
1,2-Dichloroethane	1.4	1	1	1	0.8
Carbon tetrachloride	0.9	0.7	0.7	0.7	0.7

[a] Analyses performed using LLNL's onsite laboratory.

[b] Lamp #3 was not operating during the test.

[c] Analytical result from well MW-566 prior to the treatability test.

Table 15. TFE air stripper treatability test results[a].

Constituent	0 min	5 min	10 min
	<-----------------------	Concentration (ppb)	----------------------->
Trichloroethylene	235	2.1	<0.4
Perchloroethylene	17	<0.4	<0.4
Chloroform	17	<0.4	<0.4
Trichlorotrifluoroethane (Freon 113)	7.2	<0.4	<0.4
1,1-Dichloroethylene	2.9	<0.4	<0.4
1,2-Dichloroethane	2.3	<0.4	<0.4
Carbon tetrachloride	<0.4	<0.4	<0.4

[a] Analyses performed using LLNL's onsite laboratory.

The results of the test were scaled to a design influent concentration and a 70-gpm operational flow rate to arrive at a required air/water ratio. The design criteria line in Figure 8 is based on the treatment of chloroform at an initial influent concentration of about 20 ppb. The treatability test results indicate that a ratio of about 8 scfm/gpm is required to reduce VOC concentrations to a detection limit of 0.5 ppb. At an average influent flow rate of 70 gpm, the required air flow rate is 70 gpm multiplied by 8 scfm/gpm, or 560 scfm.

Figure 8. Airflow design graph for TFE

3.2.2.3. Controls and Safeguards

The accessible TFE pipelines will be visually inspected daily for leaks. Inaccessible pipelines will be doubly contained with a leak detection system installed inside the outer pipe.

TFE will be designed to be fail-safe and will be equipped with an interlock control system (Plate 4). If any of the components listed below malfunction, the entire treatment system, including the associated extraction well pumps, will automatically shut down. The operator will be notified of a shutdown by a visual alarm. The operator must determine and correct the problem before the system can be manually restarted.

The LVB-60 has internal interlocks which can shut the facility down. The following will initiate an LVB-60 shutdown:

- High water temperature in the reactor.
- Low water flow rate.
- UV lamp failure.
- Excessive moisture in the UV lamp enclosures.
- Pressure in the H_2O_2 feed line below 10 psi.
- An open UV lamp enclosure.
- High temperature (> 120° F) in the lamp drive enclosure.
- A remote shutdown from a programmable logic controller (PLC).

Additional sensors are connected to the PLC. The facility will shut down upon the following:

- An equipment or system over pressure (initiated by pressure relief valve and pressure rupture disk operation).
- High water level in the air stripper.
- Shutdown of the air stripper blower.
- Pressure loss in the blower piping (e.g., pipe break).
- High pressure in the blower piping (e.g., closed valve).
- High water level in the holding tank.
- Activation of the manual emergency shutdown.
- Shutdown of the process control computer.

3.2.3. Discharge of Treated Ground Water

Ground water treated at TFE will be discharged to the Drainage Retention Basin located west of the East Traffic Circle in the central portion of LLNL (Fig. 2), used for irrigation, or reinjected. Reinjection will be conducted only if hexavalent chromium is shown to be naturally occurring, and only in accordance with SWRCB Resolution No. 68-16. All reinjected fluids must also be within hydraulic control of an extraction well. If overflow from the Drainage Retention Basin were to occur, the water would flow through an underground pipeline that discharges to Arroyo Las Positas (Fig. 2). Treated water may also be used for onsite irrigation and/or in LLNL cooling towers to reduce the amount of water imported to LLNL.

As discussed in Section 4.2, self-monitoring receiving water samples will be collected from the Drainage Retention Basin. Analyses of receiving water samples will be conducted according to the specifications outlined in WDR Order No. 91-091 (Appendix A).

3.3. Construction and Startup Schedule and Cost Estimates

3.3.1. Schedule

Technology evaluations and process conceptual designs were conducted by ERD in August 1993 (Table 16). Following completion of the conceptual design, LLNL Plant Engineering will complete the final design. Construction of TFE is scheduled for March 1994, and TFE is scheduled to be operational by September 30, 1994 (Dresen *et al.*, 1993).

Table 16. TFE design and construction schedule.

	Design		**Construction**[a]	
Item	**Start**	**End**	**Start**	**End**
TFE design and construction	**8/93**	**12/93**	**3/94**	**8/94**
TFE activation	**---**	**---**	**8/94**	**9/94**

[a] **Construction dates are currently under negotiation with the regulatory agencies.**

3.3.2. Cost Estimates

The estimated costs for design, construction, and O&M of TFE are shown in Table 17. The costs associated with building construction in Table 17 include design and construction for the influent and effluent pipelines, facility power, and power to the wellheads.

The costs associated with the UV/H_2O_2 unit include the hydrogen peroxide storage and injection system, and in-line water filters.

The estimated costs for the air stripper unit include the air stripping tanks, blowers, effluent air GAC filters, air stripping tank discharge pump and control, and the pH adjustment system.

The cost associated with the ion-exchange unit includes the commercially purchased treatment unit, which includes all pumps, tanks, piping, and control hardware.

Table 17. TFE cost summary.

Item	Cost[a]	Annual O&M[a]	53-year cleanup O&M[a]
TFE building (including design, construction, piping, and power)	$1,000,000	—	—
UV/H_2O_2 treatment unit	140,000	—	—
Process equipment	75,000	—	—
Ion-exchange unit	60,000	—	—
Activation cost	40,000		
9.7% MPC[b]	26,700	—	—
Subtotal	*1,341,700*	—	—
TFE Operations & Maintenance:			
Labor:			
ERD Personnel[c]	—	$516,000	$16,251,420
HWM[d]	—	12,000	636,000
Plant Support	—	60,000	3,180,000
Subtotal	—	*588,000*	*20,067,420*
Materials:			
Extraction wells	—	1,200	63,600
UV/H_2O_2 treatment unit	—	15,000	795,000
Ion-exchange unit	—	3,240	171,720
Pumps	—	240	12,720
Filters	—	3,600	190,800
Carbon housing	—	1,620	85,860
Blowers	—	144	7,632
Baker tanks	—	13,200	699,600
pH metering	—	5,400	286,200
Miscellaneous piping	—	1,200	63,600
Miscellaneous electronics	—	600	31,800
Sample analyses	—	24,000	1,272,000
HWM[d]	—	132,720	7,034,160
9.7% MPC[b]	—	5,908	313,109
Subtotal	—	*208,072*	*11,027,816*
13% G&A/LDRD[e] charge	174,400	103,489	5,484,917
Total	$1,516,100	$899,561	$36,580,153

[a] Estimated cost is in Fiscal Year 93 dollars and does not include yearly escalation.

[b] Material Procurement Charge.

[c] ERD personnel labor estimates include hydrogeologist, chemist, engineer, technician, and analyst time to meet the requirements in the ROD and milestones in the RAIP. The 53-year cleanup cost reflects time for these staff to maintain and improve treatment systems, effectively manage the well field as conditions change over the life of the cleanup, and evaluate and potentially implement new cleanup technologies as they are developed in the future. The estimated cost for ERD personnel is based on a constant level of effort for the first 5 years of the cleanup, about 83% of that effort for years 6 through 10, about 67% of that effort for years 11 through 15, and half the initial effort for years 16 through 53.

[d] LLNL Hazardous Waste Management.

[e] General and Administrative/Laboratory Directed Research and Development cost.

4. Remedial Action Workplan

The Remedial Action Workplan for TFD and TFE includes QA/QC and Health and Safety Plans for construction, operation, and maintenance. Included also are monitoring and reporting programs, requirements for onsite storage and offsite shipment of hazardous waste, and procedures for facility and well closure. As discussed in the RAIP (Dresen *et al.*, 1993), DOE/LLNL has updated the Community Relations Plan (CRP) for the post-ROD period. The Revised CRP was issued in July 1993 (Anderson *et al.*, 1993).

4.1. Quality Assurance/Quality Control and Health and Safety Plans

The QA/QC Plan for construction is applicable to all treatment facilities and was presented as Appendix B of RD1 (Boegel *et al*., 1993). The Health and Safety Plan for construction of all treatment facilities, including TFD and TFE, was included as Appendix C of RD1.

The QA/QC Plans for O&M of TFD and TFE are presented in Appendix B. These plans describe the organizational structure, responsibilities, and authority for O&M QA/QC, and the objectives, quality goals, and QA levels for O&M of TFD and TFE. Appendix C contains the Health and Safety Plans for O&M of TFD and TFE. These plans analyze the hazards and present hazard control measures and training requirements for TFD and TFE O&M, and present emergency safety procedures.

4.2. Monitoring and Reporting

The following sections discuss planned monitoring and reporting for TFD and TFE. The programs include self-monitoring required by the RWQCB, ground water quality sampling, capture zone monitoring, criteria for determining when remediation is complete, and requirements for system closeout.

QA/QC procedures for collection, analysis, and documentation of influent and effluent ground water samples are included in the LLNL Quality Assurance Project Plan (Rice, 1989), which was prepared according to EPA guidance and was approved by EPA. In addition, the procedures for collection, analysis, and documentation of water samples are described in LLNL Standard Operating Procedures (SOPs) (Rice *et al.*, 1990) Nos.: 2.6, Sampling for Volatile Organic Compounds; 4.1, General Instructions for Field Personnel; 4.2, Sample Control and Documentation; 4.3, Sample Containers and Preservation; 4.4, Guide to Handling, Packaging, and Shipping of Samples; 4.6, QA/QC Requirements for Data Generated by Analytical Laboratories; and 4.8, Calibration and Maintenance of Field Instruments Used in Measuring Parameters of Surface and Ground Water and Soils. The procedures for sample collection at TFD and TFE are presented in Appendix D.

A Compliance Monitoring Plan is planned for FY 95 that will describe the data types and interpretive methods to be used for the duration of the cleanup. Until then, DOE/LLNL will prepare ground water contour and capture zone maps and report flow, concentrations, and mass removal for each operating extraction well in the *LLNL Quarterly Progress Reports* (McConachie, 1993a).

4.2.1. Treatment Facility Self-Monitoring Programs

The TFD and TFE self-monitoring programs satisfy the requirements of RWQCB WDR Order No. 91-091 (NPDES Permit No. CA 0029289) for the Livermore Site (Appendix A). Water samples will be collected at TFD and TFE sampling stations (Figs. 9 and 10) according to the schedule presented in Table 18. Results of TFD and TFE self-monitoring activities will be reported in the LLNL Monthly Progress Reports.

TFD and TFE influent samples TFD-I004 and TFE-I005, respectively, will be collected immediately prior to treatment. TFD and TFE effluent samples TFD-E004 and TFE-E005, respectively, will be collected following treatment and prior to discharge (Figs. 9 and 10).

Receiving water samples will be collected from the body of water receiving the discharge. Ground water treated at both TFD and TFE may be discharged to the Drainage Retention Basin (Fig. 2). If treated ground water is reinjected, it will be conducted with regulatory agency oversight and will comply with SWRCB Resolution No. 68-16.

A photoionization detector or flame ionization detector will be used to determine if any residual compounds of concern remain in the air effluent stream at both TFD and TFE. The photoionization detector uses UV light to ionize a vapor sample and measure the organic constituents within the vapor. The photoionization detectors used at LLNL are organic vapor meters, Model No. 580, made by Thermo Environmental Instruments. They are equipped with 10.0 electron volt lamps and detect double- and triple-bonded molecules. The flame ionization detector uses the same principle as the photoionization detector, but a flame is used to ionize the vapor sample. LLNL uses Foxboro/Century organic vapor analyzers, Model No. 128GC, equipped with flame ionization detectors. These instruments can detect compounds within a concentration range of 1 to 100,000 ppm. The detection limit for these instruments is about 1 to 2 ppm, sufficiently low to ensure compliance with air discharge limits.

4.2.2. Ground Water Monitoring Sampling Schedule

Ground water samples will be collected from existing monitor wells and piezometers in the vicinity of TFD and TFE (including the Trailer 5475 area) according to the schedule shown in Tables 19 and 20, respectively. These well and piezometer locations are shown in Figure 11. Ground water samples will also be collected quarterly for the first year from new monitor wells and piezometers installed to monitor the progress of the cleanup. This sampling schedule may be changed quarterly, as the distribution of contaminants in ground water changes, according to the procedures detailed in McConachie (1993b).

When all wells and piezometers are installed, analytic results of self-monitoring influent water samples will be collected monthly at TFD and TFE to evaluate remediation effectiveness and calculate VOC removal. The TFD and TFE influent samples will be analyzed for VOCs, semivolatiles, chlorides, and metals according to the schedule presented in Table 18.

Figure 9. TFD self-monitoring program sampling stations

Figure 10. TFE self-monitoring program sampling stations

Table 18. TFD and TFE self-monitoring sampling schedule.

Sample location[a]	Influent[a] TFD-I004 TFE-1005	Effluent[a] TFD-E004 TFE-E005	Receiving water[a] TFD-R004 TFE-R005	Land observations[b]
Frequency		Analysis		
Daily	Flow rate	Flow rate	Flow rate	—
Weekly	—	EPA 601[c] Hexavalent Chromium[d]	—	Perform
Monthly	EPA 601[c] pH	Temperature pH	EPA 601[c] Temperature pH	Complete report
Quarterly	Chlorides	Chlorides Fish toxicity[e] Turbidity[f]	Chlorides	
Semiannually	Metals[g]	Metals[g]	Metals[g] Fish toxicity[e] Turbidity[f]	—
Annually	EPA 624[h,i] EPA 625[k]	EPA 624[h,i] EPA 625[k] Gross alpha and beta particles, and tritium[l]	EPA 602[j] EPA 625[k] Gross alpha and beta particles, and tritium	—

RWQCB specifications:

- Sampling of receiving water should be coincident with influent and effluent water sampling.
- If any instantaneous maximum limit is exceeded, the sampling frequency shall be increased to daily until two samples collected on consecutive days show compliance with instantaneous maximum.

[a] Sample locations are shown in Figures 9 and 10.

[b] As required by RWQCB NPDES Permit No. CA 0029289, WDR Order No. 91-091.

[c] EPA 601 = EPA Method 601; analysis for volatile halocarbons by gas chromatography.

[d] Weekly monitoring for hexavalent chromium will be conducted for the first three months of initial operation. At that point, the efficiency of the treatment systems will be reviewed, and the monitoring schedule will be re-evaluated.

[e] Fish toxicity, 96 hours, survival in undiluted waste.

[f] Jackson turbidity units.

[g] Priority Pollutant Metals:

antimony
arsenic
beryllium
cadmium
chromium (total)
copper
lead
mercury
nickel
selenium
silver
thallium
zinc

PLUS: boron, chromium (+6), iron, manganese, and cyanide.

[h] When schedule calls for coincident EPA 601 and 624 analyses, only EPA 624 is conducted.

[i] EPA 624 = EPA Method 624; analysis for VOCs by gas chromatography/mass spectrometry.

[j] EPA 602 = EPA Method 602; analysis for volatile aromatic hydrocarbons by gas chromatography.

[k] EPA 625 = EPA Method 625; analysis for semivolatile organic compounds by gas chromatography/mass spectrometry.

[l] Gross alpha and beta particles, and tritium will be collected semiannually at sample location TFE-E005.

Table 19. Ground water quality sampling schedule for monitor wells and piezometers in the vicinity of TFD extraction wells.

Well number	Analyses	Sampling frequency	Planned months of sampling
7D2	601	Q	March, June, September, December
MW-7	601	A	March
MW-8	601	A	September
MW-10A	601	A	September
MW-114	Cr(VI), 601	A	June
MW-119	601	Q	March, June, September, December
MW-142	601	Q	March, June, September, December
MW-220	601, Cr(VI)	Q	March, June, September, December
MW-221	601	A	September
NW-222	601	S	March, September
MW-273	601	A	September
MW-311	601	A	September
MW-312	601	A	March
MW-313	601	Q	March, June, September, December
MW-315	601	A	March
MW-316	601	Q	March, June, September, December
MW-317	601	Q	March, June, September, December
MW-318	601, Cr(VI)	A	March
MW-319	601, Cr(VI)	A	March
MW-320	601, Cr(VI)	S	March, September
MW-351	601	Q	March, June, September, December
MW-355	601	Q	March, June, September, December
MW-360	601	S	March, September
MW-361	601	Q	March, June, September, December
MW-362	601	A	June
MW-369	601	A	September
MW-370	601	A	March
MW-372	601	A	March
MW-375	601, Cr(VI)	A	September
MW-411	601	Q	March, June, September, December
MW-412	601	A	March
MW-414	601, Tritium	A	September
MW-423	601	Q	March, June, September, December
MW-424	601	A	March
MW-450	601	S	March, September
MW-461	601	A	September
MW-487	601, Cr(VI)	A	March
MW-561	601	A	March

Table 19. (Continued.)

Well ID	Analyses	Sampling Frequency	Planned months of sampling
MW-568	**601, Cr(VI)**	**S**	**March, September**
MW-569	**601**	**A**	**March**
MW-593	**601**	**A**	**March**
MW-594	**601**	**A**	**September**
MW-653	**601**	**Q**	**March, June, September, December**

A = Annual.

S = Semiannual.

Q = Quarterly.

Cr (VI) = Hexavalent chromium.

601 = EPA Method 601 for halogenated VOCs.

Note: New piezometers and wells will be sampled quarterly for the first year. Subsequent monitoring frequency will be based on concentration and location within or relative to the plume.

Table 20. Ground water quality sampling schedule for monitor wells and piezometers in the vicinity of TFE extraction wells.[a]

Well ID	Analyses	Sampling frequency	Planned months of sampling
MW-12	624	S	June, December
MW-17	601	A	September
MW-17A	601	A	September
MW-113	601	A	September
MW-204	601	A	September
MW-206	601	Q	March, June, September, December
	Cr(VI)	A	September
	Tritium	S	March, September
MW-207	601	Q	March, June, September, December
MW-212	601	A	June
MW-224	601	S	December
MW-257	601	Q	March, June, September, December
	Cr(VI)	A	September
MW-258	601	S	March, September
	Cr(VI)	A	September
MW-259	601	Q	March, June, September, December
MW-268	601	A	September
MW-271	601	Q	March, June, September, December
MW-272	624	Q	March, June, September, December
MW-274	624	Q	March, June, September, December
MW-275	601	S	June, December
MW-276	624	A	June
MW-277	601, Cr(VI)	A	March
MW-290	601	A	September
MW-292	601	S[b]	June, December
MW-304	601	S	June, December
MW-305	601	S[b]	June, December
MW-314	601	S[b]	June, December
MW-352	601	Q	March, June, September, December
MW-353	601	Q	March, June, September, December
	Cr(VI)	A	September
MW-354	601	Q	March, June, September, December
MW-356	601	S	June, December
MW-358	601	A	June
MW-359	601	Q	March, June, September, December
MW-363	601, Tritium	Q	March, June, September, December
MW-364	601	S[b]	March, September
MW-562	601	S	March, September

Table 20. (Continued.)

Well ID	Analyses	Sampling frequency	Planned months of sampling
MW-566	**601**	**Q**	**March, June, September, December**
MW-570	**601**	**A**	**September**
MW-652	**601**	**A**	**March**

[a] Includes wells in the Trailer 5474 area.

[b] If the well is used as an extraction well prior to issuing the Compliance Monitoring Plan, the sampling frequency will be increased to quarterly.

A = Annual.

S = Semiannual.

Q = Quarterly.

Cr (VI) = Hexavalent chromium.

601 = EPA Method 601 for halogenated VOCs.

Note: New piezometers and wells will be sampled quarterly for the first year. Subsequent monitoring frequency will be based on ground water concentrations and the location within or relative to the plume.

Figure 11. Monitor well, extraction well, and piezometer locations in the vicinity of TFD and TFE

Figure 11. continued

Water levels in all monitor wells and piezometers will continue to be monitored on a monthly basis either manually or using pressure transducers and data loggers. Depth to water and pumping rates in extraction wells will be measured using pressure transducers and mechanical or electronic flow meters. The data will be automatically recorded using data loggers. These data will be used to estimate actual hydraulic capture zones and areas of little or no ground water movement. Based on hydraulic data, pumping locations and rates may be varied, and/or new extraction wells may be installed, to ensure complete hydraulic capture of the VOC plumes and an expeditious remediation.

Treatment system monitoring, chemical analytic results, and ground water contour and capture zone maps will be presented in the *LLNL Quarterly Progress Reports*.

4.2.3. Extraction Well Pumping Strategy

Current simulations of long-term pumping and contaminant transport indicate that an estimated 53 years of sustained ground water pumping may be required to achieve remediation goals. Modeling results are summarized in Tompson (1990), Tompson *et al.* (1991), and Tompson *et al.* (1994, in preparation). Extraction wells will initially be pumped at the maximum sustainable rates to achieve rapid mass removal and/or plume capture possible. After steady state is achieved, monitoring data will be used to refine and update the ground water models. As these results and new data are interpreted, changes in the wellfield configuration and pumping rates will likely be needed to optimize mass removal rates, maximize treatment and minimize dilution of contaminants, ensure hydraulic capture in all zones exceeding cleanup standards, and eliminate stagnation zones. Well condition will be periodically addressed by evaluating pumping rates, drawdown, water clarity, and by visual inspection. As required, extraction wells, monitor wells, and piezometers will be rehabilitated or replaced. All of these activities will be reported in the *LLNL Monthly or Quarterly Progress Reports*.

Based on the results of LLNL pilot studies and data from other sites, the VOC concentrations in ground water are expected to decrease rapidly at first, then stabilize or decrease very slowly. Estimates of VOC removal over time at TFD and TFE are shown in Figures 12 and 13, respectively. The TFE graph (Fig. 13) does not include VOC removal estimates for the Trailer 5475 area. The VOC removal rates were estimated using results from the two-dimensional, finite-element ground water flow and transport model CFEST (Tompson *et al.,* 1991; Tompson *et al.,* 1994, in preparation). The estimated volume of VOCs removed was calculated using a weighted average density. Actual VOC removal rates will depend on the VOC concentrations in extracted ground water and long-term well yields. The mass removal analysis for TFD (Fig. 12) shows that pumping may cease after about 30 years because the model indicates that VOC concentrations will be less than 5 ppb.

Several methods are being evaluated to maximize VOC removal rates, including cyclical pumping and reinjection of treated ground water, which may include the injection of heat, surfactants, microbes, or nutrients (Isherwood *et al*., 1992). Investigations may include laboratory and field studies to evaluate the effectiveness of the methods used to enhance contaminant mobility and mass removal. Any method used to maximize mass removal rates would comply with SWRCB Resolution No. 68-16 and would be implemented with regulatory oversight.

Figure 12. Estimated cumulative volume of VOCs removed from ground water by TFD over time

Figure 13. Estimated cumulative volume of VOCs removed from ground water by TFE over time

In one approach, some of the LLNL extraction wells (i.e., those in former source areas with VOCs in the shallowest ground water) may be periodically shut off and the water levels allowed to recover. During the pump-off cycles, VOCs will desorb into the ground water from the sediments that were dewatered in the vicinity of the pumping wells. Cycling the pumps may increase VOC removal rates near former source areas, where most of the VOCs occur in the shallower water-bearing sediments. Different pump-on and pump-off cycles will be evaluated to determine the optimum periods of pumping and nonpumping to maximize VOC mass removal rates.

In another approach, reinjection of treated ground water may be used to increase the rate of flushing in regions of high VOC concentrations, and to mitigate excessive dewatering that may result from ground water extraction. Reinjection of treated water in selected locations will enhance desorption of contaminants and increase the flushing rate in regions of slow ground water flow. The reinjection process may be enhanced by other means to increase the cleanup rate. If the water is heated prior to reinjection, VOCs will have a greater tendency to desorb from the sediment into the ground water than if the water is not heated. Similar benefits may arise if the reinjected water contains surfactants, which are compounds that increase the tendency for VOCs to dissolve in ground water. Such surfactants may be manufactured or microbially produced. If these or other methods are shown to be beneficial and cost-effective, they will be implemented with regulatory agency oversight.

As discussed in the RAIP, all injection well locations will be within the capture area of an extraction well since the reinjected water may contain up to 5 ppb total VOCs. Reinjection well locations will be selected to comply with SWRCB Resolution No. 68-16, an ARAR for the Livermore Site.

4.3. Requirements for Onsite Storage and Offsite Shipment of Hazardous Waste

Particulate filters and GAC containing sorbed VOCs will be shipped offsite for regeneration or disposal, and will be managed as hazardous waste, if appropriate. LLNL can temporarily store hazardous waste onsite for up to 90 days. Shipment and disposal are in accordance with Department of Transportation (DOT) 49 Code of Federal Regulations (CFR) and EPA 40 CFR, respectively. Additionally, waste shipments are made according to California Code of Regulations, Title 22 requirements. The spent GAC will be packaged and labeled for shipment by LLNL's Hazardous Waste Management Division (HWMD). LLNL's HWMD operates under Interim Status and has submitted a RCRA Part B permit application to the DTSC. (California is a fully RCRA-authorized State). Once packaged, the GAC will be shipped to one of several RCRA-permitted facilities for regeneration or disposal.

When a treatment facility is closed, the remaining H_2O_2 and the mercury vapor lamps will be categorized as excess product and reused if possible. The H_2O_2 will be shipped according to DOT 49 CFR and California 40 CFR and Title 22 regulations.

4.4. Requirements for Closeout

Decisions regarding when extraction should cease at specific wells, and when a particular treatment facility and its influent extraction wells should be decommissioned, will be based on achieving MCLs in all the piezometers and wells in the capture zone for the well/treatment facility. Such decisions will be made with regulatory agency oversight. Because the size and configuration of capture zones will change over the course of the cleanup, the vertical and horizontal distribution of the compounds of concern at the time MCLs are achieved will also be evaluated. As specified in the ROD, sitewide cleanup will be complete when ground water samples taken from the plume demonstrate that negotiated ARARs are achieved.

It is expected that VOC concentrations may rise in wells after extraction ceases due to slow desorption from fine-grained sediments. Therefore, contaminant concentrations will be monitored quarterly for 2 years after pumping ceases. If concentrations rise above cleanup levels, extraction will resume at the appropriate wells until cleanup levels are again achieved. Several pumping cycle iterations may be required to achieve the remediation standards. Cleanup will be considered complete when contaminant concentrations remain below the remediation standards for 2 years. Cleanup completion will be determined in conjunction with the regulatory agencies. After concurrence from the regulatory agencies that cleanup is complete, most of the LLNL extraction wells and piezometers will be sealed and abandoned. All wells screened in more than one water-bearing zone will be sealed to prevent potential vertical migration of compounds of concern. Wells will be sealed by pressure grouting using a grout mixture of 98% Portland cement and 2% bentonite powder by weight, as described in LLNL SOP 1.7 (Rice *et al.*, 1990). Cement grout should extend to a depth of 2 to 3 ft below grade. Wellhead abandonment will include removal of any protective covers, instruments, concrete pads, etc., and the upper 2 to 3 ft will be filled with low permeability soil to restore grade. A minimal monitoring network, consisting of perhaps 10 to 20% of the existing wells, will remain in place for general ground water quality monitoring. Most of these monitor wells will be located at downgradient plume margins and in former source areas.

TFD and TFE and their influent and discharge piping will be decontaminated and decommissioned after remediation is complete. The portions of the process equipment and piping that contact ground water will not contain hazardous VOC concentrations because the equipment will have been thoroughly flushed with ground water containing VOC concentrations below MCLs. The process equipment will be sold or recycled, if possible. Any wash water containing hazardous materials will be collected, sampled, and disposed at one of several RCRA-permitted facilities. The portions of the facilities that contain hazardous materials, such as H_2O_2 in the tank and feed lines, the mercury vapor lamps, and GAC with sorbed VOCs, will be disposed according to the specifications described in Section 4.3 “Requirements for Onsite Storage and Offsite Shipment of Hazardous Waste.”

5. Building 518 AreaVapor Extraction Treatability Test

5.1. Introduction

A vapor extraction treatability test was performed at the Building 518 Area to evaluate the applicability and effectiveness of vapor extraction as a remediation technique and to provide preliminary design parameters. The Building 518 Area is located south of extraction location 19, adjacent to East Avenue (Fig. 7), and consists of the partially asphalted area within about 100 ft of Building 518 (Fig. 14). Building 518 was constructed in 1959 for use as a gas cylinder, solvent, and oil drum storage dock area. Anecdotal information indicates that damaged and/or leaking drums were taken to the edge of the asphalt on the southeast corner of the facility and allowed to drain onto unpaved ground (Thorpe *et al.*, 1990).

The subsurface near Building 518 was initially investigated in 1984 with eight boreholes drilled to a depth of about 60 ft (Carpenter, 1984). Subsequently in 1988 and 1989, nine additional boreholes were drilled to the water table (Dresen *et al.*, 1989; Thorpe *et al.*, 1990). The vadose zone at this location is about 110 ft thick, and consists of heterogeneous interfingered silt, clay, and sand with minor amounts of clayey gravel and gravely sand. Soil vapor surveys to depths of 5 to 15 ft were also conducted in 1988 and 1989 (Fig. 14).

Results of the investigations in 1989 indicate that up to 6,400 ppb total VOCs existed in soil from SIB-518-001 at a depth of about 20 ft; of this total, 6,100 ppb was TCE. Preliminary numerical modeling performed to evaluate VOC migration by gaseous diffusion (Appendix G in Isherwood *et al.*, 1990) indicates that the VOCs in the vadose zone at this location will impact ground water with TCE concentrations above the MCL in the future (about 50 years). Therefore, DOE/LLNL plan to remove VOCs from the vadose zone by vapor extraction.

A vapor extraction treatability test was conducted from June 1 to June 4, 1993. Soil vapor boring SVB-518-201 was completed as a soil-vapor extraction well in March 1993 to conduct this test (Fig. 15). The test consisted of extracting vapor from SVB-518-201 and monitoring the effects in nearby piezometer SIP-518-101, located about 50 ft east of the extraction well (Figs. 14 and 15). SIP-518-101 is screened from 55 to 61 ft in 1 to 2 ft of sandy gravel surrounded by sandy and clayey silt. The extracted vapor was treated by two GAC canisters in series prior to atmospheric discharge (Fig. 15).

SVB-518-201 was screened from depths of 34 to 50 ft where up to 35 ppb total VOCs in soil were reported in the initial source investigations. The lithology in this interval consists of primarily silty gravel with interfingered clayey silt. The sample containing the 35 ppb total VOCs was held 9 days before analysis. There is some evidence that holding time can greatly affect reported concentrations (Jenkins *et al.,* 1993). Data collected in October 1993 from a piezometer about 20 ft away indicated that up to 4.3 ppm total VOCs exist near the interval screened in this well.

Figure 14. Sampling locations and total VOC soil-vapor concentrations at 5-ft depth

Figure 15. Building 518 soil-vapor extraction test setup

5.2. Test Setup

To conduct this test, a liquid-ring vacuum pump was connected to the extraction wellhead via a 5-in. PVC pipe (Fig. 15). A number of monitoring devices were attached to the PVC pipe throughout the system. Figure 15 shows the extraction system assembly. A 0- to 30-in. mercury (Hg) vacuum gauge and a pressure transducer were placed at the wellhead to monitor the vacuum at the well. The Hg vacuum gauge was used to calibrate and verify the pressure transducer measurements at the extraction well. To evaluate whether the daily ambient temperature changes affected the pressure transducer, a thermistor was installed to monitor the air temperature at the wellhead. Data from all the sensors except the Hg vacuum were recorded by a data logger. A sample port and small vacuum pump located about 3 ft from the wellhead were used to collect vapor samples.

A flow meter (Merian gauge), a 0- to 8-in. water differential pressure gauge (Magnahelic), and a pressure transducer were installed upstream of the liquid-ring vacuum pump. The liquid-ring vacuum pump was powered by a three-phase generator. A ball valve located on the pump assembly was used to control the vacuum at the wellhead. Two GAC canisters were attached via a 2-in. PVC pipe downstream of the pump to treat the VOCs (primarily TCE) from the vapor stream. A 10-ft stack was installed for sampling effluent gas and measuring air flow rates.

A pressure transducer and a 0- to 1-in. water vacuum gauge were used to measure the pressure at the piezometer.

The pressure transducers were calibrated *in situ* by linear regression analysis from vacuum gauge readings and temperature sensor responses collected prior to vapor extraction. All the thermistors were factory-calibrated. The flow meter was calibrated to 80 scfm in the laboratory with a flow meter calibration station.

On June 1, prior to starting the soil-vapor extraction system, pressure measurements were continuously recorded at the wellhead and at piezometer SIP-518-101, and averages were logged by the data logger at 15-minute intervals for 72 h.

5.3. Test Description

Vapor extraction began on June 2, 1993, and continued for approximately 8 h. The vacuum pump was set at a constant vacuum. However, throughout the test, the actual flow rate steadily decreased from 130 to 100 scfm. During the test, the effects of soil-vapor extraction were measured by continuously recording the vacuum in piezometer SIP-518-101 and periodically measuring water levels in nearby monitor well MW-255, screened from 115 to 124 ft in the first water-bearing zone (Fig. 14). Ambient air temperature, wellhead temperature, and pressure drop across the flow meter were also logged throughout the test. During the first testing day, soil surface flux (SSF) measurements were made at SSF-518-020, SSF-518-030, SSF-518-040, SSF-518-050, and SSF-518-060 (Fig. 14), using a soil surface flux chamber. Each location was measured prior to pumping, at midday during vapor extraction and after pumping stopped to evaluate the effect of vapor extraction on surface VOC emissions.

During the first day of pumping, it was determined that the 0- to 1-in. water vacuum gauge at the piezometer was undersized, so it was replaced with a 0- to 5-in. unit. In addition, the vapor flow rate could not be measured during the first day due to a malfunction in the flow meter. A Kurzt hot wire anemometer was installed in the exhaust stack for manual vapor flow readings the following day. An approximate vapor flow rate for the first day was calculated using a correlation between vacuum and flow data obtained during the second day of testing.

After the wellhead vacuum had stabilized, five vapor samples were collected using evacuated stainless steel spheres, following the procedures specified in Method 18 in 40 CFR, part 60.

On June 3, 1993, a second test was performed to evaluate the effect of vacuum extraction at various flow rates. The vacuum at the wellhead was incrementally increased from 0.36 to 11.55 in. of mercury. The flow rate was determined using the Kurzt hot wire anemometer installed in the exhaust stack. After the pressure and flow rate stabilized at each step, vapor samples were collected using evacuated stainless steel spheres.

Surface flux measurements were made on the second day of testing at location SSF-518-020 (Fig. 14) before pumping was started, at midday and after pumping stopped.

5.4. Results

Table 21 summarizes the pressures at the extraction wellhead and observation piezometer SIP-518-101, TCE concentrations in the vapor, and estimated flow rates at specific times for the first day of testing. Piezometer SIP-518-101 showed significant response to vapor extraction from SVB-518-201 (Fig. 16). Over the course of the test, the vacuum in the piezometer increased while the vacuum at the wellhead decreased. The increase in pressure at the piezometer over time may indicate a gradual propagation of a vacuum front through the relatively low-permeability materials between the extraction well and piezometer.

Table 21. Selected vapor extraction test data using relatively constant vacuum, June 2, 1993.

Time (minutes)	Wellhead vacuum (inches of Hg)	Piezometer vacuum (inches of water)	TCE concentration ($ppm_{V/V}$)	Flow rate (scfm)
7.5	18.0	0.25	50	130
15.0	18.8	0.63	340	140
75.0	15.9	1.01	448	120
210.0	14.2	1.19	390	110
443.0	12.7	1.21	296	100

TCE concentrations appeared to slightly decrease by the end of the first day of extraction (Fig. 17). The measured TCE concentrations were adjusted using the Ideal Gas Law to compensate for the slight one-third of an atmosphere vacuum in the sample spheres. As discussed above and shown in Figure 16, the vacuum in SVB-518-201 also decreased throughout the test.

Figure 16. Piezometer and wellhead vacuum over time (June 2, 1993)

Figure 17. Wellhead vacuum and TCE concetration over time (June 2, 1993)

As shown in Figure 18, TCE surface flux concentrations measured at location SSF-518-020 generally decreased, similar to the wellhead vacuum curve in Figure 17. Although each SSF location was somewhat affected by the vapor extraction process, SSF-518-020 was the only location to show a measurable effect. The results for the variable vacuum test over time are presented in Table 22.

Table 22. Selected vapor extraction test data using variable vacuum, June 3, 1993.

Time (minutes)	Wellhead vacuum (inches of Hg)	Piezometer vacuum (inches of water)	TCE concentration ($ppm_{v/v}$)	Flow rate (scfm)
57	0.36	0.00	456	1.9
90	0.69	0.00	525	3.5
119	1.10	0.00	546	7.6
173	1.47	0.00	555	9.9
200	3.13	0.20	525	22.9
241	5.80	0.40	498	41.5
323	11.55	1.10	496	86.2

The piezometer vacuum response to the variations of applied vacuum at the extraction well is presented in Figure 19. Although the magnitude of the vacuums differ, the response pattern measured at the piezometer closely followed the pattern measured at the extraction wellhead. The relation between the vapor extraction rate and wellhead vacuum is shown in Figure 20. These data indicate response in the piezometer to changing vacuum in the extraction well at a horizontal distance of about 50 ft.

The temperature measurements from the thermistor indicate that temperature did not seem to have a significant effect on the output of the pressure transducer. The water level in MW-255 did not appear to be affected by the vapor extraction.

5.5. Conclusions

The results of this soil-vapor extraction treatability test indicate that vapor extraction is an applicable and effective technique for removing VOCs from the vadose zone beneath the Building 518 Area. Test results also indicate that an extraction flow rate of 100 to 200 scfm may be appropriate for a preliminary system design. Soil vapor extraction at 100 scfm significantly influenced a piezometer 50 ft away, and GAC effectively treated the extracted VOC vapor.

Figure 18. Wellhead vacuum and TCE flux over time at SSF-518-020 (June 2, 1993)

Figure 19. Wellhead and piezometer vacuum over time (June 3, 1993)

Figure 20. Vapor flow rate versus extraction wellhead vacuum for test of June 3, 1993

6. References

6.1. References Cited

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6.2. References for LLNL Facilities Standards, Specifications, and Guide Documents

6.2.1. General

Designs, construction drawings, and specifications will conform to and comply with the applicable requirements of the latest adopted edition of the references listed herein, which will be considered minimum requirements.

6.2.2. Regulations

U.S. Department of Energy (DOE)

DOE 5480.7A	Fire Protection Program
DOE 6430.1A	General Design Criteria

Code of Federal Regulations (CFR)

10 CFR 435	Energy Conservation Standards
29 CFR 1910	Occupational Safety and Health Standards (OSHA)
29 CFR 1910.7	Definitions and Requirements for a Nationally Recognized Testing Laboratory (NRTL)
47 CFR 15	Telecommunication (FCC Rules, Part 15)

State of California Department of Labor (DOL)

DOL Labor Code	Division 5—Safety in Employment; Chapter 9—Miscellaneous Labor Provisions

California Code of Regulations (CCR)

CCR Title 8	Industrial Relations; Chapter 4, Subchapter 6
CCR Title 20	Public Utilities; Chapter 53—Energy Conservation in New Building Construction

University of California, Lawrence Livermore National Laboratory (UCRL)

UCRL 15910	Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards
UCRL 15714	Suspended Ceiling System Survey and Seismic Bracing Recommendations

6.2.3. Codes

American Concrete Institute (ACI)

ACI 318	Building Code Requirements for Reinforced Concrete

American Institute of Steel Construction (AISC)

AISC	Steel Construction Manual (Allowable Stress Design)

American National Standards Institute (ANSI)

ANSI A58.1	Building Code Requirements for Minimum Design Loads for Buildings and Other Structures

American Welding Society (AWS)

AWS D 1.1	Structural Welding Code—Steel

International Conference of Building Officials (ICBO)

ICBO UBC	Uniform Building Code
ICBO UMC	Uniform Mechanical Code
ICBO UPC	Uniform Plumbing Code

National Fire Protection Association (NFPA)

NFPA 70	National Electrical Code
NFPA 90A	Installation of Air Conditioning and Ventilating Conditioning Systems

6.2.4. Standards

American Concrete Institute (ACI)

ACI 347	Recommended Practice for Concrete Form Work

American Society for Testing and Materials (ASTM)

American Water Works Association (AWWA)

Construction Specifications Institute (CSI)

National Electric Manufacturers Association (NEMA)

Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACCNA)

6.2.5. LLNL Manuals and Reports

M-010	LLNL Health and Safety Manual

LLNL Site Development and Facilities Utilization Plan

LLNL Landscape Master Plan and Design Guidelines

7. Acronyms and Abbreviations

1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethylene
1,2-DCE	1,2-dichloroethylene
1,1,1-TCA	1,1,1-trichloroethane
A	amps
ACGIH	American Conference of Governmental Industrial Hygienists
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
ARAR	Applicable or Relevant and Appropriate Requirement
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Water Works Association
BAAQMD	Bay Area Air Quality Management District
BACT	Best Available Control Technology
CAL/OSHA	California Occupational Safety and Health Administration
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CI	Construction Inspector
CPR	cardiopulmonary resuscitation
CRP	Community Relations Plan
CSI	Construction Specifications Institute
dB	decibel
DDWM	Dissolved Drinking Water Metals
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
DTSC	California Department of Toxic Substances Control
EE	Electronic Engineering
EPA	U.S. Environmental Protection Agency
ERD	Environmental Restoration Division
ES&H	Environmental Safety & Health
F	Farenheit
FFA	Federal Facility Agreement
FHC	fuel hydrocarbon
Freon 11	trichlorofluoromethane

Freon 113	trichlorotrifluoroethane
FS	Feasibility Study
FY	fiscal year
GAC	granular activated carbon
gal	gallons
gpm	gallons per minute
G&A/LDRD	General and Administrative/Laboratory Directed Research and Development
Hg	mercury
H_2O	water
H_2O_2	hydrogen peroxide
HSP	Health and Safety Plan
HWM	Hazardous Waste Management
HWMD	Hazardous Waste Management Division
ICBO	International Conference of Building Officials
kW	kilowatt
kWh	kilowatt hour
LEL	lower explosive limit
LLNL	Lawrence Livermore National Laboratory
LSRSL	Livermore Site Restoration Section Leader
LWRP	Livermore Water Reclamation Plant
MCL	Maximum Contaminant Level
ME	Mechanical Engineering
M&I	materials and items
MPC	Material Procurement Charge
MSDS	Material Safety Data Sheet
M&TE	measuring and test equipment
MW	monitor well
NEMA	National Electric Manufacturers Association
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NPDES	National Pollution Discharge Elimination System
NQA	National Quality Assurance
NRTL	Nationally Recognized Testing Laboratory
$OH^\bullet$	hydroxyl radical
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
OSP	Operational Safety Procedure
OSWER	U.S. EPA Office of Solid Waste and Emergency Response
OTL	Operations Team Leader
OVM	organic vapor meter
PCE	perchloroethylene
PEPE	Plant Engineering Project Engineer
PEPM	Plant Engineering Project Manager
P&ID	piping and instrument diagram
PID	photoionization detector
PLC	programmable logic controller
PO	purchase order
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch

PVC	polyvinyl chloride
QA	quality assurance
QAM	Quality Assurance Manager
QC	quality control
RAIP	Remedial Action Implementation Plan
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RDOSL	Remedial Design and Operations Section Leader
RE	Remediation Engineer
ROD	Record of Decision
RWQCB	California Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
scfm	standard cubic feet per minute
SMACCNA	Sheet Metal and Air Conditioning Contractors National Association, Inc.
SOP	Standard Operating Procedure
SSF	surface soil flux
TBI	to be installed
TCE	trichloroethylene
TFC	Treatment Facility C
TFD	Treatment Facility D
TFE	Treatment Facility E
TTO	total toxic organics
TWA	time-weighted average
UBC	Uniform Building Code
UCRL	University of California, Lawrence Livermore National Laboratory
UEL	upper explosive limit
UL	Underwriter's Laboratory
UV	ultraviolet
UV/H_2O_2	ultraviolet/hydrogen peroxide
V	volts
VOC	volatile organic compound
v/v	volume per volume basis
WDR	Waste Discharge Requirement

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Appendix B

Operations and Maintenance Quality Assurance/Quality Control Plan

B-1. Introduction

This QA/QC plan has been developed in support of the O&M of TFD for ground water remediation located in Building 472, north of the LLNL Drainage Retention Basin, and of TFE for ground water remediation located in Building 437. This plan was prepared to meet the O&M requirements of TFD and TFE using the American Society of Mechanical Engineers (ASME) National Quality Assurance (NQA)-1-1989 Edition as a guideline.

The purpose of this plan is to define the quality objectives and areas of responsibility in accordance with the requirements of the O&M of TFD and TFE.

B-2. Organization

This section documents the organizational structure, functional responsibilities, levels of authority, and lines of communications for those aspects of the O&M of TFD and TFE that affect quality.

Figure B-1 shows the organizational structure for QA activities. The descriptions below generally describe the QA responsibilities of those mainly involved in carrying out the QA program for the O&M of TFD and TFE. The LLNL ERD Livermore Site Restoration Section Leader, the Quality Assurance Manager, the Remediation Engineer, and the other individuals shown in Figure B-1 have the following responsibilities:

- The Livermore Site Restoration Section Leader (LSRSL) issues this QA plan and periodically reviews its implementation. The LSRSL may request an independent review or formal audit of the QA program.

- The Quality Assurance Manager (QAM) is responsible for the development and implementation of the QA plan, establishment and control of the QA document files, coordination with appropriate project personnel to assure compliance within groups over which the quality organization has no administrative control, and development of tracking and reporting systems to provide management visibility of implementation activities and results.

- The Remediation Engineer (RE) is responsible for overseeing facility startup and monitoring its performance and operations.

- The LLNL Plant Engineering Project Manager (PEPM) reports to the ERD LSRSL and RE. The PEPM is Plant Engineering's primary contact with ERD for each assigned project. Working as the project team leader, the PEPM is responsible for achieving the objectives of each specific project within the allocated budget and schedule while meeting the established

Figure (Note: In Nans computer) B-1

performance criteria, as well as DOE, LLNL, and regulatory standards.

- The LLNL Plant Engineering Project Engineer (PEPE) performs the design or monitors and provides direction to engineers/architects with regard to design concepts, schedule, and budget. The PEPE reports operationally to the PEPM.

- The Construction Manager (CM) acts as the single point contact with construction subcontractors, and reports and advises on status, projected cost, and time of completion. Working in conjunction with the Construction Inspector, the CM protects LLNL's interest by assuring that all work is accomplished safely and in conformance with the contract documents. The CM reports operationally to the PEPM.

- The Construction Inspector (CI) will perform all inspector's duties as specified in the "Construction Inspector's Policy and Procedures Manual," the "Construction Manager Manual," and this QA plan. The CI is assigned to specific projects as the LLNL field representative, and provides quality control and status of all construction activities. The CI reports operationally to the CM.

- The Operations Team Leader (OTL) is responsible for the day to day maintenance and operation of ground water and soil treatment facilities. This includes scheduling required maintenance and ensuring that the maintenance requested is completed in a timely fashion.

- State Certified Analytical Laboratories using EPA methods are responsible for providing independent chemical analytical results on soil and ground water samples. For TFD and TFE, these samples are submitted as part of the self-monitoring program required by LLNL's discharge permit, in addition to operational testing samples collected prior to the official operation of a facility, and routine samples taken to evaluate facility performance.

B-3. Quality Assurance Program

This section covers objectives, quality goals, and QA levels. The procedures for implementation of QA are included in the plan or cited in the list of codes, standards, and specifications (Table B-1).

The objectives of the project supported by this QA plan are to:

- Assure excellence in maintenance services and operations to achieve quality.
- Provide the QA requirements to meet all programmatic and institutional needs.

This QA plan defines the process for providing confidence that these QA objectives will be achieved and that achievement will include due consideration for health, safety, property, and the environment. Table B-2 shows a list of auditable records (including responsible personnel) that are required to document compliance with the requirements of this plan. Table B-3 shows the 18 elements of NQA-1 and their applicability to the Livermore Site Restoration Section activities.

Table B-1. Applicable Codes, Specifications, and Standards for Operation and Maintenance QA for TFD and TFE.

“LLNL Procurement Manual,” Vol II, Books 1, 2, and Book 4 (Construction Subcontract Manual).

“LLNL Plant Engineering Manual,” Volumes 1-5, latest revision.

“LLNL Plant Engineering Drafting Manual,” PEL-P-02065.

“Guidelines For In-House Design Reviews and Project Presentations,” Frank Tokarz/ Roger Lake, Plant Engineering Department, Engineering/ Construction Division, LLNL, March 27, 1989 (with May 25, 1989 Rev.).

“Construction Manager Manual, Subcontracted Construction Projects,” Plant Engineering Department, LLNL, W. Kleck, January 1989.

“Construction Inspector's Policy and Procedures Manual,” Plant Engineering Department, LLNL (July 1984).

LLNL “Health and Safety Manual” (M010-May 1991).

Electronics Engineering / Instrument Services Calibration and Certification Manual, LER 87-1007-99.

Quality Assurance Plan for Calibration Services, Engineering Measurements and Analysis Section, Engineering Sciences Division, M.E.

LLNL Management Policy Memorandum MPM 02.2 “National Environmental Policy Act (NEPA) Compliance.”

DOE Order 4330.4A, Real Property Maintenance Management.

Plant Engineering (PE) QA Program Plan, Rev. 1.

PE QA Manual PEL-P-01010, Rev. 0.

LLNL Environmental Protection Handbook, issued by the Environmental Protection Department.

PE Policy and Operations Manual PEL-P-01000.

PE Specifications, PEL-P-02075.

PE Maintenance and Operations QA Plan, M-078-30.6, September 1990.

PE Maintenance and Operations Electric Utilities QA Plan, M-078-30.10, October 1990.

PE Maintenance Services/Operations QA Plan, M-078-30.9, December 1990.

PE Maintenance and Operations Utilities QA Plan, M-078-30.7, July 1991.

PE Maintenance and Operations Maintenance Engineering and Production Control QA Plan, M-078-30.8, September 1991.

PE Maintenance and Operations Electric Utilities QA Plan, M-078-30.10, October 1991.

Table B-2. Required QA records.

QA files	QA record title	Person responsible
TFD/E-2-1	**Personnel Training Records**	**QAM**
TFD/E-3-1	**Design Criteria**	**PEPE**
TFD/E-3-2	**Design Calculations**	**PEPE**
TFD/E-3-3a	**Design Changes**	**PEPE**
TFD/E-3-3b	**Specifications**	**PEPE**
TFD/E-3-4a	**Drawing List**	**PEPM**
TFD/E-3-4b	**Specifications List**	**PEPM**
TFD/E-3-6	**NEPA Compliance Documents**	**PEPM**
TFD/E-4-1	**Design or Construction Purchase Orders**	**PEPM**
TFD/E-5	**Work Performance and Facility Operations log**	**OTL**
TFD/E-6-1	**As-Built Prints**	**CM**
TFD/E-7-1	**Notice of Completion**	**CM**
TFD/E-9-1	**Welder Certification**	**CI**
TFD/E-9-2	**Welding Test Reports**	**CI**
TFD/E-9-3	**Cemented Joints Test Reports**	**CI**
TFD/E-10-1	**Inspection Prints**	**CI**
TFD/E-10-2	**Final Inspection Report**	**CI**
TFD/E-10-3	**Final Acceptance Report**	**CI**
TFD/E-18-1	**Audit Requests and Reports**	**PEPM**

Table B-3. Applicability of NQA-1 Elements to the Quality Assurance of TFD and TFE.

NQA-1 requirement	Title	Applicable ?
Basic 1	Organization	Y
Supplement S-1	Terms and Definitions	Y
Supplement 1S-1	Supplementary Requirements for Organization	N
Basic 2	Quality Assurance Program	Y
Supplement 2S-1	Supplementary Requirements for the Qualification of Inspection and Test Personnel	N
Supplement 2S-2	Supplementary Requirements for the Qualification of Nondestructive Examination Personnel	N
Supplement 2S-3	Supplementary Requirements for the Qualification of Quality Assurance Program Audit Personnel	N
Supplement 2S-4	Supplementary Requirements for Personnel Indoctrination and Training	N
Basic 3	Design Control	Y
Supplement 3S-1	Supplementary Requirements for Design Control	N
Basic 4	Procurement Document Control	Y
Supplement 4S-1	Supplementary Requirements for Procurement Document Control	N
Basic 5	Instructions, Procedures, and Drawings	Y
Basic 6	Document Control	Y
Supplement 6S-1	Supplementary Requirements for Document Control	N
Basic 7	Control of Purchased Items and Services	Y
Supplement 7S-1	Supplementary Requirements for Control of Purchased Items and Services	N
Basic 8	Identification and Control of Items	Y
Supplement 8S-1	Supplementary Requirements for Identification and Control of Items	N
Basic 9	Control of Processes	Y
Supplement 9S-1	Supplementary Requirements for Control of Processes	N
Basic 10	Inspection	Y
Supplement 10S-1	Supplementary Requirements for Inspection	N
Basic 11	Test Control	Y
Supplement 11S-1	Supplementary Requirements for Test Control	N
Supplement 11S-2	Supplementary Requirements for Computer Program Testing	N
Basic 12	Control of Measuring and Test Equipment	Y
Supplement 12S-1	Supplementary Requirements for Control of Measuring and Test Equipment	N
Basic 13	Handling, Storage, and Shipping	Y

Table B-3. (Continued.)

NQA-1 requirement	Title	Applicable ?
Supplement 13S-1	**Supplementary Requirements for Handling, Storage, and Shipping**	**N**
Basic 14	**Inspection, Test, and Operating Status**	**Y**
Basic 15	**Control of Nonconforming Items**	**Y**
Supplement 15S-1	**Supplementary Requirements for the Control of Nonconforming Items**	**N**
Basic 16	**Corrective Action**	**Y**
Basic 17	**Quality Assurance Records**	**Y**
Supplement 17S-1	**Supplementary Requirements for Quality Assurance Records**	**N**
Basic 18	**Audits**	**Y**
Supplement 18S-1	**Supplementary Requirements for Audits**	**N**

B-4. Operations and Maintenance

B-4.1. Scope

TFD and TFE will operate to treat ground water containing VOCs. The ground water will be treated to meet the requirements for TFD and TFE specified in California RWQCB WDR Order No. 91-091 (NPDES Permit No. CA 0029289). A table summarizing the effluent discharge requirements is presented in Section A.2., in Appendix A. Therefore, O&M activities at these facilities shall be controlled by quality procedures.

B-4.2. Operations

The LSRSL is responsible for ensuring the quality of operations at these facilities. The OTLs are responsible for ensuring that all field operations, including maintenance and operations, are performed with the appropriate quality procedures and are completed in a timely fashion. Each treatment facility, per their respective permits, has a required Self-Monitoring Program. This involves collecting water samples for submission to State-certified analytical laboratories for analysis by EPA methods. The results of these analyses are used by LLNL, EPA, RWQCB, and DTSC to monitor the performance of each treatment facility. The OTLs are responsible for ensuring that the technicians are properly trained to collect these samples according to documented procedures.

Each treatment facility has its own set of operating procedures. These procedures, which are being developed, cover the different modes of operation, including startup and shutdown, and are described in the TFD and TFE operating procedure manuals.

Daily operational logs are kept at each facility. These logs record the operating parameters of each system (i.e., temperature, pressure, etc.), the number and type of samples taken, all maintenance performed on the system, and all adjustments made by the operators to the system.

B-4.3. Maintenance

Two types of maintenance are performed at TFD and TFE:

- Preventive.
- Corrective.

B-4.3.1. Preventive Maintenance

Preventive maintenance is performed on those components that need routine servicing and are part of systems related to quality. The preventive maintenance schedule is kept at each facility with the operations procedures for TFD and TFE. The OTL is responsible for ensuring that the preventive maintenance items are scheduled and completed. Maintenance is performed by the LLNL Plant Operations and/or ERD personnel and follows the QA/QC manuals to ensure quality maintenance is performed.

TFD and TFE are treatment facilities designed to operate on a 24-hour-per-day, 7-day-per-week schedule. To keep these systems in continuous 24-hour operation, a preventive maintenance program is required.

B-4.3.1.1. TFD Preventive Maintenance Plan

Table B-4 is a tentative schedule of the preventive maintenance for TFD.

Table B-4. Preventive Maintenance for TFD.

Action	Frequency/Comments
Check all components and pipelines for leaks	**Daily. If leaks are found, determine potential effects of leak and take appropriate action**
Check prefilter pack #1 and #2	**Daily. Pressure drop across filter greater than 2 psi (maximum variation of 5 psi is allowable) indicates a need to change filters**
Check air stripper tank for scale build-up (calcium carbonate deposits/iron scale) on the aeration diffusers	**Daily. Scale build-up on any of the indicators requires system shut down and lock-out of power to the blowers and source well pumps. Exchange the scaled diffusers for both tanks with refurbished diffusers using manufacturers procedures**
Sample effluent	**Weekly. See WDR Order No. 91-091 (NPDES Permit No. CA 0029289)**
Clean organic debris from area surrounding the building	**Weekly, or as needed. Notify the gardeners (Ext. 3-0495)**
Check for proper operation of eye wash and shower	**Weekly. Open eye wash valve. Dust covers should pop off as water flows from eye wash ports, and water should spray up a minimum of 6 in.**
Regenerate one of the two resin columns for the ion- exchange unit with 1 to 2 Molar NaCl	**Every 12 days**

Table B-4. (Continued.)

Action	Frequency/Comments
Recharge the ion-exchange unit with NaCl with approximately 500 gal of 1 to 2 Molar NaCl	**Every 12 days**
Remove waste 1 to 2 molar NaCl and hexavalent chromium (approximately 500 gal) from the ion-exchange unit	**Every 12 days**
Top off the ion-exchange unit columns at regular intervals	**To be determined. Requires approximately 5 ft^3 per year**
Shut down and clean out the ion-exchange unit tanks with built-up deposits of calcium bicarbonate or other precipitates	**As required**
Replenish the acid supply (HCl) for the pH adjustment tank. The use rate is approximately 43 gal of HCl per day	**Change the 55-gal drums daily**
Floor maintenance	**Semiannually. Contact custodians (Ext. 2-9744) to set up date for stripping and waxing of floors**
Replace ion-exchange unit pump seals and lubricating bearings, according to manufacturer's recommendations	**About every 6 months**
Service blower motors on air stripper tank	**Annually. Motors and pumps to be serviced by Plant Engineering motor shop (Ext. 2-7751), Bldg. 511**
Test interlock control system	**Monthly**
Service well pumps	**Annually**
Service air stripper variable speed discharge pump	**Annually**
Cycle vapor carbon adsorption filters	**Annually**
Certify flow sensors	**Annually**
Operationally verify and/or service level sensors	**Annually**
Service air compressor	**Annually**
Replace demister pads	**Annually**
Replace the entire resin charge for the ion-exchange unit	**Every 5 years. Requires about 60 ft^3**
Service the ion-exchange unit hydraulic valves	**Every 5 years**

B-4.3.1.2. TFE Preventive Maintenance Plan

To ensure reliable and safe operation of TFE, preventive maintenance is performed regularly by vendors of certain treatment system components and by LLNL Plant Operations and ERD personnel according to LLNL QA/QC manuals. Maintenance records and the preventive maintenance schedule are stored in Building 406.

The following maintenance tasks are performed by Peroxidation Systems, Inc., or ERD personnel on the LVB-60 UV/H_2O_2 Oxidation Unit:

- Replace UV lamp.
- Replace ruptured disc.
- Perform routine and corrective maintenance on the Liquid Metronics, Inc., H_2O_2 pumps.
- Replace and/or service UV lamp ballast.
- Repair and/or service internal LBV-60 electrical components.

The following maintenance tasks are performed by Continental Recovery Systems or other qualified personnel on the GAC vapor treatment system:

- Test and maintain control system, as necessary.
- Inspect Nash positive displacement blower, lubricate bearings as necessary.

Additional preventive maintenance tasks on all other TFE components include:

- Inspect pump controller, replace worn rubber parts.
- Inspect air compressor, replace air filter, and change oil.
- Inspect and lubricate bearings in water transfer pumps.
- Inspect particulate filters on UV/oxidation unit influent, replace as needed. Flush spent filters with clean air introduced into the vapor extraction system for GAC treatment. Dispose of filters after VOC concentrations in flush air drop to nondetectable concentrations.
- Inspect air stripping blowers.
- Inspect air stripping tanks.
- Replace GAC air stripping vapor stream.
- Inspect water condensate transfer tank on vapor extraction system.
- Inspect miscellaneous hoses, seals, fittings, valves, etc.

Table B-5 is a tentative schedule of the preventive maintenance for TFE.

Table B-5. Preventive maintenance at TFE.

Action	Frequency
Inspect pump controller, replace worn rubber parts	**Monthly/as needed**
Inspect air compressor, replace air filter and change oil	**Weekly/as needed**
Inspect and lubricate water transfer pumps on bearings	**Weekly**

Table B-5. (Continued.)

Action	Frequency
Inspect particulate filters on UV/oxidation unit influent	**Daily**
Replace GAC on air stripping vapor stream	**As needed**
Test interlock control system	**Monthly**
Check air stripper tank for scale build-up (calcium carbonate deposits/iron scale) on the aeration diffusers	**Daily. Scale build-up on any of the indicators requires system shutdown and lock-out of power to the blowers and source well pumps. Exchange the scaled diffusers for both tanks with refurbished diffusers using manufacturer's procedures.**
Service blower motors on air stripping tank	**Annually. Motors and pumps to be serviced by Plant Engineering Motor Shop (Ext. 2-7751)**
Service air stripper variable speed discharge pump	**Annually**
Inspect miscellaneous hoses, seals, fittings, valves, etc.	**Weekly**
Inspect and test eye wash station	**Weekly**

B-4.3.2. Corrective Maintenance

Corrective maintenance is performed when a system component fails or is beginning to fail and the quality of facility operations could be compromised if operation continues. Root cause analyses are performed each time a component fails before the corrective maintenance action commences. This is to ensure that the nature of the problem is understood and can be prevented. This root cause analysis is also used to modify the preventive maintenance plan where appropriate. The results of the root cause analyses are documented in the daily facility operations log. As with preventive maintenance, corrective maintenance is performed by the Plant operations personnel or ERD in accordance with their maintenance procedures and QA/QC plan.

All corrective maintenance actions and their time of completion are recorded in the facility daily operations log. Once complete, the specific component or system is started up and operated. This ensures that the maintenance was correctly performed and that system quality is maintained. An entry in the facility log is made, indicating that an operational check was made following preventive or corrective maintenance and the performance of the system's new component is noted. If successful, the system is allowed to resume normal operations.

The O&M manuals for TFD and TFE, which are currently being developed, will indicate the required spare parts for system components that have relatively high risk of failure or require a long lead time to obtain. These components are to be maintained onsite to prevent extended shutdown of the treatment systems.

B-4.4. Drawing and Specification

The PEPM is responsible for preparation and updating complete drawing and specification lists. The lists shall include all drawings, specifications, and changes for Purchase Order (PO) contracts, labor only contracts, Job Orders, and Mechanical and Electronic Engineering Department drawings. This list will serve as the index for the QA print files and as the list of prints required in the QA files.

QA records to be filed as required in Table B-2:

(TFD/E-3-4a) A current and/or final copy of the drawing list.

(TFD/E-3-4b) A current and/or final copy of the specification list.

B-4.5. National Environmental Policy Act (NEPA)

The PEPM is responsible for assuring compliance with NEPA requirements. Completed documentation consists of LLNL Plant Engineering Form 1, NEPA Compliance Project Notification Form, and the NEPA Compliance Environmental Checklist. Memos to and from DOE, and Environmental Impact Studies, as applicable, are evidence of NEPA compliance.

QA records to be filed as required in Table B-2:

(TFD/E-3-6) NEPA Compliance Documents.

B-5. Procurement

B-5.1. Procurement Contracts

Preparation and approval of PO contracts, when necessary for the purchase of equipment or services needed for maintenance, shall comply with standard LLNL purchasing policies.

QA records to be filed as required in Table B-2:

(TFD/E-4-1) Copy of all material and equipment POs over $5,000.

B-5.2. Documents

The approval and control of procurement documents shall conform to LLNL Procurement Manual, Vol. II, Books 1, 2, and 4. The control and approval of maintenance construction drawings shall conform to LLNL Plant Engineering Drafting Manual, PEL-P-02065. Control, format, and approvals of specifications shall conform to Plant Engineering Standard PEL-P-02075 Specifications.

All drawings shall be approved for maintenance construction and have all applicable approval signatures before the bidding process, or, for LLNL construction, before the estimate process. Approvals of major changes to instructions, drawings, and specifications shall be the same as for the original issue.

Minor technical design changes made in the field shall be approved by the CM and the CI on the inspection print, and on the as-built drawings.

QA records to be filed (as required in Table B-2):

(TFD/E-6-1) One set of as-built prints for each project.

B-5.3. Control of Purchased Items and Services

Purchased items and services shall be controlled in accordance with standard LLNL Purchasing Policies. A Notice of Completion shall be prepared with all required LLNL signature approvals, and sent to the LLNL Procurement Department before contract close-out.

QA records to be filed (as required in Table B-2):

(TFD/E-7-1) Copy of the Notice of Completion for each project.

B-5.4. Handling, Storage, and Shipping

Items and materials shipped to LLNL shall be packaged, shipped, and stored according to instructions on drawings, specifications, contracts, and POs. The RE or OTL will perform a receiving inspection and/or the CI shall inspect incoming items and materials to identify any damage that may have occurred during shipping and storage.

Handling equipment, such as fork lifts and cranes, shall be operated, maintained, and tested in compliance with DOE and California State regulations. When LLNL equipment is used, compliance with the LLNL Health and Safety Manual is required.

Inspection reports are initiated and maintained per the CI’s Policy and Procedures Manual. No additional QA records are required for the QA files.

B-5.5. Control of Nonconforming Items

The CI and CM shall maintain cognizance of salvage (rejected or damaged) materials and items (M&I), and arrange for segregation, and prompt disposition of LLNL supplied rejected M&I. The construction subcontractor shall be notified to immediately remove any rejected subcontractor-supplied M&I from LLNL. Any nonconformance which cannot be immediately corrected and verified by the CI shall be documented on a Deficiency Notice or punch list as applicable. Nonconformances to be dispositioned as “use as is” or “repair” (as opposed to rework) must be recorded on a Deficiency Report, approved and signed by the CM.

Inspection reports are initiated and maintained per the CI’s Policy and Procedures Manual. No additional QA records are required for the QA files.

B-6. Maintenance Support

B-6.1. Identification and Control of Items

Material delivered to the job site is inspected to verify compliance with the approved submittals to assure that only correct and accepted items are used or installed.

The CM will request identification and inspection of items arriving at the construction site, when required. Acceptance of M&I not in conformance with requirements shall be approved by the LSRSL and PEPE, and shall comply with the LLNL Procurement Manual.

Inspection reports are initiated and maintained per the CI’s Policy and Procedures Manual. No additional QA records are required for the QA files.

B-6.2. Inspection, Test, and Operating Status

The CI and CM shall maintain cognizance of incoming and stored M&I, and inspect or test them for conformance to requirements. When the CI or CM is concerned with maintaining identification of the status of a shipment of critical M&I, they shall tag them to ensure that untested or rejected items are not inadvertently used.

Lockout tags shall be tied on electrical equipment, lifts and hoists, valves, etc., where such items are unsafe to use, are uncertified, or to protect personnel working on the system.

Inspection reports are initiated and maintained per the CI's Policy and Procedures Manual. No additional QA records are required for the QA files.

B-6.3. Control of Processes

Procedures for welding, bonding, and other processes shall be called out in specifications or drawings, as required.

When required in construction specifications, bonded joints, welding tests, and inspections, welder certifications shall be verified by the CM and the CI, as required.

QA records to be filed (as required in Table B-2):

(TFD/E-9-1) Welder certifications.

(TFD/E-9-2) Welding test reports.

(TFD/E-9-3) Cemented joints test reports.

B-6.4. Inspection

All maintenance work, and LLNL acceptances within the scope of this QA plan, including PO contract and labor only contract, are subjected to inspection. Work shall be inspected and documented according to the "Construction Inspector's Policy and Procedures Manual" and the "Construction Manager Manual." The inspection team shall delay progress payments to the subcontractor if the work is not in place, or is not up to contract quality.

During construction of modifications, the CI shall maintain a set of as-built marked prints to compare with the subcontractor's prints, and shall review and approve the subcontractor's prints.

After construction, the CI shall verify the accuracy of the as-built drawings in accordance with the construction inspector's policy and procedures manual. The CI and PEPM shall indicate approval of the subcontractors marked up print by signing the as-built drawing.

QA records to be filed (as required in Table B-2):

(TFD/E-10-1) All inspection prints, with copies of field memos, change orders, calculations, and sketches attached.

(TFD/E-10-2) Final inspection report per Construction Manager Manual.

(TFD/E-10-3) Final acceptance report per Construction Manager Manual.

B-6.5. Control of Measuring and Test Equipment

Certified testing laboratory subcontractors shall periodically calibrate measuring and test equipment used for LLNL work according to the requirements in the contract and according to Federal and State codes.

B-7. Activation of Measuring and Testing Equipment

All measuring and test equipment (M&TE) used in acceptance testing of electronic, monitoring, and interlocks systems and items shall be calibrated in accordance with the applicable LLNL calibration manual or plan. The individual conducting the test shall be responsible for assuring that all test equipment is calibrated and within its certification period.

The two major calibration laboratories at LLNL are the Engineering Measurements & Analysis Section, Mechanical Engineering (ME), and the Instrument Services Group, Engineering Services Division, Electronic Engineering (EE). The ME facility typically calibrates M&TE that make pressure, force, displacement, flow, humidity, acceleration, velocity, or temperature measurements. The EE facility services and calibrates M&TE that measures frequency, time, and electrical and magnetic measurements.

Calibration of M&TE may be performed by LLNL calibration laboratories or by outside vendors providing calibration services. Vendors providing calibration shall be required to meet the requirements of MIL-STD-45662, where necessary.

No additional QA records are required in QA files, but such records are filed in the EE and ME calibration facilities.

B-8. Quality Assurance Records

B-8.1. Quality Assurance Records

QA records shall be prepared, archived, and made readily available as evidence that TFD and TFE were specified, designed, constructed, operated, and maintained to meet the quality goals of this QA plan. They shall be protected and maintained for a minimum of 6 months after completion of the project, prior to being microfilmed and archived for long-term storage.

The QA records specified by this plan do not include all the project records generated in the project. In addition to the QA records, there are microfilmed records maintained by LLNL Plant Engineering, and contract records maintained by the LLNL Procurement Department. Although these records are not defined as QA records, they are available for examination if required.

B-8.2. Filing Systems

QA records required by this plan shall be filed in lockable cabinets in the order given in Table B-2. Before filing, each record shall be numbered and titled according to Table B-2, and stamped with a black ink stamp:

QA RECORD

QA PLAN NO. X-XXX-XX

DATE:_________

A file drawer insert shall be set up and labeled for each file number, and each record shall be placed in a labeled folder or binder and kept in the QAM's office. QA records are not working files, and shall not be so utilized. If files are borrowed, a file checkout system shall be used to track record location and to ensure their prompt return.

B-8.3. Plant Engineering Records

In addition to the separate QA records file of this QA plan, the PEPM, PE, CM, and CI shall organize and maintain working engineering files for the project. These files are not QA records files; they are files normally kept when required for compliance or legal purposes. Records, as specified in the CM Manual and the Construction Inspector's Manual, shall be collected by the CM, CI, and the PEPE, and transmitted by the PEPM to the Standards and Documentation group of Plant Engineering for microfilming. These files shall be preserved for a period of not less than 6 years after project completion.

B-9. Audits

The PEPM shall arrange for periodic independent audits of the implementation of this QA plan.

QA records to be filed:

(TFD/E18-1) Audit requests and reports.

B-10. References

American Society of Mechanical Engineers (ASME), 1989, NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*, ASME NQA-1-1989 edition.

MIL-STD-45662, “Calibration System Requirements.”

PEL-01000, “Plant Engineering Policy and Operations Manual.”

Appendix C
Operations and Maintenance Health and Safety Plan

Section C-1 of this appendix is the O&M Health and Safety Plan (HSP) for TFD. The HSP for O&M of TFE is presented in Section C-2.

C-1. HSP for Ground Water Remediation at TFD

C-1.1. Reason for Issue

Safety procedures are required to operate and maintain the TFD air-stripping system, ion-exchange unit, and water filtering system. This HSP also serves as an administrative tool to summarize many of the requirements of the LLNL Health and Safety Manual which are pertinent to TFD's O&M. This HSP supplements the vendor's operating instruction manuals for the ion-exchange unit.

C-1.2. Work to be Done and Location of Activity

C-1.2.1.

TFD, when constructed, will be in Building 472, which is located north of the drainage retention basin.

C-1.2.2.

TFD is used to treat VOCs and chromium. Ground water containing VOCs and chromium will be extracted from extraction wells utilizing submersible pumps generating from 10 to 60 gpm output.

C-1.2.3.

The influent passes through two 5-micron filters that have differential pressure gauges across them in the range of 0 to 25 psi.

C-1.2.4.

Water passes through two air-stripping tanks in parallel and then through one air stripping tank. Acid or carbon dioxide may be injected into the flow as needed to reduce the formation of precipitates and achieve a pH within discharge limits.

C-1.2.5.

VOCs are removed from the water by injecting air into the bottom of the tanks and subjecting the water to intense aeration.

C-1.2.6.

The effluent passes through an ion-exchange unit to reduce the concentration of hexavalent chromium at or below the 11 ppb discharge limit (detection limit is 10 ppb). As discussed in Section 2.1, the ion-exchange unit will be installed only if needed.

C-1.2.7.

The vapors from each stripping tank pass through demister pads to remove the water droplet fraction. The air stream then passes through three parallel GAC canisters that trap the VOCs.

C-1.3. Responsibilities

C-1.3.1.

Ed Folsom, phone number (510) 422-0389, LLNL pager number 02892, and home phone number (510) 490-7028, is responsible for the safety of this operation and for assuring that all work is performed in conformance with this HSP and applicable sections of the LLNL Health and Safety Manual and Environmental Protection Handbook. In the absence of the responsible individual, Sally Bahowick, phone number (510) 423-6773, LLNL pager number 05565, or Jerry Duarte, phone number (510) 423-2638, LLNL pager number 03180, shall assume these responsibilities.

C-1.3.2.

Any changes in operations that improve or do not significantly affect safety and environmental controls may be approved by the authorizing individuals in Section C-1.3.1. and the LLNL Environmental Safety & Health (ES&H) team leader. The responsible individual will ensure that this action is documented in a memorandum. Any changes in the operation that increase the hazard level, introduce additional hazards, or decrease safety shall not be made until a revision to this HSP has been reviewed and approved consistent with the review and approval process of the original HSP.

C-1.3.3.

Before starting operation, the responsible individual shall verify and document that the operating personnel have read and understand the HSP.

C-1.4. Hazard Analysis

C-1.4.1. Pressure Hazard

None is anticipated.

C-1.4.2. Chemical Hazard

Injury may occur from the ion-exchange unit to personnel exposed to the 1 to 2 Molar sodium chloride solution. Also, injury may occur from the pH adjustment unit to personnel exposed to the corrosive substances hydrochloric acid and sodium hydroxide.

C-1.4.3. Confined Space

Injury may occur while entering, working in, and leaving the Baker tanks and the treatment system stripping tanks.

C-1.4.4. Noise Hazard

Injury may occur if continued exposure to the aeration system's blowers exceeds two hours.

C-1.4.5. Electrical Hazard

Injury may occur if the ion-exchange unit panel door is open and contact is made with energized electrical components .

C-1.5. Hazard Control

C-1.5.1. Chemical Hazard Control

Corrosives are stored in doubly contained tanks in the ion-exchange unit. Facility operators will follow Health and Safety Manual Sections 21 and 21.05.

C-1.5.2. Confined Hazard Control

C-1.5.2.1.

Facility operators will follow Health and Safety Manual Section 26, and Supplement 26.14, and will notify the responsible individual designated in Section C-1.3 of this HSP prior to entry into the confined space.

C-1.5.2.2.

Unauthorized access to the Baker tanks is controlled by removing the access ladder and securing the access with a chain and keyed lock. A key is stored in a lock box in Building U187.

Unauthorized access to the polishing tank is accomplished by bolts and by attached equipment that require physical removal by two or more personnel.

C-1.5.2.3.

The stripping tanks will remain closed unless a facility operator with a second person is present to perform maintenance on the tanks.

C-1.5.3. Noise Hazard Control

C-1.5.3.1.

Noise protection is required in the aeration system blower room.

C-1.5.3.2.

The facility operator is required to follow noise safety precautions as outlined in the LLNL Health and Safety Manual, Section 10.08 and Supplement to 10.08.

C-1.5.4. Electrical Hazard Control

C-1.5.4.1.

An interlock system and panel doors with keyed locks prevent contact with energized electrical components. Keys to panel door locks are kept in a lock box in Building 472.

C-1.5.4.2.

All personnel will follow safety precautions as outlined in the Health and Safety Manual.

C-1.6. Environmental Concerns and Controls

C-1.6.1.

Concern: Discharge of untreated ground water.

Controls: Interlocks will shut off the flow and the system if physical damage to the treatment system occurs; scheduled sampling per discharge permit monitors discharge; and facility operator inspects the system daily.

C-1.7. Training

C-1.7.1.

Basic Facility Operators Courses:

- HS-0039-SARA/OSHA Training (40-hour course with refreshers every year).
- HS-0001-New Employee Safety Orientation.
- HS-1620-Standard First Aid.
- HS-1640–CPR.
- HS-5300-Back Care Workshop.

C-1.7.2.

Facility Operator Courses:

- HS-4150–Confined Space.
- HS-4240–Chemical Safety.
- HS-4360–Noise Safety.
- HS-5220–Electrical Safety.
- HS-5230–High Voltage Safety.
- HS-0006–Hazardous Waste Handling Practices.

C-1.7.3.

Training courses identified in this section do not qualify a person to operate the treatment equipment and treatment systems located at Building 472. Only the responsible individual identified in Section C-1.3.1 of this HSP will determine if and when a person is qualified to operate the treatment facility at Building 472. Once qualified, each technician's personnel file is updated to reflect their status as a treatment facility operator.

C-1.8. Maintenance

Items requiring periodic maintenance do not impact the safety of the operation.

C-1.9. Quality Assurance

C-1.9.1.

Scheduled weekly, monthly, quarterly, and annual sampling of water at various parts in the system ensure compliance and quality.

C-1.10. Emergency Response Procedures

C-1.10.1.

In the event of an emergency, facility operations personnel will first dial "911" to report to the Emergency Dispatcher, then administer first aid if necessary to injured personnel. The Emergency Dispatcher uses reserved telephone lines to promptly relay the emergency call to the following members of the LLNL Emergency Response Team:

- Fire Department.
- Security Department.
- Hazards Control Safety Teams.
- Plant Engineering.
- Health Services.

The Emergency Response Team will go to the scene of the emergency immediately.

During off-shift hours, the phone numbers of individuals to be notified in the event of an emergency are posted at TFD. The LLNL Health and Safety Plan describes the emergency response procedures.

C-1.11. References

C-1.11.1.

Operating manual for the ion-exchange unit.

C-1.11.2. Health and Safety Manual Sections

1. LLNL General Policies and Responsibilities.
2. Work Planning and Safety Procedures.
10.08 Hearing Protection.
21. Chemicals.
21.04 Facilities and Equipment.

21.05 Handling Solid and Liquid Chemicals.

23.00 Electricity.

23.01 Introduction.

23.02 Biological Effects of Electrical Hazards.

23.03 Emergency Assistance and Rescue.

23.04 Personal Protective Equipment.

23.05 Design and Documentation Electrical Equipment.

23.06 Training Requirements for Electrical Work.

23.10 General Practices for Work on Electrical Equipment.

23.13 Work on Other Electrical Apparatus and Systems.

23.20 Clearances and Illumination for Electrical Enclosures.

23.21 Power Disconnect Points.

23.23 Extension Cords.

23.30 Portable Electric Tools and Equipment.

23.35 Power Supplies.

23.36 Microwave and Electromagnet Sources.

23.37 Electromagnets and Inductors.

23.38 Batteries.

23.39 Capacitors.

26.14 Working in Confined Spaces.

C-1.11.3. Health and Safety Manual Supplements

10.08 Noise–Its Measurements, Evaluation, and Control.

26.14 Working in Confined Spaces.

C-1.11.4. Environmental Protection Handbook

C-1.12. Reviewers

C-1.12.1.

The following are reviewers for this Operation and Maintenance Health and Safety Plan:

Facility Supervisor.

Section Head or Group Leader.

Hazard Control Safety Team 4.

Individual assigned responsibility for safety.

Division/Department who authorized HSP.

Supervisor of matrixed technical personnel.

C-2. HSP for Ground Water Remediation at TFE

C-2.1. Reason for Issue

Safety procedures are required to operate and maintain the TFE ultraviolet light (UV) system, aeration system, and hydrogen peroxide (H_2O_2) delivery system. This HSP also serves as an administrative tool to summarize many of the requirements of LLNL Health and Safety Manual, which are pertinent to TFE's O&M. This HSP supplements the vendor's operating instruction manuals for the UV-LVB-60 treatment unit.

C-2.2. Work to be Done and Location of Activity

C-2.2.1.

TFE, when constructed, will be in Building 437 located south of Building 543.

C-2.2.2.

The treatment system consists of a commercially available UV/H_2O_2 unit and two air stripping tanks in series to further treat the water from UV/H_2O_2 system.

C-2.2.3.

The vapors from the air stripping tanks pass through two activated carbon filters in parallel to ensure that no measurable VOCs are released to the air.

C-2.2.4.

Operation of TFE includes monitoring its status, maintaining and cleaning extraction and treatment equipment, and sampling liquid and vapor.

C-2.3. Responsibilities

C-2.3.1.

Ed Folsom, phone number (510) 422-0389, LLNL pager number 02892, and home phone number (510) 490-7028, is responsible for the safety of this operation and for assuring that all work is performed in conformance with this HSP and applicable sections in the Health and Safety Manual and Environmental Protection Handbook. In the absence of Ed Folsom, Jerry Duarte, phone number (510) 423-2638, LLNL pager number 03180, shall assume these responsibilities.

C-2.3.2.

Any changes in operations that improve or do not significantly affect safety and environmental controls may be approved by the authorizing individuals listed in Section C-2.3.1 and the ES&H Team Leader. The responsible individual will ensure that such actions are documented in a memorandum. Any changes in operations that increase the hazard level, introduce additional hazards, or decrease safety shall not be made until a revision of or supplement to this HSP has been reviewed and approved consistent with the review and approval process for the original HSP.

C-2.3.3.

Before starting operation, the responsible individual shall verify and document that the operating personnel have read and understand the HSP.

C-2.4. Hazards Analysis

C-2.4.1. Pressure Hazard

Injury may occur if LVB-60 reactor chamber rated at 25 psig is overpressurized. However, an inline 15 psi pressure relief valve prior to reactor chamber and 20 psi pressure rupture disk located at the end of the reactor chamber mitigate the overpressurization potential.

C-2.4.2. Chemical Hazard

Injury may occur from the 50% H_2O_2 solution stored in the 300-gallon-dual-containment tank should eyes or skin come in contact with the solution, should ingestion occur, or should inhalation occur.

C-2.4.3. Confined Space

Injury may occur while entering, working in, or leaving the Baker tanks. Unauthorized access to the Baker tanks is controlled by removing the access ladder and securing the access with a chain and keyed lock.

C-2.4.4. Noise Hazard

C-2.4.4.1.

Injury may occur if continued exposure to the aeration system's blowers exceed 6 hours.

C-2.4.4.2.

Injury may occur when aeration system's waste gate valve is actuated.

C-2.4.5. Electrical Hazard

Injury may occur if LVB-60 panel door is open and contact is made with energized electrical components.

C-2.5. Hazard Control

C-2.5.1. Pressure Hazard Control

A 15-psi pressure control valve is utilized and a 20-psi pressure safety disk ensures that the LVB-60 reactor chamber can not be overpressurized.

C-2.5.2. Chemical Hazard Control

The 50% H_2O_2 solution is managed by the Peroxidation Systems qualified chemical handler. Therefore, facility operations personnel should not be exposed to the chemical hazard. If facility operations personnel elect to handle the 50% H_2O_2 solution, they must adhere to the following:

- Notify the responsible individual as designated in Section C-2.3.1. of this HSP prior to start of any work activity requiring H_2O_2 solution handling.
- Read and adhere to Health and Safety Manual Sections 21, 21.05, and 21.045 and the Environmental Handbook prior to start of any work activity requiring the H_2O_2 solution handling.

C-2.5.3. Confined Hazard Control

C-2.5.3.1.

Facility operators will follow Health and Safety Manual Section 26, Supplement 26.14, and will notify responsible individual designated in this HSP Section C-2.3 prior to entry into the confined space.

C-2.5.3.2.

Ladders are removed from Baker Tanks and secured with a chain and keyed lock. Key is stored in lock box in Building 437.

C-2.5.4. Noise Hazard Control

C-2.5.4.1.

Noise protection is required when continuous exposure to aeration system blowers exceeds 6 hours.

C-2.5.4.2.

Noise protection is required for all personnel when the aeration system waste gate valve is actuated.

C-2.5.4.3.

Facility operator is required to follow noise safety precautions as outlined in Health and Safety Manual Section 10 and Supplement 10.08.

C-2.5.5. Electrical Hazard Control

C-2.5.5.1

Interlock system and panel door with keyed locks prevent contact with energized electrical components. Keys to panel door locks are kept in lock box at Building 437.

C-2.5.5.2.

All personnel will follow safety precautions as outlined in Health and Safety Manual sections.

C-2.6. Environmental Concerns and Controls

C-2.6.1.

Concern: H_2O_2 spill from 300-gallon storage tank.

Control: Secondary containment vessels encloses the primary 300-gallon tank.

C-2.6.2.

Concern: Discharge of untreated ground water.

Control: Interlocks will shut off flow and system if physical damage occurs.

Scheduled sampling per discharge permit monitors discharge.

Daily inspection by Facility Operator.

C-2.7. Training

C-2.7.1. Basic Facility Operator Courses

- HS-0001—New Employee Safety Orientation.
- HS-0039—SARA/OSHA Training (40-hour course with 8-hour refreshers every year).
- HS-1620—Standard First Aid.
- HS-1640—Cardiopulmonary Resuscitation (CPR) repeated every 2 years.

C-2.7.2. Facility Operator Courses

- HS-1680—Fire Extinguisher Training.
- HS-4150—Confined Space Entry.
- HS-5030—Pressure Safety Orientation.
- HS-5210—Capacitor Safety Orientation.
- HS-5220—Electrical Hazards Awareness.
- HS-5230—High Voltage Safety.
- HS-6010—Radiation Safety.

C-2.7.3.

The training courses identified in this section do not qualify a person to operate the treatment equipment and treatment systems located in Building 437. Only the responsible individual identified in Section C-2.3.1 of this HSP will determine if and when a person is qualified to operate the treatment facility at Building 437. Once qualified, each technician’s personnel file is updated to reflect their status as a treatment facility operator.

C-2.8. Maintenance

Items requiring periodic maintenance do not impact the safety of the operation.

C-2.9. Quality Assurance

Scheduled weekly, monthly, quarterly, and annual sampling and analysis ensure compliance and quality. These data will be analyzed by the Remediation Engineer to monitor performance and verify compliance with permits.

C-2.10. Emergency Response Procedures

C-2.10.1.

In the event of an emergency, facility operations personnel will first dial “911” to report to the Emergency Dispatcher, then administer first aid if necessary to injured personnel. The Emergency Dispatcher uses reserved telephone lines to promptly relay the emergency call to the following members of the Emergency Response Team:

- Fire Department.
- Security Department.
- Hazards Control Safety Teams.
- Plant Engineering.
- Health Services.

The Laboratory’s Emergency Response Team will go to the scene of the emergency immediately. During off-shift hours, the phone numbers of individuals to be notified in the event of an emergency are posted at the facility. The LLNL Health and Safety Plan describes the emergency response procedures.

C-2.11. References

C-2.11.1.

Peroxidation Systems operating manual for the LVB-60 Perox-Pure Systems.

C-2.11.2 Health and Safety Manual Sections

1. LLNL General Policies and Responsibilities.
2. Work Planning and Safety Procedures.
10.08 Hearing Protection.
21. Chemicals.
21.04 Facilities and Equipment.
21.05 Handling Solid and Liquid Chemicals.

23.00 Electricity.

23.01 Introduction.

23.02 Biological Effects of Electrical Hazards.

23.03 Emergency Assistance and Rescue.

23.04 Personal Protective Equipment.

23.05 Design and Documentation Electrical Equipment.

23.06 Training Requirements for Electrical Work.

23.10 General Practices for Work on Electrical Equipment.

23.13 Work on Other Electrical Apparatus and Systems.

23.20 Clearances and Illumination for Electrical Enclosures.

23.21 Power Disconnect Points.

23.23 Extension Cords.

23.30 Portable Electric Tools and Equipment.

23.35 Power Supplies.

23.36 Microwave and Electromagnet Sources.

23.37 Electromagnets and Inductors.

23.38 Batteries.

23.39 Capacitors.

26.14 Working in Confined Spaces.

C-2.11.3. Health and Safety Manual Supplements

10.08 Noise–Its Measurements, Evaluation, and Control.

26.14 Working in Confined Spaces.

C-2.11.4. Environmental Protection Handbook

C-2.12. Reviewers

C-2.12.1.

The following are reviewers for this Operation and Maintenance Health and Safety Plan:

Facility Supervisor.

Section Head or Group Leader.

Hazard Control Safety Team.

Individuals assigned responsibility for safety.

Division/Department who authorized HSP.

Supervisor of matrixed technical personnel.

Appendix D

TFD and TFE Sampling Procedures

Water samples will be collected prior to and following treatment, and prior to discharge to the Drainage Retention Basin. Samples will be collected according to the schedule outlined in WDR Order No. 91-091 (NPDES Permit No. CA 0029289) and presented in Table 18 of this report. Prior to collecting a sample, the office preparation procedures described in SOP No. 2.6— "Sampling for Volatile Organic Compounds" and SOP No. 4.2— "Sample Control and Documentation" will be followed (Rice *et al.*, 1990).

Samples will be collected from the TFD and TFE designated sampling stations shown on Figures 8 and 9, respectively. The influent, effluent, and receiving water samples will be collected by opening the valve at the sampling port and allowing water to flow through it for about 15 seconds A bottle will be introduced into the flow stream and filled. If the bottle is not certified clean, it will be rinsed first with the water to be sampled. For the influent sample, the untreated water flowing through the valve prior to and during sampling will be captured with a bucket and returned to the system for treatment.

A specific sample container is used depending on the analysis. In addition, some analyses require sample preservation. Such requirements for each analysis are described in SOP No. 4.3— "Sample Containers and Preservation" (Rice *et al.*, 1990). Samples are then packaged and shipped to a certified analytical laboratory according to SOP No. 4.4— "Guide to the Handling, Packaging, and Shipping of Samples" (Rice *et al.*, 1990).

Results of the treatment facility sampling are discussed in the self-monitoring section of the Ground Water Project Monthly Progress reports.