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Interim Remedial Design for the High Explosives Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300

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August 2002

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Environmental Protection Department
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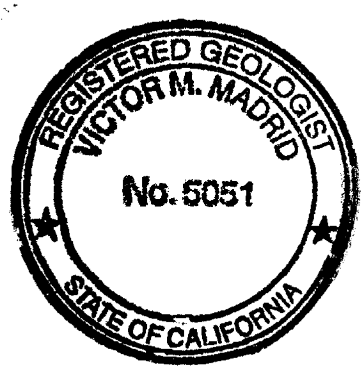
Certification

I certify that the work presented in this report was performed under my supervision. To the best of my knowledge, the data contained herein are true and accurate, and the work was performed in accordance with professional standards.



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Executive Summary

The U.S. Department of Energy (DOE) and Lawrence Livermore National Laboratory (LLNL) have prepared this Remedial Design (RD) report for the High Explosives (HE) Process Area Operable Unit (OU) at Site 300 in accordance with the Federal Facility Agreement (FFA). LLNL Site 300 is a DOE-owned experimental test facility operated by the University of California. An interim remedial action for the HE Process Area OU was selected in the Interim Site-Wide Record of Decision (DOE, 2001). The selected remedy consists of continued and expanded ground water extraction and treatment with monitoring and risk and hazard management.

This RD report summarizes the site history, geology, hydrogeology, treatability testing, removal actions, and presents the existing and proposed remedial designs for the HE Process Area OU. In addition, it summarizes performance data for existing treatment facilities and presents a Remedial Action Work Plan for the selected remedy. All necessary administrative controls for the existing and proposed remedial designs are described in the Risk and Hazard Management Program. The Risk and Hazard Management Program will be included in the Site-Wide Compliance Monitoring Plan due in 2002.

For the purpose of this RD report, the HE Process Area OU is divided into three treatment areas: (1) Source Area (SRC), (2) Proximal Area (PRX), and (3) Distal Site Boundary Area (DSB). The Source Area refers to the area around Buildings 806/807, 810, 815, and 817, where the majority of confirmed contaminant releases occurred. The Proximal Area refers to the area immediately downgradient (south) of the Source Area, from Building 815 to the vicinity of Buildings 818 and 823. Contaminants, mainly the volatile organic compound (VOC) trichloroethylene (TCE) and HE compounds cyclo-1,3,5-trimethylene-2,4,6-trinitramine (RDX) and perchlorate (ClO_4^-), reside in ground water beneath the Source and Proximal Areas. TCE and RDX have also been detected in soil and bedrock samples collected from the vadose zone beneath the Source Area. The bulk of TCE mass in the $Tnbs_2$ aquifer resides beneath the Proximal Area. The Distal Site Boundary Area is located in the southern part of the HE Process Area OU, where the Site 300 boundary is located. This area contains TCE at low concentrations, generally below 30 micrograms per liter (µg/L), however, RDX and perchlorate are not present in the Distal Site Boundary Area at concentrations above Environmental Protection Agency (EPA) method detection limits for those chemicals.

Ground water treatment technologies, including aqueous-phase granular activated carbon (GAC) and bioremediation using an *ex situ* anaerobic bioreactor, were tested to evaluate their efficiency for treating RDX, perchlorate and nitrate. GAC was found to be cost-effective for removing RDX from ground water and the anaerobic bioreactor was found to be cost-effective for nitrate destruction. Based on treatability testing, GAC did not prove to be a cost-effective technology for removal of perchlorate; therefore, ion-exchange technology will be used to remove any perchlorate remaining after GAC treatment. Discharge of treated effluent will be accomplished using one of two methods: (1) a misting system to discharge to the atmosphere, or (2) an infiltration trench to discharge to the subsurface.

The proposed remedial strategy for the HE Process Area OU will be implemented in four phases: (1) prevent offsite migration of ground water contaminants, (2) minimize influence of site boundary pumping on the RDX plume, (3) maximize contaminant mass removal, and (4) cleanup fine-grained source areas.

Phase 1 began in 1999 with the installation of a treatment facility (B815-DSB) in the Distal Site Boundary area. The purpose of this facility is to prevent offsite migration of TCE. Phase 2 began with the installation of a second treatment facility (B815-SRC) in 2000 in the Source Area. The purpose of this facility is to minimize influence of site boundary pumping on the RDX plume. Phase 3 will begin with the installation of a third facility (B815-PRX) which is scheduled for installation in 2002. The primary objective of this facility is TCE mass removal. Two additional facilities, B817-SRC and B817-PRX, are planned for 2004 and 2005, respectively, as part of this phase of the cleanup effort. The proposed extraction wellfield, which consists of ten wells, was designed using a calibrated, finite element flow and transport model. The calibrated model will be used to manage and optimize the extraction wellfield. Additional extraction wells will be added, if necessary, to achieve the cleanup standards that will be specified in the Final Site 300 Record of Decision (ROD). Phase 4, which involves cleanup of fine-grained source areas, will begin using conventional pump-and-treat techniques. If these methods prove impracticable, innovative techniques such as enhanced *in situ* bioremediation may be considered.

1. Introduction

This Remedial Design (RD) report describes the existing and proposed remedial designs for the High Explosives (HE) Process Area Operable Unit (OU) at Lawrence Livermore National Laboratory (LLNL), Site 300. Site 300 is a U.S. Department of Energy (DOE)-owned experimental test facility operated by the University of California. The site is located in the southeastern Altamont Hills of the Diablo Range, about 17 miles east-southeast of Livermore and 8.5 miles southwest of Tracy, California (Fig. 1).

In 2001, an Interim Site-Wide Record of Decision (ROD) was signed by DOE and the regulatory agencies. In the Interim ROD, interim remedial actions were selected for a majority of the Site 300 OUs, including the HE Process Area OU. The selected remedy for the HE Process Area OU is ground water extraction and treatment with compliance monitoring and administrative controls (e.g., risk and hazard management). A Remedial Design Work Plan (Ferry et al., 2001) presents the strategic approach and schedule to implement the remedies selected in the Interim ROD.

DOE is the lead agency for cleanup at Site 300 with regulatory oversight by the U.S. Environmental Protection Agency (EPA), the California Department of Toxic Substances Control (DTSC), and the Regional Water Quality Control Board (RWQCB)-Central Valley Region.

The scope and format of this document are consistent with EPA guidance documents (EPA, 1989; 1990). As suggested by EPA, this RD report contains engineering design specifications for the ground water extraction and treatment systems, including Process and Instrumentation Diagrams (P&IDs), system descriptions, monitoring and construction schedules, and cost estimates. This RD report also includes Quality Assurance/Quality Control (QA/QC) Plans and Health and Safety Plans for both construction and operation and maintenance (O&M), and the requirements for onsite storage and offsite shipment of hazardous waste and project closeout.

Section 1 of this RD report describes the location of the HE Process Area OU, the history of the OU, previous investigations and removal actions, and regulatory history. Section 2 presents a summary of the geology and hydrogeology and contaminant distribution. Section 3 describes the treatability studies conducted in the OU, the current remedial system design, and presents the proposed long-term remedial design. Section 4 contains the Remedial Action Work Plan. The following appendices are also included:

Appendix A: Monitoring and Reporting Requirement Documents

Appendix B: Ground Water Flow and Contaminant Transport Modeling and Capture Zone Analysis

Appendix C: Nitrate Study

Appendix D: Construction Quality Assurance/Quality Control Plan

Appendix E: Construction Health and Safety Plan

Appendix F: Operations and Maintenance Quality Assurance/Quality Control Plan

Appendix G: Operations and Maintenance Health and Safety Plan

1.1. Location

The HE Process Area OU occupies approximately 934 acres (approximately 1.5 mi^2) in the southeastern part of Site 300 (Fig. 2). This area is characterized by steep, hilly terrain with northwest-southeast trending canyons and ridges (Fig. 3). The HE Process Area OU is bounded by the Building 832 Canyon OU to the east, the Pit 6 OU to the west, the Building 850/Pits 3 and 5 OU to the north, and the Site 300 boundary to the south. Access to Site 300 and the HE Process Area OU is restricted for security and safety reasons.

The main focus of this RD report is the area around Buildings 806, 807, 810, 815, and 817. Technical operations, mainly former waste water disposal practices at these facilities, led to soil and ground water contamination at the site.

1.2. Site History

Prior to the purchase of the land that is now Site 300 in 1955, this area was used for livestock grazing and ranching. Facility construction began in 1955 and most of the HE processing facilities were constructed by the early 1960s. Technical operations, which began in the late 1950s, involve the chemical formulation, mechanical pressing, and machining of HE compounds into shaped detonation devices. These devices are used in open-air detonation experiments conducted on firing tables in the East-West Firing Area, located in the northern part of Site 300. Solid HE waste remaining after machining operations was disposed of by incineration at the HE Open Burn Facility located near Building 829 in the northern part of the HE Process Area OU. Liquid waste generated during machining operations was discharged to former unlined disposal lagoons.

In 1982, the volatile organic compound (VOC), trichloroethylene (TCE), was detected in a ground water sample collected from former water-supply Well 6, screened in the $Tnbs_2$ aquifer. Well 6 was located in the southern part of the HE Process Area OU near the Site 300 boundary (Fig. 3). It was operated from the late 1950s to the mid-1980s to supply water for Site 300 operations. TCE concentrations in this well increased to levels above the drinking water standard of 5 µg/L by 1986. At that time, Well 6 was taken out of service and destroyed. It was replaced in 1989 with the installation of Well 20, which is located approximately 600 feet (ft) west of where Well 6 was located. Well 20 is the main water-supply well for Site 300 and it is screened in the deeper $Tnbs_1$ aquifer.

In 1985, two double-lined HE surface impoundments were installed south of Building 817 to receive all HE process waste water and replace the unlined disposal lagoons. The surface impoundments allow dissolved explosives chemicals in the waste water to degrade from exposure to ultraviolet rays in sunlight. These surface impoundments are still in operation today and regulated under waste discharge order 96-248 issued by the RWQCB.

In 1997, the Final Closure Plan for the HE Open Burn Facility at Building 829 was submitted to the regulatory agencies (Lamarre et al., 1997). This facility consisted of three unlined pits and an open-air burn unit to incinerate HE waste. This facility was operated under 40 Code of Federal Regulations (CFR), Part 265, Subpart P and 22 California Code of Regulations (CCR), Division 4.5, Chapter 15, Article 16. As specified in the Final Closure Plan, this Burn Facility was dismantled, capped, and three deep ground water wells were installed in the regional $Tnbs_1$ aquifer for post-closure monitoring.

1.3. Site Characterization

Environmental site characterization activities in the HE Process Area OU are briefly summarized in this section. More detailed information can be found in the Final Site-Wide Remedial Investigation (SWRI) report (Webster-Scholten, 1994) and the Building 815 Operable Unit Engineering Evaluation/Cost Analysis (EE/CA) report (Madrid and Jakub, 1998).

Site characterization began in the HE Process Area OU in the early 1980s to evaluate whether waste water discharges into unlined disposal lagoons at Buildings 806/807, 817, 826, 827C/D, 827E, and 828 could result in contamination of the local ground water. This investigation determined that the lagoon waters contained parts per million (ppm or milligrams per liter [mg/L]) levels of chemical explosives cyclo-1,3,5-trimethylene-2,4,6-trinitramine (RDX), cyclotetramethylene tetranitramine (HMX), and trinitrotoluene (TNT). In addition, barium was detected at 2.35 mg/L in the 806/807 lagoon and nitrate at levels exceeding the 45 mg/L drinking water standard in lagoons 806/807 (391 mg/L), 827 C/D (170 mg/L), and 817 (77 mg/L). The study also concluded that discharges to the lagoons would reach ground water in less than 20 years (Raber, 1983).

Additional investigations, including the collection and analyses of surface soil samples, subsurface soil and bedrock samples, water samples from springs, soil vapor samples from passive and active vacuum induced (AVI) soil vapor surveys (SVS), and the installation of ground water monitor wells, were conducted to determine the nature and extent of soil and ground water contamination beneath the site. To date, 84 ground water monitor wells have been installed in the HE Process Area OU. Sixteen of these wells monitor the shallow Tps water-bearing zone and 39 monitor the upper blue sandstone $Tnbs_2$ aquifer. These investigations have identified VOCs; HE compounds, including HMX, RDX, and perchlorate (ClO_4^-); and nitrate as the primary contaminants of concern (COCs) in ground water.

Twelve confirmed chemical release sites (source areas) have been identified. Among the confirmed release sites, the former TCE Hard Stand located near Building 815 is considered to be the primary source of VOCs. The HE rinse-water disposal lagoons at Buildings 806/807 and 817 and the dry well at Building 810 are considered the primary source areas for HE compounds, including perchlorate and nitrate.

From 1989 to 1990, 14 exploratory boreholes were drilled within the Building 829 HE Open Burn Facility. Eleven of the exploratory boreholes were drilled inside the Burn Pits and three were drilled in the vicinity of the former Hazardous Waste Accumulation Area (HWAA) or Drying Shed. Two of the exploratory boreholes located near the Drying Shed were completed as ground water monitor wells (W-829-06 and -08). These wells were completed in perched ground water contained in the Neroly $Tnsc_1$ unit. This perched water-bearing zone is about 300 ft above the regional aquifer. Elevated levels of TCE in ground water samples collected from these monitor wells in combination with passive soil vapor surveys confirmed the Drying Shed as a primary source of VOCs in this area. Subsequent ground water monitoring has detected perchlorate and nitrate at concentrations above their respective drinking water standards in these wells.

A baseline human health risk assessment for the HE Process Area OU was conducted as part of the SWRI report. This risk assessment consisted of conservatively estimating potential excess lifetime cancer risk associated with residential use of contaminated ground water from a hypothetical water-supply well located at the site boundary. Exposure-point concentrations were estimated for TCE in ground water using the 2-D saturated flow and transport model, PLUME (Webster-Scholten, 1994). Modeling results indicated that TCE would reach the site boundary at a concentration exceeding the 5.0 micrograms per liter (µg/L) drinking water standard in about 10 years and reach an average maximum concentration of about 6.0 µg/L at 20 years. The estimated incremental cancer risk from exposure to contaminants in this aquifer exceeds 1×10^{-6}.

1.4. Past Remedial Actions

A regulatory closure involving the capping of the HE Open Burn Facility and a Removal Action near the site boundary have been implemented in the HE Process Area OU. A Resource Conservation and Recovery Act (RCRA) cap was installed in 1997 to satisfy requirements of the Closure Plan for the former Building 829 HE Open Burn Facility. This remedial action is briefly described in Section 1.4.1. A second remedial action, the Building 815 Removal Action, was implemented in 1999. This remedial action involves the extraction and treatment of ground water near the Site 300 boundary and is briefly described in Section 1.4.2.

1.4.1. HE Open Burn Facility Capping

In 1997, the Final Closure Plan for the HE Open Burn Facility was submitted to the regulatory agencies (Lamarre et al., 1997). In accordance with this Closure Plan, this facility was dismantled, removed, and covered with a multi-layer cap consisting of geosynthetic and natural materials. As shown in Figure 3, post-closure monitoring of the deep regional aquifer ($Tnbs_1$) is conducted using three ground water monitor wells (W-827-05, W-829-15, and W-829-22) located downgradient and cross-gradient of the facility. To date, no anthropogenic chemicals have been detected in these post-closure monitor wells. Ground water was not encountered in the equivalent stratigraphic interval ($Tnsc_1$) that is contaminated beneath the facility.

1.4.2. Building 815 Removal Action

The Building 815 Removal Action, which began in June 1999, is designed to prevent offsite migration of contaminants in the $Tnbs_2$ aquifer. This Removal Action was described in two reports submitted to the regulatory agencies: (1) Engineering Evaluation/Cost Analysis (EE/CA) for the Building 815 Operable Unit, Lawrence Livermore National Laboratory Site 300 (Madrid and Jakub, 1998) and (2) Action Memorandum for the Building 815 Operable Unit, Lawrence Livermore National Laboratory Site 300 (Jakub, 1998). This Removal Action was implemented in two phases:

1. Installation of two offsite compliance well clusters (W-35B well clusters) to monitor the leading edge of the TCE plume in the site boundary area.
2. Extraction and treatment of contaminated ground water from onsite wells located near the Site 300 boundary.

This removal action represents the initial phase of ground water cleanup at this OU. The Building 815 Removal Action has been superceded by regulatory approval of the Interim ROD. A multi-phase cleanup strategy for the entire OU is presented in Section 3.1.2.

1.5. Regulatory History

Site 300 was placed on the EPA's National Priorities List in 1990. In June 1992, DOE, EPA, DTSC, and the RWQCB signed a Federal Facility Agreement (FFA) to facilitate compliance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). As part of the CERCLA process, the LLNL Environmental Restoration Division (ERD) has prepared a series of reports for the HE Process Area OU:

- The Draft High Explosives Process Area Remedial Investigation/Feasibility Study (RI/FS) was the first comprehensive characterization of the site hydrogeology and contaminant distribution.
- The Final Site-Wide Remedial Investigation (SWRI) report, Chapter 13 (Webster-Scholten, 1994) further characterized the site hydrogeology and contaminant distribution.
- The Final Closure Plan for the High-Explosives Open Burn Facility at Lawrence Livermore National Laboratory, Site 300 (Lamarre et al., 1997) was submitted to the regulatory agencies in 1997. This facility was dismantled and capped with native and geosynthetic materials in accordance with the Closure Plan. It is currently in the post-closure monitoring phase.
- The Building 815 Operable Unit Engineering Evaluation/Cost Analysis (EE/CA) (Madrid and Jakub, 1998) proposed a Removal Action involving the installation of offsite ground water compliance wells and extraction and treatment from onsite wells to prevent offsite migration of TCE-contaminated ground water.
- An Action Memorandum for Building 815 Removal Action (Jakub, 1998) authorized the early phase of ground water cleanup under the Building 815 OU EE/CA as a Non-time Critical Removal Action.
- The Site-Wide Feasibility Study (SWFS) (Ferry et al., 1999) screened and evaluated remedial alternatives for all OUs at Site 300.
- The Interim Site-Wide Record of Decision (ROD) (DOE, 2001) specifies ground water extraction and treatment, ground water monitoring, and administrative controls (e.g., risk and hazard management) as components of the remedy for the HE Process Area OU.
- The Remedial Design Work Plan (RDWP) (Ferry et al., 2001) describes strategic approach and schedule to implement cleanup as established in the Interim Site-Wide ROD.

2. Geology and Hydrogeology

The geology and hydrogeology of the HE Process Area OU are discussed in more detail in Chapter 13 of the SWRI report (Webster-Scholten, 1994) and Section 1.3 of the EE/CA report

(Madrid and Jakub, 1998). The following sections briefly describe the main aspects of the HE Process Area OU hydrogeology that are relevant to this RD report.

2.1. Geology and Hydrogeology

The HE Process Area OU is located in an area of steep northwest-southeast trending ridges and canyons that drain to the southeast (Fig. 3). As shown on the geologic map presented in Figure 4 and the cross-section presented in Figure 5, this area is underlain by Quaternary alluvial deposits associated with the modern Corral Hollow Creek drainage, Quaternary terrace deposits, Pliocene non-marine deposits (Tps), and Miocene bedrock units of the Neroly Formation. The Quaternary deposits of Corral Hollow Creek consist mainly of unconsolidated sand and gravel ranging up to 30 ft in thickness. The Quaternary terrace and Pliocene deposits consist mainly of sand, silt, clay and gravel ranging up to 100 ft in thickness. These units are variably saturated throughout the HE Process Area OU and contain isolated, perched water-bearing zones.

As shown in Figure 4, the shallow Quaternary and Pliocene deposits are underlain by over 400 ft of interbedded sandstone, siltstone, claystone, and conglomerates of the Neroly Formation. As described in the SWRI report, the Neroly Formation has been sub-divided into different regional stratigraphic units. These stratigraphic units contain two sandstone aquifers, the upper ($Tnbs_2$) and lower ($Tnbs_1$) blue sandstone aquifers. Cleanup of the $Tnbs_2$ aquifer is the main focus of this RD report. This aquifer is 50 to 60 ft thick and consists mainly of medium grained sandstone and minor conglomerate. The deeper $Tnbs_1$ aquifer is not contaminated beneath the HE Process Area OU and it is the main water-supply aquifer for Site 300. This aquifer is 200 to 250 ft thick and consists of interbedded sandstone, conglomerate, and claystone. The two aquifers are separated by about 100 ft of interbedded fine-grained deposits ($Tnsc_1$) that hydraulically isolate the two aquifers.

The main geologic structure in the area is the southeast plunging Lone Tree syncline. This syncline is defined by the bedrock structure which dips from 4 to 12 degrees to the southwest along the eastern flank of the syncline and from 4 to 12 degrees to the southeast along the western flank of the syncline in the western part of the HE Process Area OU. This geologic structure is the main feature that controls the extent of saturation in the bedrock aquifers.

2.2. Conceptual Hydrogeologic Model

A simplified conceptual hydrogeologic model of the HE Process Area OU is presented in Figure 6. As shown in the model, this area contains three main water-bearing zones:

- Quaternary aquifer.
- Tps perched ground water.
- $Tnbs_2$ bedrock aquifer.

The bedrock and alluvial aquifers exhibit different flow characteristics and recharge/discharge mechanisms. The Quaternary alluvial aquifer is recharged by:

- Surface runoff from nearby canyons.
- Direct infiltration from rainfall.

- Confined bedrock aquifers that subcrop beneath the alluvium.

The alluvial aquifer discharges into the San Joaquin Valley. Typical Quaternary alluvial hydrographs exhibit 10 to 15 ft of water elevation rise in response to seasonal rainfall events.

Shallow ground water in the Tps unit occurs as localized, hydraulically isolated, perched water-bearing zones. These zones are recharged:

- Naturally by direct infiltration from rainfall.
- Artificially through various forms of discharge from nearby buildings.
- Anthropogenically by sources such as boiler system blow down, septic system, former HE lagoons, former dry wells, etc.

The main form of discharge from Tps perched water-bearing zones is via springs (e.g., Spring 5) and through evapo-transpiration on nearby hillslopes. Typical Tps hydrographs exhibit 2 to 10 ft of water elevation rise in response to seasonal rainfall events.

The extent of saturation, potentiometric surface, and recharge/discharge locations for the $Tnbs_2$ aquifer are shown in Figure 7. The primary source of recharge to the $Tnbs_2$ aquifer is through infiltration along northwest-trending canyons where this aquifer crops out. Typical $Tnbs_2$ hydrographs for wells located near recharge areas exhibit 2 to 5 ft of ground water elevation rise following seasonal rainfall events.

The main discharge for this aquifer is into the overlying alluvial aquifer, along the eastern flank of the Lone Tree syncline, where the $Tnbs_2$ aquifer subcrops beneath the alluvial aquifer. Under unstressed, natural flow conditions, $Tnbs_2$ water levels in this discharge area are higher than water levels in the overlying alluvial aquifer, indicating an upward hydraulic gradient. However, under stressed conditions associated with nearby pumping, this upward hydraulic gradient can be reversed if water levels in the $Tnbs_2$ aquifer are lowered below the alluvial water levels. Under these conditions, this discharge boundary will be converted to a recharge boundary as water from the alluvial aquifer flows downward into the $Tnbs_2$ aquifer. Understanding the flow dynamics associated with this discharge area is crucial for determining a defensible offsite compliance monitoring program and developing an effective pumping strategy to prevent offsite migration of contaminants.

Estimates of annual recharge and onsite storage for the $Tnbs_2$ aquifer are summarized in the following section. An accurate water budget for this aquifer is required to develop a ground water flow and contaminant transport model which is summarized in Section 3.1.1 and presented in more detail in Appendix B of this report.

2.2.1. Water Budget

A water-budget analysis was conducted to estimate annual recharge and onsite storage in the $Tnbs_2$ aquifer. Accurate estimates of annual recharge are crucial for calibrating flow using a numerical model. Annual recharge was estimated to be 1.7 to 2.7×10^7 liters [1,730 to 2,600 cubic feet per day (cfd)], assuming 10% of average annual precipitation (10.5 in/year) recharges the aquifer through a catchment area of 7.2×10^6 square feet (ft^2). An independent determination of recharge by Pelmulder and Maxwell (1997) estimated recharge to be in the range of 925 to 3,655 cfd. Onsite storage was projected to be 3×10^9 liters based on estimates of aquifer volume generated using EarthVision. EarthVision is a three-dimensional (3-D) visualization and geospatial modeling software package developed by Dynamic Graphics, Inc. Three surfaces were used to define the volume that is representative of onsite storage, the upper and lower $Tnbs_2$ stratigraphic contacts, and an average water table. This volume estimate assumed 30% porosity.

2.3. Contaminant Distribution

Details of the nature and extent of contamination in the HE Process Area OU are discussed in Chapter 13, Section 13-4 of the SWRI report (Webster-Scholten, 1994), summarized in Chapter 1 of the SWFS (Ferry et al., 1999), and briefly discussed below. The main confirmed contaminant release sites are presented in Figure 8. The approximate distribution of ground water contamination in the $Tnbs_2$ aquifer is presented in Figures 9, 10, and 11. The distribution of nitrate in the $Tnbs_2$ aquifer is presented in Figure 12.

2.3.1. Soil and Bedrock

Over 2,000 soil and rock samples were collected from 131 boreholes drilled in the HE Process Area OU as part of environmental investigations conducted during the 1980s and 1990s. These samples were analyzed mainly for VOCs and HE compounds, HMX and RDX.

TCE was the most common VOC detected in soil/bedrock samples. It was detected in about one third of the 68 samples collected in the vicinity of Building 815. With the exception of one anomalous detection of 33 milligrams of TCE per kilogram of soil (mg/kg) in a sample collected at a depth of 69 ft in the W-815-02 borehole, the maximum concentration detected was 0.24 mg/kg at a depth of 15.5 ft in the W-815-01 borehole. The 33 mg/kg TCE detection is believed to be a laboratory error because samples collected immediately above and below this sample are five orders-of-magnitude lower in concentration and the next highest detection in the vicinity of Building 815 is three orders-of-magnitude lower. Of all the areas investigated, the Building 815 area has the highest frequency of TCE detections, thus confirming it as a TCE source area.

Both HMX and RDX were detected in soil/bedrock samples collected in the HE Process Area OU. Although trace amounts of HMX and RDX were detected in soil/bedrock samples collected in the vicinity of Building 815, these chemicals were never stored, used, or discharged at this facility. The highest HE concentrations were detected in samples collected in the vicinity of the former Building 806/807 rinse-water lagoon (29 mg/kg at 8 ft) and the Building 810 dry well (21 mg/kg at 2 ft), confirming these areas as HE source areas. The origin of HE detected in the Building 815 area remains uncertain but most likely migrated into this area from upgradient vadose zone source areas.

Fourteen exploratory boreholes were drilled in the Building 829 HE Open Burn Facility area between 1989 and 1990. Analytical results from these samples are presented in Appendix C of the Final Closure Plan for the HE Open Burn Facility and briefly summarized here. Soil samples were collected at approximately 5-ft intervals in these boreholes, which ranged up to a depth of 100 ft. These samples were analyzed for VOCs, HE compounds (HMX, RDX, and TNT) and metals by the CAM Wet procedure for Soluble Threshold Limit Concentration (STLC). TCE, HMX, and RDX were detected above their respective method detection limits. The maximum

HMX (3.95 mg/kg) and RDX (0.9 mg/kg) concentrations were detected in near surface samples collected within the Burn Pit area. Although low levels (< 0.2 mg/kg) of HMX and RDX were detected to depths of 100 ft, these compounds have never been detected in ground water. TNT was not detected in any of the soil samples collected in this area. Low levels of TCE (0.002 to 0.028 mg/kg) were detected in eight soil samples collected in these exploratory boreholes at maximum depth of 40 ft. Although no metals were detected above their respective STLC-limit values, elevated levels of barium up to 28 mg/L were detected in leachates derived from soil samples collected within 10 ft of the surface in the Burn Pit area.

2.3.2. Soil Vapor

Both active and passive (Petrex) SVS have been conducted in the HE Process Area OU. A passive SVS was conducted in the Building 815 and Building 829 HE Open Burn Facility areas. Active SVS were conducted in the Building 815 and 817 areas and the area surrounding the Gallo-1 well. Gallo-1 is an offsite water-supply well located south of the HE Process Area OU, near Corral Hollow Road.

The highest TCE concentrations detected in both passive and active SVS samples were in the vicinity of the Building 815 TCE Hard Stand [2.4 parts per million volumetric (ppm_v)]. VOCs were not detected above the 0.005 ppm_v detection limit in any of the active SVS samples collected in the Building 817 area.

VOCs were detected in soil vapor based on a passive SVS (Petrex) at the former Building 829 HE Open Burn Facility. The origin of these vapors is thought to be related to releases from solvent-soaked HE and clarifier materials that were temporarily stored at the former HWAA or Drying Shed, prior to incineration at the Burn Facility. The highest soil vapor level was detected just south of the Drying Shed.

Low concentrations of TCE (< 0.1 ppm_v) were detected using an active soil vapor survey in the vicinity of the Gallo-1 well. The origin of these TCE vapors is not known.

2.3.3. Ground Water

The distribution of contaminants in ground water in the $Tnbs_2$ aquifer beneath the HE Process Area OU are presented in Figures 9, 10, and 11. TCE is the main VOC detected in ground water; RDX and perchlorate (ClO_4^-) are the main explosives compounds detected in ground water. Estimates of dissolved TCE (13 kg), RDX (3 kg), and perchlorate (7 kg) mass in $Tnbs_2$ ground water are presented in Table 1. These estimates were made using EarthVision, assuming a 30% aquifer porosity and using chemical data from second quarter 2001. In addition to these anthropogenic contaminants, nitrate has been detected in ground water at concentrations exceeding the 45 mg/L drinking water Maximum Contaminant Level (MCL). The current distribution of nitrate in the $Tnbs_2$ aquifer is presented in Figure 12.

The historic maximum TCE concentration detected in ground water from the $Tnbs_2$ aquifer is 110 µg/L (May 1992) in well W-818-08, located approximately 1,000 ft downgradient (south) of Building 815. Well W-818-08 was installed in 1991. Well W-818-11, which was installed in 1996 approximately midway between well W-818-08 and Building 815, contains TCE at essentially the same concentration as well W-818-08. As shown in Figure 9, TCE is also present in wells (e.g., W-817-06A) located upgradient of Building 815, suggesting that other VOC sources (e.g., former Building 806/807 lagoon) exist in the HE Process Area OU.

TCE occurs at concentrations exceeding the 5 µg/L MCL near the Site 300 boundary (e.g., W-35C-04 and W-6ER) and sporadic detections of TCE have been reported in W-35B-series offsite monitor wells at concentrations ranging from 0.7 to 1.3 µg/L. TCE was reported below the 0.5 µg/L detection limit for all samples collected from these wells during the first two quarters of 2001. The occurrence and shape of the TCE plume in the vicinity of the Site 300 boundary is related to pumping from former water-supply Well 6. TCE has also been reported at low concentrations (generally < 1 µg/L) in offsite water-supply well Gallo-1. These sporadic detections are believed to be related to local offsite sources unrelated to Site 300 operations.

As shown in Figure 10, the distribution of RDX in the $Tnbs_2$ aquifer is more limited than TCE. The historic maximum RDX concentration detected in this aquifer is 200 µg/L (August 1992) in well W-817-01, located east of the Building 817. RDX has also been detected in $Tnbs_2$ wells W-815-02 and -04 at concentrations exceeding 100 µg/L. The current maximum RDX concentration (140 µg/L) occurs in well W-815-04. RDX decreases rapidly downgradient of these three wells to concentrations less than 20 µg/L and RDX has never been detected above the 1 µg/L detection limit near the Site 300 boundary. Currently, nine $Tnbs_2$ wells, located in the vicinity of Buildings 815 and 817, exceed the 0.6 µg/L EPA Preliminary Remediation Goal (PRG) limit for RDX.

Perchlorate is a recently discovered contaminant in ground water at Site 300. It was detected in 1998 following a request by the RWQCB to analyze Site 300 ground water for this chemical. As shown in Figure 11, the distribution of perchlorate (ClO_4^-) in the $Tnbs_2$ aquifer is intermediate in extent, between the RDX and TCE plumes. The historic maximum perchlorate concentration is 50 µg/L (February 1998). This detection occurred in well W-817-01, the same well with the historic maximum RDX concentration. The current maximum perchlorate concentration is less than 30 µg/L in the $Tnbs_2$ aquifer and five wells (W-817-01, W-817-02, W-817-03, W-817-04, and W-815-02) exceed the 18 µg/L California State Health Advisory Limit. Perchlorate has never been detected above the 4 µg/L detection limit near the Site 300 boundary.

In addition to the anthropogenic chemicals discussed above, ground water in the $Tnbs_2$ aquifer contains nitrate (as NO_3^-) at concentrations exceeding the drinking water standard of 45 mg/L. A maximum historical nitrate concentration of 120 mg/L was reported in wells W-817-03 and -04 in 1996. Since nitrate monitoring began in 1987, the long-term time series trends in these wells have remained relatively constant ranging from 80 to 120 mg/L. As shown in Figure 12, nitrate concentrations decrease significantly where the $Tnbs_2$ aquifer is under confined conditions near the Site 300 boundary. Nitrate concentrations near the Site 300 boundary are significantly lower than the drinking water standard of 45 mg/L, ranging from < 1 to 10 mg/L. Additional information regarding ground water nitrate loading from natural and anthropogenic sources is presented in Appendix C.

All of the contaminants detected in the $Tnbs_2$ aquifer are also present in perched ground water beneath the HE Process Area OU. Contaminated perched ground water occurs beneath Buildings 815 and 817 and the former Building 829 HE Open Burn Facility. Contaminants in these areas are contained in variably saturated, low permeability sediments. These perched water-bearing zones are recharge-limited and generally exhibit very low sustainable yields [< 0.5 gallons per minute (gpm)].

Perched ground water beneath Buildings 815 and 817 occurs in the shallow Tps unit, which is monitored by wells W-815-01, W-815-03, W-815-05, and W-817-03A. The maximum historical TCE (450 µg/L), RDX (350 µg/L), and perchlorate (50 µg/L) concentrations were detected beneath Building 815 (W-815-01). RDX concentrations in these wells are decreasing, while TCE concentrations have remained relatively constant.

Contaminated perched ground water also occurs in fractured Neroly bedrock beneath the former Building 829 HE Open Burn Facility. This contaminated ground water is monitored by wells W-829-06 and -08. The maximum historical TCE (1,000 µg/L in 1993) and perchlorate (29 µg/L) concentrations were detected in perched ground water collected from well W-829-06. TCE concentrations in well W-829-06 have decreased from 1,000 µg/L to 280 µg/L, while TCE has increased from 1 µg/L to 31 µg/L in well W-829-08. HE compounds, such as HMX and RDX, have never been detected above method detection limits in ground water samples collected from these wells. The contaminated perched ground water beneath the HE Open Burn Facility is limited in areal extent. This facility is located on a hilltop adjacent to a steep canyon and there is no evidence of saturation where this perched water-bearing zone crops out on the canyon wall. In addition, no ground water was encountered in the equivalent stratigraphic interval in any of the deep boreholes that were drilled in this area. Anthropogenic chemicals have not been detected in the regional aquifer, located about 300 ft below this perched water-bearing zone and monitored by post-closure detection monitor wells W-827-05, W-829-15, and W-829-22.

3. Remedial Design

This section presents the remedial design for ground water cleanup in the HE Process Area OU. Treatment areas and treatment facility locations are shown in Figure 13. Design specifications, including treatment technology, influent flow rate and contaminant levels, extraction wells, and effluent discharge method for each treatment area are summarized in Table 2. The existing and proposed extraction wellfield is shown in Figure 14 along with each treatment facility.

3.1. Remedial Strategy

The remedial strategy for ground water cleanup in the HE Process Area OU is derived from the phased, risk-based approach presented in the RDWP (Ferry et al., 2001). In accordance with the RDWP, the first priority is to prevent contaminants from migrating offsite. The second priority is to minimize the influence of site-boundary-pumping on up-gradient plume mobility (e.g., RDX plume), and the third priority is cost-effective contaminant mass removal. The remedial strategy developed for the HE Process Area OU is based on hydrogeologic analysis, ground water flow and transport modeling, and capture zone analysis. The flow and transport model and capture zone analysis are briefly discussed in the following section.

3.1.1. Ground Water Flow and Contaminant Transport Modeling

A 2-D numerical model was developed to simulate ground water flow and contaminant transport within the $Tnbs_2$ aquifer beneath the HE Process Area OU and for use as a decision-making tool to design and optimize the extraction wellfield. Details about model development, assumptions, boundary conditions, flow and transport calibration, and simulation results are presented in Appendix B.

The FEFLOW model that was used is a finite-element simulation code developed by Diersch (1998). This code was used to solve for steady-state flow and transient contaminant transport. The initial model domain had 8,591 elements and 8,810 nodes, covering approximately 265 acres. Boundary conditions were imposed based on an analysis of expected inflows and outflows from the aquifer.

In general, ground water flow and contaminant transport calibration involves varying boundary conditions and key input parameters, such as hydraulic conductivity, to minimize differences between observed and measured data. After the initial calibration was complete, the model was used to evaluate capture zones and simulate cleanup under different pumping strategies. The existing and proposed extraction wellfields for the HE Process Area OU, which are presented in Section 3.3, are based on capture zone analysis and contaminant transport simulations using FEFLOW.

3.1.2. Phased Approach Summary

Due to budgetary constraints, the remedial strategy for the HE Process Area OU is implemented in the following phases:

Phase 1: Prevent offsite migration.

Phase 2: Minimize influence of site boundary pumping on RDX plume.

Phase 3: Mass removal.

Phase 4: Fine-grained Source Area Cleanup.

Phase 1 began in fiscal year (FY) 1999 with the installation of treatment facility (B815-DSB) in the Distal Site Boundary area. The purpose of Phase 1 is to prevent offsite migration of TCE.

Phase 2 began with the installation of B815-SRC in FY 2000 in the Source Area at Building 815. The purpose of Phase 2 is to minimize influence of site boundary pumping on the RDX plume and to begin RDX mass removal.

Phase 3 will begin with the installation of treatment facility B815-PRX in FY 2002. The primary purpose of Phase 3 is TCE mass removal. Another objective of Phase 3 is to minimize the influence of downgradient pumping on source areas. As part of Phase 3, two additional facilities, B817-SRC and B817-PRX, are planned for FY 2004 and FY 2005, respectively.

In Phase 4, source removal will target contaminated perched ground water beneath Buildings 815, 817, and the Building 829 HE Open Burn Facility. These perched zones will be remediated to prevent any further migration of contaminants to deeper aquifers. Conventional pump-and-treat methods will be used initially to cleanup fine-grained source areas; however, these methods may not be technically practicable. If conventional methods are not effective in remediating these zones in a reasonable amount of time, innovative technologies, such as *in situ* enhanced bioremediation will be considered. Due to the very low expected yield at the Building 829 source area, a separate treatment facility is not planned for this area. Instead contaminated ground water will be pumped from extraction wells W-829-06 and -08 into a portable storage tank and this water will be periodically transported to the B815-SRC facility for treatment.

3.2. Treatability Testing

A number of treatability tests have been conducted at Site 300, primarily to evaluate the operational efficiency of different ground water extraction and treatment technologies. Ground water treatment in the HE Process Area OU is complicated by the fact that extracted ground water may contain a mixture of VOCs, perchlorate, HE compounds, and nitrate. Where these contaminants are co-mingled, several treatment units configured in series are needed to meet discharge requirements.

Three treatability tests were conducted specifically for ground water treatment in the HE Process Area OU. One test was conducted to determine the effectiveness of aqueous-phase granular activated carbon (GAC) for removing TCE, RDX, nitrate, and perchlorate. A second test was conducted to evaluate the effectiveness of an *ex situ* anaerobic bioreactor for treating nitrate. These tests are summarized in Tables 3 and 4 and discussed in Sections 3.2.2 and 3.2.3, respectively. A third test was conducted to evaluate the effectiveness of ion exchange to remove perchlorate. The ion-exchange treatability test is summarized in Section 3.2.4. Test results are presented in Figure 15.

3.2.1. Hydraulic Testing

Twenty-two hydraulic tests have been conducted in the HE Process Area OU to determine hydraulic parameters, such as hydraulic conductivity and sustainable yield, for each water-bearing zone beneath the site. As summarized in Table 5, the long-term yield for the Tps water-bearing zone is fairly low, generally less than 0.5 gpm per well; the long-term yield for the $Tnbs_2$ aquifer ranges from < 1 gpm to 10 gpm per well. Long-term sustainable yield tends to increase toward the site boundary where the $Tnbs_2$ aquifer is fully saturated and under confining pressure. Wells located near Building 815 tend to exhibit lower sustainable yield (< 2 gpm) due, in part, to less available drawdown. Construction details and estimated sustainable yield for the existing and proposed extraction wells are summarized in Table 6. Additional hydraulic tests will be performed, as needed, for extraction wellfield optimization.

3.2.2. Aqueous-Phase GAC

A long-term treatability test was performed to evaluate the efficiency of GAC for removing ground water contaminants in the HE Process Area OU. The ground water beneath the HE Process Area OU contains VOCs, HE compounds, and nitrate at concentrations above regulatory limits. The test was conducted from March through August 1999 by extracting and treating ground water from monitor well W-817-03, located east of the HE Surface Impoundments and north of Buildings 823 and 818 (Fig. 3).

The treatment unit for this test was a portable Solar-powered Treatment Unit (STU) outfitted with aqueous-phase GAC. The test was conducted at a 2 gpm flow rate. Ground water levels were monitored throughout the test using pressure transducers in nearby monitor wells, and ground water samples were collected before, during, and after the test. During the test, pressure readings at the GAC canisters were recorded in order to track possible increases in pressure that may indicate build-up of fines or carbon dioxide gas in the GAC canisters. Effluent fluids were temporarily stored in a tank awaiting analytical results prior to discharging to nearby soil. Once discharge limits were met, effluent fluids were discharged to nearby surface soil.

Analytical results from the treatability test are presented in Table 3. The results show that the GAC removed TCE and RDX from the ground water, but that perchlorate broke through after 20,000 gallons of water at an average concentration of 24 µg/L had been treated. GAC profiling results indicated that the sorption capacity of GAC for perchlorate is 18 mg/kg, or about 2 grams of perchlorate per 55-gallon GAC canister. Based on these results, it was decided to add a downgradient ion-exchange unit to the treatment system for perchlorate removal. No significant removal of nitrate was observed using GAC treatment.

3.2.3. *Ex situ* Bioreactor

An *ex situ* anaerobic bioreactor was tested at the B815-SRC to determine its efficiency for treating nitrate. The bioreactor consists of three 190-gallon tanks that are operated in series in a down-flow mode. Each tank is filled with a packing material (several 1-inch diameter plastic spheres) with a large surface area to support microbial growth. Acetic acid (i.e., vinegar) is injected at the bioreactor inlet to provide a nutrient source for the denitrifying microorganisms.

Analytical results from the bioreactor test are shown in Table 4. The results indicate that this bioreactor was capable of reducing nitrate from 90+ mg/L to below discharge limits (45 mg/L) at a 1 gpm flow rate. Results of the bioreactor test are also discussed in the B815-SRC performance summary in Section 3.5.2.

3.2.4. Ion Exchange

Perchlorate is removed at the 815-SRC treatment facility by an ion exchange, which falls at the end of the treatment train, after the GAC adsorption unit and bioreactor. The resin chosen for this application was Sybron SR-7™, a nitrate selective resin that has also been found effective in removing perchlorate. Perchlorate concentrations at various locations within the treatment train are shown in Figure 15. Perchlorate removal during the first eight months of operation was due mainly to adsorption of the perchlorate to the GAC. After breaking through the GAC unit, perchlorate was then removed by ion exchange from approximately May 2001 until October 2001 (Fig. 15). The capacities of GAC and Sybron SR-7™ for perchlorate, estimated from these data, are: for GAC, 29 g perchlorate/g GAC; and for Sybron SR-7™ resin, 183 g perchlorate/g resin. Although GAC has a smaller capacity for perchlorate than the Sybron SR-7™ resin, it removed perchlorate for a longer period of time because of the much larger mass of GAC present in the GAC canisters.

3.3. Extraction Wellfield Design

Two extraction wellfields area planned for the HE Process Area OU. The main wellfield is located in the Building 815 area. This wellfield, which is presented in Section 3.3.1, is designed to cleanup the Tnbs. A second wellfield is located in the former Building 829 HE Open Burn Facility. This wellfield is presented in Section 3.3.2.

3.3.1. $Tnbs_2$ Extraction Wellfield

The existing and proposed ground water extraction wellfield for the $Tnbs_2$ aquifer is presented in Figure 14 and extraction well construction details are summarized in Table 6. This extraction wellfield is based on an evaluation of multiple data sets including geologic, hydrologic, chemical, hydraulic test data, and capture zone analysis.

As shown in Figure 16, this ten-well extraction wellfield captures $Tnbs_2$ ground water contaminants at concentrations above drinking water standards. These capture zones are based on flow rates specified in Table 2. In order to maximize mass removal, extraction wells located in Source and Proximal Areas will be pumped at higher rates than site boundary extraction wells and wells located in plume exterior areas. The ground water model summarized in Section 3.1.1, and presented in more detail in Appendix B, will be used as a decision-making tool for $Tnbs_2$ extraction wellfield optimization. Additional extraction wells will be added and/or individual well flow rates will be adjusted to optimize mass removal and prevent offsite migration of contaminants.

3.3.2. HE Open Burn Facility Extraction Wellfield

The proposed ground water extraction wellfield for the Building 829 HE Open Burn Facility is presented in Figure 17; extraction well construction details are summarized in Table 6. This wellfield consists of only two extraction wells, W-829-06 and -08. Yield from these wells is expected to be very low because this fractured bedrock water-bearing zone appears to be limited in areal extent. As mentioned in Section 3.1.2, no treatment facilities are planned for this area. Instead, ground water will be pumped into a portable storage tank and periodically transferred to B815-SRC for treatment.

3.4. Design and Operable Status

Two ground water extraction and treatment facilities are currently in operation in the HE Process Area OU:

1. Treatment Facility 815-Source (B815-SRC) which consists of a combined GAC/bioreactor/ion-exchange treatment system located in the Source Area as described in Section 3.4.2.
2. Treatment Facility 815-Distal Site Boundary (B815-DSB) which consists of a solar-powered GAC treatment system located near the Site 300 boundary as described in Section 3.4.1.

Three additional treatment facilities (B815-PRX, B817-SRC, and B817-PRX) are planned for the HE Process Area OU. They are briefly described in Section 3.4.3. The location of the existing and proposed facilities are shown in Figure 14. Relevant engineering data for each facility, including flow rates, influent concentrations, treatment methods, effluent discharge methods, etc. are summarized in Table 2.

3.4.1. Treatment Facility B815-DSB

B815-DSB treats low concentrations (< 10 µg/L) of TCE contained in ground water extracted from wells W-35C-04 and W-6ER located near the Site 300 boundary. The main objective of this facility is to prevent offsite migration of VOCs. This treatment facility, which has been in operation since September 1999, is equipped with a solar-powered aqueous-phase GAC treatment unit (STU04). Eight Solarex MSX83 solar panels generate 83 watts each and the battery bank is 115 amp/hours at 24 volts. Three GAC canisters connected in series are designed to treat up to 5 gpm of ground water at the expected influent concentrations. Equipment specifications for this treatment facility are presented in Table 7. The P&ID for this facility is shown in Figure 18A. Treated effluent is discharged to an infiltration trench which is presented in Figure 18B and described in Section 3.5.

3.4.1.1. Aqueous-Phase Granular Activated Carbon

Ground water is pumped from wells W-35C-04 and W-6ER through 1-in. inside-diameter Schedule 80 PVC pipe (Fig. 18A) using Shurflo submersible pumps. Prior to entering the first GAC canister, the ground water passes through a five-micron filtration system to remove suspended particles from the ground water. Influent water passes from the filtration system to three aqueous-phase GAC canisters connected in series. Each GAC canister contains 200 pounds (lb) of GAC. The influent water passes through the first GAC canister for sorption of VOCs. The second and third GAC canisters are safeguards against breakthrough of VOCs. When VOCs are detected between the second and third GAC canister above the effluent discharge limits (Table 2), the GAC in the first canister is replaced with new, clean GAC and the first GAC canister is placed in the third position. The remaining, partially saturated GAC canisters move up in position (e.g., the third GAC canister moves to the second position and the second GAC canister moves to the first position) to optimize GAC usage.

Routine monitoring is conducted between the first and second and second and third canisters. Monitoring of effluent from the third GAC canister is conducted for compliance with Substantive Requirements issued by the RWQCB. The spent GAC is removed by a vendor for regeneration or offsite disposal at a RCRA-permitted facility. DOE/LLNL complies with the Offsite Rule (40 CFR 300.440) for the offsite shipment of CERCLA waste. Following treatment in the GAC units, ground water is discharged to an infiltration trench located 100 ft south. The infiltration trench is described in Section 3.5.1.

Additional wells, such as W-4A and -4B, may be added to B815-DSB, if necessary, to achieve the primary objective of this facility which is to prevent offsite migration of contaminants.

3.4.2. Treatment Facility B815-SRC

B815-SRC currently treats ground water extracted from well W-815-02 for TCE, RDX, perchlorate, and nitrate. This facility has been in operation since September 2000 to minimize influence of pumping at the site boundary on the RDX plume and to begin RDX mass removal. It consists of an aqueous-phase GAC unit, an *ex situ* anaerobic bioreactor, and an ion-exchange unit. These treatment sub-units are connected in series. Each sub-unit is briefly described in the following sections. Equipment specifications for the treatment system are presented in Table 7 and the P&ID is shown in Figures 19A, 19B, and 19C.

Well W-815-04 (screened in the $Tnbs_2$ aquifer) and wells W-815-01 and W-815-03 (screened in the Tps unit) are planned to be connected to this facility. Additionally, contaminated ground water extracted from HE Open Burn Facility wells W-829-06 and W-829-08 will be pumped into a portable storage tank and periodically treated at B815-SRC.

3.4.2.1. Aqueous-Phase Granular Activated Carbon

The GAC sub-unit consists of three aqueous-phase, 35-gallon GAC canisters connected in series (GTU02) and mounted on a 4- by 9-ft skid. This system was designed to treat up to 5 gpm, corresponding to a minimum empty bed contact time of 21 minutes.

Ground water is pumped from well W-815-02 through a 1-in. inside-diameter PVC pipe using a 1/2 horsepower (hp) Grundfos (SP195) submersible pump. Prior to entering the first GAC canister, the ground water passes through a five-micron filtration system (Cuno model #4 DC1) to remove suspended particles from the ground water. Influent water passes from the filtration system to three aqueous-phase GAC canisters connected in series. Each GAC canister contains 200 pounds (lbs) of GAC. All other operational and monitoring specifications are the same as those described above in Section 3.4.1.1. Following treatment in the GAC units, ground water enters the *ex situ* bioreactor.

3.4.2.2. Ex situ Bioreactor

Ground water discharged from the GAC unit flows into an *ex situ* anaerobic bioreactor (BTU02) mounted on a 6- by 10-ft skid as shown in Figure 19C. Denitrifying microorganisms within the bioreactor reduce nitrate concentrations to below discharge limits. The bioreactor consists of three 191-gallon canisters filled with 1-inch diameter plastic spheres which provide a physical support for microbial growth. A mixture of acetic and phosphoric acids is added to the bioreactor influent as electron donor and nutrient sources, respectively, to sustain microbial populations. Nitrogen gas is vented off through Hoffman valves with connections for back-flushing, if needed. A 25-micron backfilter (Hayward model #FLT4202) screens particulates and sloughed biomass. Following treatment in the bioreactor, ground water enters an ion-exchange unit.

3.4.2.3. Ion-exchange

Ground water discharged from the bioreactor flows into two 26-gallon ion-exchange (IX) canisters connected in series for perchlorate removal prior to discharge (Fig. 19A). Each IX canister is filled with approximately 3.5 cubic feet of Sybron SR-7™ resin. Although SR-7 resin has a high affinity for nitrate, operational data indicate the resin has a high selectivity for perchlorate as well. Perchlorate loading on the resin column is expected to be low because of the low influent concentration (< 20 µg/L). The treated ground water is detained in a 200-gallon holding tank mounted on a 4- by 6-ft skid and subsequently discharged to the atmosphere using a misting tower equipped with a 1-hp pump. The misting system is described in Section 3.5 and presented in a P&ID diagram in Figure 19A.

3.4.3. Proposed Treatment Facilities

Three additional ground water treatment facilities (B815-PRX, B817-SRC, and B817-PRX) are proposed for the HE Process Area OU. As presented in the P&IDs, all three facilities will be equipped with an aqueous-phase GAC system followed by an IX unit and a misting system to discharge treated effluent (Figs. 20A, 20B, 21A, 21B, 22A, and 22B).

As presented in Figure 14, B815-PRX will be located near Building 814 and it will treat ground water extracted from wells W-818-08 and W-818-09. This facility will use Site 300 utility power to operate extraction well pumps, convey extracted ground water to the facility via an above-ground pipeline, and discharge treated effluent. The P&ID for this facility is presented in Figures 20A and 20B. This location was selected for the B815-PRX facility because it is the closest area to the proposed extraction wells that has no access restrictions and has available electrical utility power.

Facilities B817-SRC and B817-PRX will be located near Building 817 and 823, respectively (Fig. 14). Both facilities will use solar or utility power to operate extraction well pumps and discharge treated water. B817-SRC will treat ground water extracted from wells W-817-01 and W-817-06A, and B817-PRX will treat ground water extracted from well W-817-03, W-817-04, and W-817-03A.

3.5. Performance Summary

This section summarizes performance data for the two existing HE Process Area OU treatment facilities, B815-DSB (Section 3.4.1) and B815-SRC (Section 3.4.2), and presents expected performance for the three proposed facilities (Section 3.5.3). Treatment facility performance is expected to vary greatly within the HE Process Area OU depending on a number of factors, including logistics, operational limitations, extraction well yield, influent concentrations, and effluent disposal method. The total combined flow rates (3.4 gpm and 4.5 gpm) from extraction wells located in the Source and Proximal treatment areas are designed to exceed pumping rates in the Distal Site Boundary treatment area (4.5 gpm) to maximize TCE mass removal and minimize mobility of the RDX plume.

3.5.1. B815-DSB Performance

The primary objective of B815-DSB is to prevent offsite migration of contaminants in the $Tnbs_2$ aquifer. B815-DSB operations began in September 1999 with one extraction well, W-35C-04, which was pumped at rate of 1 to 1.5 gpm. This facility was shut down for about three months in early 2000 due to problems associated with discharge of treated effluent to Corral Hollow Creek. In April 2001 after the discharge problems were corrected, a second extraction well (W-6ER) was connected to this facility. These wells are currently being pumped at a total rate of 3.8 gpm. Although mass removal is not the primary objective of this facility, it does remove mass at a rate of about 1 gram of TCE per month. As presented in Figure 23, this facility has removed 18 grams of TCE since it began operation.

The main factors controlling the performance of this facility with respect to meeting its primary objective are:

- Operational limitations.
- Extraction well yield.
- Effluent disposal method.

As described in Section 3.4, B815-DSB is a solar-powered treatment unit, so one of its main operational limitations is the amount of available sunlight. As presented in Figure 24, this facility operated from 300 to 500 hours per month for an average daily operating time of 10 hours during winter months and a maximum of 17 hours during summer months. Another limitation is the maximum power that can be stored in this type of facility, which limits the maximum pumping rate to about 5 gpm. At the present time the maximum power capacity for this solar-powered facility is not limiting its performance because the total flow rate is being maintained below 5 gpm. However, this may be a limiting factor in the future if pumping needs to be increased above 5 gpm.

Based on hydraulic testing and operational data, the estimated long-term yield for extraction well W-35C-04 is 4 to 5 gpm. W-35C-04 is currently being pumped at 2 gpm with about 30 ft of drawdown, which is less than 1/3 of the available drawdown in this well. A second extraction well, W-6ER, was added to this facility in April 2001. This well is being pumped at 1.8 gpm with about 10 ft of drawdown. Given the current extraction rate from these wells, their long-term yield is not a limiting factor in the performance of this facility.

Another possible operational limitation to facility performance is the effluent discharge method. At the startup of B815-DSB, this facility discharged treated effluent to Corral Hollow Creek floodplain alluvium at a rate of 1 to 1.5 gpm. After several months of operation the discharge area became saturated and signs of wetland vegetation began appearing. To avoid creating a wetland, the facility was shut down for 2 to 3 months while an alternative discharge method, an infiltration trench, was designed and constructed. An infiltration trench capable of receiving 5+ gpm was constructed near the facility and has been in use since April 2001. To date, this trench has adequately received the discharge rate from this facility.

Two approaches are presented here to evaluate the performance of B815-DSB with respect to its primary objective of preventing offsite migration of contaminants:

- Capture zone analysis.
- Offsite compliance well monitoring.

Extraction wells W-35C-04 (2.0 gpm) and W-6ER (1.3 gpm) are currently pumping at a combined flow rate of 3.8 gpm. Influent TCE concentrations to this facility from these wells have steadily increased up to 8 µg/L during the period of facility operation. Figure 25 presents the estimated capture zone for each well after 2 and 5 years of pumping at 1.5 gpm per well. The influence of current pumping rates on the $Tnbs_2$ potentiometric surface is presented in Figure 26.

Another indicator of this facility's performance is measured by offsite compliance well monitoring (W-35B-01 through -05). As summarized in Table 8, TCE has been detected in three wells (W-35B-01, -02, and -04) at low concentrations ranging from 0.7 to 1.3 µg/L. These detections occurred in May and October of 2000, while the facility was operating at 1.0 to

1.5 gpm and extracting from a single well (W-35C-04). TCE has not been detected above the 0.5 µg/L detection limit since extraction well W-6ER was added to this facility.

3.5.2. B815-SRC Performance

The primary objectives of B815-SRC are twofold:

- Minimize influence of site-boundary pumping at B815-DSB on the RDX plume.
- Contaminant mass removal.

One way to measure the performance of this facility with respect to the first objective is based on monitoring data from wells W-818-08, W-818-09, W-823-03, and W-6G. RDX has not been detected in any of these wells above detection limits for this compound.

The main factors controlling the performance of B815-SRC to meet the second objective, contaminant mass removal, are

- Sustainable well yield.
- Treatment rate efficiency.
- Effluent discharge.

As summarized in Table 2, B815-SRC has been pumping from a single well (W-815-02) at flow rates ranging from 0.5 to 1.4 gpm since September 2000. This facility was operated nearly continuously during this time using Site 300 electrical power. The long-term sustainable yield from extraction well W-815-02 is about 1.5 gpm. Nearby well W-815-04, which will be connected to this facility during FY 2002, is expected to yield 1.5 to 2 gpm, for a total influent flow rate of 3.5 to 4 gpm. Mass removal for B815-SRC is presented in Figure 27. Among the main anthropogenic contaminants, TCE, RDX and perchlorate, RDX has the highest mass removal rate at this facility.

B815-SRC uses an *ex situ* denitrifying bioreactor for nitrate treatment. The bioreactor is followed by an ion-exchange unit for perchlorate removal prior to discharge. The bioreactor reduced influent nitrate concentrations of 74 to 83 mg/L (as NO_3^-) to concentrations below the discharge limit of 45 mg/L at continuous flow rates up to 1.4 gpm. Under optimal operating conditions, this bioreactor should be capable of continuous treatment rates up to 5 gpm.

Another operational limitation is the effluent discharge method. Initially, treated effluent from this facility was discharged to a subsurface infiltration trench. Due to low permeability soils, the maximum discharge rate to the infiltration trench was about 1 gpm. The infiltration trench was replaced with a misting system that can accommodate up to 4 to 5 gpm. The main limitation with the misting system is that it must be operated in such a way to prevent creation of a wetland in the discharge area.

3.5.3. Expected Performance from Proposed Facilities

Three additional treatment facilities (B815-PRX, B817-SRC, and B817-PRX) are proposed for the HE Process Area OU (Fig. 13). The proposed design for these facilities is essentially identical, consisting of aqueous-phase GAC, ion-exchange for perchlorate removal and misting for effluent discharge. The expected influent concentrations and extraction flow rates for all facilities are summarized in Table 2.

B815-PRX is expected to be the main TCE mass removal facility for the $Tnbs_2$ aquifer. Extracion wells for this facility (W-818-08 and W-818-09) are located in the center-of-mass of the TCE plume. The estimated mass removal rate from this facility, assuming two extraction wells at 1.5 and 3.0 gpm, respectively is 21 grams per month. Although this facility will be treating RDX and perchlorate in addition to TCE, most of the mass removal at this facility will be due to TCE removal.

Proposed facilities B817-SRC (W-817-01 and W-817-06A) and B817-PRX (W-817-03, -04, and -03A), which are planned for FY 2004 and FY 2005, respectively, will be used mainly for perchlorate removal. As summarized in Table 2, these facilities will be operated at 1 to 2 gpm total influent flow rates. Expected mass removal rates range up to about 15 grams per month from each facility.

Ground water extraction from wells W-817-01, W-817-03, and W-817-04, that are currently part of the compliance monitoring network for the operation of the Class II Surface Impoundments, may impact the hydraulics of the area with the result that the current compliance ground water monitoring network, designed to detect statistical evidence of a release from the surface impoundments, will become ineffective. Well W-817-03A currently monitors shallow ground water in the vicinity of Spring 5. Extracting low volumes of ground water at this location will not decrease the representativeness of the surveillance monitoring system for the surface impoundments. The surface impoundments are currently regulated under Waste Discharge Requirement (WDR) Order No. 96-248 issued by the RWQCB. DOE/LLNL will evaluate alternate compliance monitoring strategies (possibly including a new point-of-compliance) and recommend a new monitoring network for WRD detection compliance monitoring of the surface impoundments. The results of this evaluation, as well as a discussion of alternate monitoring technologies considered, will be summarized in a report that will be submitted to the RWQCB for approval. Ground water extraction from these wells will not begin until the approved detection compliance monitoring network has been implemented.

3.6. Performance Standards and Monitoring

Performance standards are set by effluent discharge requirements for ground water treatment systems. To ensure these standards are met, periodic monitoring of influent and effluent concentrations are specified in the Monitoring and Reporting Program issued by the RWQCB (Appendix A). Facility sample port locations for B815-DSB and B815-SRC are identified in the P&IDs (Figs. 18A, 18B, 19A, 19B, and 19C). System performance will also be monitored and optimized, as needed, to maximize mass removal or prevent offsite migration of contaminants.

3.7. Controls and Safeguards

All HE Process Area OU ground water treatment facilities are designed to be fail-safe. For example, the failure of any component, energy source (mechanical or electrical), or loss of control signal will cause the system to shut down safely. Each facility is equipped with interlocks and an interlock control panel. If one of the main treatment facility components malfunctions, the entire system will automatically shut down. Following a shutdown, the treatment facility operator will identify and correct the problem that caused the shutdown before restarting the facility.

System shutdown, which involves de-energizing extraction well pumps, would be initiated by the following interlocks:

- Thermal overload on pump motors due to low flow rates.
- Low flow rate in the combined influent line.
- Loss of power to controls and instrumentation.
- High pressure at the particulate filter influent due to the discharge line blockage.

In addition to the interlock fail-safe system, all facility pipelines will be visually monitored on a weekly basis for leaks. A preventative maintenance schedule for the treatment systems is presented in Appendix F.

3.8. Discharge of Treated Ground Water

This section briefly describes the two discharge methods (infiltration trench and misting system) currently being used in the HE Process Area OU to discharge treated effluent.

3.8.1. Infiltration Trench

At B815-DSB, treated water is discharged directly into an engineered infiltration trench which introduces the treated water into the shallow alluvial aquifer without causing any accumulation of water at the ground surface. This trench was specifically designed for an anticipated maximum flow rate not to exceed 10 gpm. It is 28 ft long, 3 ft wide, and 9 ft deep. Treated ground water is conveyed to a perforated pipe at 3.5 ft below grade along the entire length of the trench. The perforated pipe is PVC with 0.5 inch holes every 2 inches. The perforated pipe rests on 5.5 ft of gravel and is covered with 1.5 ft of gravel to approximately 2 ft below grade. Two sheets of PVC laminate are placed over the gravel to prevent infiltration of fine particulate matter which could reduce the permeability of the gravel within the trench. Two feet of compacted native soil were placed above the PVC laminate to grade. Several piezometers are located within the lower gravel layers of the trench to facilitate performance monitoring. A fitting in the process piping similar to a sewer clean-out allows for maintenance of the perforated pipe within the trench. This infiltration technique has worked well for 18 months with no sign of biological or sediment buildup.

3.8.2. Misting System

At B815-SRC, treated water is collected in a holding tank prior to discharge using a misting system. When a pre-determined volume has accumulated, the water is pumped via a high pressure pump through a pipeline to a misting tower. The tower consists of several misting heads about 10 to 12 ft above the ground and spaced so as to minimize the overlapping of the spray pattern. The number of heads is dependent on the flow requirement of the discharge system. The purpose of the misting tower is to distribute the treated water into the atmosphere in the form of a mist and subsequently over a large area of soil and vegetation. Similar systems will be designed and implemented at B815-PRX, B817-SRC, and B817-PRX to discharge treated effluent.

The impact of misting nitrate-bearing, treated ground water from proposed facilities B815-PRX, B817-SRC, and B817-PRX on nearby soil and ground water will be evaluated by:

1. Visually inspecting nearby grasses and vegetation to determine the area of impact due to wet deposition.
2. Sampling soil in the misting area to establish pre-application “background” nitrate soil concentrations and moisture content.
3. Periodic, post-application soil sampling to evaluate changes in nitrate soil concentrations and moisture content.
4. Collecting meteorological data, such as air temperature, humidity, wind direction, and wind speed to evaluate fate of misted water.
5. Continued ground water monitoring.

These data will be used to estimate nitrate loading to nearby soil on a per acre basis due to misting operations. If acceptable levels are exceeded, then modifications to reduce nitrate loading will be considered.

3.9. Construction and Startup Schedule

DOE/LLNL has completed the design, construction, and startup of two of the five treatment facilities planned for the HE Process Area OU. B815-DSB began operation in September 1999 and B815-SRC began operation in September 2000 in accordance with their respective milestone dates. As summarized in Table 2, B815-PRX is scheduled for installation in FY 2002, B817-SRC is scheduled for FY 2004, and B817-PRX is scheduled for FY 2005. Design and construction of B815-PRX has begun and this facility is on schedule for installation and startup in September 2002. Construction of B817-SRC and B817-PRX will begin in 2003 and 2004, respectively.

3.10. Cost Estimates

Cost estimates for design and construction, startup, and O&M of treatment facilities B815-PRX, B817-SRC, and B817-PRX are summarized in Tables 9, 10, and 11, respectively. These cost estimates are based on experience of constructing and operating similar units in the HE Process Area OU and over 30 treatment facilities at other LLNL locations.

3.10.1. B815-PRX

Treatment facility B815-PRX is designed to treat ground water contaminants in the proximal treatment area of the HE Process Area OU (Fig. 13). Two extraction wells (W-818-08 and W-818-09) are planned for this facility. Additional extraction wells will be added, if necessary, to achieve cost-effective cleanup. As presented in Table 2, the estimated combined flow rate from the two planned extraction wells is 4.5 gpm. Water from the extraction wells will be conducted to the treatment unit through above ground pipelines with a combined length of approximately 1,550 ft. Treatment will be done using aqueous phase GAC to remove VOCs from the ground water followed by IX columns to remove perchlorate. As shown in Figure 14, B815-PRX will be located near Building 814. This location was chosen for this facility because this area is easily accessible and electric power is available there. The treated water will be discharged through a nearby misting system.

Cost estimates are provided in Table 9 and are $506,500 for design and construction, $13,000 for startup, and $66,000 for annual O&M.

3.10.2. B817-SRC

Treatment facility B817-SRC is designed to treat ground water contaminants in the source treatment area of the HE Process Area OU (Fig. 13). Initially, two extraction wells (W-817-01 and W-817-06A) will be connected to this facility. As presented in Table 2, the estimated combined flow rate from the two extraction wells is 2.0 gpm. Water from the extraction wells will be transported to the treatment unit through above ground pipelines with a combined length of approximately 210 ft. Treatment will be done using aqueous phase GAC to remove VOCs from the ground water followed by IX columns to remove residual perchlorate in a portable solar-powered treatment unit (STU). An STU was chosen for this location to minimize O&M cost and because there is no electric power source nearby. As shown in Figure 14, B817-SRC will be located near extraction well W-817-01. The treated water will be discharged through a nearby misting system.

Cost estimates are provided in Table 10 and are $109,000 for design/construction, $13,000 for startup, and $49,000 for annual O&M.

3.10.3. B817-PRX

Treatment facility B817-PRX is also designed to treat ground water contaminants in the proximal treatment area of the HE Process Area OU (Fig. 13). Initially, three extraction wells (W-817-03, W-817-04, and W-817-03A) will be connected to this facility. As presented in Table 2, the estimated combined flow rate from the two extraction wells is 2.1 gpm. Water from the extraction wells will be transported to the treatment unit through above ground pipelines with a combined length of approximately 250 ft. Treatment will be done using aqueous-phase GAC to remove VOCs from the ground water followed by IX columns to remove residual perchlorate in a portable STU. A solar-powered unit was chosen for this location to minimize O&M cost and because there is no electric power source nearby. As shown in Figure 14, B817-PRX will be located near extraction well W-817-03. The treated water will be discharged through a nearby misting system.

Cost estimates are provided in Table 11 and are $108,000 for design/construction, $13,000 for startup, and $49,000 for annual O&M.

4. Remedial Action Work Plan

The Remedial Action Work Plan for the HE Process Area OU treatment facilities includes design and implementation of extraction and treatment systems as described in Section 3, QA/QC Plans and Health and Safety Plans for construction, and O&M that are attached in Appendices D, E, F, and G. The Remedial Action Work Plan also includes the monitoring and reporting requirements for the ground water treatment systems and monitor wells (Appendix A). In addition, requirements for onsite storage and offsite shipment of hazardous waste, preliminary remediation completion criteria, and procedures for facility and well closure are discussed in this section.

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

The QA/QC and the Health and Safety Plans for construction are presented as Appendices D and E of this document. The QA/QC Plan for construction defines the quality objectives and areas of responsibility for the construction of new extraction and treatment facilities in the HE Process Area OU. The Health and Safety Plan for treatment system construction defines areas of responsibility for health and safety during construction activities and references existing LLNL Health and Safety documents which address construction health and safety issues.

The QA/QC Plan for O&M of the HE Process Area OU treatment facilities is presented in Appendix F. This plan describes the organizational structure, responsibilities, and authority for O&M QA/QC and the objectives, quality goals, and QA elements for O&M of the HE Process Area OU treatment facilities. Appendix G contains the Health and Safety Plan for O&M of the HE Process Area OU treatment facilities. This plan presents: (1) organizational structure and responsibilities, (2) hazard analyses and control measures, (3) training requirements for the HE Process Area OU treatment facilities O&M, and (4) emergency safety procedures.

4.2. Monitoring and Reporting Programs

A Site-Wide Compliance Monitoring Plan (CMP) for Site 300 is scheduled to be completed in 2002. The CMP will supersede the monitoring and reporting program for the HE Process Area OU presented in this report (Appendix A).

4.2.1. Ground Water Treatment System Influent and Effluent

As stipulated by the California RWQCB-Central Valley Region Substantive Requirements for the Building 815 Removal Action and the Monitoring and Reporting Program Requirements, ground water treatment system influent and effluent sampling and/or monitoring will be used to evaluate facility performance and verify that discharge requirements are met. Influent and effluent reporting requirements are specified in the Monitoring and Reporting Program issued by the RWQCB (Appendix A).

4.2.2. Ground Water Extraction and Monitor Wells

Ground water concentrations will be determined by analyzing samples collected from extraction and monitor wells to track changes in plume concentration and extent that result from remediation and natural processes such as dispersion, adsorption, advection, and biodegradation. Chemical analyses will be performed according to EPA Methods or analytical methods contained in the ERD Standard Operating Procedures (Dibley and Depue, 2002). Results will be evaluated according to QA/QC procedures contained in the Quality Assurance Project Plan (QAPP) (Dibley, 1999). Measured ground water concentrations will be used to prepare contaminant isoconcentration contour maps to assess the cleanup progress.

Ground water monitoring frequency is specified in Tables 1 and 2 of the Monitoring and Reporting Program issued by the RWQCB (Appendix A). These frequencies are generally dependent on: (1) the rate of observed or expected changes in concentrations in each well and other nearby wells, (2) the location of the well, and (3) the purpose or current use of the well.

Based on data from previous remediation, significant changes in ground water contaminant concentrations are expected to occur over time intervals of months to years.

4.3. Hazardous Waste Handling

Aqueous-phase GAC and the ion-exchange resin in the HE Process Area OU treatment facilities will be replaced as needed to remain in compliance with the RWQCB Substantive Requirements discharge limits. Aqueous-phase GAC containing sorbed VOCs and HE compounds will be shipped offsite for regeneration or disposal, and will be managed as hazardous waste, if appropriate. Nitrate biodegrades to nitrogen gas in the bioreactor; therefore, no hazardous waste is generated. The spent ion-exchange resin with perchlorate will be shipped offsite for disposal, and will be managed as hazardous waste, as appropriate.

Shipment and disposal are in accordance with Department of Transportation (DOT) 49 CFR and EPA 40 CFR. Additionally, waste shipments are made according to CCR, Title 22 requirements. The spent GAC from the facilities will be packaged and labeled for shipment by LLNL's Hazardous Waste Management Division (HWMD). The DTSC issued a RCRA Part B permit application for the HWMD's new hazardous waste treatment and storage facility in May 1999. (California is a RCRA-authorized State). Once packaged, the GAC will be shipped to a RCRA-permitted facility for regeneration or disposal. DOE/LLNL will comply with the Offsite Rule (40 CFR 300.440) for the offsite shipment of CERCLA waste.

4.4. Requirements for Closure

This section specifies requirements for determining when ground water cleanup has been completed and site closure activities, including post-closure monitoring, can begin.

4.4.1. Ground Water Cleanup

HE Process Area OU ground water cleanup will be complete when ground water samples demonstrate that cleanup standards, which will be selected and codified in the Final Site-Wide ROD, are achieved. When contaminant concentrations in ground water have been reduced to agreed upon cleanup standards, the ground water extraction and treatment systems will be shut off and placed on standby with agreement from the regulatory agencies. Contaminant concentrations may rise in ground water after extraction ceases due to slow desorption from fine-grained sediments. Therefore, ground water post-closure monitoring will be performed for two years after pumping ceases. Should contaminant concentrations in ground water rebound above cleanup standards, re-initiation of remediation efforts will be discussed with the regulatory agencies.

Cleanup will be considered complete when contaminant concentrations in ground water remain below the cleanup standards for two years. After concurrence with the regulatory agencies that cleanup is complete, the HE Process Area OU extraction wells and monitor wells will be decommissioned. Wells will be closed by *in situ* casing perforation and pressure grouting, or by well removal as appropriate, consistent with the approved LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs) (Dibley and Depue, 2002). 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.

After remediation is complete, the HE Process Area OU ground water treatment systems and their influent and discharge piping will be decontaminated, dismantled, and salvaged, or used at other locations. Any wash water containing hazardous materials will be collected, sampled, and disposed at one of several offsite RCRA-permitted facilities. GAC with sorbed VOCs and HE compounds and spent ion-exchange resin will be disposed according to the specifications described in Section 4.3 “Hazardous Waste Handling.”

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

5.1. 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.

5.2. 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

5.3. 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	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

5.4. Standards

American Concrete Institute (ACI)

ACI 347	Recommended Practice for Concrete Form Work

American Society for Testing and Materials

American Water Works Association

Construction Specifications Institute

National Electric Manufacturers Association

Sheet Metal and Air Conditioning Contractors National Association, Inc.

5.5. 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

6. References

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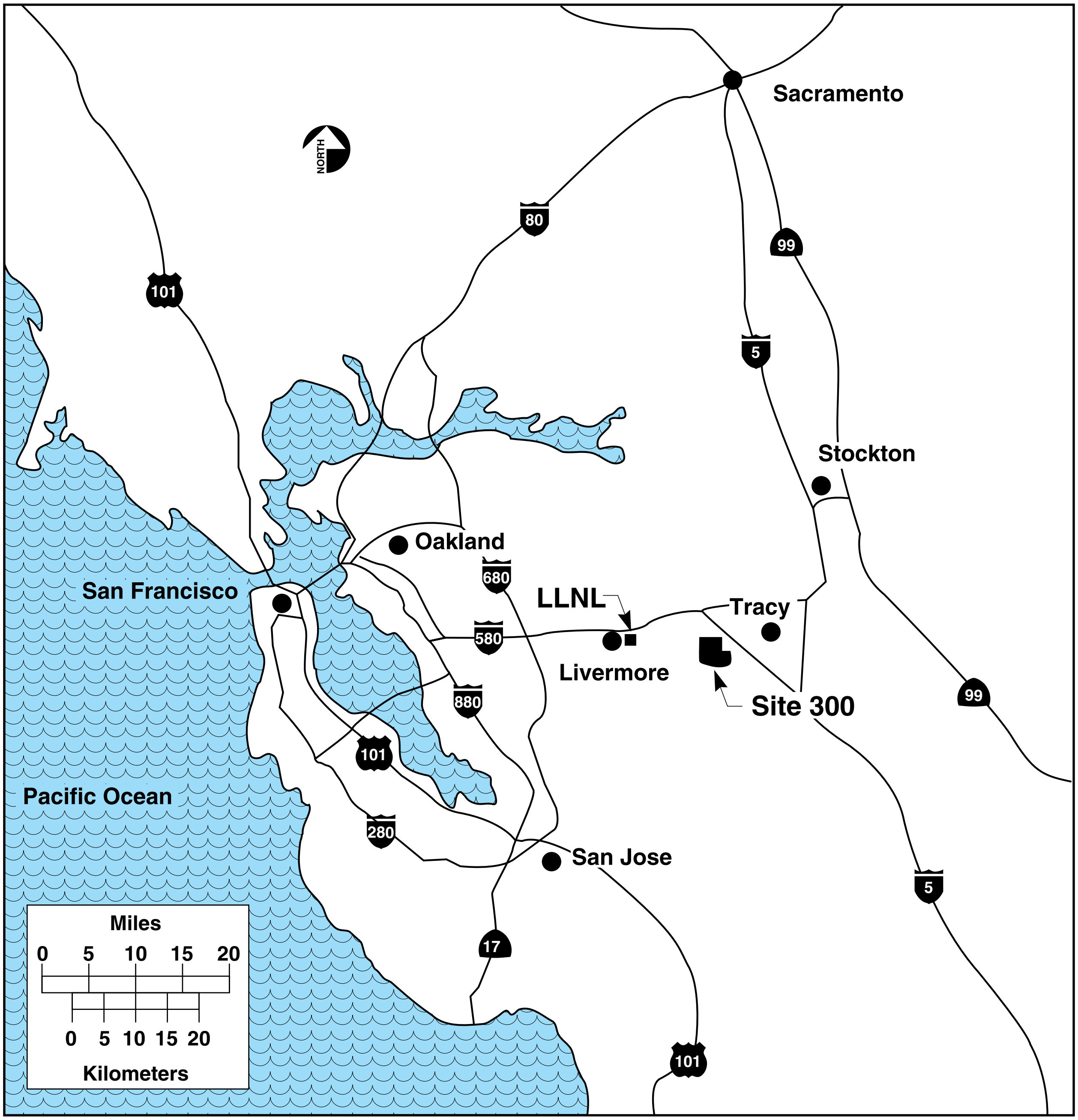
Figures



ERD-S3R-01-0225

Figure 1. Locations of LLNL Main Site and Site 300.

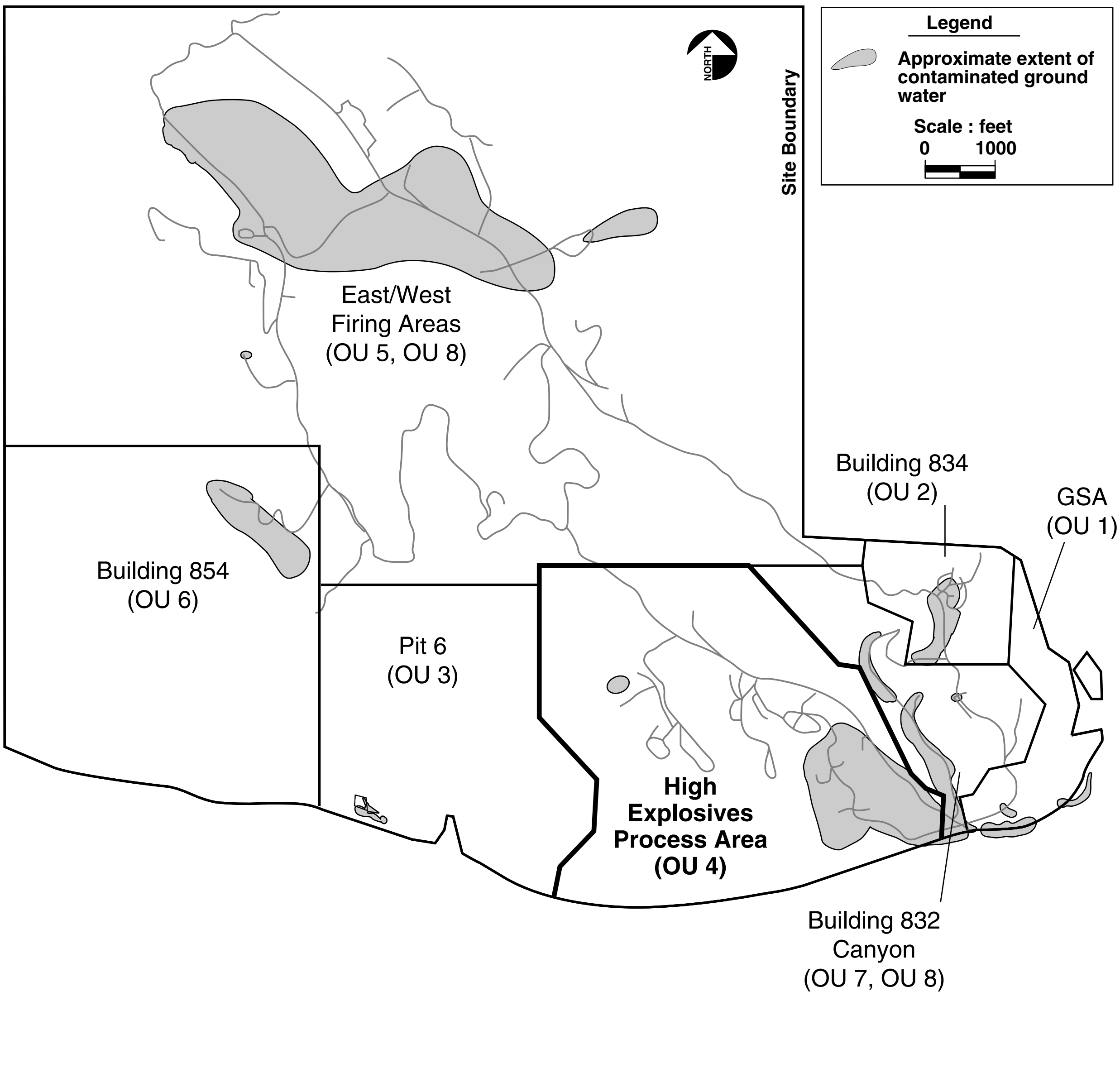


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Figure 2. Locations of High Explosives (HE) Process Area Operable Unit and other Operable Units at Site 300.

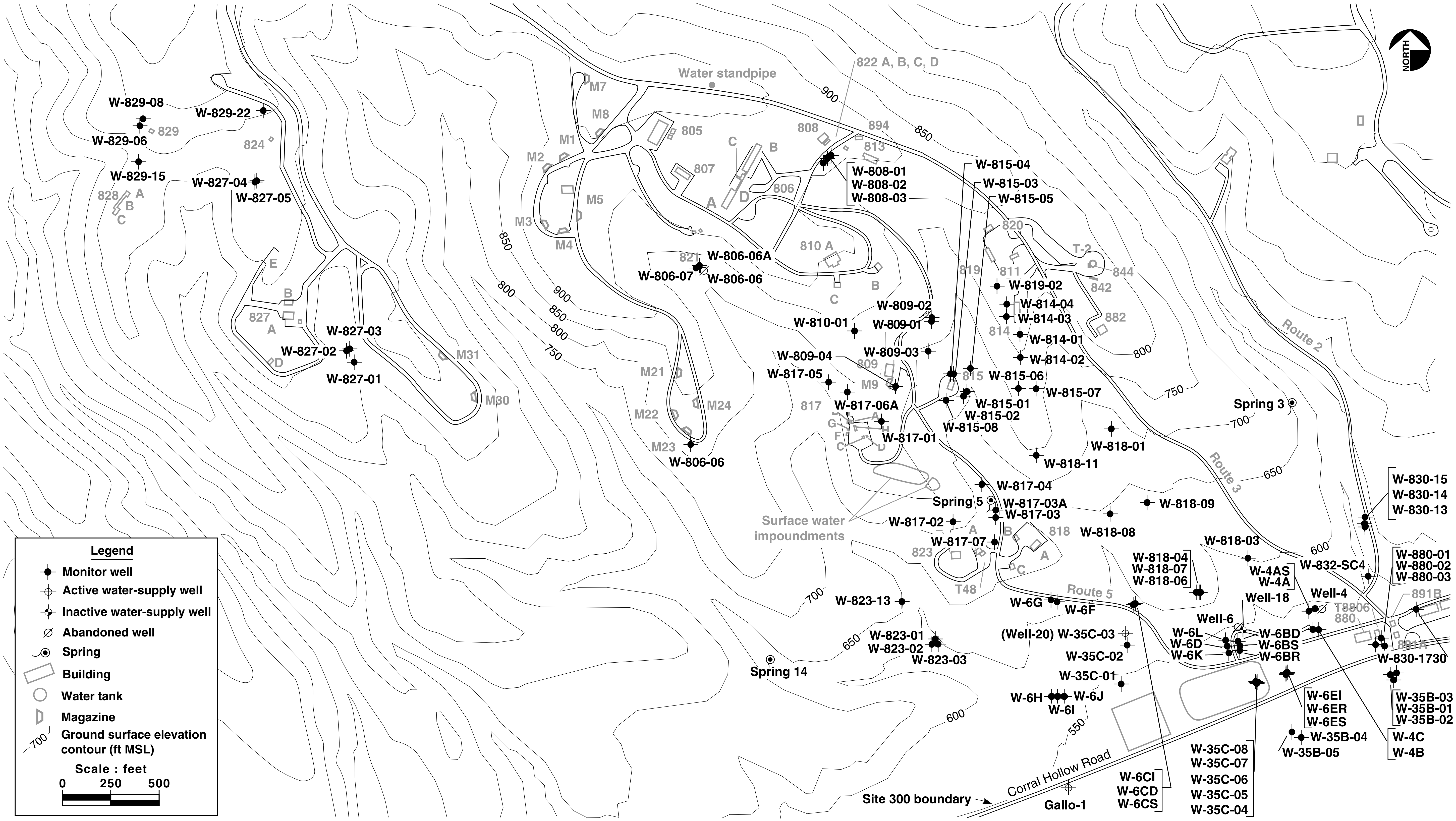

Figure 3. HE Process Area OU map showing buildings, topography, roads, ground water monitoring wells and water-supply wells.

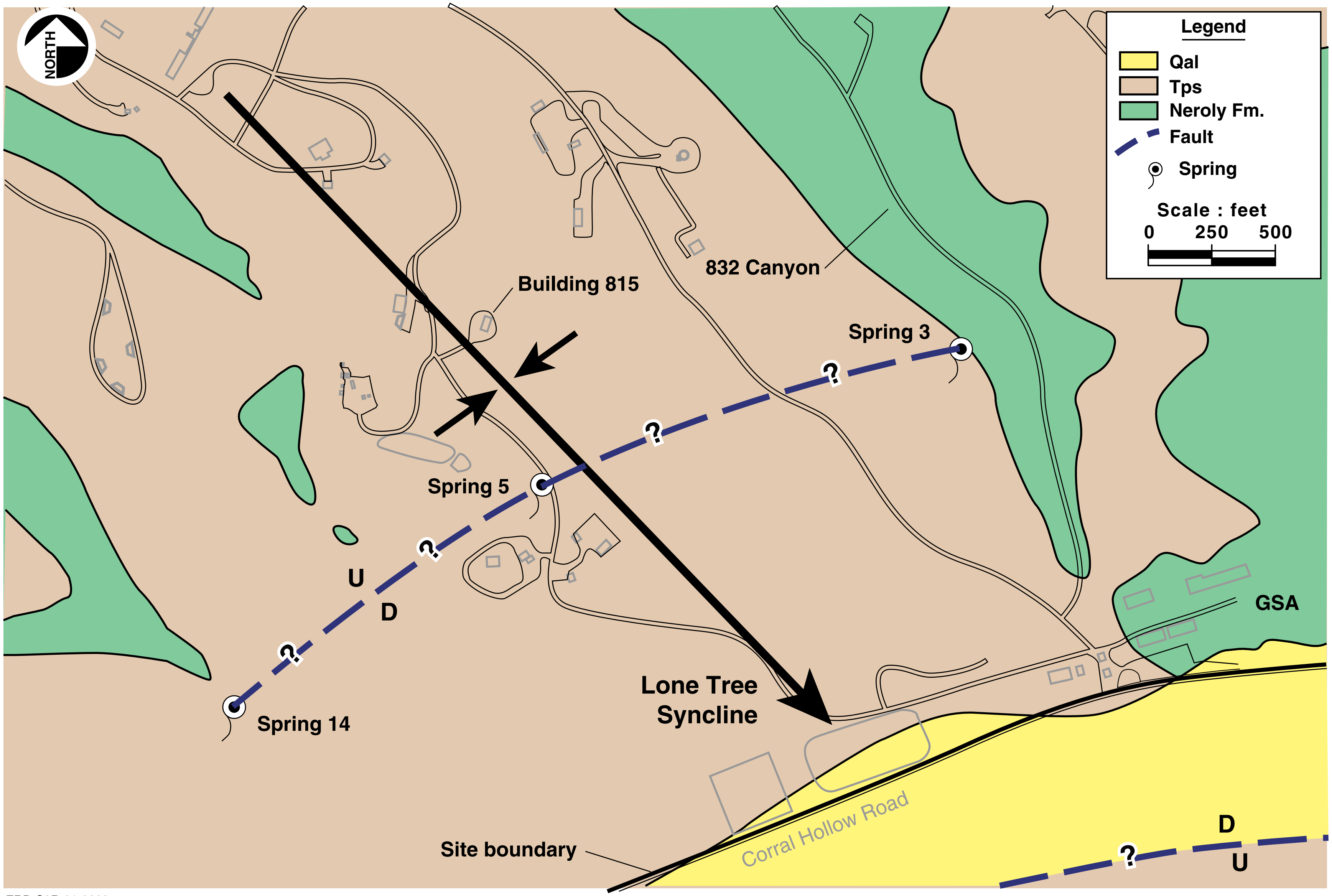

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Figure 4. Geologic map of the HE Process Area OU showing axis of Lone Tree Syncline and postulated faults.

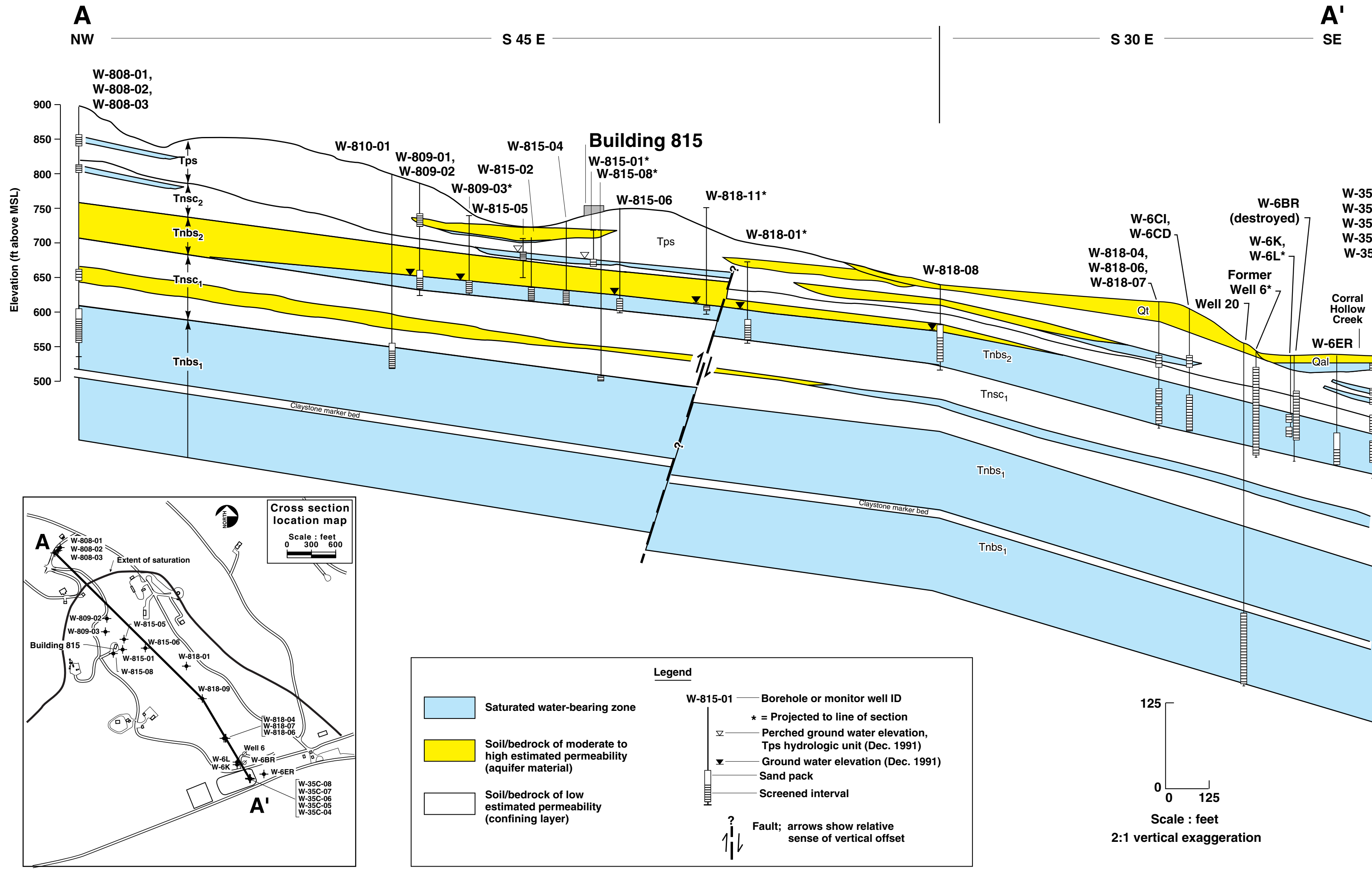

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Figure 5. Hydrogeologic cross-section A-A'.

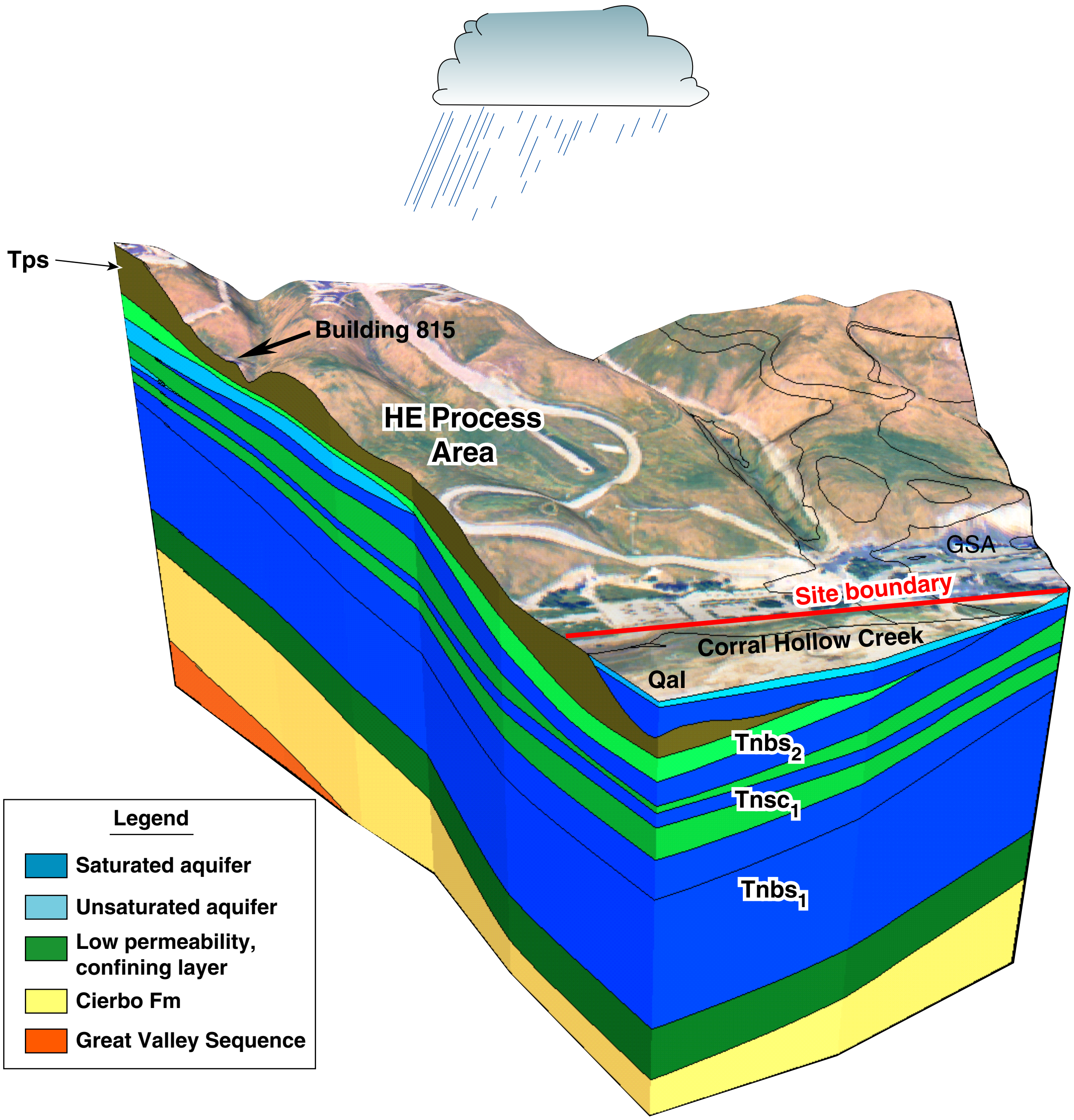

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Figure 6. 3-D Hydrogeologic Model of the alluvial and Neroly Formation bedrock aquifers beneath the HE Process Area OU.

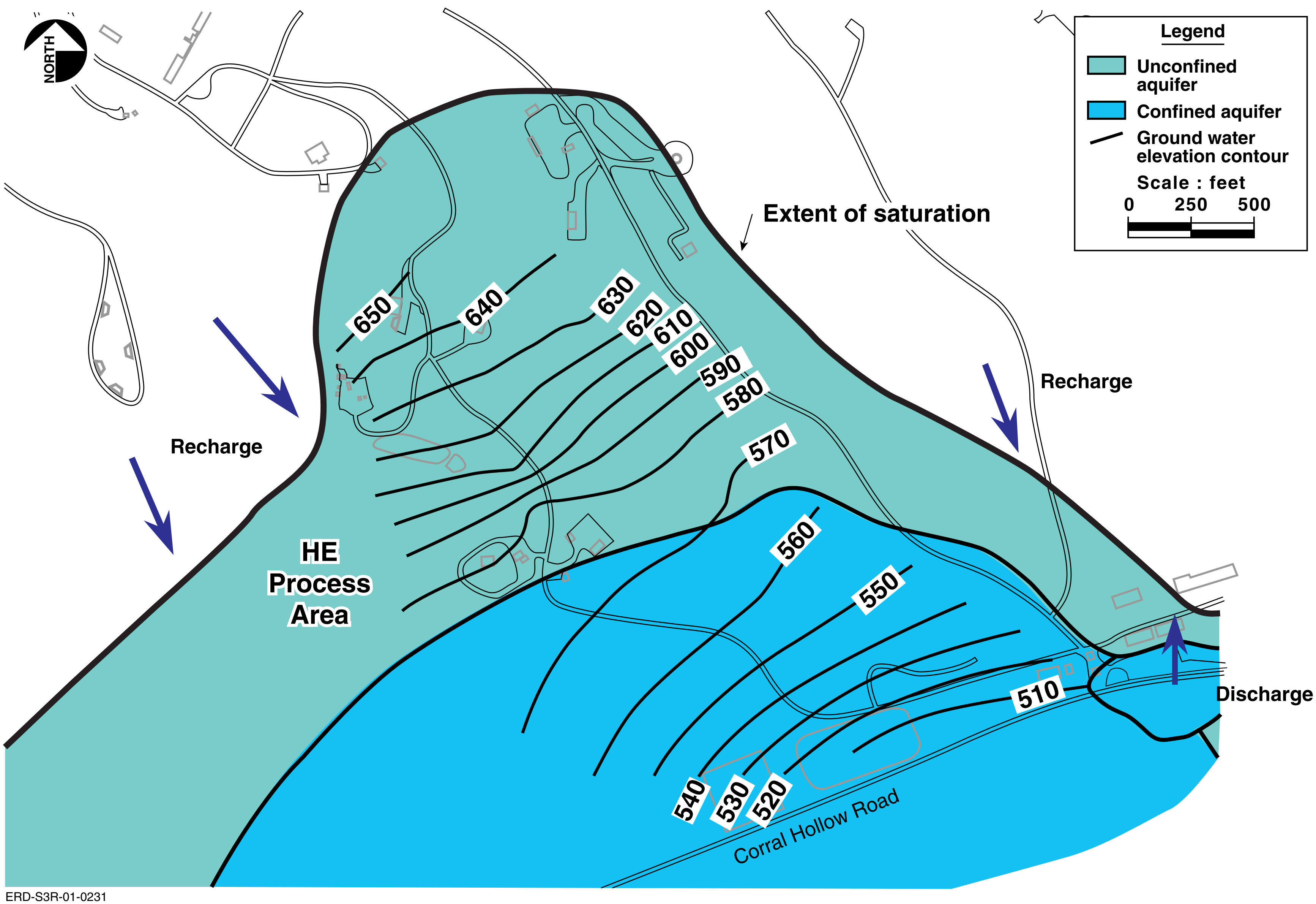


Figure 7. Map showing extent of saturation, ground water elevation contours, confined and unconfined areas, and recharge/discharge areas for Tnbs$_2$ aquifer.

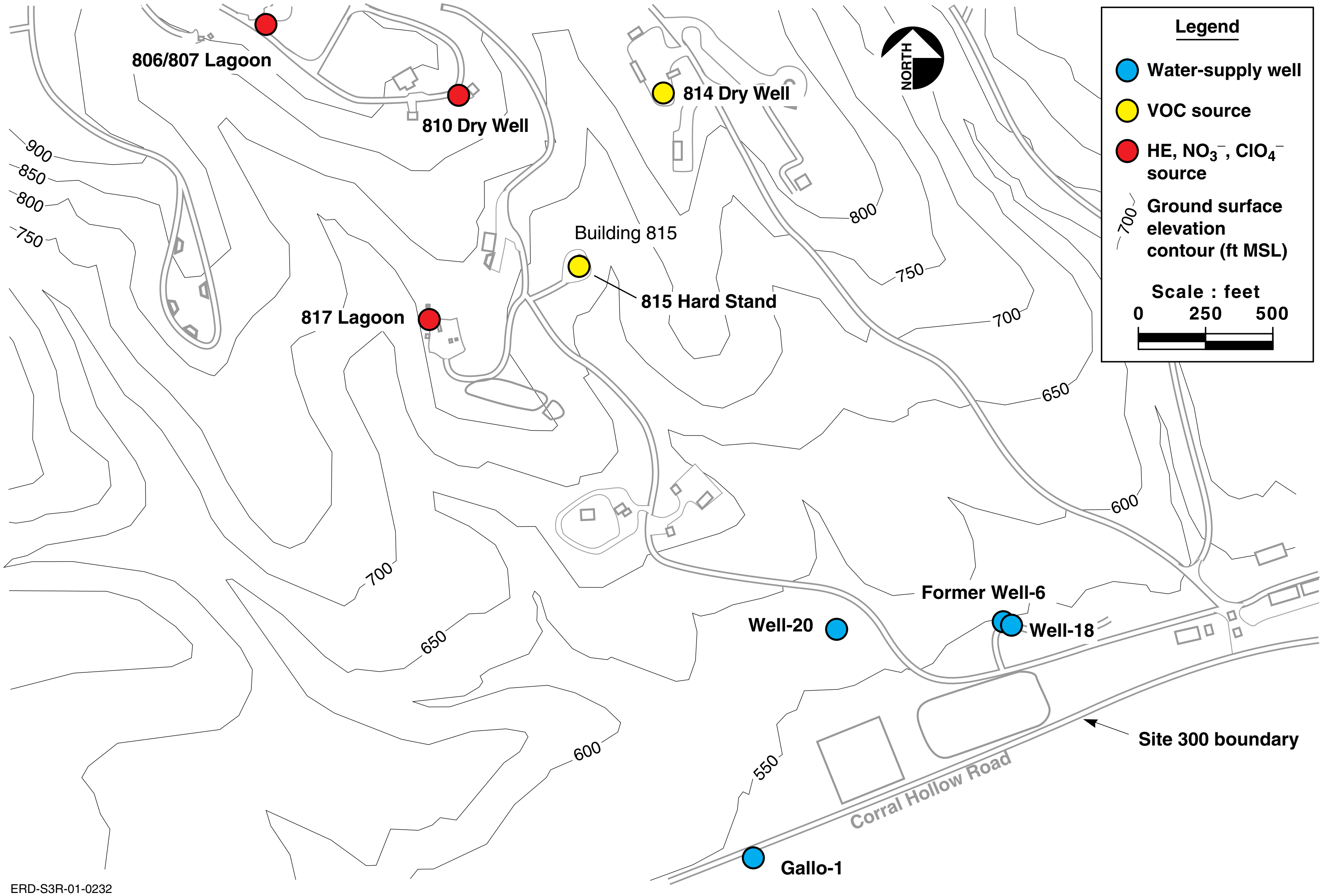


Figure 8. HE Process Area OU showing contaminant source areas and former and active water-supply wells.

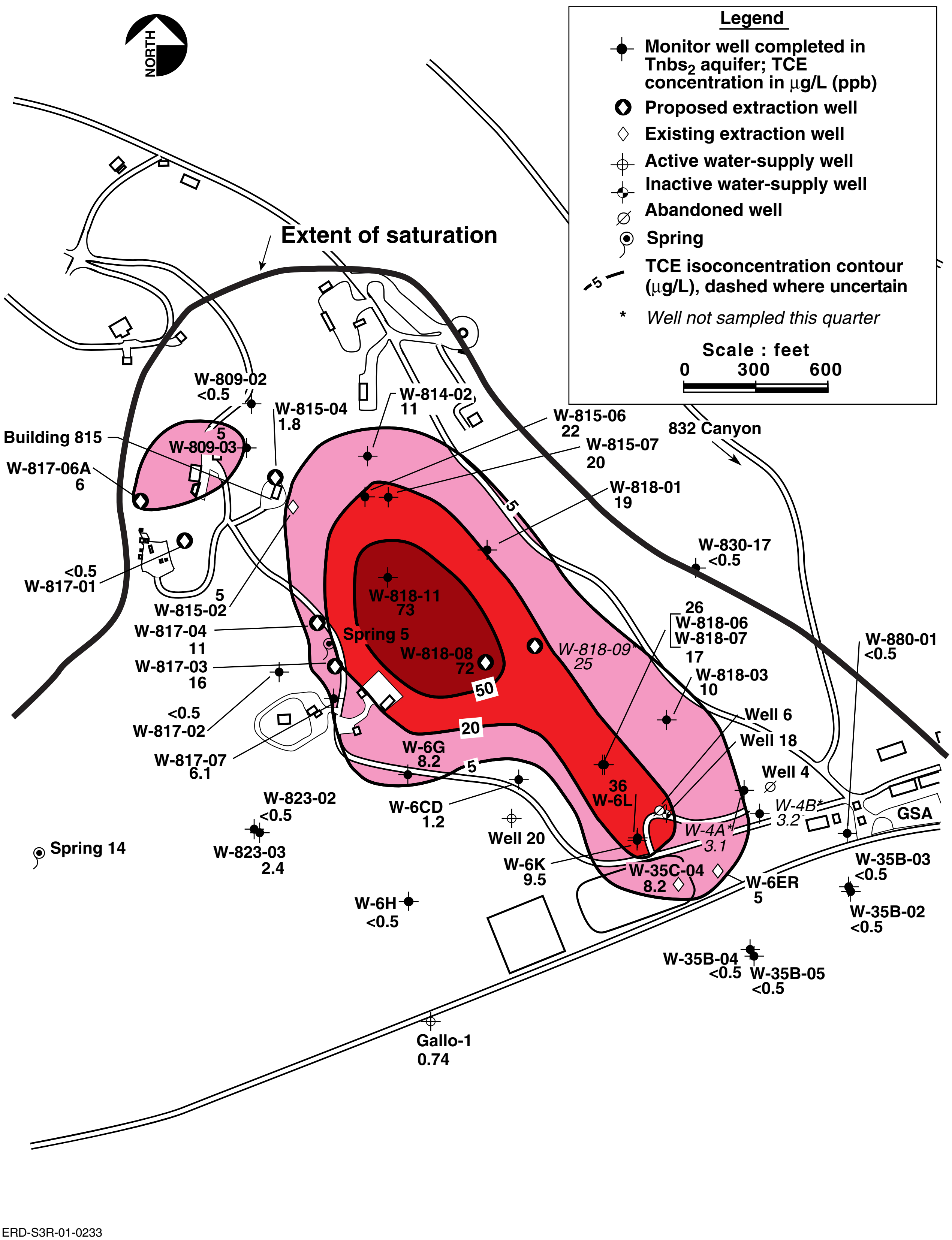
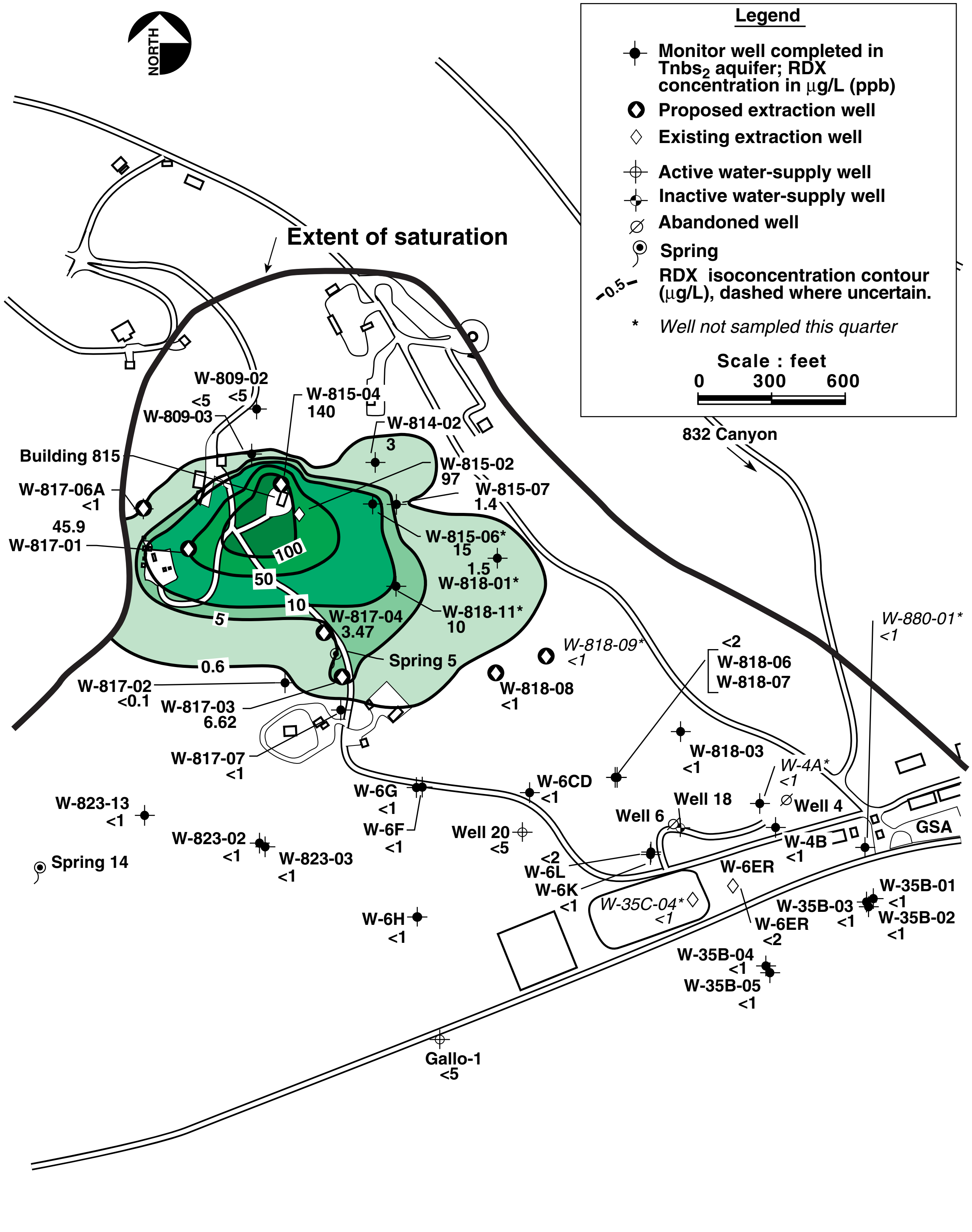
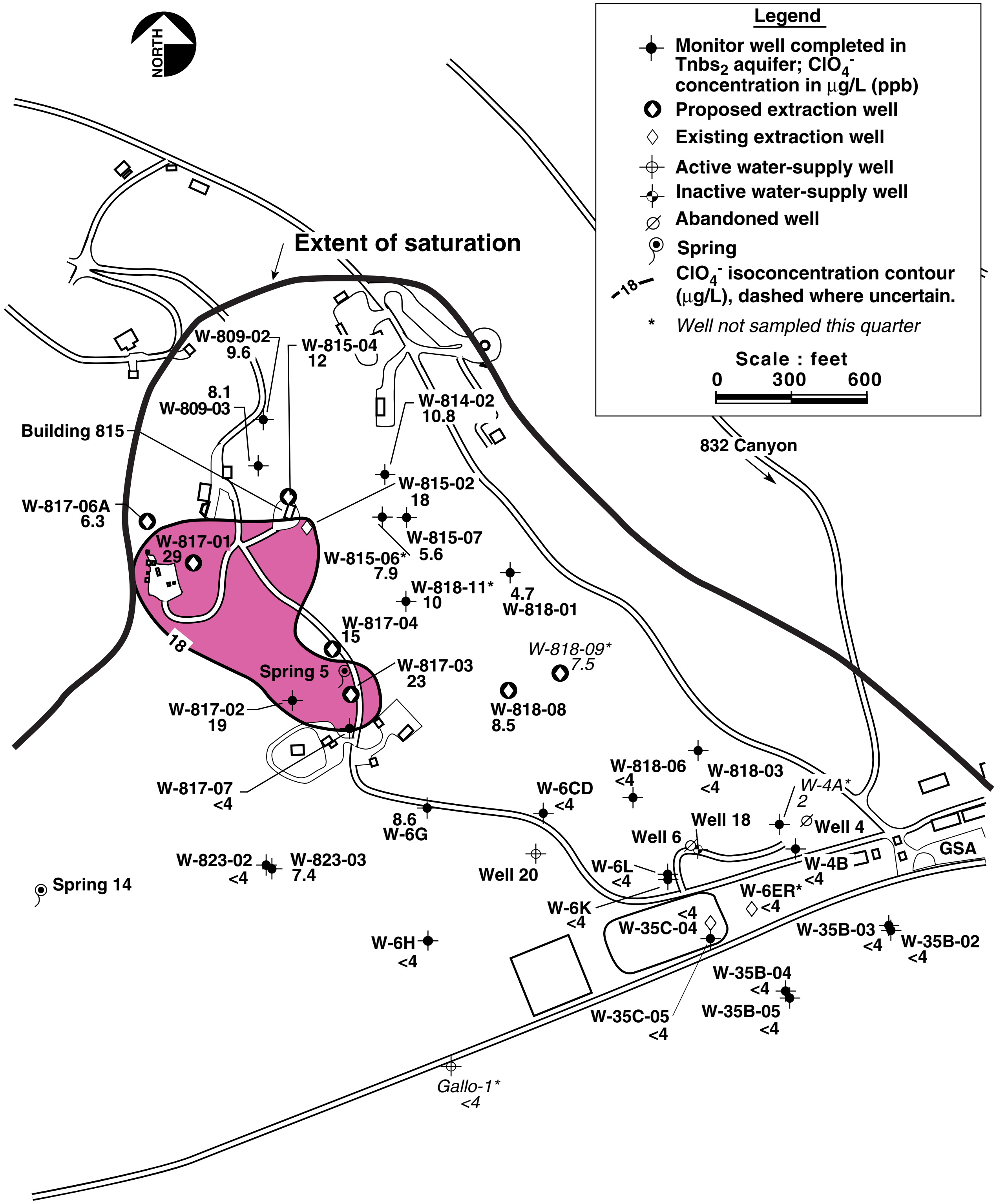


Figure 9. Trichloroethylene (TCE) isoconcentration contour map (>5 µg/L, MCL) in the Tnbs$_2$ aquifer. Based on second quarter 2001 or most recent data.



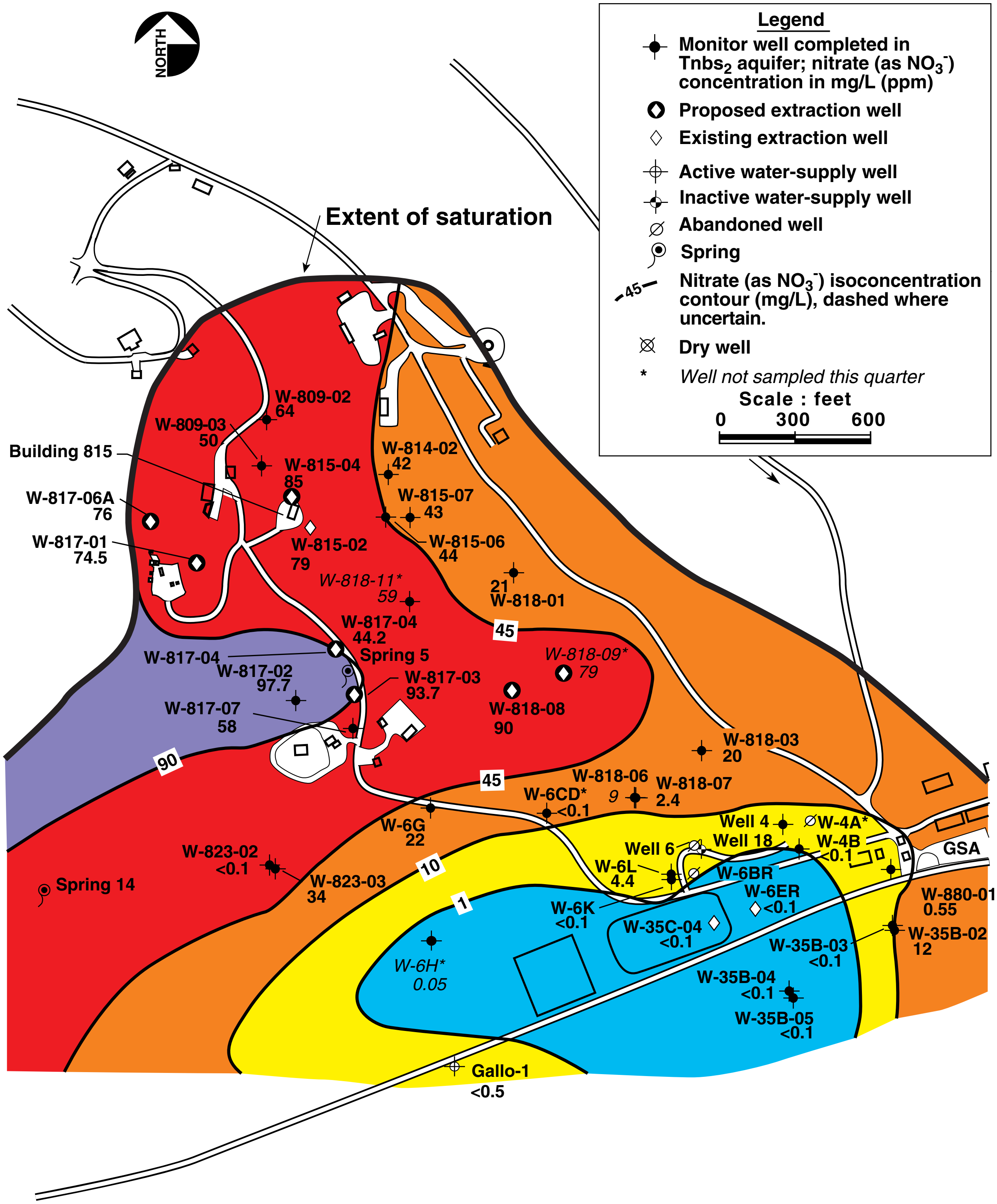
ERD-S3R-01-0234

Figure 10. High explosive compound (RDX) isoconcentration contour map (>0.6 µg/L, PRG) in the Tnbs$_2$ aquifer. Based on second quarter 2001 or most recent data.



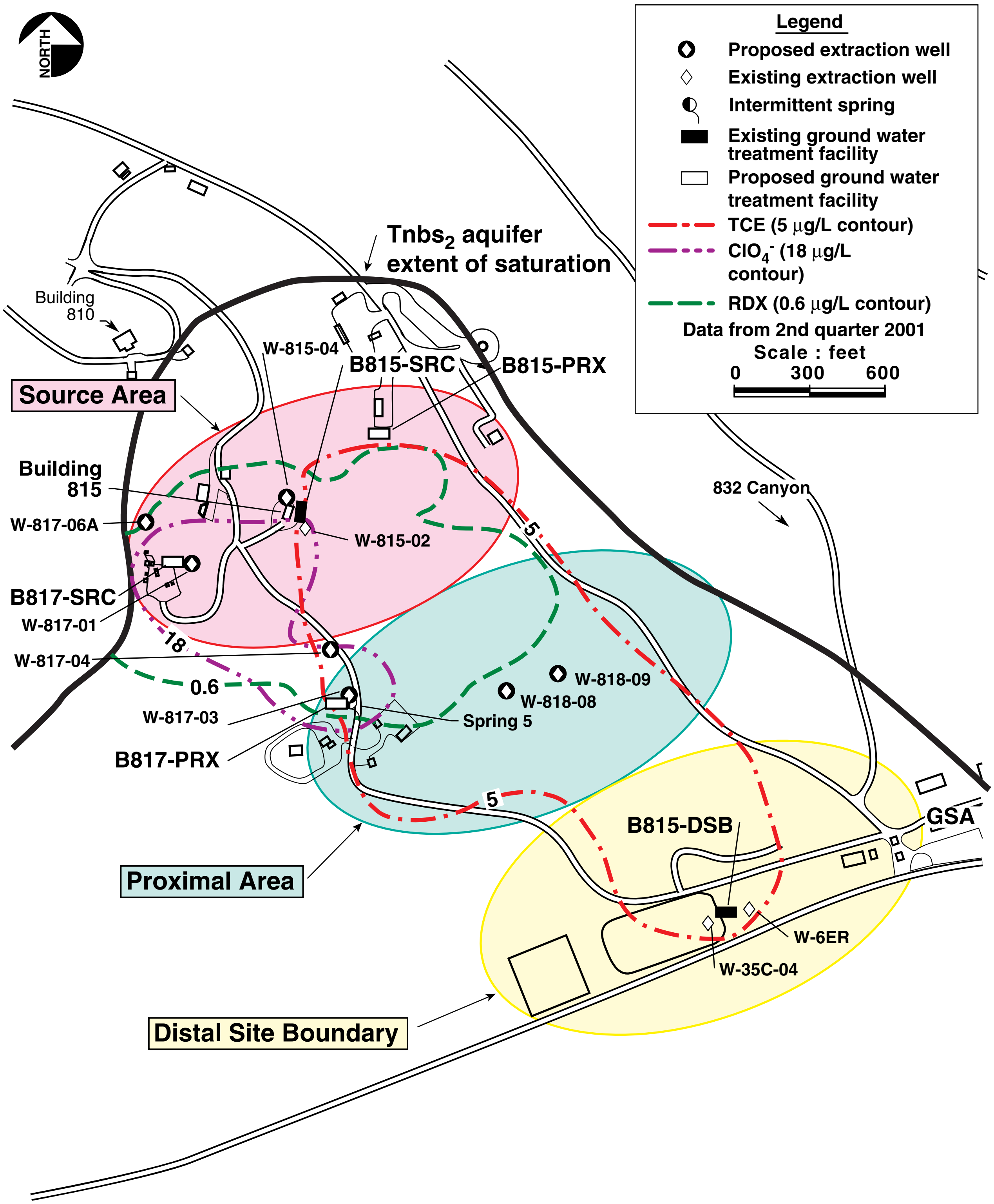
ERD-S3R-01-0235

Figure 11. Perchlorate (ClO_4^-) isoconcentration contour map (>18µg/L, State of California Health Advisory Limit) in the $Tnbs_2$ aquifer. Based on second quarter 2001 or most recent data.



ERD-S3R-01-0236

Figure 12. Nitrate (as NO_3^-) isoconcentration contour map in the Tnbs$_2$ aquifer. Based on second quarter 2001, or most recent data.



ERD-S3R-01-0237

Figure 13. Building 815 treatment areas, existing and proposed treatment facilities and extraction wells, and outline of TCE, RDX, and ClO_4^- plumes.

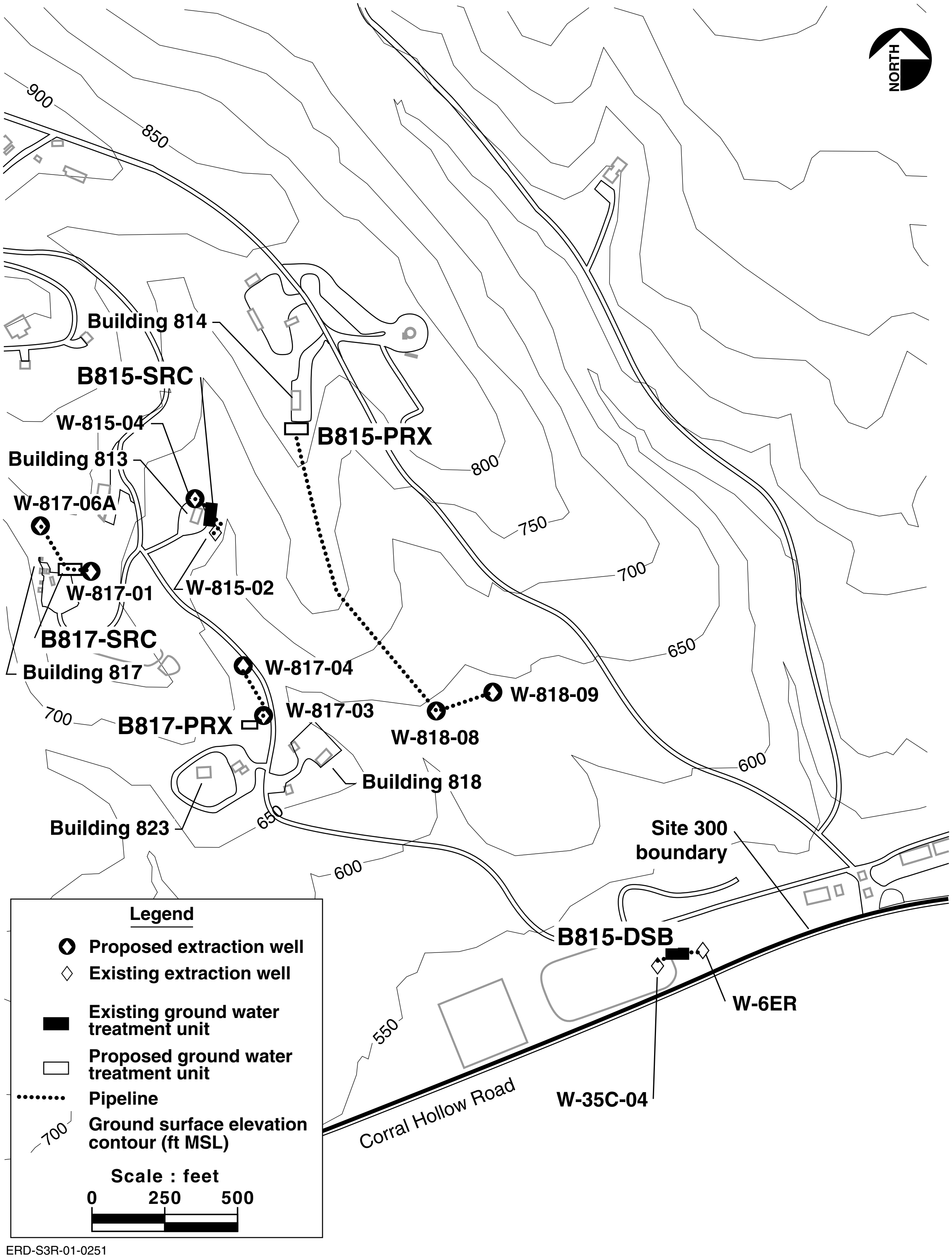
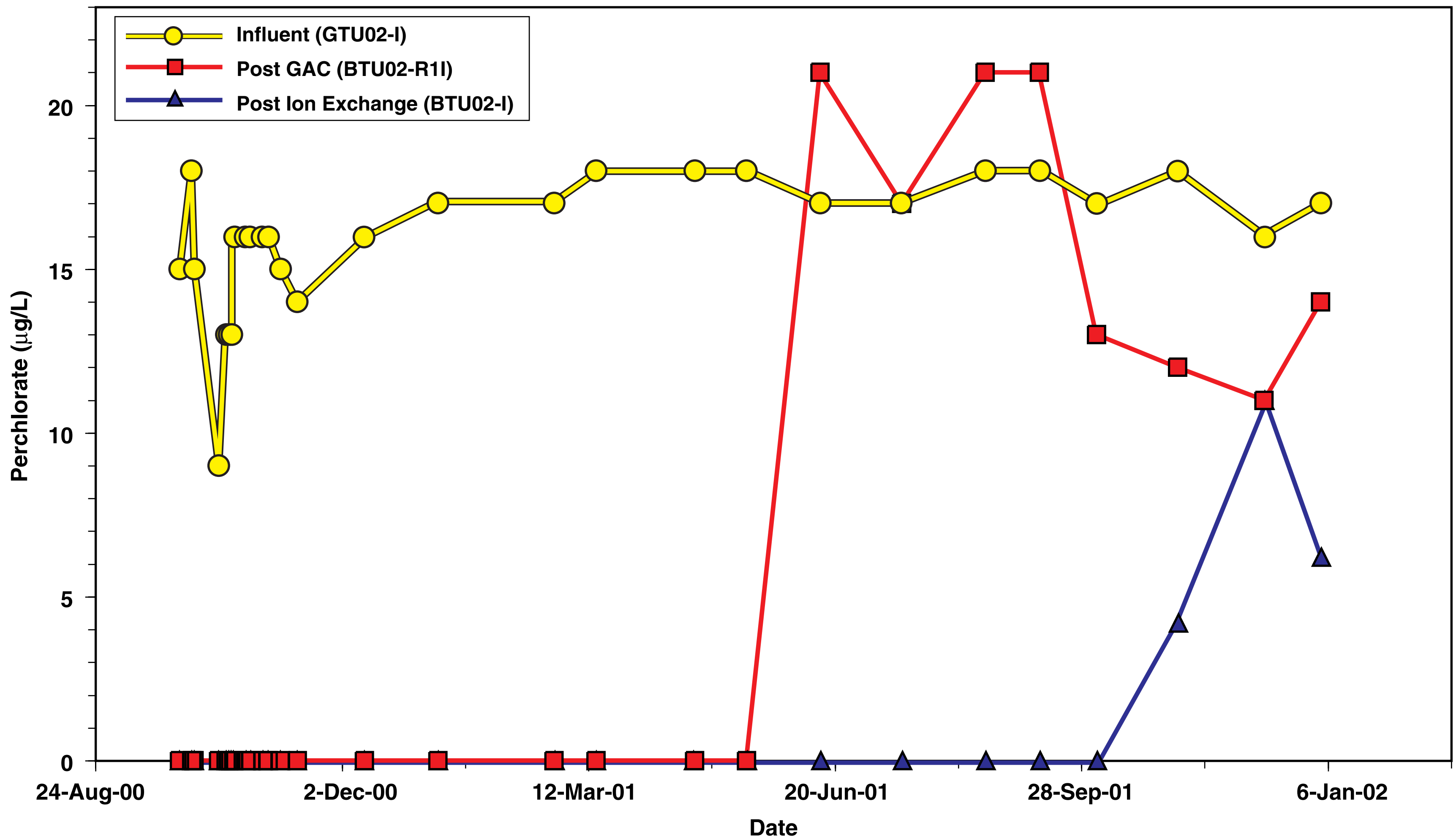
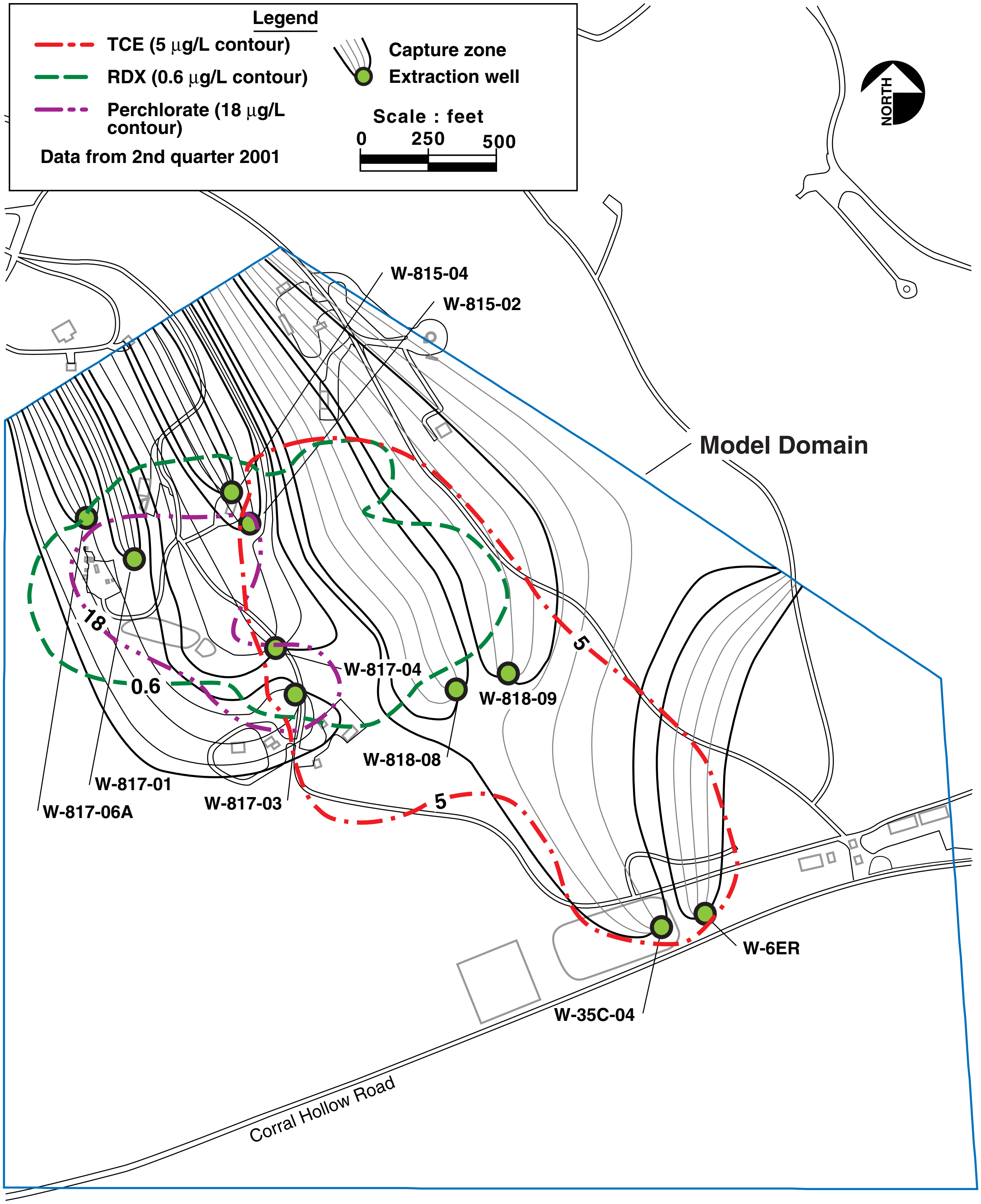


Figure 14. Location of existing and proposed extraction wells and treatment facilities.



ERD-S3R-02-0144

Figure 15. Time-series plot showing performance of ion exchange removal of perchlorate. (See Figures 19A, 19B, and 19C for exact position of sample ports.)



ERD-S3R-01-0276

Figure 16. Map showing extraction well capture zones and second quarter TCE, RDX, and ClO_4^- isoconcentration contours.

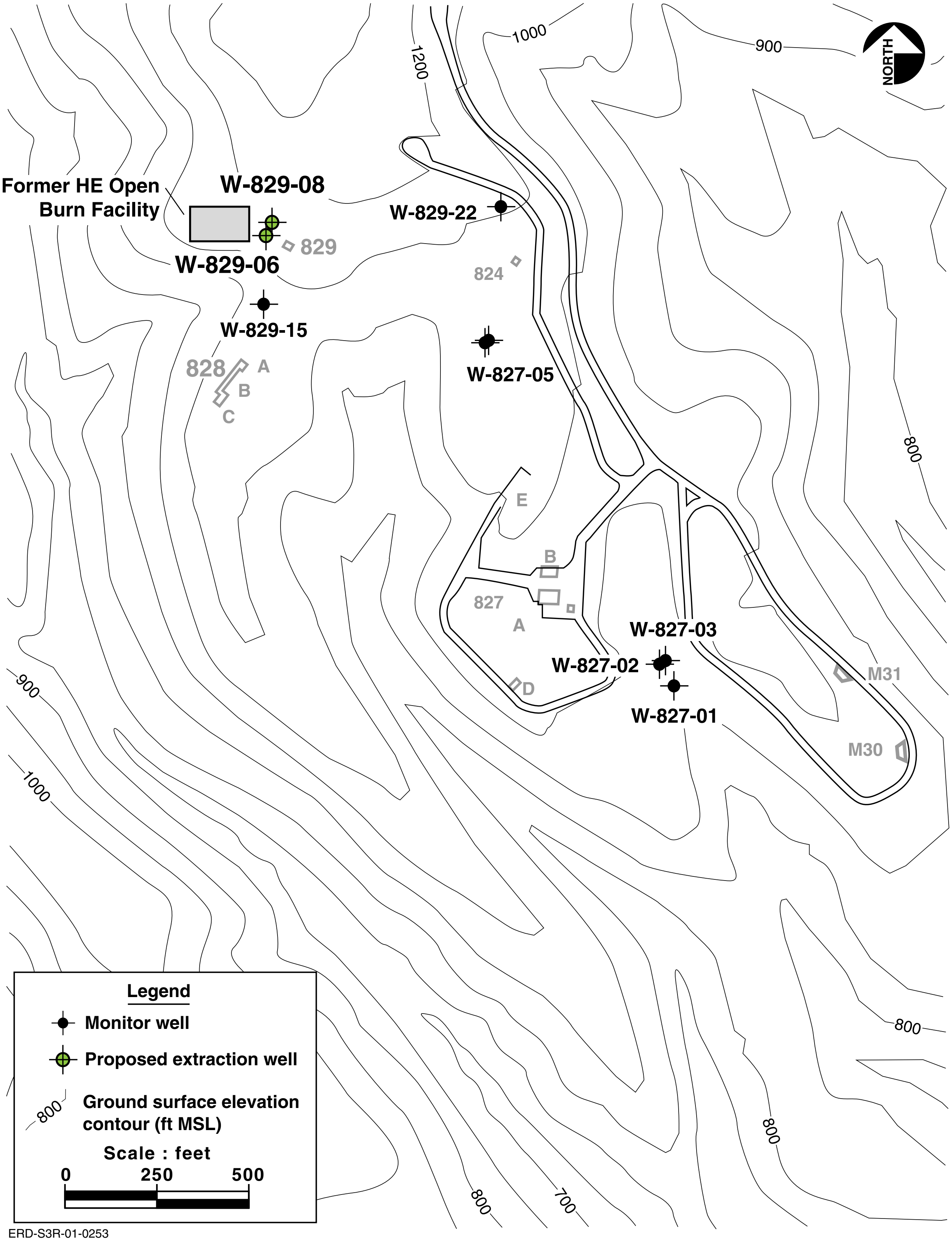
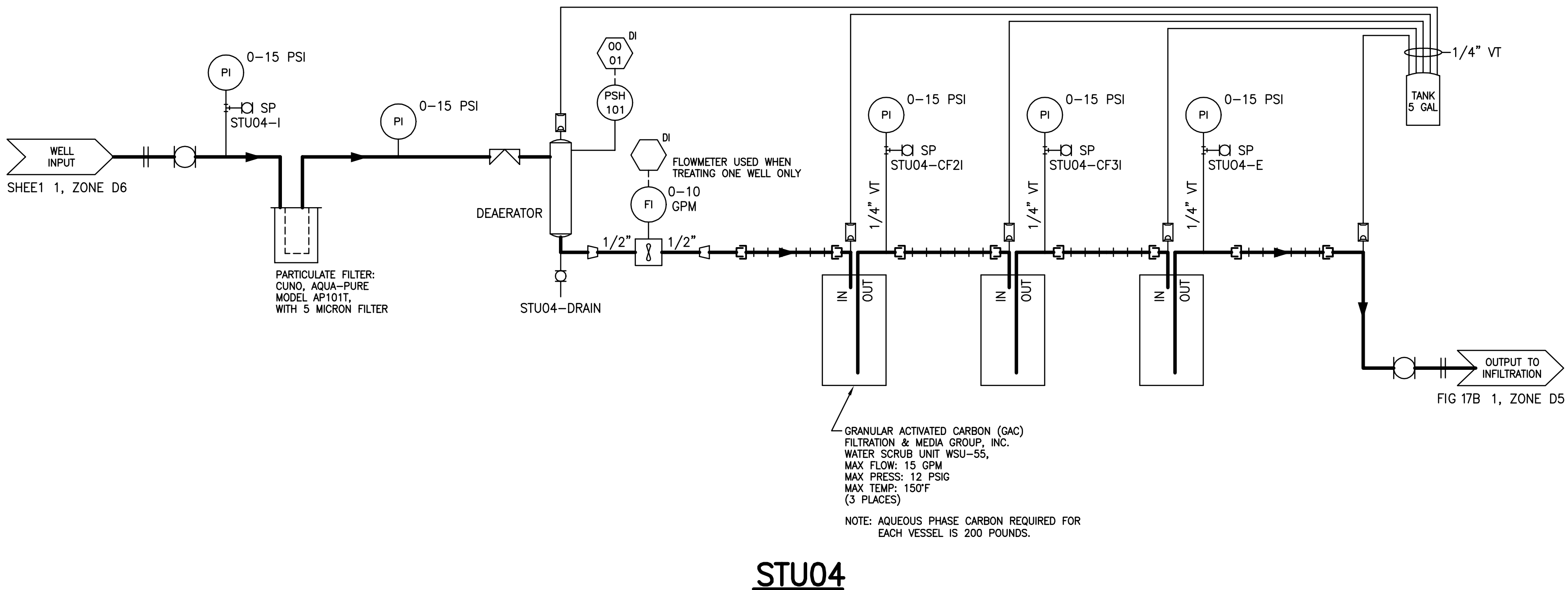


Figure 17. Map of former Building 829 HE Open Burn Facility showing proposed extraction wells W-829-06 and W-829-08 and existing monitoring wells.



ERD-S3R-01-0258

Figure 18A. Piping and instrument diagram for B815-DSB (solar treatment unit). Legend on Figure 18B.

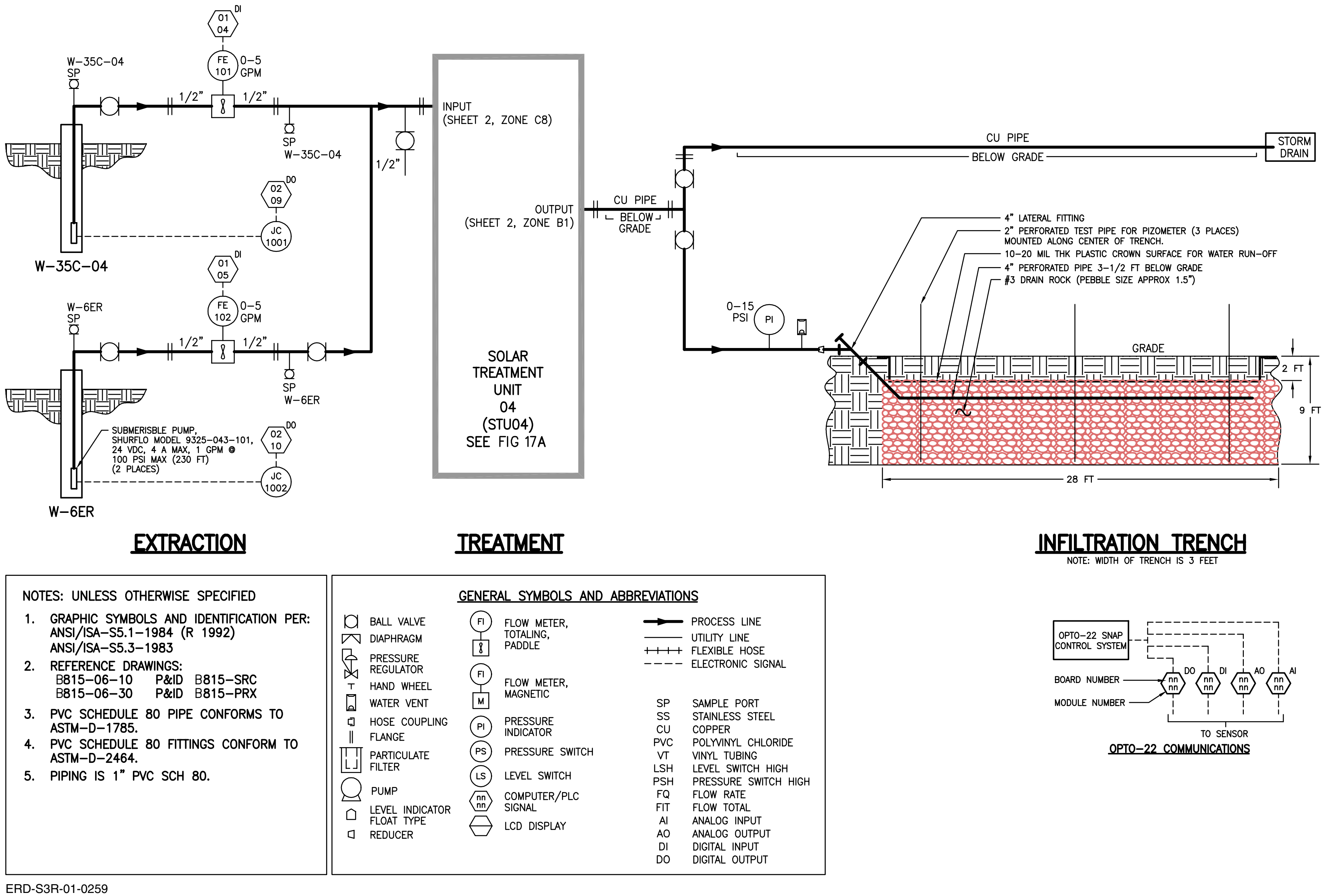
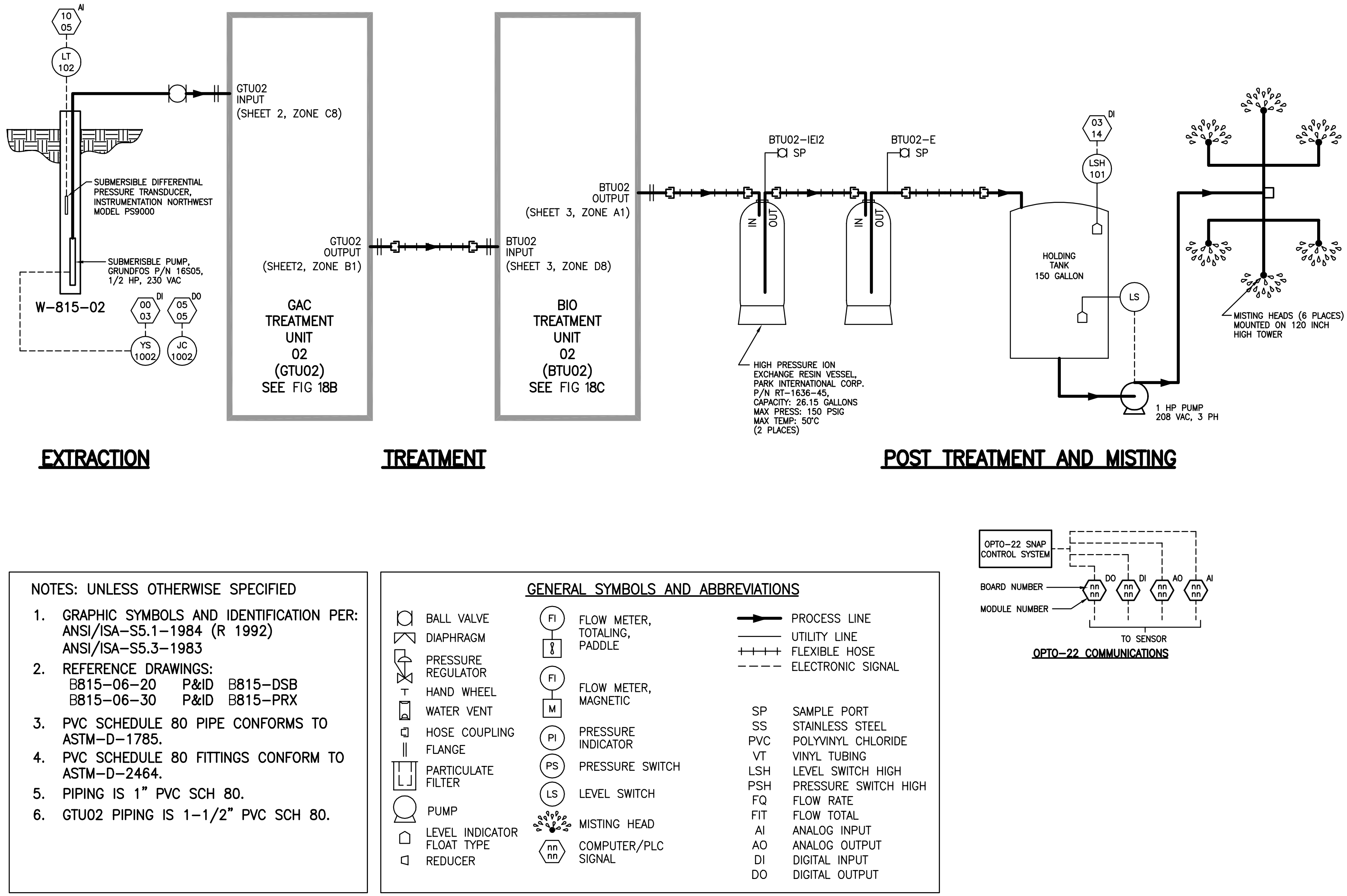
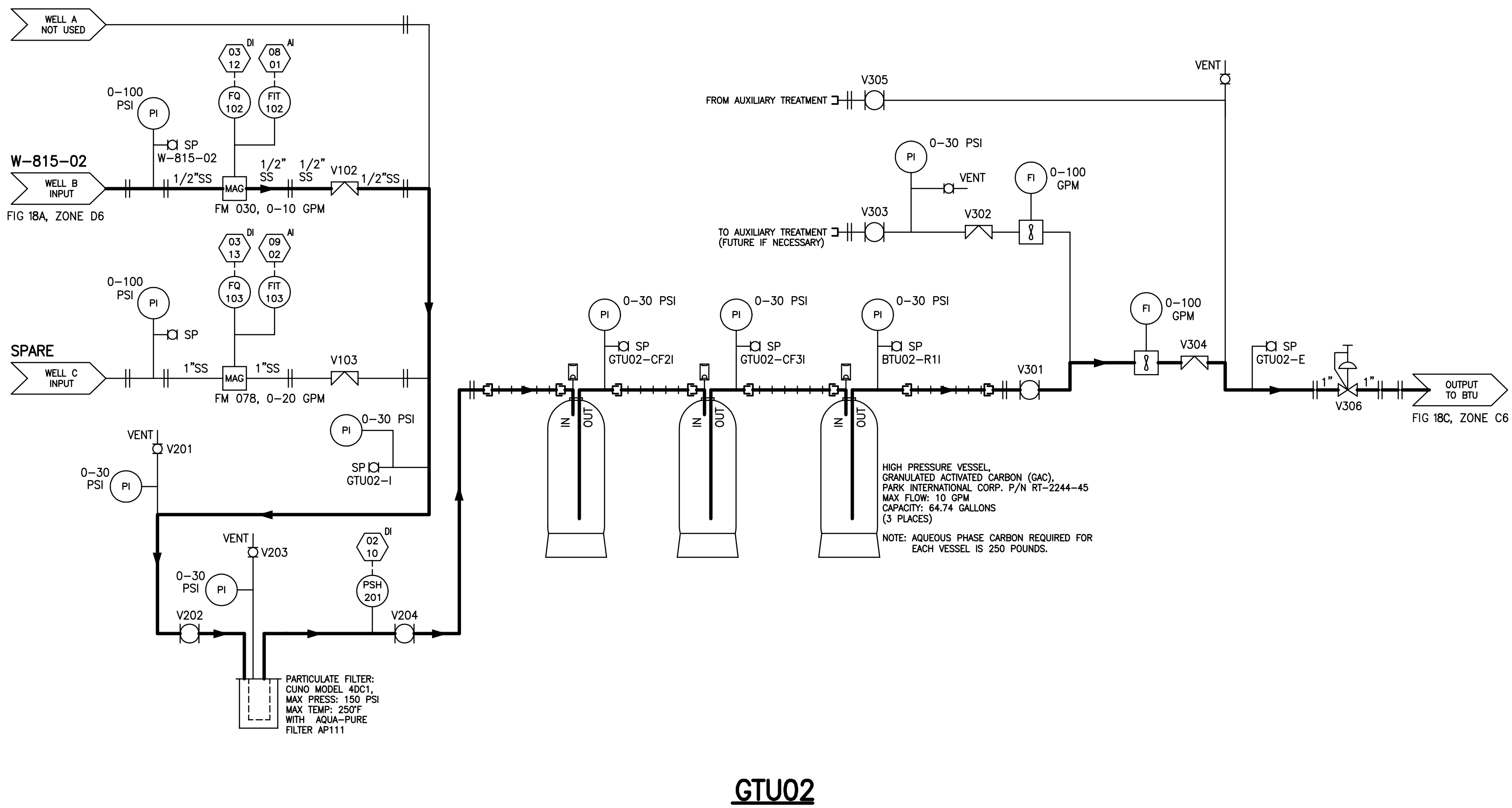


Figure 18B. Piping and instrument diagram for B815-DSB (infiltration trench).



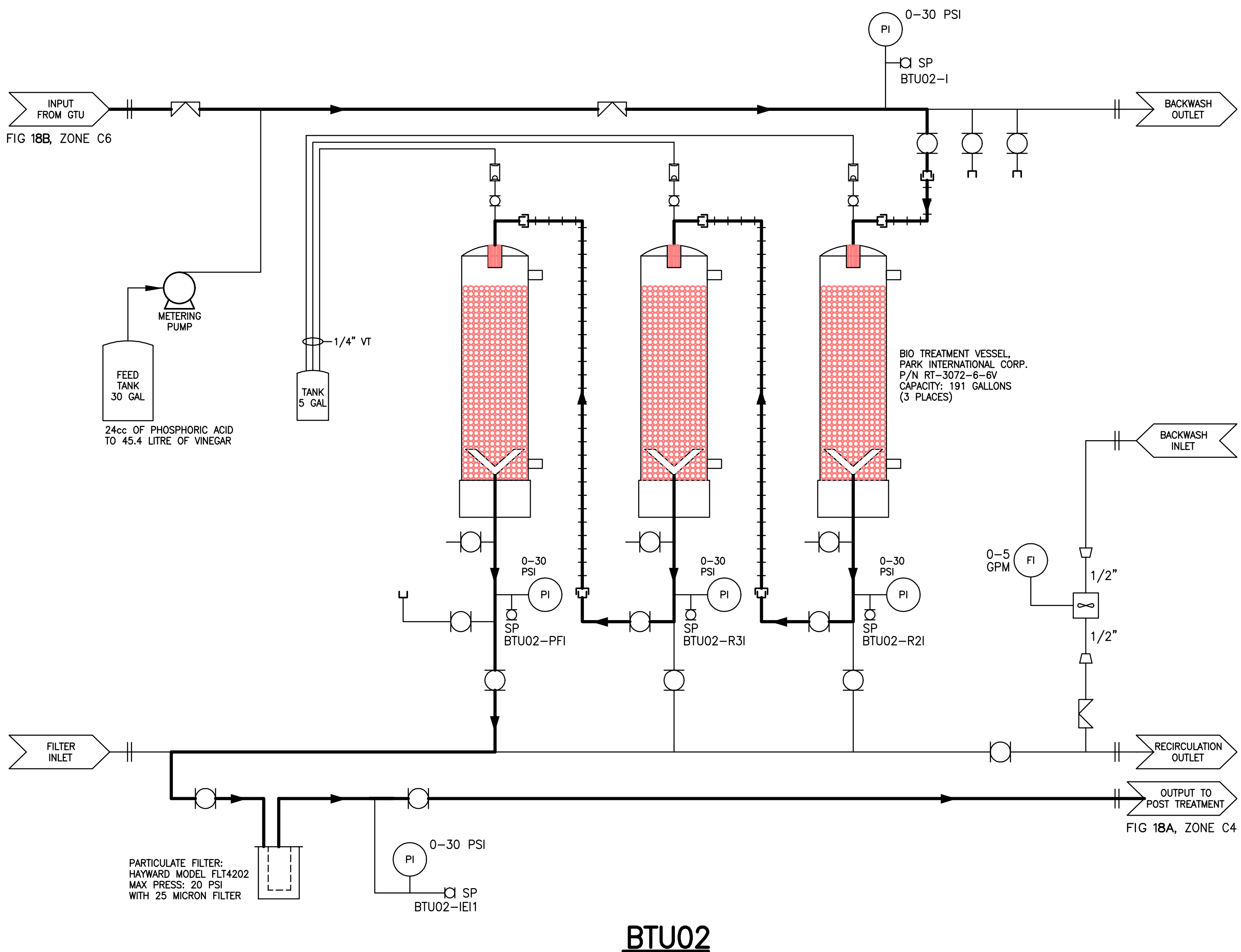
ERD-S3R-01-0260

Figure 19A. Piping and instrument diagram for B815-SRC.



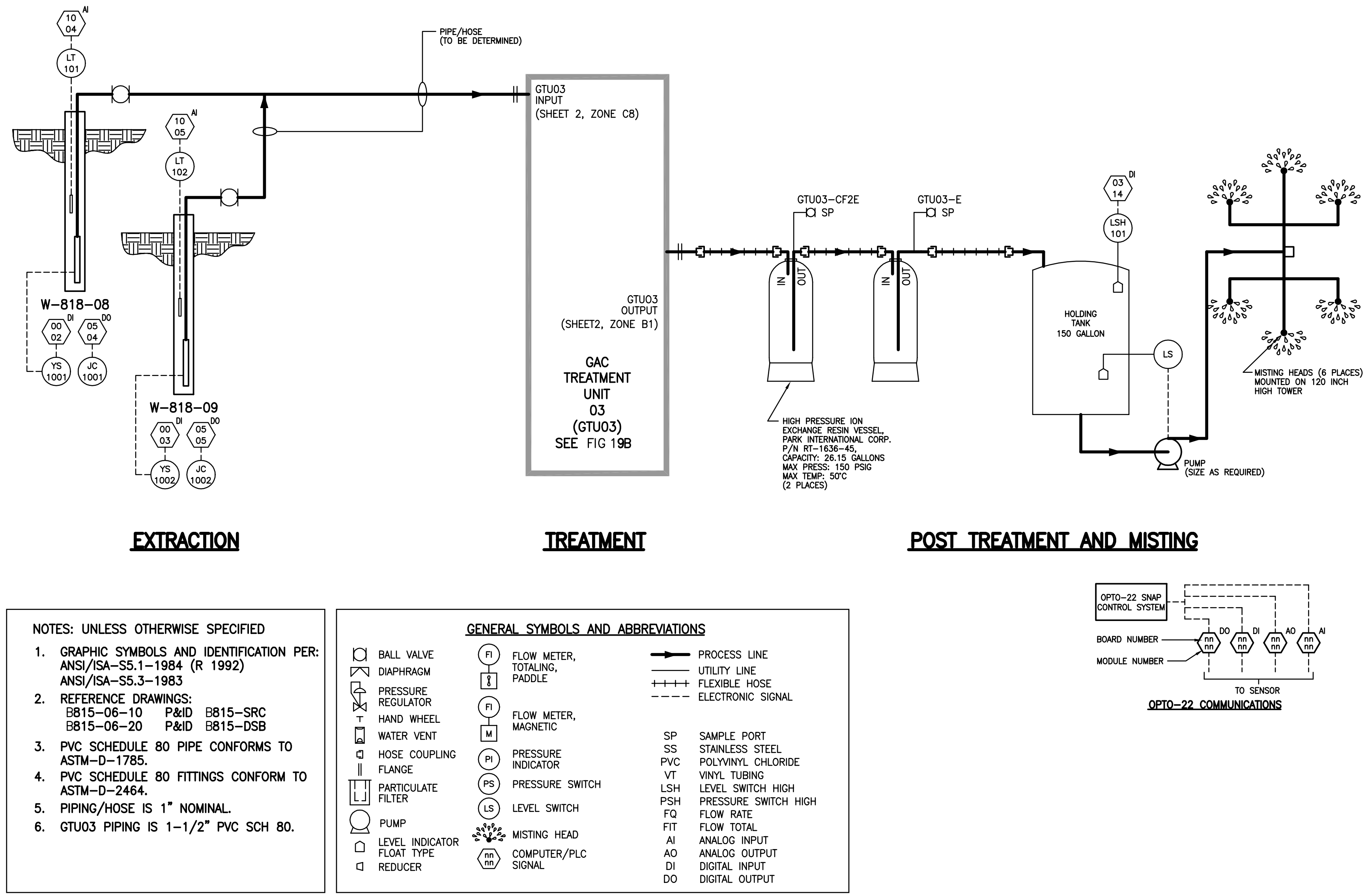
ERD-S3R-01-0261

Figure 19B. Piping and instrument diagram for B815-SRC (GAC treatment). Legend on Figure 19A.



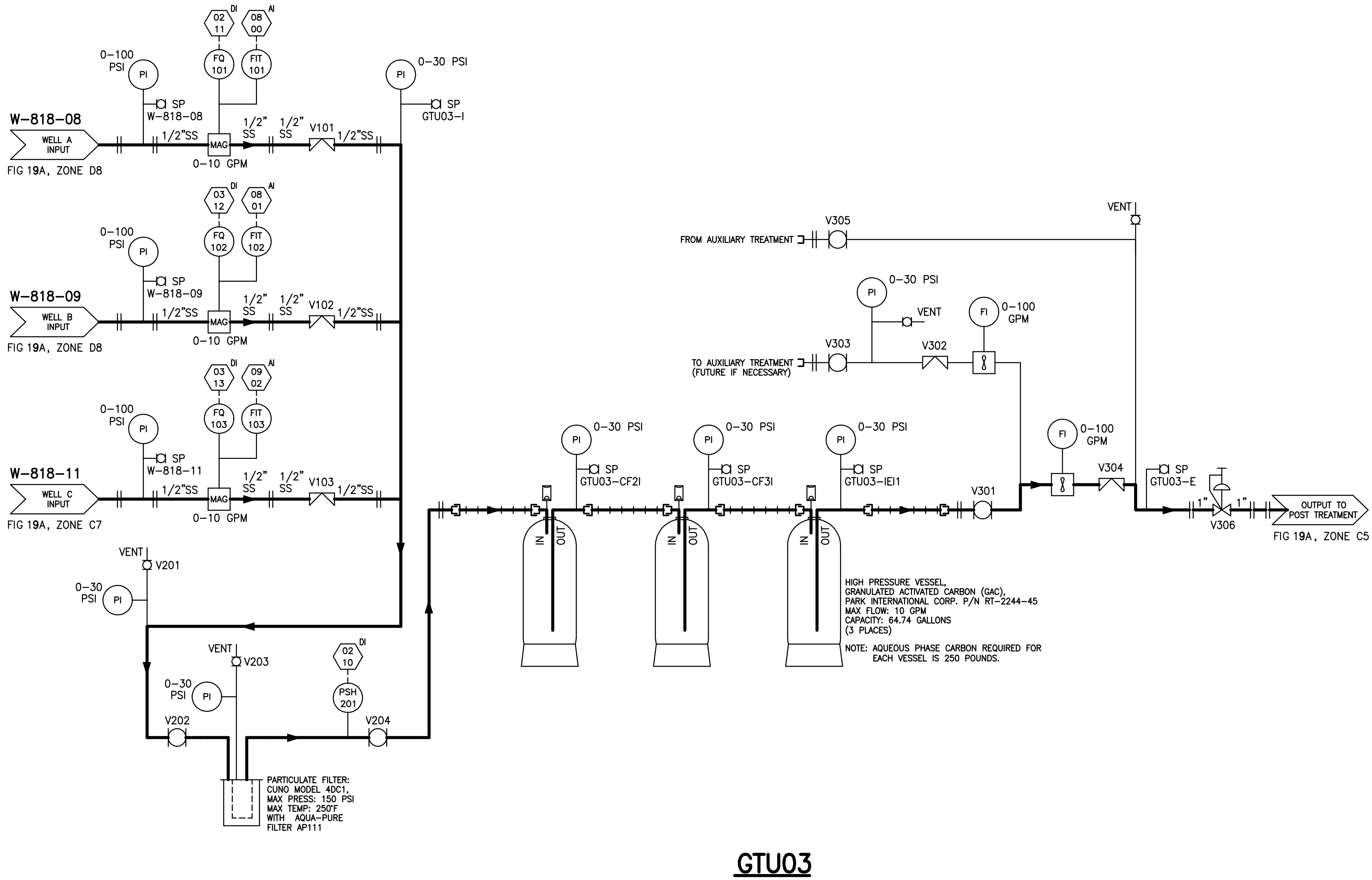
ERD-S3R-01-0262

Figure 19C. Piping and instrument diagram for B815-SRC (bioreactor treatment). Legend on Figure 19A.



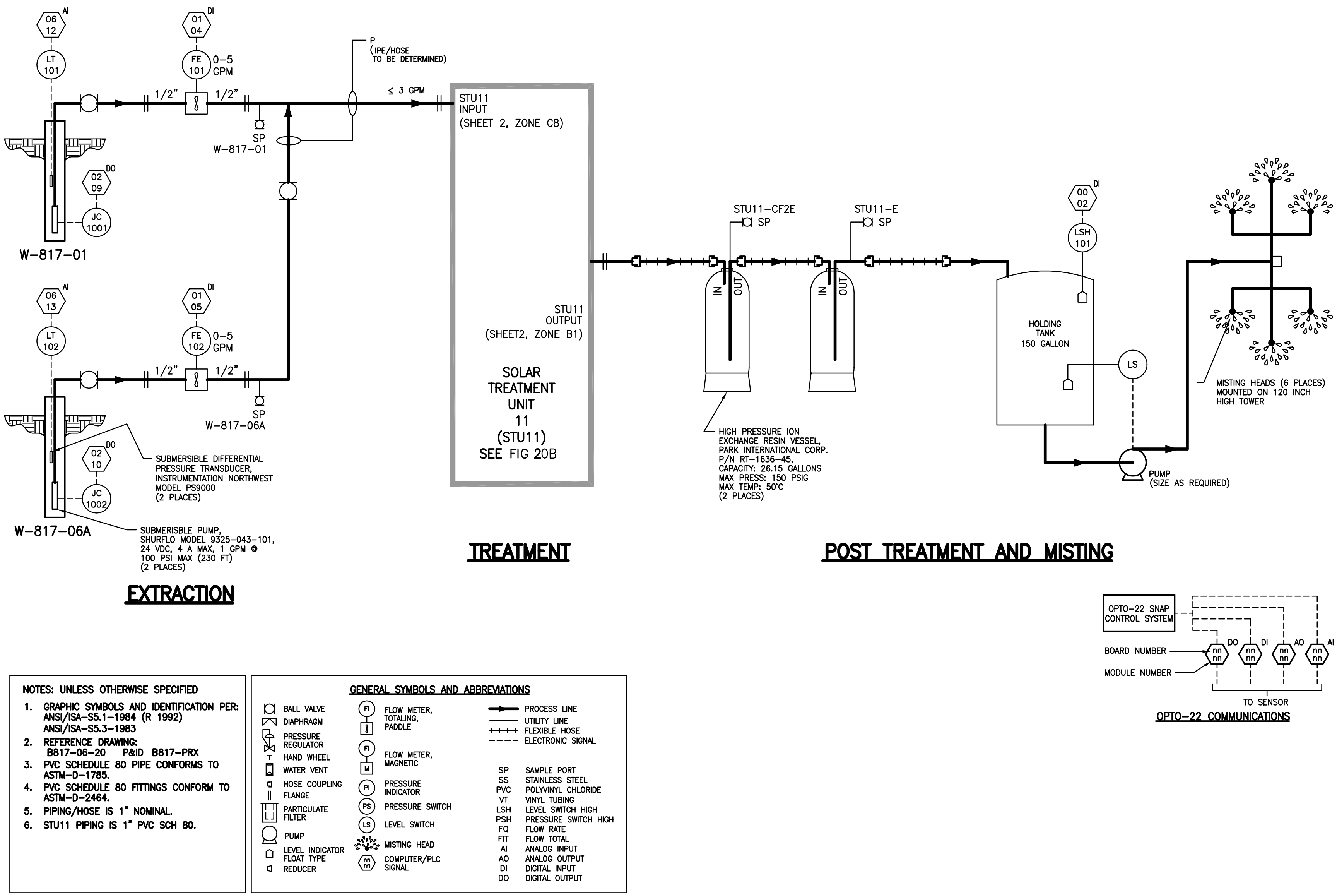
ERD-S3R-02-0041

Figure 20A. Piping and instrument diagram for B815-PRX.



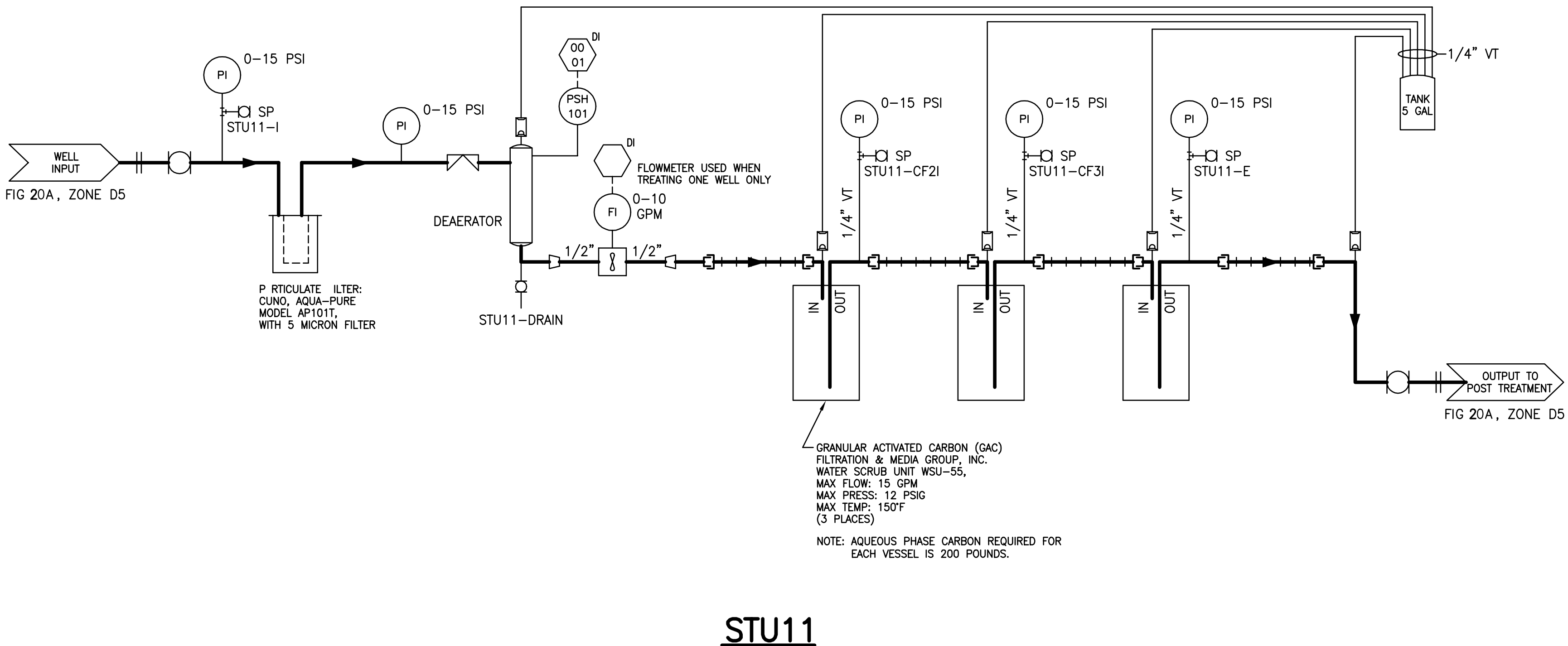
ERD-S3R-02-0042

Figure 20B. Piping and instrument diagram for B815-PRX (GAC treatment). Legend on Figure 20A.



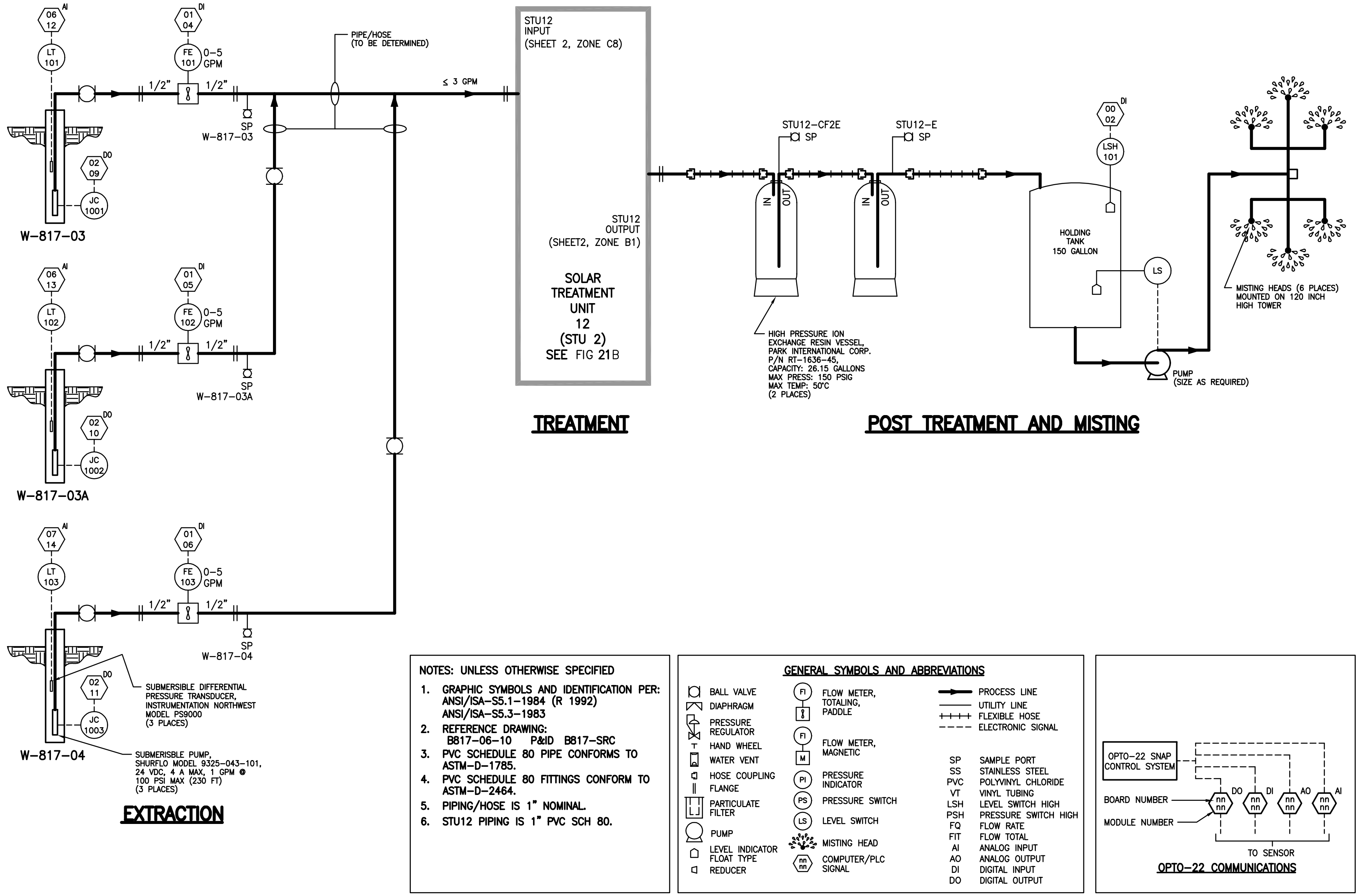
ERD-S3R-02-0043

Figure 21A. Piping and instrument diagram for B817-SRC.



ERD-S3R-02-0044

Figure 21B. Piping and instrument diagram for B817-SRC (solar treatment unit). Legend on Figure 21A.



ERD-S3R-02-0045

Figure 22A. Piping and instrument diagram for B817-PRX.

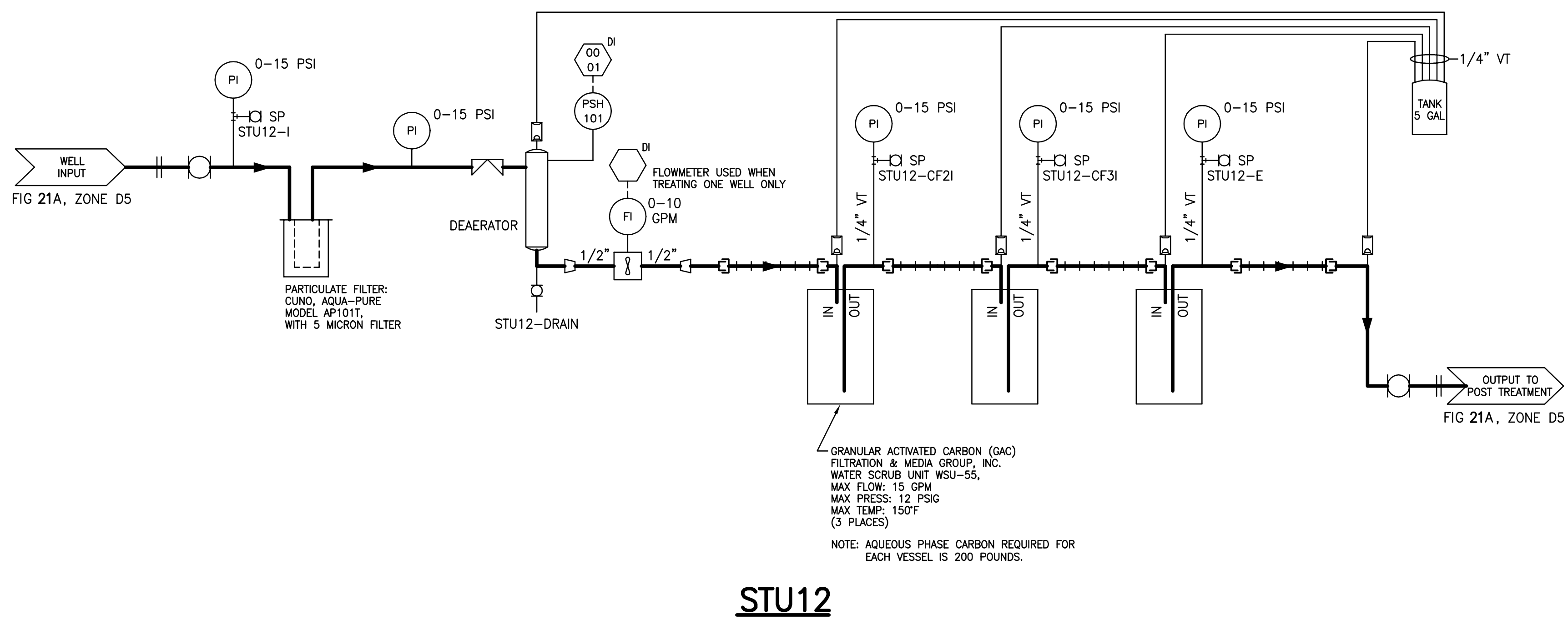
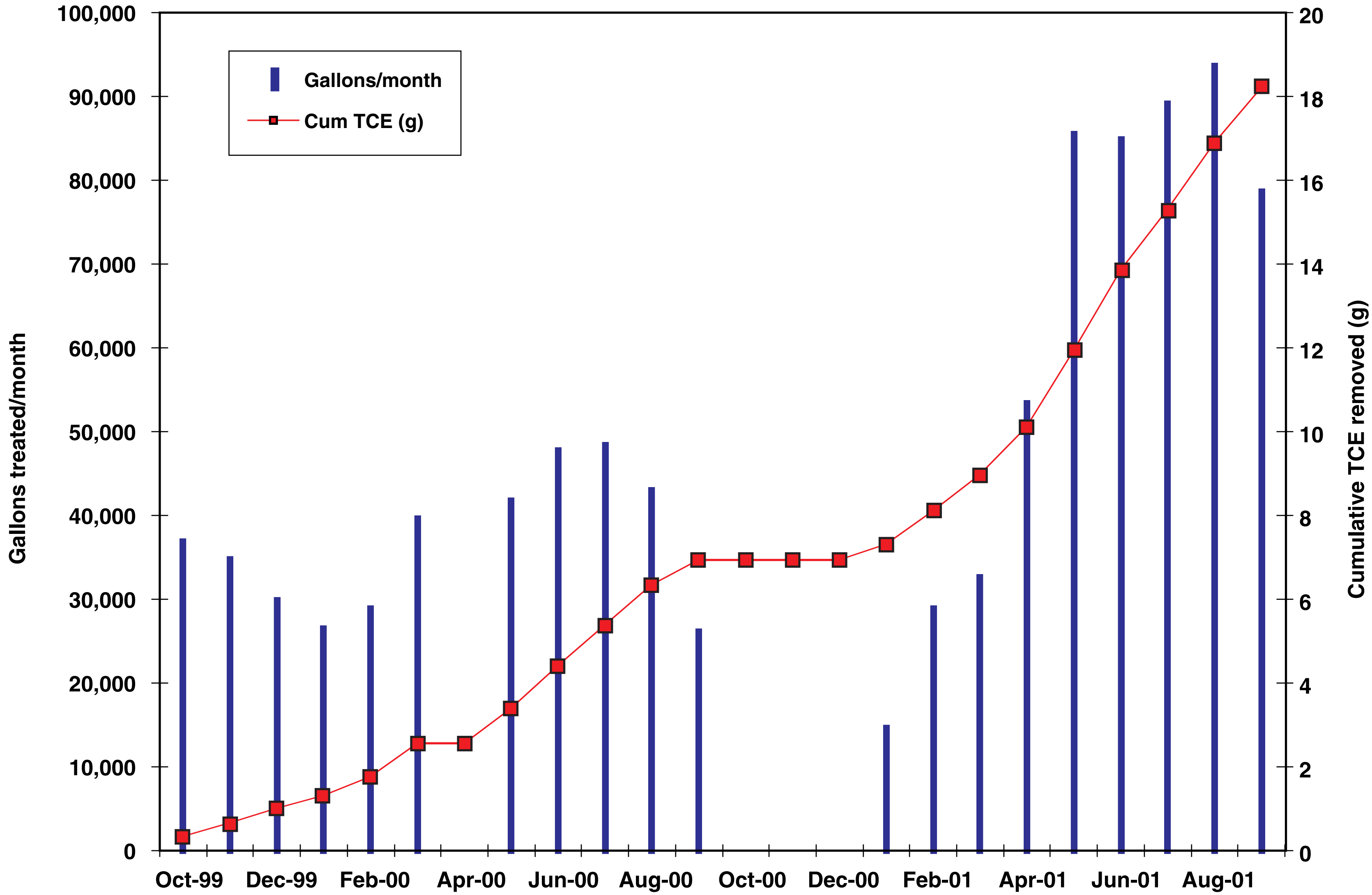
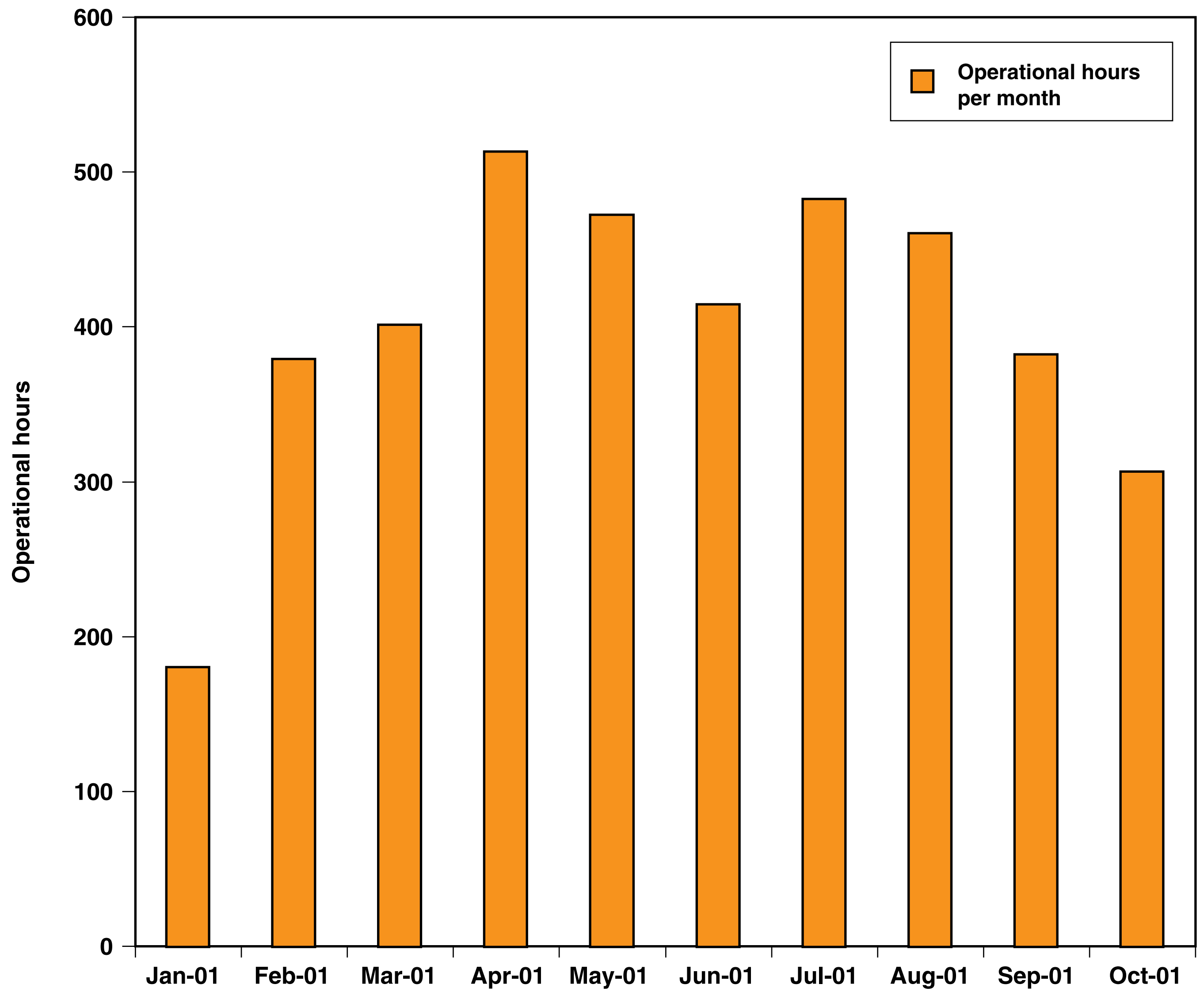


Figure 22B. Piping and instrument diagram for B817-PRX (solar treatment unit). Legend on Figure 22A.



ERD-S3R-01-0257

Figure 23. B815-DSB mass removal plot.



ERD-S3R-01-0255

Figure 24. B815-DSB operational hours per month.

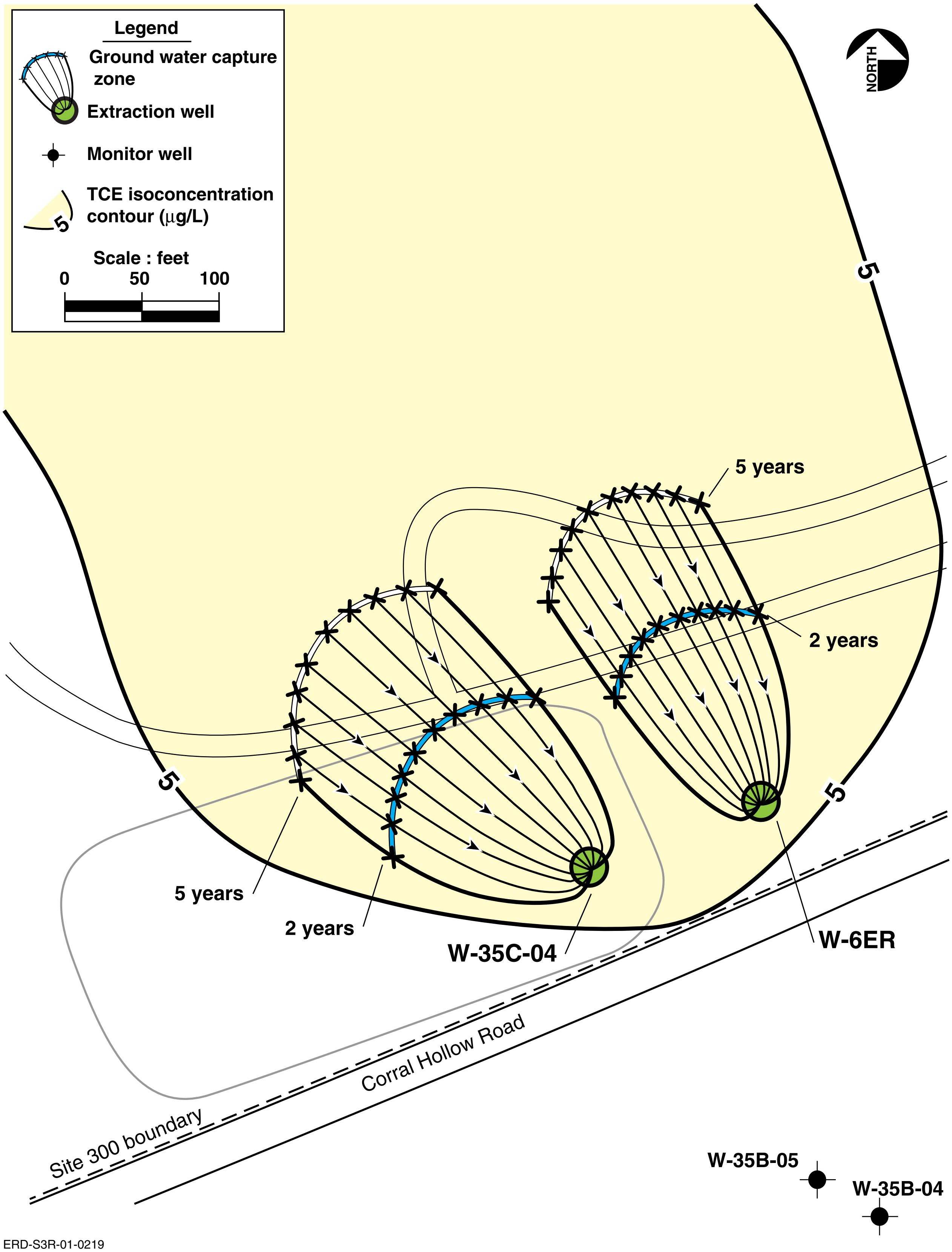


Figure 25. Two and five year capture zones for extraction wells (W-35C-04 and W-6ER) each pumping 1.5 gpm.

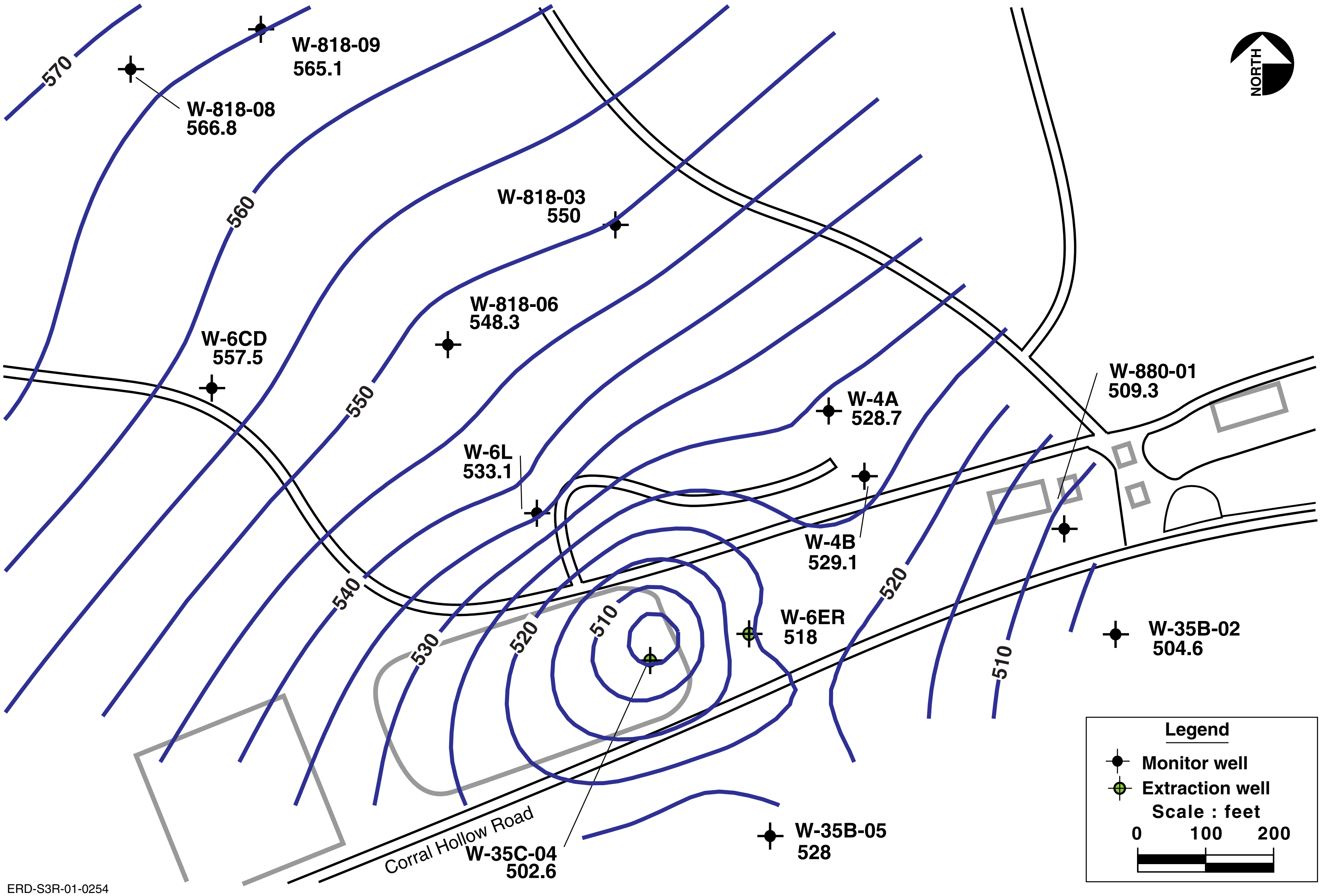
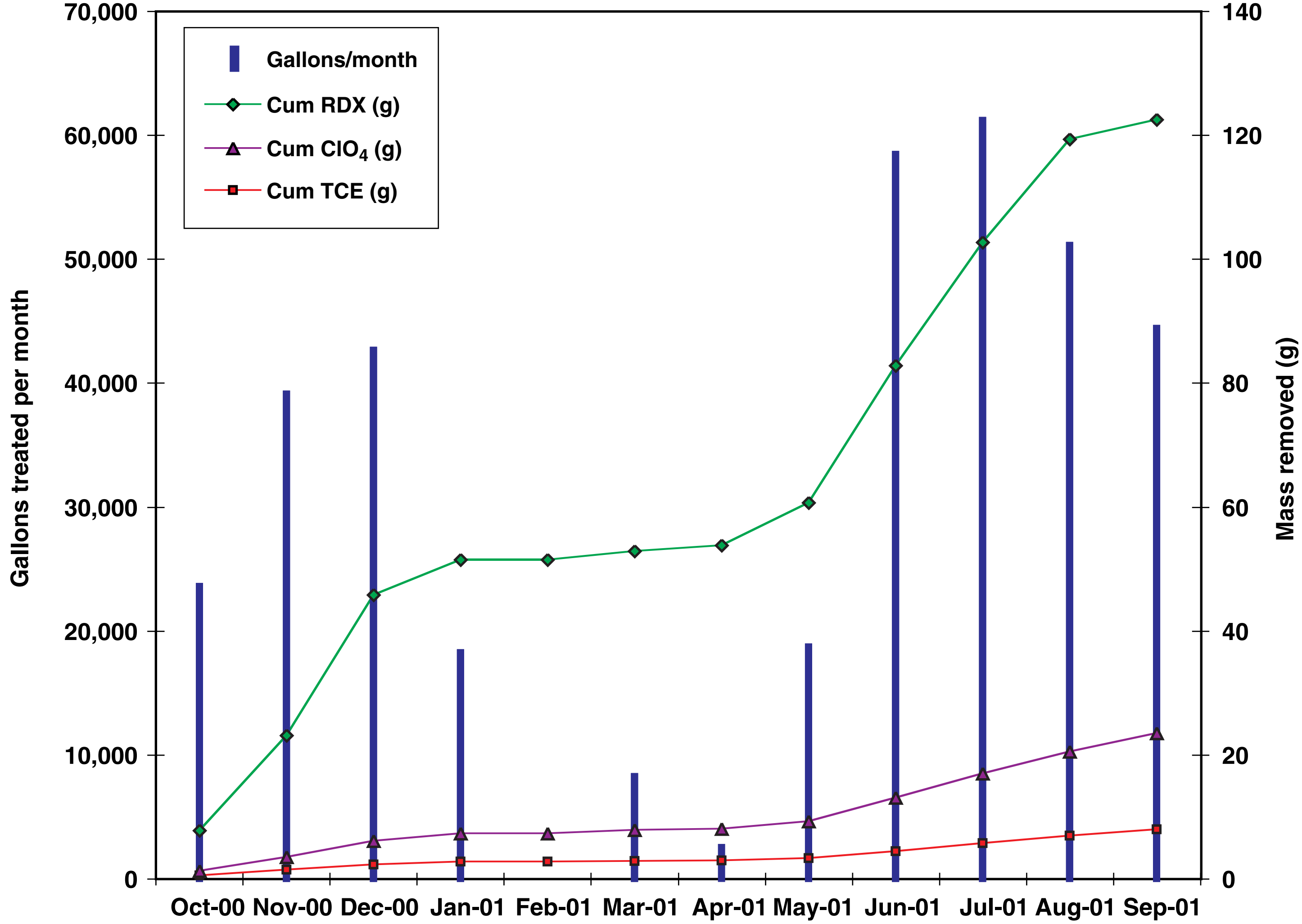


Figure 26. Pumping water levels in the vicinity of B815-DSB.



ERD-S3R-01-0256

Figure 27. B815-SRC mass removal plot.

Tables

Table 1. Estimates of dissolved TCE, RDX, and perchlorate mass in $Tnbs_2$ ground water.

Contaminant of concern	Dissolved mass (kg)	Volume of contaminated ground water (x 10E06 liters)
TCE	13	726
RDX	3	163
Perchlorate	7	678

Notes:

Based on second quarter 2001 data.

kg = Kilograms.

RDX = Cyclo-1,3,5-trimethylene-2,4,6-trinitramine.

TCE = Trichloroethylene.

$Tnbs_2$ = Miocene Neroly Formation – Upper Blue Sandstone aquifer.

Table 2. Design specifications for the HE Process Area OU treatment facilities.

Treatment facility	Type	Extraction wells	HSU	Pumping rate (gpm)	TCE (μg/L)	RDX (μg/L)	ClO_4^- (μg/L)	NO_3^- (mg/L)	Discharge method
B815-DSB	Aq GAC	W-35C-04	$Tnbs_2$	2.0	8.0	<1	<4	<0.5	Infiltration Trench
FY99		W-6ER	$Tnbs_2$	1.5	4.0	<1	<4	<0.5	
Possible TF Expansion		W-4A	$Tnbs_2$	0.5	3.0	<1	<4	<0.5	
		W-4B	$Tnbs_2$	0.5	3.0	<1	<4	<0.5	
Total influent				4.5	5.6	<1	<4	<0.5	
B815-SRC[a]	Aq GAC/BIO/IX	W-815-02	$Tnbs_2$	1.5	7.0	100.0	18.0	72.0	Misting System
FY00		W-815-04	$Tnbs_2$	1.5	3.0	120.0	12.0	86.0	
TF Expansion		W-815-01	Tps	0.1	160.0	70.0	<4	56.0	
		W-815-03	Tps	0.1	10.0	20.0	<4	58.0	
Former HE Open Burn Facility		W-829-06[c]	$Tnsc_1$	0.1	280.0	<1	29.0	240.0	
		W-829-08[c]	$Tnsc_1$	0.1	30.0	<1	18.0	190.0	
Total influent				3.4	10.0	105.9	14.3	74.3	
B815-PRX	Aq GAC/IX	W-818-08	$Tnbs_2$	1.5	72.0	<1	9.0	85.0	Misting System
FY02		W-818-09	$Tnbs_2$	3.0	25.0	<1	7.0	85.0	
Total influent				4.5	41	<1	8.0	85	
B817-SRC	Aq GAC/IX	W-817-01	$Tnbs_2$	1.0	<0.5	60.0	30.0	82.0	Misting System
FY04		W-817-06A	$Tnbs_2$	1.0	7.0	<1	6.0	90.0	
Total influent				2.0	3.8	30.5	18.0	86.0	
B817-PRX[b]	Aq GAC/IX	W-817-03	$Tnbs_2$	1.0	18.0	8.0	23.0	94.0	Misting System
FY05		W-817-04	$Tnbs_2$	1.0	12.0	6.0	22.0	90.0	
		W-817-03A	Tps	0.1	95.0	<1	15.0	125.0	
Total influent				2.1	18.8	6.7	22.1	93.6	
Discharge criteria					<0.5	<1	<4	45 (Inf Tr)	
Regulatory standard					5 (MCL)	0.6 (PRG)	18 (DHS)	45 (MCL)	

Notes and footnotes appear on following page.

Table 2. Design specifications for the HE Process Area OU treatment facilities (Cont. Page 2 of 2)

Notes:

Aq GAC = Aqueous-phase granular activated carbon.
BIO = Bioreactor.
ClO_4 = Perchlorate.
DHS = Department of Health Services.
FY02 = Fiscal Year 2002.
gpm = Gallons per minute.
HE = High explosives.
HSU = Hydrostratigraphic unit.
Inf Tr = Infiltration trench.
IX = Ion exchange.
μg/L = Micrograms per liter.
MCL = Maximum Contaminant Level. A drinking-water standard.
mg/L = Milligrams per liter.
NO_3 = Nitrate.
PRG = Preliminary remediation goal.
PRX = Proximal.
RDX = Cyclo-1,3,5-trimethylene-2,4,6-trinitramine.
SRC = Source.
TF = Treatment facility.
TCE = Trichloroethylene.
$Tnbs_2$ = Miocene Neroly Formation – Upper Blue Sandstone aquifer.
$Tnsc_1$ = Miocene Neroly Formation – Middle Siltstone/Claystone Member.
Tps = Pliocene nonmarine unit.

[a] Additional Tps wells planned.
[b] Additional Tps wells planned.
[c] Wells W-829-06 and -08 are HE Burn facility extraction wells. Contaminated ground water from these wells will be pumped into a portable storage tank and periodically treated at B815-SRC. Note that these wells are not included in the influent concentration estimates.

Total influent concentration assumes wells with non-detectable contamination are actually at detection limit.

Table 3. Aqueous-phase GAC treatability test summary.

Gallons treated	Date	TCE (μg/L) (influent/effluent)	RDX (μg/L) (influent/effluent)	ClO_4^- (μg/L) (influent/effluent)	NO_3^- (mg/L) (influent/effluent)
Start up	03/10/99	16/ND	7/ND	24/ND	92/78
1,000	03/15/99	14/ND	7/ND	22/ND	92/78
5,000	05/04/99	15/ND	5/ND	20/ND	90/83
10,000	06/01/99	17/ND	6/ND	25/ND	95 /116
15,000	06/09/99	16/ND	9/ND	23/ND	94/95
20,000	07/12/99	17/ND	9/ND	23/8	94/95
25,000	08/09/99	16/ND	8/ND	26/26	94/93

Notes:

RDX = Cyclo-1,3,5-trimethylene-2,4,6-trinitramine.
GAC = Granulated activated carbon.
μg/L = Micrograms per liter.
mg/L = Milligrams per liter.
ND = Not detected above analytical method detection limit.
NO_3^- = Nitrate.
ClO_4^- = Perchlorate.
TCE = Trichloroethylene.

Table 4. Bioreactor treatability test summary.

Sample date	Nitrate influent (mg/L)	Nitrate effluent (mg/L)	Flow rate (gpm)
10/02/00	70.5	<0.9	1
10/03/00	76.1	<0.9	1
10/13/00	73.0	<0.4	1
10/16/00	74.5	16.1	1
10/17/00	73.6	<0.4	1
10/19/00	74.9	<0.4	1
10/24/00	74.8	<0.4	1
10/26/00	74.6	<0.4	1
10/31/00	74.0	8.8	1
11/02/00	74.7	13.9	1
11/07/00	74.9	3.9	1
11/14/00	76.2	61.5	1
12/11/00	77.7	31.9	1
01/10/01	78.1	37.7	1
02/26/01	79.2	1.6	1
03/15/01	79.2	<0.4	1
04/24/01	79.1	5.0	1
05/15/01	79.8	14.0	1
06/14/01	81.2	41.5	2
07/17/01	80.8	40.3	2

Notes:

gpm = Gallons per minute.
mg/L = Milligrams per liter.

Table 5. Summary of hydraulic testing conducted in HE Process Area OU wells.

Well ID	Hydrogeologic unit	Test type	Flow rate (gpm)	Hydraulic conductivity (gpd/ft^2)	Estimated sustainable yield (gpm)	Hydraulic conductivity (cm/sec)	Hydraulic conductivity (ft/day)
W-6BS	Qal	Drawdown	3.6	450	<3	2.1E-02	60.26
W-6BD	Tps	Slug/Bail	NA	20	<1	9.4E-04	2.68
W-6CS	Tps	Slug/Bail	NA	0.5	<1	2.4E-05	0.07
W-809-01	Tps	Slug/Bail	NA	0.5	<1	2.4E-05	0.07
W-815-05	Tps	Slug/Bail	NA	0.5	<1	2.4E-05	0.07
W-823-01	Tps	Step Drawdown	5.9	30	5	1.4E-03	4.02
W-818-04	$Tnsc_2$	Drawdown	4.6	9	<5	4.3E-04	1.21
W-35C-04	$Tnbs_2$	Step Drawdown	3.3	2.3	10	1.1E-04	0.31
W-6BR*	$Tnbs_2$	Drawdown	43.0	1,600	20	7.6E-02	214.27
W-815-06	$Tnbs_2$	Drawdown	1.3	2	1.5	9.4E-05	0.27
W-817-01	$Tnbs_2$	Drawdown	1.0	10	1	4.7E-04	1.34
W-818-01	$Tnbs_2$	Step Drawdown	4.1	7	5	3.3E-04	0.94
W-818-03	$Tnbs_2$	Step Drawdown	11.5	8	10	3.8E-04	1.07
W-818-06	$Tnbs_2$	Step Drawdown	12.0	33	10	1.6E-03	4.42
W-818-08	$Tnbs_2$	Drawdown	3	1	1.5	4.7E10-05	0.13
W-818-09	$Tnbs_2$	Drawdown	3	8.5	6	4.0E10-04	1.1
W-818-11	$Tnbs_2$	Drawdown	0.5	<1	<0.5	<1.0E-05	<0.1
W-823-02	$Tnbs_2$	Drawdown	0.4	6	<0.5	2.8E-04	0.80
W-823-03	$Tnbs_2$	Step Drawdown	14.4	20	15	9.4E-04	2.68
W-35C-03	$Tnbs_1$	Step Drawdown	108.0	4,400	200+	2.1E-01	589.25
Well 18	$Tnbs_1$	Step Drawdown	290.0	6,000	200+	2.8E-01	803.52
Well 20 (W-35C-02)	$Tnbs_1$	Step Drawdown	43.0	3,200	200+	1.5E-01	428.54
Average values							
Qal				450	<3	2.1E-02	60.26
Tps				10.3	<1	4.9E-04	1.38
$Tnsc_2$				9	<5	4.3E-04	1.21
$Tnbs_2$				11	6	5.0E-04	1.42
$Tnbs_1$				4,500	200+	2.1E-01	607.10

Notes appear on following page:

Table 5. Summary of hydraulic testing conducted in HE Process Area OU wells. (Cont. Page 2 of 2)

* **Well has been sealed and abandoned.**
cm/sec = Centimeters per second.
ft/day = Feet per day.
gpd/ft^2 = Gallons per day per square foot.
gpm = Gallons per minute.
HE = High explosives.
ID = Identification.
$\mu g/L$ = Micrograms per liter.
$Tnbs_1$ = Miocene Neroly Formation – Lower Blue Sandstone aquifer.
$Tnbs_2$ = Miocene Neroly Formation – Upper Blue Sandstone aquifer.
$Tnsc_2$ = Miocene Neroly Formation – Upper Siltstone/Claystone Member.
NA Not applicable.
OU = Operable Unit.
Qal = Quaternary Alluvium.
Tps = Pliocene nonmarine unit.

Table 6. Design specifications for the HE Process Area OU extraction wells.

Extraction well name	Date completed	Well type and status	Casing depth (ft bgs)	Screen interval (ft bgs)	Sand-pack interval (ft bgs)	Hydro-geologic unit	Estimated sustainable yield (gpm)	Average TVOC concentration (µg/L)	Pump type
W-35C-04[a]	10/25/90	Active GWE	156.0	136–156	124-157	$Tnbs_2$	5	7	Shurflo
W-6ER [a]	04/29/88	Active GWE	140.0	115–140	110–140.5	$Tnbs_2$	5	4	Shurflo
W-815-01	04/27/87	Active MW; Proposed GWE	48.0	43–48	41.5–48.8	Tps	<0.5	180	Poly bailer
W-815-02[a]	05/05/87	Active GWE	115.0	100–115	91–116	$Tnbs_2$	2	14	Grundfos
W-815-03	01/19/88	Active MW; Proposed GWE	45.0	34.2–39	31–41	Tps	<0.5	17	Well Wizard
W-815-04[a]	02/08/88	Active MW; Proposed GWE	104.8	84.5–99	83.5–100	$Tnbs_2$	1.5	3	Grundfos
W-818-08[a]	10/07/91	Active MW; Proposed GWE	121.5	85–120	83.5–120.5	$Tnbs_2$	1.5	70	Grundfos
W-818-09[a]	07/17/91	Active MW; Proposed GWE	125.0	75–125	67–127	$Tnbs_2$	6	25	Grundfos
W-817-01[a]	10/30/84	Active MW; Proposed GWE	144.0	121–144	112.5–145	$Tnbs_2$	1	<1	Grundfos
W-817-06A[a]	06/16/88	Active MW; Proposed GWE	122.0	102–117	98–120	$Tnbs_2$	2.5	7	Well Wizard
W-817-03[a]	11/01/84	Active MW; Proposed GWE	119.5	85–119.5	76.5–120	$Tnbs_2$	4	18	Grundfos
W-817-03A	11/07/84	Active MW; Proposed GWE	9.5	4.5–9.5	2–9.5	Tps	<0.5	95	Poly bailer
W-817-04[a]	11/09/84	Active MW; Proposed GWE	95.0	60–95	52.5–99.0	$Tnbs_2$	1	12	Grundfos
W-829-06	12/18/86	Active MW; Proposed GWE	98.0	76–98	70.5–99	$Tnsc_1$	<0.5	500	Poly bailer
W-829-08	01/14/87	Active MW; Proposed GWE	109.5	89.5-109.5	83.5-109.5	$Tnsc_1$	<0.5	20	Well Wizard

Notes and footnote appear on the following page.

Table 6. Design specifications for the HE Process Area extraction wells. (Cont. Page 2 of 2)

Notes:

ft bgs = Feet below ground surface.
gpm = Gallons per minute.
GWE = Ground water extraction.
HE = High explosives.
μg/L = Micrograms per liter.
$Tnbs_2$ = Miocene Neroly Formation - Upper Blue Sandstone aquifer.
MW = Monitor well.
Tps = Pliocene nonmarine unit.
TVOC = Total volatile organic compound.

[a] **$Tnbs_2$ extraction well.**

Table 7. Design specifications for the existing HE Process Area OU treatment facilities.

Equipment	Specifications[a]
B815-SRC ground water extraction and treatment system	
Well pump	Grundfos 16S05 electrical submersible pump, 1/2 hp, 230 VAC, 1 Ph.
Well water-level transducer	Instrumentation Northwest Model PS9000 submersible pressure transmitter, 0-50 psi, 4-20 mA output.
GTU02 particulate filter canister	Cuno Model 4DC1, stainless steel, 150 psi maximum operating pressure.
GTU02 particulate filter cartridges	Cuno, Aqua Pure AP111.
BTU02 particulate filter canister	Hayward Model FLT4202, 20 psi.
BTU02 particulate filter cartridges	Hayward, 25 Micron.
GTU02 Treatment vessels	Three each, Park International Corp. high pressure vessels, P/N RT-2244, capacity is 64.74 gal, max flow is 10 gpm. Carbon required per vessel is 250 lb. Vessel capacity is 191 gallons.
BTU02 treatment vessels	Three each, Park International Corp. vessels, P/N RT-3072-6-6V.
Post treatment vessel	High pressure Ion exchange resin vessel, Park International Corp. P/N RT-1636-45, 26.15 gal capacity, 150 psi maximum operating pressure.
Pressure switch	SQR Control Devices, pressure adjust 12–100 psi.
Magnetic water flow meter	Rosemount 8711 flowtube with 0.5 in. line size. Transmitter 8732C, 0-10 gpm, 24 VDC input, 4-20 mA and digital outputs.
Well pressure gauges	Ashcroft, 0 to 100 psi, ANSI Grade B.
All other pressure gauges	Ashcroft, 0 to 30 psi, ANSI Grade B.
Feed tank	Polyethylene, 30 gal, DOT drum.
Electronic metering pump	LMI Milton Roy Model A741-352SI, 120 VAC, 1.4 amps.
	250 psi maximum operating pressure at 0.58 GPH.
Effluent storage tank	Polyethylene, 150 gal.
Misting transfer pump	1 hp, 208 VAC, 3 Ph.
Misting heads	Six each, 1 gal per hour heads.
GTU02 pressure retaining valve	George Fischer Type V 86, PVC, flanged, 60 psi maximum operating pressure. Temperature range 32°F–140°F.
Real time data transmission	Remote desktop computer running SCADA manager software.
B815-DSB ground water extraction and treatment system	
Particulate filter canister	Cuno, Aqua-Pure Model AP101T.
Particulate filter cartridge	Cuno, 5 Micron.
Deaerator	5-in. diameter by 24-in. long PVC vessel.
Pressure switch	SQR Inc., pressure adjust 2–15 psi.
STUO4 treatment vessels	Three each, Filtration & Media Group Inc., water scrub unit WSU-55, maximum flow is 15 GPM, 12 psi maximum operating pressure. Carbon required per vessel is 200 lb.

Table 7. Design specifications for the existing HE Process Area OU treatment facilities. (Cont. Page 2 of 2)

Equipment	Specifications[a]
B815-DSB ground water extraction and treatment system (cont.)	
Pressure gauges	Ashcroft, 0 to 15 psi, ANSI Grade B.
Vent residue tank	Polyethylene, 5 gal.
Equipment used on either treatment system	
Paddle-wheel water flow transmitter	GF Signet P/N P51530-P0, nominal flow rate from 1 to 20 ft/s, Output 1 V p-p @ 6 Hz per ft/s, Rotor/Pin is black PVDF/Titanium.
Meter for paddle-wheel transmitter	GF Signet P/N P58640, digital, battery operated.
Diaphragm valves	Georg Fischer Type 314, PVC, true union design.
Ball valves	Georg Fischer Type 346, PVC, true union design.
Pipe	PVC Schedule 80, conforms to ASTM-D-1785.
Pipe fittings	PVC Schedule 80, conforms to ASTM-D-2464.
Flexible hose	RyanHerco P/N 0514-110 chemical black PVC hose, 1-in. diam Nylon reinforcement, max pressure 100 psi.
Programmable logic controller	OPTO-22 Snap I/O equipment manager system.

Notes:

ANSI = American National Standards Institute.
ASTM = American Society for Testing and Materials.
BTU = Bio treatment unit.
DOT = Department of Transportation.
ft/s = Feet per second.
GAC = Granular activated carbon.
gal = Gallon(s).
GTU = Granular activated carbon treatment unit.
gpm = Gallons per minute.
hp = Horsepower.
Hz = Hertz.
in. = Inch.
I/O = Input/output.
lb = Pound(s).
mA = Milliamp.
P/N = Part number.
Ph = Phase.
psi = Pounds per square inch.
PVC = Polyvinyl chloride.
PVDF = Polyvinylidene fluoride.
SCADA = Supervisory Control and Data Acquisition.
STU = Solar-powered Treatment Unit.
V = Volts.
V p-p = Volts peak to peak.
VAC = Volts alternating current.
VDC = Volts direct current.

[a] If a specific model is not available, an equivalent device that satisfies the intended function will be procured.

Table 8. Summary of offsite compliance well detections.

Compliance well	Screen interal (ft bgs)	Began monitoring	HSU	No. of TCE detections	Sample date	TCE concentration (μg/L)
W-35B-01	15.5–20.5	Nov-97	Qal	1	10/26/00	0.7
W-35B-02	44–54	Nov-97	U $Tnbs_2$	1	10/26/00	0.7
W-35B-03	64–74	Nov-97	L $Tnbs_2$	0	NA	NA
W-35B-04	151–161	Apr-98	U $Tnbs_2$	2	05/31/00 10/26/00	1.3
W-35B-05	180–190	Apr-98	L $Tnbs_2$	0	NA	NA

Notes:

ft bgs = Feet below ground surface.
HSU = Hydrostratigraphic unit.
L $Tnbs_2$ = Miocene Neroly Formation – Lower part of the Upper Blue Sandstone aquifer.
NA = Not applicable.
Qal = Quaternary alluvium.
TCE = Trichloroethylene.
U $Tnbs_2$ = Miocene Neroly Formation – Upper part of the Upper Blue Sandstone aquifer.

Table 9. Cost estimate for design/construction, startup, and operation and maintenance of B815-PRX.

Activity			Capital/One-time Costs ($)	Annual O&M ($)
Design and Construct GTU				
Fabricate GTU			$76,500	
Site Preparation Design/Construction			$100,000	
Electric Power Hookup			$65,000	
Influent Pipeline Construction				
		1,550 linear feet @ $150	$232,500	
Extraction Well Hookup				
		2 wells @ $5000	$10,000	
Subtotal Cost			**$484,000**	**$0**
Design and Construct Ion Exchange Unit				
Fabricate 2 IX Units				
	Parts	2 @ $300	$600	
	Assembly	2 @ 16 hrs @ $70	$2,240	
Subtotal Cost			**$2,840**	**$0**
Design and Construct Misting System				
Fabricate Mist Water Holding Tank				
	Parts		$2,800	
	Assembly	3 man-weeks @ 70/hr	$8,400	
Fabricate Mister				
	Parts		$2,000	
	Assembly	5 man-days @ 70/hr	$2,800	
Efflluent Pipeline		50 linear feet @ $75	$3,750	
Subtotal Cost			**$19,750**	**$0**
Startup Treatment Systems				
Labor		1 man-week @ $70	$2,800	
Analytical Chemistry Lab			$10,140	
Subtotal Cost			**$12,940**	**$0**
Operate Treatment Systems				
Annual O&M of GTU				$58,800
Annual O&M of IX Units				$2,240
Annual O&M of Misting System				$5,040
Subtotal Cost			**$0**	**$66,080**
Total costs (Rounded)			**$519,500**	**$66,000**

Table 10. Cost Estimate for design/construction, startup, and operation and maintenance of B817-SRC.

Activity		Capital/One-time Costs ($)	Annual O&M ($)
Design and Construct STU			
Fabricate STU		$27,000	
Site Preparation Design/Construction		$10,000	
Influent Pipeline Construction			
	250 linear feet @ $150	$37,500	
Extraction Well Hookup			
	2 wells @ $5000	$10,000	
Subtotal Cost		**$84,500**	**$0**
Design and Construct Ion Exchange Unit			
Fabricate 2 IX Units			
Parts	2 @ $300	$600	
Assembly	2 @ 16 hrs @ $70	$2,240	
Subtotal Cost		**$2,840**	**$0**
Design and Construct Solar Powered Misting System			
Fabricate Mist Water Holding Tank			
Parts		$4,300	
Assembly	3 man-weeks @ 70/hr	$8,400	
Fabricate Mister			
Parts		$2,000	
Assembly	5 man-days @ 70/hr	$2,800	
Efflluent Pipeline	50 linear feet @ $75	$3,750	
Subtotal Cost		**$21,250**	**$0**
Startup Treatment Systems			
Labor	1 man-week @ $70	$2,800	
Analytical Chemistry Lab		$10,140	
Subtotal Cost		**$12,940**	**$0**
Operate Treatment Systems			
Annual O&M of STU			$41,700
Annual O&M of IX Units			$2,240
Annual O&M of Misting System			$5,040
Subtotal Cost		**$0**	**$48,980**
Total costs (Rounded)		**$122,000**	**$49,000**

Table 11. Cost estimate for design/construction, startup, and operation and maintenance of B817-PRX.

Activity		**Capital/One-time Costs ($)**	**Annual O&M ($)**
Design and Construct STU			
Fabricate STU		$27,000	
Site Preparation Design/Construction		$10,000	
Influent Pipeline Construction			
	210 linear feet @ $150	$31,500	
Extraction Well Hookup			
	3 wells @ $5000	$15,000	
Subtotal Cost		**$83,500**	**$0**
Design and Construct Ion Exchange Unit			
Fabricate 2 IX Units			
Parts	2 @ $300	$600	
Assembly	2 @ 16 hrs @ $70	$2,240	
Subtotal Cost		**$2,840**	**$0**
Design and Construct Solar Powered Misting System			
Fabricate Mist Water Holding Tank			
Parts		$4,300	
Assembly	3 man-weeks @ 70/hr	$8,400	
Fabricate Mister			
Parts		$2,000	
Assembly	5 man-days @ 70/hr	$2,800	
Effluent Pipeline	50 linear feet @ $75	$3,750	
Subtotal Cost		**$21,250**	**$0**
Startup Treatment Systems			
Labor	1 man-week @ $70	$2,800	
Analytical Chemistry Lab		$10,140	
Subtotal Cost		**$12,940**	**$0**
Operate Treatment Systems			
Annual O&M of STU			$41,700
Annual O&M of IX Units			$2,240
Annual O&M of Misting System			$5,040
Subtotal Cost		**$0**	**$48,980**
Total costs (Rounded)		**$121,000**	**$49,000**

Appendix A

Monitoring and Reporting Requirement Documents

Substantive Requirements, Building 815 Removal Action, Lawrence Livermore National Laboratory Site 300, San Joaquin County

Monitoring and Reporting Program Requirements for the Building 815 Removal Action, Lawrence Livermore National Laboratory Site 300, San Joaquin County

(Upon Completion in September, the Site-Wide Compliance Monitoring Plan will supercede the monitoring and reporting program for the Building 815 removal action presented in Appendix A)

California Regional Water Quality Control Board

Central Valley Region

Steven T. Butler, Chair

Winston H. Hickox
Secretary for Environmental Protection

Gray Davis
Governor

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20 July 1999

Ms. Donna Sutherland
U.S. Department of Energy
Environmental Restoration Division
Lawrence Livermore National Laboratory
P.O. Box 808 L-574
Livermore, CA 94551

SUBSTANTIVE REQUIREMENTS, BUILDING 815 REMOVAL ACTION, LAWRENCE LIVERMORE NATIONAL LABORATORY SITE 300, SAN JOAQUIN COUNTY

The Department of Energy (DOE) has completed initial startup of the groundwater treatment system for the Building 815 removal action. The removal action will consist of pumping and treating groundwater contaminated with volatile organic compounds, primarily trichloroethylene. The treated groundwater will be discharged to ground. DOE plans to begin full-scale operation of the groundwater extraction and treatment as soon as the Board issues substantive requirements for the discharge of treated groundwater.

I have enclosed the Substantive Requirements for the discharge of treated groundwater for the Building 815 removal action. If you have any questions, please call me at (916) 255-3057.

Susan Timm

SUSAN TIMM
Remedial Project Manager

ST:st

Enclosure

cc: Ms. Kathy Setian, U.S. Environmental Protection Agency, San Francisco
Mr. Mark Piros, Department of Toxic Substances Control, Berkeley
Mr. John Ziagos, Lawrence Livermore National Laboratory, Livermore
Mr. Peter Strauss, PM Strauss and Associates, San Francisco

Substantive Requirements, High Explosives Process Area Operable Unit, Building 815 Area, Lawrence Livermore National Laboratory Site 300, San Joaquin County

The California Regional Water Quality Control Board, Central Valley Region, (hereafter Board) finds that:

(a) The Regents of the University of California, Lawrence Livermore National Laboratory Site 300, and the U.S. Department of Energy (hereafter jointly referred to as Discharger), propose to conduct a Removal Action at the Building 815 area in the High Explosives (HE) Process Area Operable Unit (OU) (hereafter referred to as the Building 815 Removal Action).

2. The Building 815 area contains a former steam plant that used trichloroethylene (TCE) as a solvent to clean organic scaling in boiler system piping. Contaminants were released to the subsurface as a result of these activities. Releases occurred mainly at the location of a TCE hardstand near Building 815.

3. Ground water beneath the Building 815 area is contaminated with volatile organic compounds (VOCs), primarily TCE. The objective of this Removal Action is to prevent ground water contaminants in the Neroly $Tnbs_2$ aquifer from migrating offsite. This will be accomplished by pumping and treating ground water from well W-35C-04 located near the Site 300 boundary (Figure 1).

4. Site 300 is located in San Joaquin County in the Altamont Hills of the North Diablo Range, approximately 20 kilometers east of the Livermore Valley and 10 kilometers southwest of the town of Tracy. The Building 815 area is located in the southeastern part of Site 300. This area is underlain by Pliocene-age non-marine sediments of the Tps unit and Tertiary-age Neroly Formation sedimentary bedrock. Quaternary terrace deposits crop out on hill slopes in the area and Quaternary alluvial deposits of Corral Hollow Creek form its southern boundary. Depth to ground water in the $Tnbs_2$ aquifer is approximately 120 feet below ground surface. The depth to ground water in Quaternary alluvial deposits beneath the discharge location is approximately 15-20 feet.

5. Groundwater will be extracted from W-35C-04 and treated by ground water treatment facility B815TF1. Other wells located near W-35C-04 (e.g., W-6ER, W-6K,or W-6L) may be tested in the future for potential use as extraction wells, if additional extraction wells are needed. In this event, a list of additional extraction wells will be submitted to the Board for review.

6. B815TF1 will consist of aqueous-phase granular activated carbon (GAC) contained in a Solar-powered Water Activated Carbon Treatment (SWAT) unit.

7. The treatment system will be located on property owned by the U.S. Department of Energy and will be managed under the direction of the Regents of the University of California. B815TF1 will be located adjacent to well W-35C-04 (Figure 1).

8. B815TF1 works as follows:

   1) Extracted ground water is pumped from W-35C-04 to B815TF1.
   2) Prior to entering the aqueous-phase GAC units, the ground water passes through a five-micron filtration system to remove suspended particles from ground water.
   3) The influent passes from the filtration system to three aqueous-phase GAC units connected in series to allow the VOCs to adsorb to the GAC.
   4) Treated ground water is pumped to the discharge location where it will be discharged to a nearby storm drain, which discharges to the ground surface (Fig. 1).

If ground water is discharged to the ground surface at locations other than those listed above as a result of the testing of additional wells, discharge locations will be submitted to the Board for review.

9. The Discharger anticipates that 1,000 to 2,000 gallons per day will be extracted from W-35C-04.

The Discharger, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, shall comply with the following:

A. Discharge Prohibitions

(a) Bypass or overflow of untreated or partially treated waste is prohibited.

2. Discharge of waste classified as 'hazardous' or 'designated', as defined in Sections 2521(a) and 2522(a) of Chapter 15, is prohibited.

3. Discharge in violation of State Board Resolution 68-16 is prohibited.

B. Effluent Limitations

(a) The discharge of ground water effluent, in excess of the following limits is prohibited:

Compound	Maximum Daily Concentration (μg/L)[1]	Monthly Median Concentration (μg/L)
Tetrachloroethylene	5.0	0.5
Trichloroethylene	5.0	0.5
1,1-Dichloroethylene	5.0	0.5
1,2-Dichloroethylene	5.0	0.5
1,1,1-Trichloroethane	5.0	0.5
1,2-Dichloroethane	5.0	0.5
Total Volatile Organic Compounds [2]	5.0	0.5

[1] Using EPA Method 601 with a detection limit of 0.5 μg/L or less for halogenated VOCs and EPA Method 353.2 with a detection limit of 500 μg/L for nitrate.
[2] Total VOCs will be the sum of all VOCs detected above the 0.5 μg/L concentration.

B. Effluent Limitations (continued)

2. The discharge of individual VOCs other than those listed in B.1 above in excess of the 5.0 μg/L maximum daily concentration and the 0.5 μg/L monthly median concentration using EPA Method 601 is prohibited.

3. All chromatograph peaks for EPA Method 601 shall be identified.

4. The treated ground water will not have a pH less than 6.5 or greater than 8.5.

5. The 30-day average daily dry weather discharge of treated ground water will not exceed 7,000 gallons from B815TF1.

6. The Discharger shall use the best practicable cost-effective control technique currently available to limit mineralization to no more than a reasonable increment.

C. Discharge Specifications

1. SYSTEM CHECK

Prior to operating the ground water treatment system with contaminated ground water, a system check shall be conducted to confirm the proper construction and operation of the treatment system. The following minimum requirements apply to this system check phase:

a. A conformance inspection shall be conducted to confirm that all equipment, piping, instrumentation, and control systems of the ground water treatment system have been installed according to the approved design. Any deficiencies in the ground water treatment system shall be corrected.

b. To confirm piping integrity, piping of the collection system and treatment system shall be pressure tested at 150 percent of the design pressure with potable water. Any leaks shall be repaired.

c. All instrumentation, control systems, and equipment shall be inspected for malfunctions. All automatic controls, such as shutdown or alarm switches necessary for the operation of each treatment system phase, shall be certified operational prior to startup of that phase. Mechanical equipment, such as pumps and valves, required for the operation of the treatment system, will be cycled or operated. Any functional deficiencies shall be corrected.

2. FULL SCALE OPERATION

a. All extracted ground water will be treated by the treatment system and discharged directly to a nearby storm drain which discharges to the ground surface.

b. The Discharger shall operate the treatment systems to maximize the removal of VOCs from the extracted ground water.

c. The system operations shall be monitored in accordance with the full scale operational phase monitoring plan in the MRP.

d. All treatment, transport, and disposal components (including pumping valves, liquid level controllers, pipelines, blowers, flow meters, pressure gauges, etc.) will be periodically inspected for leaks and/or malfunctions.

3. DURING ALL PHASES OF OPERATIONS

a. Neither the treatment nor the discharge shall cause a nuisance or condition of pollution as defined by the California Water Code, Section 13050.

b. The discharge shall not cause degradation of any water supply.

c. Any collected screenings, sludge, and other solids removed from liquid wastes shall be disposed of in a manner consistent with Chapter 15, Division 3, Title 23, CCR.

d. The discharge of treated ground water from B815TF1 will not exceed the design capacity determined without prior approval from the Board, DTSC, and the U.S. EPA.

D. Provisions

1. The Discharger shall not allow pollutant-free wastewater to be discharged into the collection, treatment, and disposal system in amounts that significantly diminish the system's capability to comply with these Substantive Requirements. Pollutant-free wastewater means rainfall, ground water, cooling waters, and condensates that are essentially free of pollutants.

2. The Discharger may be required to submit technical reports as directed by the Board.

3. The Discharger shall comply with the attached MRP, which is part of these Substantive Requirements and any revision thereto, i.e., monitoring frequency, locations, constituent changes, etc. as ordered by the Board.

4. The Discharger shall notify the Board immediately, during normal working hours via telephone, and at least within 24 hours of any spill of untreated ground water. This notification shall include the size and cause of the spill, any immediate damage to the environment, any corrective/cleanup actions taken and/or additional monitoring proposed.

5. The Discharger shall report to the Board, DTSC, and the U.S. EPA quarterly operation reports during Remedial Project Manager (RPM) meetings. These operational reports shall contain a summary of operating parameters, operation and maintenance activities, and any shut down or spill events that occurred during the quarter.

6. The Discharger shall comply with the "Standard Provisions and Reporting Requirements for Waste Discharge Requirements", date 1 March 1991, which are attached hereto and by reference a part of these Substantive Requirements except for those Provisions and Requirements which are superceded by CERCLA requirements. This attachment and its individual paragraphs are commonly referenced as "Standard Provisions".

7. The Discharger shall report promptly to the Board any material change or proposed change in the character, location, or volume of the discharge.

8. In the event of any change in ownership of land or waste discharge facilities presently owned or controlled by the Discharger, and associated with the ground water cleanup of the Building 815 area ground water, the Discharger shall notify at that time the succeeding owner or operator of the existence of these Substantive Requirements by letter. A copy of the notification shall be forwarded to this office.

9. A copy of the Substantive Requirements shall be kept at the discharge facility for reference by operating personnel. Key operating personnel shall be familiar with its contents.

10. The Board will review these Substantive Requirements periodically and may revise them. The Discharger shall be notified prior to the review of these Substantive Requirements by the Board, and have the opportunity to review and comment on the proposed changes.

MONITORING AND REPORTING PROGRAM
FOR
LAWRENCE LIVERMORE NATIONAL LABORATORY
AND U.S. DEPARTMENT OF ENERGY

SITE 300 BUILDING 815 Removal Action

The following Monitoring and Reporting Program (MRP) contains the minimum monitoring and reporting requirements necessary to determine compliance with the effluent limitations and other requirements for the Building 815 Removal Action Substantive Requirements. In addition, monitoring requirements are established to characterize ground water during the Building 815 Removal Action.

All monitoring samples will be 'grab' type samples, except for extraction and discharge rates and total volume which will be continuous, and water level measurements which will be instantaneous.

The Discharger may propose reductions in monitoring frequency, locations, and constituent one year after start of full-scale operations.

FULL SCALE OPERATION MONITORING

Influent and Effluent Monitoring

Influent samples shall be collected at approximately the same time as effluent samples and shall be representative of the influent for the period sampled. Effluent samples shall be collected downstream from the last connection through which wastes can be admitted into the outfall and shall be representative of the volume and nature of the discharge. Because extraction well W-35C-04 does not currently contain detectable concentrations of nitrate, only influent samples will be analyzed for nitrate. If nitrate is detected in the influent samples, then nitrate will be monitored in the effluent samples.

Samples shall be analyzed monthly with sufficient time between sample collection to avoid sample clustering. Time of collection of grab samples shall be recorded. At the initial system startup and following a shutdown due to a system failure that could result in non-compliance with the discharge requirements, samples will be analyzed daily for the first five days of operation, weekly for the following month, and monthly thereafter.

The following analyses shall be conducted at the influent and effluent of B815TF1:

Constituents	Units	Type of Samples
Volatile Organic Compounds[1]	µg/L	Grab
Nitrate[2,3,4]	µg/L	Grab
Electrical Conductivity	µmhos/cm	Grab
Total Dissolved Solids	mg/L	Grab
PH	pH units	Grab
Temperature	°C	Grab
Total Volume of Water Treated	gallons	Cumulative
Flow	gallons per day	Cumulative

1. Analysis by EPA Method 601 or similar approved method.
2. Analysis by EPA Method 353.2 or similar approved method.
3. Extraction well W-35C-04 does not contain nitrate above EPA Method 353.2 detection limit of 0.4 mg/L
4. Nitrate will be analyzed in the influent. If nitrate is detected in the influent then effluent samples will also be analyzed for nitrate.

Ground Water Monitoring

In addition to the influent and effluent monitoring, Building 815 area monitoring wells shall be monitored as indicated in tables 1 through 4. Any extraction or monitoring wells which may be installed in the future will be considered for additional monitoring. All existing monitoring and extraction wells included in the Building 815 Removal Action shall be monitored as follows:

Electrical conductivity, pH and temperature values will be measured in the field. All other analysis will be conducted using the appropriate EPA Method as listed in Tables 1-4.

The Discharger shall measure water levels to an accuracy of 0.01 feet mean sea level (MSL) in all wells listed in Tables 1-4. This information shall be used to determine the magnitude and direction of ground water flow and shall be displayed on a water table contour map.

The volume of contaminant mass removed by the ground water extraction systems shall be calculated and reported in the quarterly monitoring reports.

QUALITY CONTROL SAMPLES

For quality control purposes, the Discharger shall collect and have analyzed one sampling blank and one duplicate for every ten samples collected and analyzed. Each of these quality control samples shall be analyzed for the same parameters as the other samples collected.

REPORTING

When reporting the data, the Discharger shall arrange the information in tabular form so that the sampling location, date, constituent/parameters, and concentrations/measurements are readily discernible. The data shall be summarized in such a manner to illustrate clearly the compliance with the Substantive Requirements.

Quarterly monitoring reports shall be submitted to the Board, DTSC, and the U.S. EPA by the last day of the third month following the quarter in which the samples were taken or observations made. Quarterly monitoring reports shall include data from all Building 815 Removal Action ground water monitoring program wells listed in Tables 1 through 4.

Each quarterly report shall contain the following minimum information:

a) ground water elevation map for the $Tnbs_2$ aquifer;
b) isoconcentration maps of TCE, RDX, perchlorate, and nitrate maps for the $Tnbs_2$ aquifer;
c) cumulative data tables containing the water quality analytical results and depth to ground water;
d) a copy of the laboratory analytical data reports;
e) the status of any ongoing remediation, including cumulative information on the mass of contaminant removed from the subsurface, system operating time, the effectiveness of the remediation system, and any field nots pertaining to the operation and maintenance of the system; and
f) the reasons for and duration of all interruptions in operation on any remediation system and actions planned or taken to correct and prevent interruptions.

An annual report shall be submitted to the Board, DTSC, and the U.S. EPA by January 30 of each year. This report shall contain an evaluation of the effectiveness and progress of the investigation and remediation, and may be submitted with the fourth quarter monitoring report. The annual report shall contain the following minimum information:

a) both graphical and tabular summaries of all data obtained during the previous year;
b) ground water elevation and isoconcentration maps of TCE, RDX, perchlorate, and nitrate maps for the $Tnbs_2$ aquifer containing all data obtained from the previous year;
c) a discussion of the long-term trends in contaminant concentrations;
d) an analysis of whether the contaminant plume is being captured by the extraction system or is continuing to spread;
e) a description of all remedial activities conducted during the year, an analysis of their effectiveness in removing contaminants, and plans to improve remediation system effectiveness;

f) an identification of any data gaps and potential deficiencies/redundancies in the monitoring system or reporting program; and
g) a proposal and rationale for any revisions to the ground water monitoring program frequency of sampling and/or list of analytes.

These reporting requirements are consistent with the requirements specified in Section 3.1 Compliance Monitoring, for the Revised Building 815 Removal Action Design Workplan (March, 1999). The reporting requirements for the Building 815 Removal Action and the Substantive Requirements shall be combined into a single quarterly report. An annual report shall also be submitted that includes information from all the quarterly reports submitted during that year.

The results of any monitoring done more frequently or in addition to that required at the locations specified in this Monitoring and Reporting Program shall be reported to the Board, DTSC, and the U.S. EPA. The Discharger shall implement the above program as of the date of the Order.

Table 1. Removal action ground water monitoring program for extraction well W-35C-04 and nearby monitoring wells.

Well	Analyte[a]	Sampling frequency
TCE leading edge wells		
Tnbs$_2$ wells		
W-35C-04	VOCs, nitrates	Quarterly
	HE compounds	Annually
W-6ER	VOCs, nitrates	Quarterly
	HE compounds	Annually
W-4A	VOCs, nitrates	Quarterly
	HE compounds	Annually
W-4B	VOCs, nitrates	Quarterly
	HE compounds	Annually
W-6K	VOCs, nitrates	Quarterly
	HE compounds	Annually
W-6L	VOCs, nitrates	Quarterly
	HE compounds	Annually
W-880-01	VOCs, nitrates	Quarterly
	HE compounds	Annually
Alluvial aquifer well		
W-880-02	VOCs, nitrates	Quarterly
	HE compounds	Annually
Offsite compliance wells		
Alluvial aquifer well		
W-35B-01	VOCs, nitrates	Quarterly
Tnbs$_2$ wells		
W-35B-02	VOCs, nitrates	Quarterly
W-35B-03	VOCs, nitrates	Quarterly
W-35B-04	VOCs, nitrates	Quarterly
W-35B-05	VOCs, nitrates	Quarterly
Gallo 1 guard wells		
Tnbs$_2$ wells		
W-6H	VOCs, nitrates	Quarterly
	HE compounds	Annually
W-6J	VOCs, nitrates	Quarterly
	HE compounds	Annually
Tps well		
W-6I	VOCs, HE compounds	Annually

Table 1 continued

[a] **Samples analyzed by the following U.S. EPA analytical methods:**
Volatile organic compounds (VOCs) = EPA Method 601.
Nitrates = EPA Method 300.
High explosive (HE) = EPA Method 8330, including perchlorate using EPA Method 300.

Table 2. Removal action ground water monitoring program for TCE mass-tracking wells.

Well	Analyte[a]	Sampling frequency
TCE mass tracking wells		
W-6CD	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-809-02	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-809-03	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-814-02	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-815-02	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-815-04	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-815-06	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-815-07	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-817-01[b]	VOCs, HE compounds, nitrates	Quarterly
W-817-02[b]	VOCs, HE compounds, nitrates	Quarterly
W-817-03[b]	VOCs, HE compounds, nitrates	Quarterly
W-817-04[b]	VOCs, HE compounds, nitrates	Quarterly
W-817-06A	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-818-01	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-818-03	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-818-06	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-818-07	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-818-11	VOCs	Semi-annually
	HE compounds, nitrates	Annually
W-823-02	VOCs, HE compounds	Semi-Annually
	Nitrates	Annually

[a] Samples analyzed by the following U.S. EPA analytical methods:
Volatile organic compounds (VOCs) = EPA Method 601.
Nitrates = EPA Method 300.
High explosive (HE) = EPA Method 8330, including perchlorate using EPA Method 300.

[b] Wells are sampled under a waste discharge requirement (WDR) for the surface impoundments by the LLNL Water Guidance and Monitoring Group (WGMG).

Table 3. Removal action ground water monitoring program for RDX compliance wells in the HE Process Area OU.

Well	Analyte[a]	Sampling frequency
RDX compliance wells		
W-818-08	VOCs, HE compounds, nitrates	Semi-annually
W-818-09	VOCs, HE compounds, nitrates	Semi-annually
W-823-03	VOCs, HE compounds	Semi-Annually
	Nitrates	Annually
W-6G	VOCs, HE compounds	Semi-annually
	Nitrates	Annually

[a] Samples analyzed by the following U.S. EPA analytical methods:
Volatile organic compounds (VOCs) = EPA Method 601.
Nitrates = EPA Method 300.
High explosive (HE) = EPA Method 8330, including perchlorate using EPA Method 300.

Table 4. Removal action ground water monitoring program for the Tps wells in the HE Process Area OU.

Well	Analyte[a]	Sampling frequency
W-35C-05	VOCs, HE compounds	Quarterly
W-4AS	VOCs, HE compounds	Semi-Annually
W-6BD	VOCs, HE compounds	Semi-Annually
W-6BS	VOCs, HE compounds	Annually
W-6CS	VOCs, HE compounds	Annually
W-808-01	VOCs, HE compounds	Annually
W-809-01	VOCs, HE compounds	Annually
W-814-01	VOCs, HE compounds	Annually
W-814-03	VOCs, HE compounds	Annually
W-815-01	VOCs, HE compounds	Annually
W-815-03	VOCs, HE compounds	Annually
W-815-05	VOCs, HE compounds	Annually
W-817-03A	VOCs, Nitrates, HE compounds	Quarterly
W-823-01	VOCs, HE compounds	Annually

[a] Samples analyzed by the following U.S. EPA analytical methods:
Volatile organic compounds (VOCs) = EPA Method 601.
Nitrates = EPA Method 300.
High explosive (HE) = EPA Method 8330, including perchlorate using EPA Method 300.

Appendix B

Ground Water Flow and Contaminant Transport Modeling and Capture Zone Analysis

Appendix B
Ground Water Flow and Contaminant Transport Modeling and Capture Zone Analysis

B-1. Objective

The primary objective of the finite element model was to create a tool for extraction wellfield management of the $Tnbs_2$ aquifer within the High Explosives (HE) Process Area Operable Unit (OU). The model also serves as a framework for organizing field and laboratory data, and aids in understanding and refining the conceptual model of ground water flow and contaminant transport within the $Tnbs_2$ aquifer. The model focuses on the $Tnbs_2$ aquifer as the primary pathway for trichloroethylene (TCE), cyclo-1,3,5-trimethylene-2,4,6-trinitramine (RDX), and perchlorate migration beneath the HE Process Area OU.

B-2. Conceptual Model

This model focuses on single-phase (saturated-zone) ground water flow within a single hydrostratigraphic unit ($Tnbs_2$). The aquifer was modeled as confined, although actual field conditions vary from unconfined to confined. The conceptual model of flow and transport within the $Tnbs_2$ aquifer is described in the Section 2, Geology and Hydrogeology, of this report.

The following assumptions apply to the model:

- The model was built using three-dimensional discretization; however, due to vertically averaged properties, the model is representative of a two-dimensional domain.
- Model solves for steady-state ground water flow and transient transport.
- Aquifer is homogeneous and isotropic within two distinct zones.
- Each chemical species, such as TCE, RDX, or perchlorate, was modeled individually.
- Retardation and first order decay are neglected; however, sorption effects may be included in future TCE and RDX modeling efforts.
- Flow and transport occur only through porous media. Fracture flow is ignored.
- Biological effects are assumed negligible.
- Model is isothermal.

B-3. Model Description

B-3.1. Numerical Code

All modeling was conducted using FEFLOW, a finite element subsurface flow and transport simulation system developed at the Institute for Water Resources Planning and Systems Research, Ltd. (Diersch, 1998). Version 4.8, which was used for the simulations, features an interactive graphical interface and PEST, an add-in module for automated parameter estimation. Details about the equations governing ground water flow and contaminant transport are included in FEFLOW's reference manual (Diersch, 1998).

B-3.2. Model Domain and Grid

The northern, eastern, and western boundary of the model domain were chosen to approximately outline the extent of saturation within the $Tnbs_2$ aquifer. The southern boundary of the model extends past the site boundary and Corral Hollow Road to include data from offsite wells. The model domain contains 8,591 elements and 8,810 nodes, encompassing approximately 265 acres. The irregular, finite element mesh was created using FEFLOW's automated mesh generation program (see Fig. B-1). Each side of the 8,591 triangles in the mesh was approximately 60 feet. The mesh was refined near the Building 815 Source Area (also shown on Fig. B-1) to minimize problems with numerical dispersion during the transport calibration. Mass balances were checked after flow and transport was calibrated to confirm that the mesh was adequately refined.

B-3.3. Boundary Conditions, Aquifer Type, Top and Bottom Layers

Boundary conditions were selected based on an analysis of expected recharge to and discharge from the $Tnbs_2$ aquifer, and to allow comparison with previous modeling efforts. Figure B-2 shows the areas of expected recharge and discharge to the model in relation to surface geology. Recharge to the model was primarily along the northern boundary, representing inflow from the catchment area. Some recharge was also expected along the western and eastern boundaries where the $Tnbs_2$ is exposed at the surface or where narrow canyons intersect with the model boundaries (e.g., near Spring 14). Because of the steep topography and high evapo-transpiration rates at Site 300, areal recharge was not expected to be significant within the model domain. Discharge from the model was expected to occur along the southeastern border of the model where the $Tnbs_2$ subcrops beneath the alluvial aquifer and an upward gradient is present.

Recharge and discharge model boundaries were initially set as constant head based on ground water elevation data, and revised as appropriate during the flow calibration (see Section B-3.5). Figure B-1 shows the locations where boundary conditions other than no flow were specified. Recharge boundaries using 'constant head' boundary conditions were changed to 'specified flux' boundary conditions during evaluations of different pumping strategies. Top and bottom boundaries of the model were no flow, and the surfaces used to create these layers were imported using a 3-D geologic model specifically developed for the southeast corner of Site 300.

B-3.4. Input Parameters

B-3.4.1. Flow Model Input Parameters

Hydraulic conductivity for the calibrated model was 0.7 feet per day (ft/day) for the primary model domain and 0.2 ft/day in the fault zone. Hydraulic conductivity within the aquifer and fault was calibrated as described in Section B-3.5.1. The fault was defined as an area where an increase in the potentiometric gradient indicated that the fault could be represented as a "leaky barrier." As shown in Figure B-1, a non-uniform hydraulic conductivity (K) was defined within the fault (0.02 ft/day K near the center) to better match the observed ground water elevation data. Geologic mapping studies also indicated the presence of a fault (Spring 5 fault) within the HE Process Area OU. The location of the fault within the model domain was initially based on ground water elevation data. The final location, which was refined during the calibration process, is shown in Figure B-1.

B-3.4.2. Transport Model Input Parameters

A porosity value of 0.32 was chosen using average core porosity measured during laboratory testing (Madrid and Jakub, 1998). Initial concentrations of TCE, RDX, and perchlorate used for production runs were based on second quarter 2001 data. Concentrations were input into FEFLOW at discrete points, and the program's linear interpolation scheme was used to assign values between data points. Values of less than 5 µg/L TCE, 4 µg/L perchlorate, and 0.5 µg/L RDX were set to a very low value to minimize problems with numerical dispersion during initial time steps. Longitudinal dispersivity was assigned to be 25 meters (m), which is 10% of the distance from the Building 815 Source Area to the center of the TCE mass (approximately 250 m). Transverse dispersivity, assumed to be 20% of the longitudinal dispersivity or 5 m, was determined as part of the transport calibration process.

B-3.5. Calibration

B-3.5.1. Flow Calibration

The model was calibrated using FEFLOW's automated parameter estimation tool (PEST), which minimized the sum of the squared differences between measured and modeled head data at 32 observation wells located within the model domain. The initial range of hydraulic conductivities used as input to PEST was based on pumping test data described in Section 3.2.1, Hydraulic Testing. Calibrated values of 0.7 ft/day for the aquifer fall within this range. Both aquifer and fault conductivities (0.2/0.02 ft/day for the fault zone) were consistent with previous modeling work done by Pelmulder and Maxwell (1997), which used 0.5 ft/day for the primary domain and 0.09 ft/day for the Spring 5 fault. After initial calibration with PEST, minor (< 2 ft) adjustments in the initial specified head data used as boundary conditions were made to improve calibration results. The resulting ground water elevation map was also subject to visual inspection to confirm the direction of the flow gradient. Recharge to the model from the northern boundary [2,600 cubic feet per day (cfd)] was compared with independent estimates of recharge (925-3655 cfd) that were determined considering the size of the catchment area (Pelmulder and Maxwell, 1997).

Figure B-3 shows a comparison between measured and modeled ground water elevation data after calibration. July 2000 ground water elevation data were used for the calibration. The average difference between measured and modeled data was 2.7 feet. R^2, which is defined as R^2=1-? [(measured$_i$-predicted$_i$)^2/(mean measured$_i$)^2], where measured$_i$ are the measured ground water head data, predicted$_i$ are the modeled ground water dead data, and mean is the mean of measured ground water head data, was 0.99.

A final step of the flow calibration was to observe the behavior of the model under stressed conditions by comparing drawdowns observed during long-term pumping tests at wells W-35C-

04 and W-818-06 with modeled drawdowns. The steady-state model was used for the simulations; however, a transient model may be used in the future to better match observed data. Average differences between measured and modeled drawdowns were 3.1 ft for the well W-35C-04 test and 4.2 ft for the well W-818-06 test. FEFLOW drawdowns were generally greater than observed drawdowns.

B-3.5.2. Transport Calibration

This model relies primarily on the flow calibration to ensure robustness, however some transport parameters (longitudinal and transverse dispersivity) were also calibrated. For the transport calibration, a 2.5 µg/L point source was applied at the Building 815 Source Area, assumed to be the primary TCE source area. The point source was a "step function" that was applied at a constant rate for 25 years, approximating the period between 1955–1980. The contaminant plume was then observed after another 20 years of transient transport and compared with present-day (2nd quarter 2001) TCE data. The calibrated TCE plume was modeled using 10 gpm of steady-state pumping from Well 6, a now-discontinued water supply well that had intermittent pumping of up to 30 gpm during the 1970s and 1980s.

As shown in Figure B-4, the model does a fairly good job in matching the TCE plume, and a closer match is not likely using a steady-state approximation of intermittent pumping. The total mass entering the model as a point source (10 kg) also compares favorably with independent estimates of the TCE mass made using EarthVision (12 kg). The capability of the model to match observed data using a 'step-function' point source suggests that the Building 815 Source Area is no longer contributing significant mass to the TCE plume within the $Tnbs_2$ aquifer.

B-4. Results

The objective of this section is to demonstrate the model's capabilities as an extraction well field optimization tool. Although several alternative pumping strategies have been simulated, only the results of a 10 extraction well scenario are presented here. For this scenario, each well was pumped at the rates shown in Table 2, Design Specifications for the $Tnbs_2$ aquifer. Extraction wells W-4A and W-4B were not included in these simulations. Future scenarios may incorporate alternative flow rates or pumping wells to optimize mass removal and to prevent the offsite migration of contaminants. Figure B-5 shows the location of the 10 extraction wells. Figures B-6, B-7, and B-8 show isoconcentration contour maps for the TCE, RDX and perchlorate plumes. As shown, simulations of cleanup using the 10-well pumping scenario indicate that plume concentrations greater than drinking water standards persist after 25 years of cleanup. See Table 2 for the list of 10 extraction wells used in this simulation.

B-5. Sensitivity Analysis

Although a comprehensive sensitivity analysis was not conducted for this report, the sensitivity of many input parameters was observed during calibration. In general, the flow model is most sensitive to boundary conditions. Hydraulic conductivity is also important in determining flux rates, water levels, and plume migration patterns. Although the non-uniform fault conductivity (lower K near the center of the fault) has a localized impact on water levels and the hydraulic gradient, its effect on plume migration patterns is minimal. With regard to transport, the model showed significant sensitivity to the values of longitudinal and transverse dispersivities, and little sensitivity to the diffusion coefficient.

B-6. Extraction Wellfield Capture Zones

FEFLOW modeling output was used to delineate the capture zones for each extraction well for the HE Process Area OU. Capture zones were created in FEFLOW using the velocity field resulting from each simulation. The configuration of the capture areas includes the interference patterns developed between nearby wells. Streamlines can be shown with or without time stamps which indicate the extent of a capture zone within a specified period of time.

Figure B-5 shows the capture zones created by the 10-well, mixed flow pumping scenario. As shown, this scenario captures the contaminants of concern at their respective drinking water standard concentrations.

B-7. Conclusions

This appendix provides an overview of the FEFLOW model developed for the HE Process Area OU. Based on this modeling, the following conclusions were reached:

- The model shows good calibration to field data with respect to water levels, ground water gradients, pumping rates, and plume migration patterns.
- Results of the transport calibration show that a source term of 2.5 µg/L applied for 25 years is needed to match the current TCE plume, providing an independent estimate of TCE mass of 10 kg.
- The capability of the model to match observed data using a time-dependent point source suggests that the Building 815 Source Area is no longer contributing significant mass to the TCE plume within the $Tnbs_2$ aquifer.
- As shown in Section B-6 (Extraction Wellfield Capture Zones), the capture zones created with the 10-well pumping scenario adequately capture the contaminants of concern to drinking water standards.
- Simulations of cleanup using the 10-well pumping scenario indicate that plume concentrations greater than drinking water standards persist after 25 years. This model will be used to optimize the extraction wellfield to achieve cleanup levels.

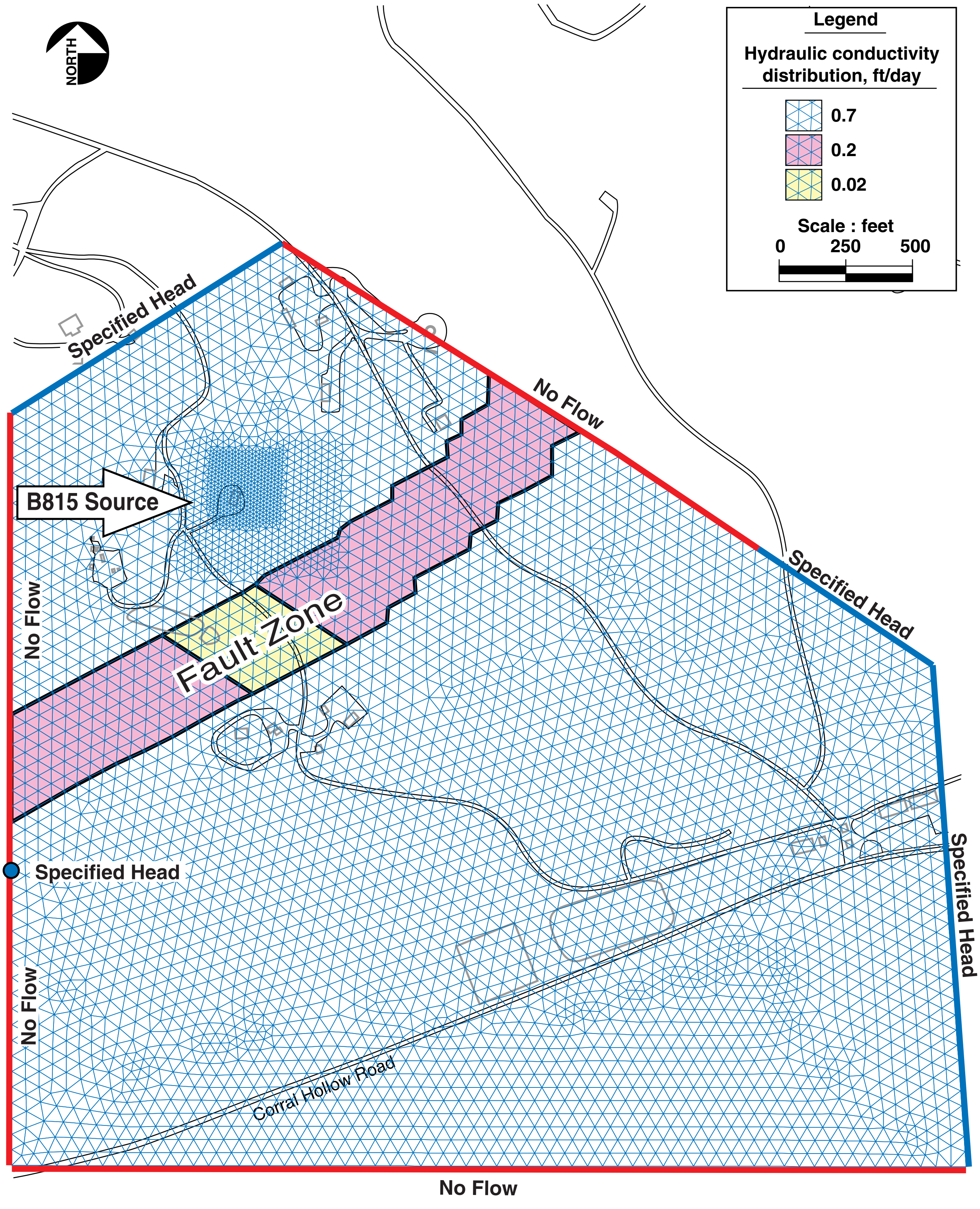
Overall the model shows good calibration to observed data. Although additional calibration and fine-tuning of the input parameters may be performed in the future, these changes are not expected to substantially alter the general character of flow and transport presented here.

B-8. References

Diersch, H. G. (1998), Reference Manual, "FEFLOW- Interactive, Graphics-based Finite-Element Simulation System for Modeling Ground water Flow, Contaminant Mass and Head Transport Processes," WASY Institute for Water Resources Planning and Systems Research Ltd., Berlin, Germany.

Madrid, V. M. and B. J. Jakub (1998), *Engineering Evaluation/Cost Analysis for the Building 815 Operable Unit Removal Action Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-126639).

Pelmulder, S. D., and R. M. Maxwell (1997), "Site 300 Building 815 Ground water Modeling Report," The Center for Nuclear and Toxic Waste Management, University of California-Berkeley, Berkeley, CA (Draft).



ERD-S3R-01-0242

Figure B-1. Figure showing mesh, model boundary conditions, Building 815 Source Area, fault zone, roads and buildings.

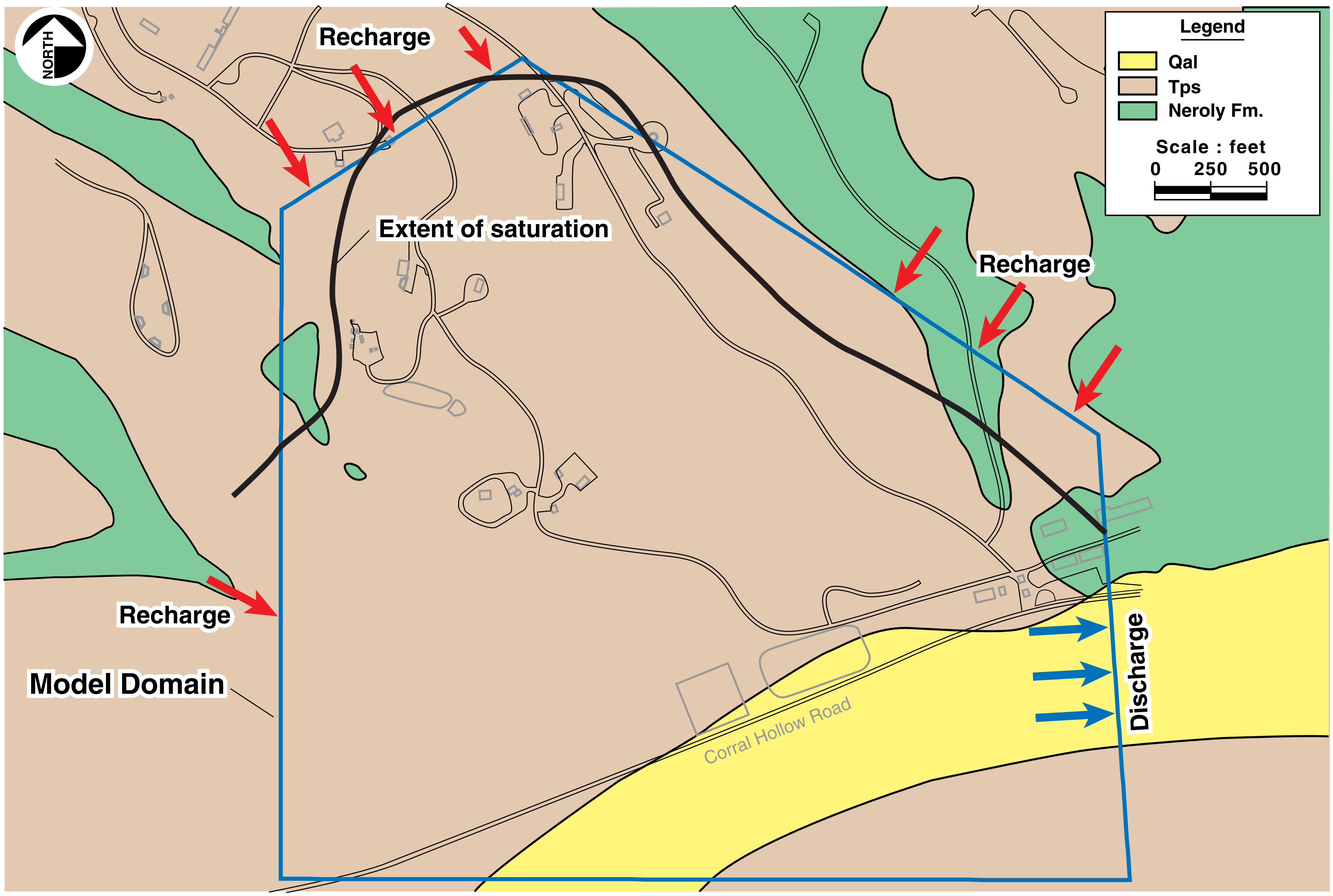


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Figure B-2. Figure showing surface geology, outline of Model Domain, extent of saturation, areas of recharge and discharge for the $Tnbs_2$ aquifer.

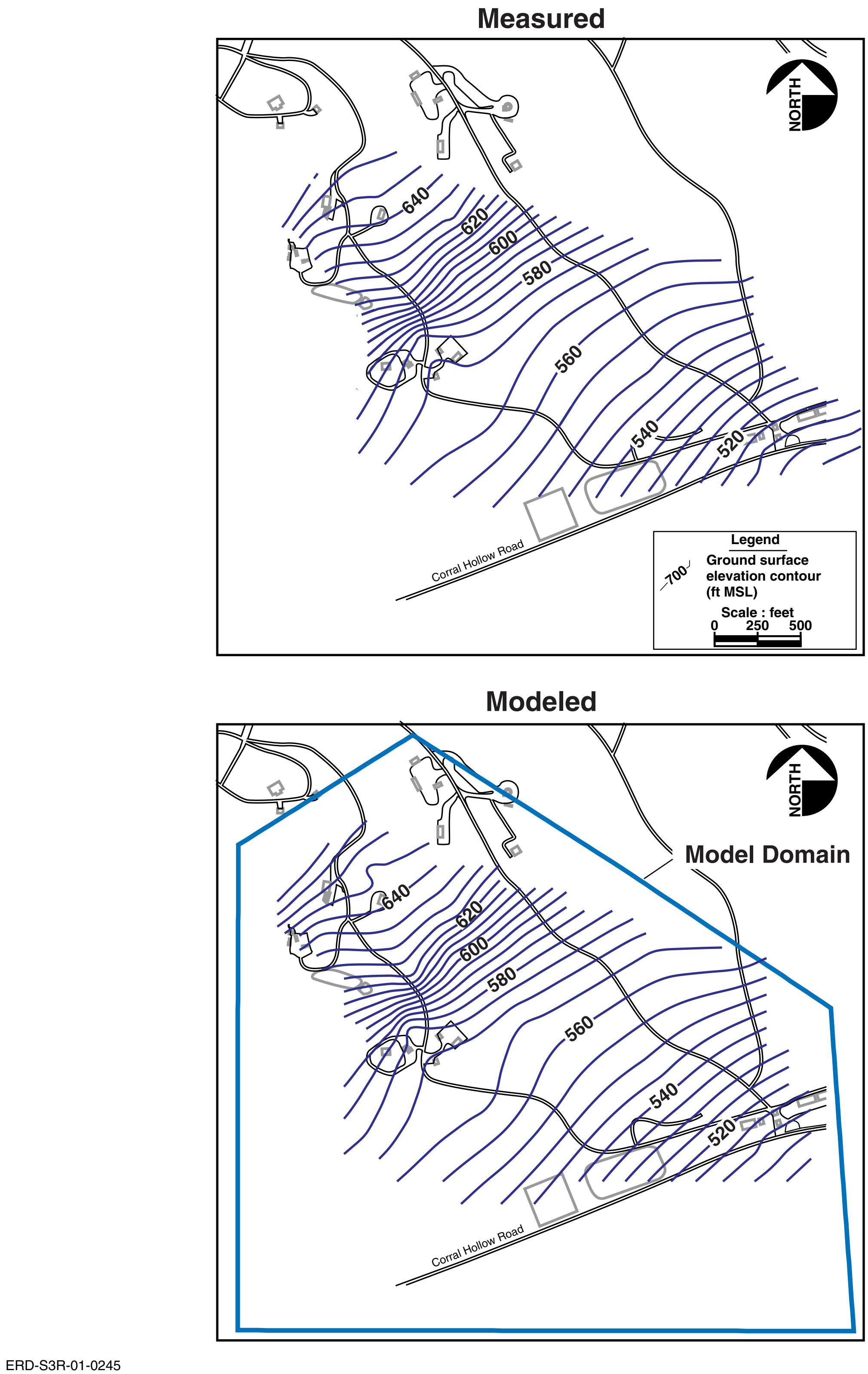

Figure B-3. Figure showing measured and modeled ground water elevation data contoured using 32 observation points. July 2000 data were used for the calibration.

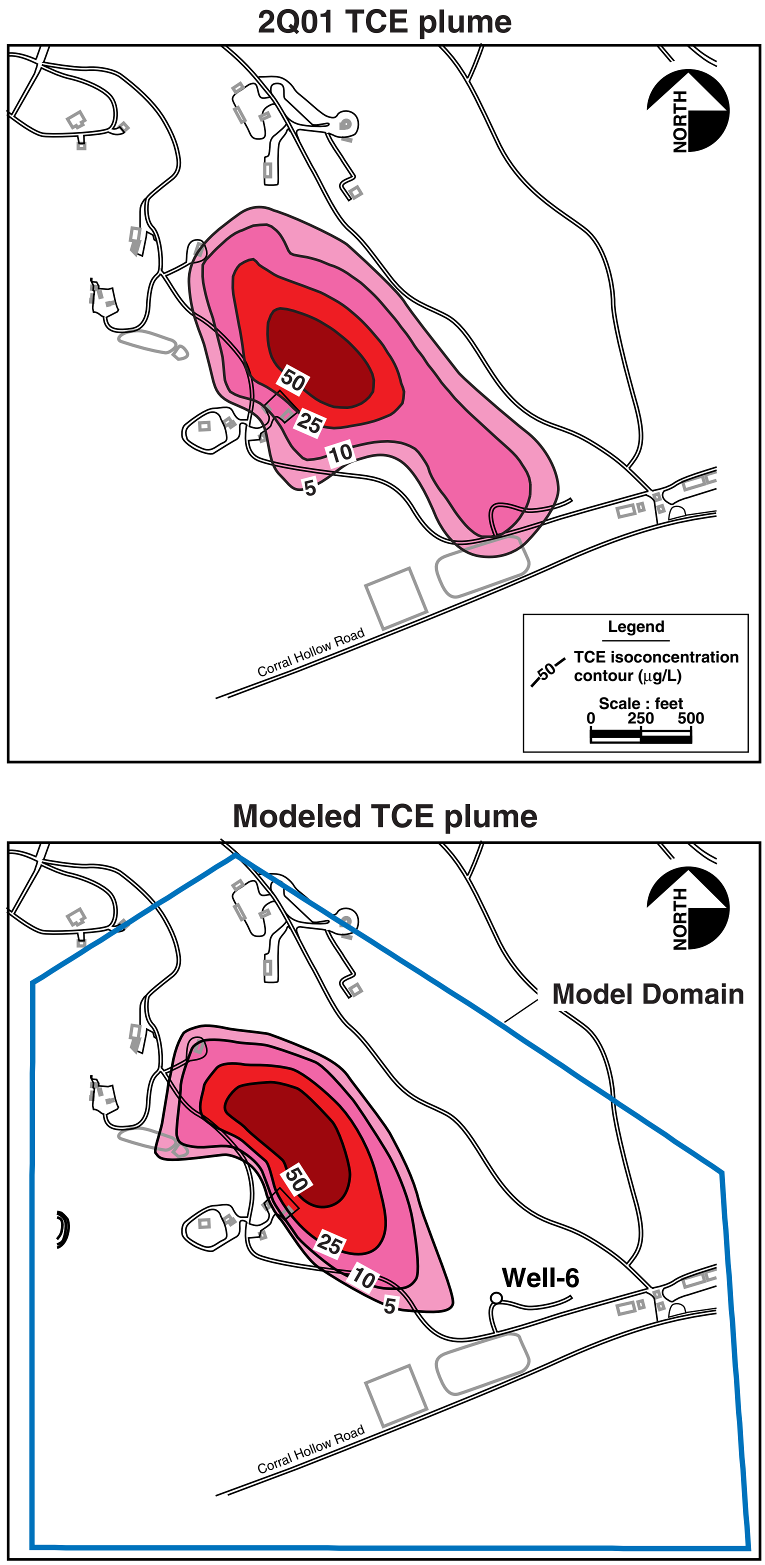

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Figure B-4. Figure showing comparison between measured and modeled TCE plume. Modeled plume created using "step-function" point source and 10 gpm pumping at Well 6.

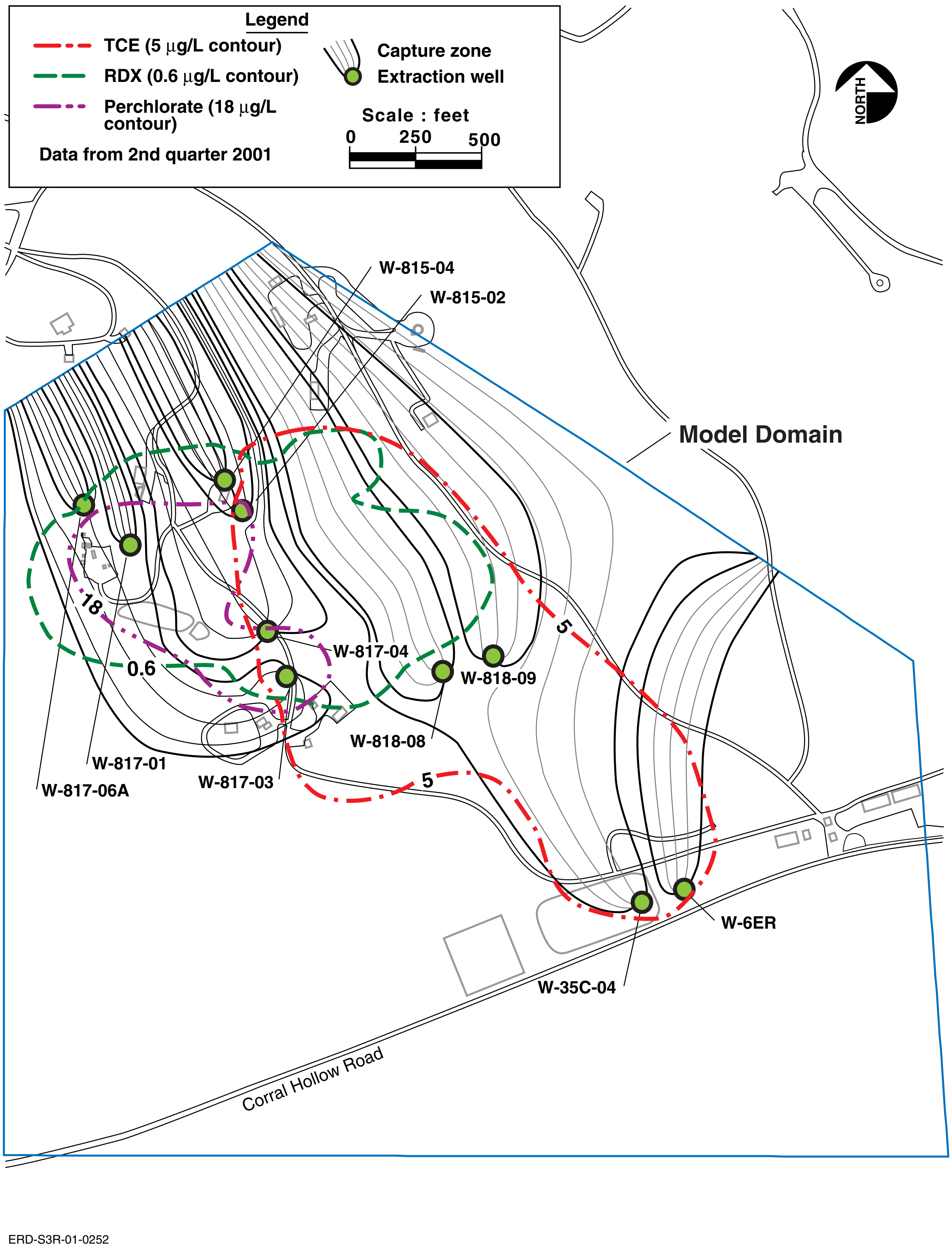

Figure B-5. Figure showing extraction well capture zones and second quarter TCE, RDX, and ClO_4^- isoconcentration contours.

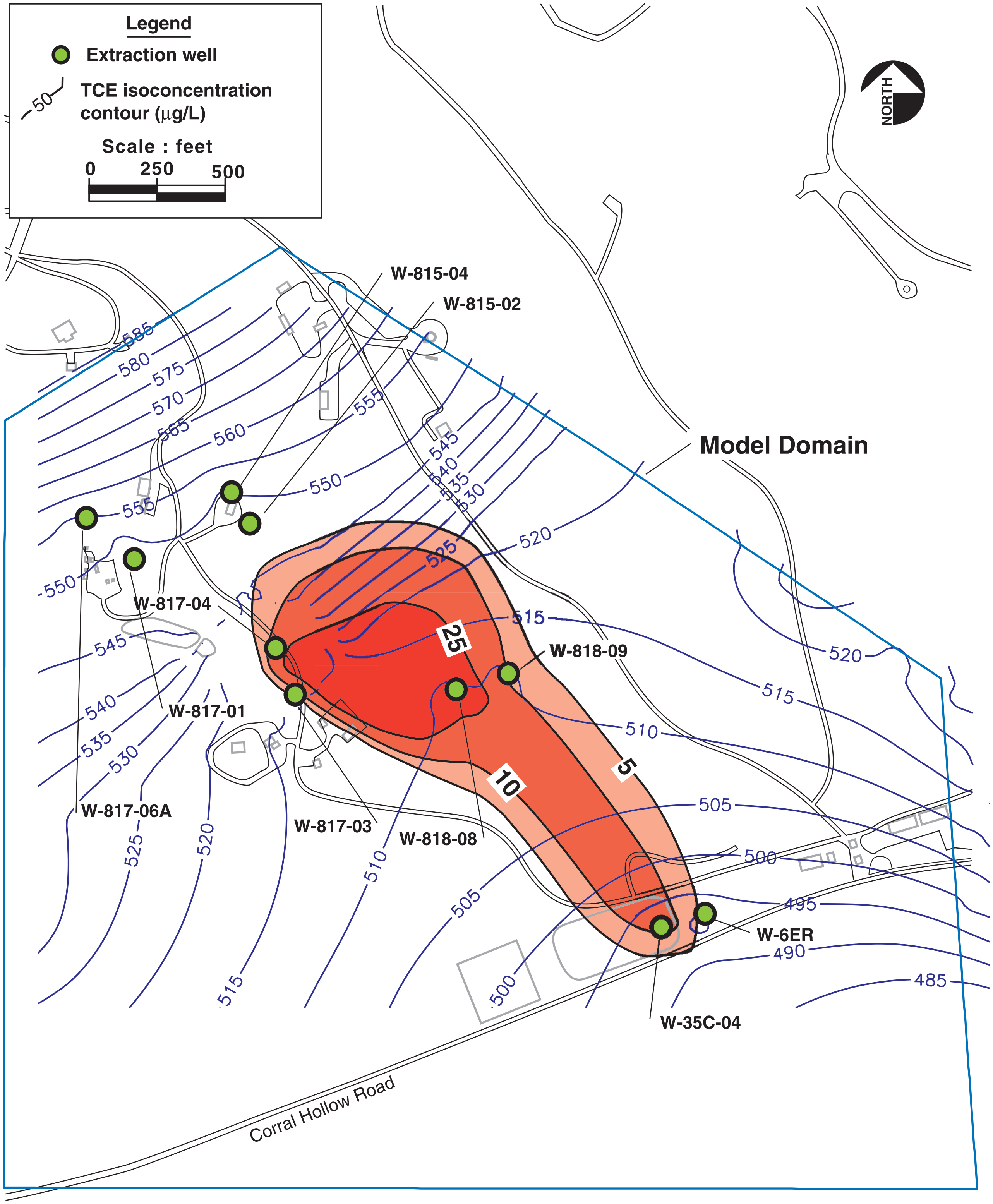

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Figure B-6. Figure showing isoconcentration contours for TCE plume after simulating 25 years of pumping 10 extraction wells (see Table 2 for extraction flow rates).

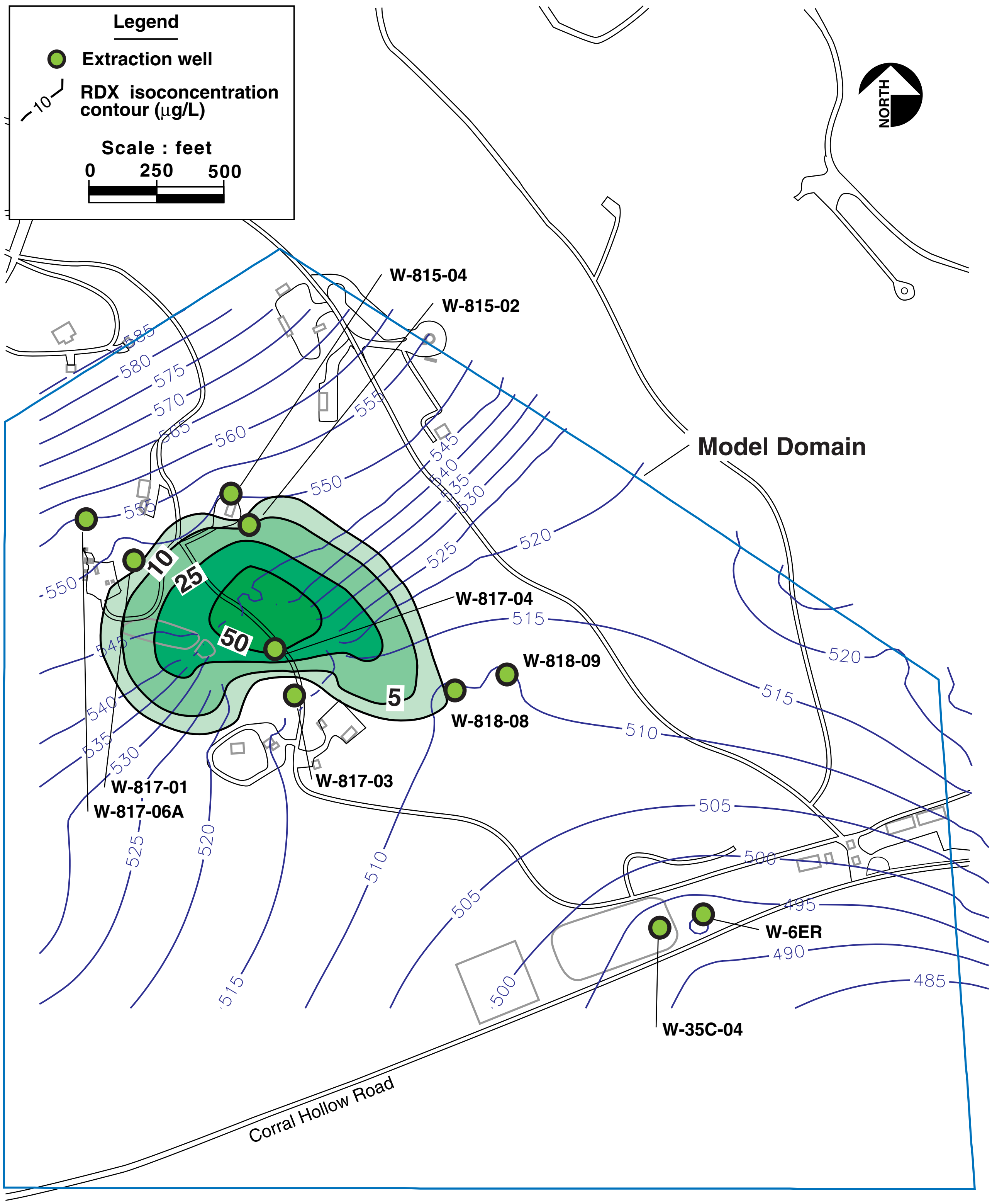

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Figure B-7. Figure showing isoconcentration contours for RDX plume after simulating 25 years of pumping 10 extraction wells (see Table 2 for extraction flow rates).

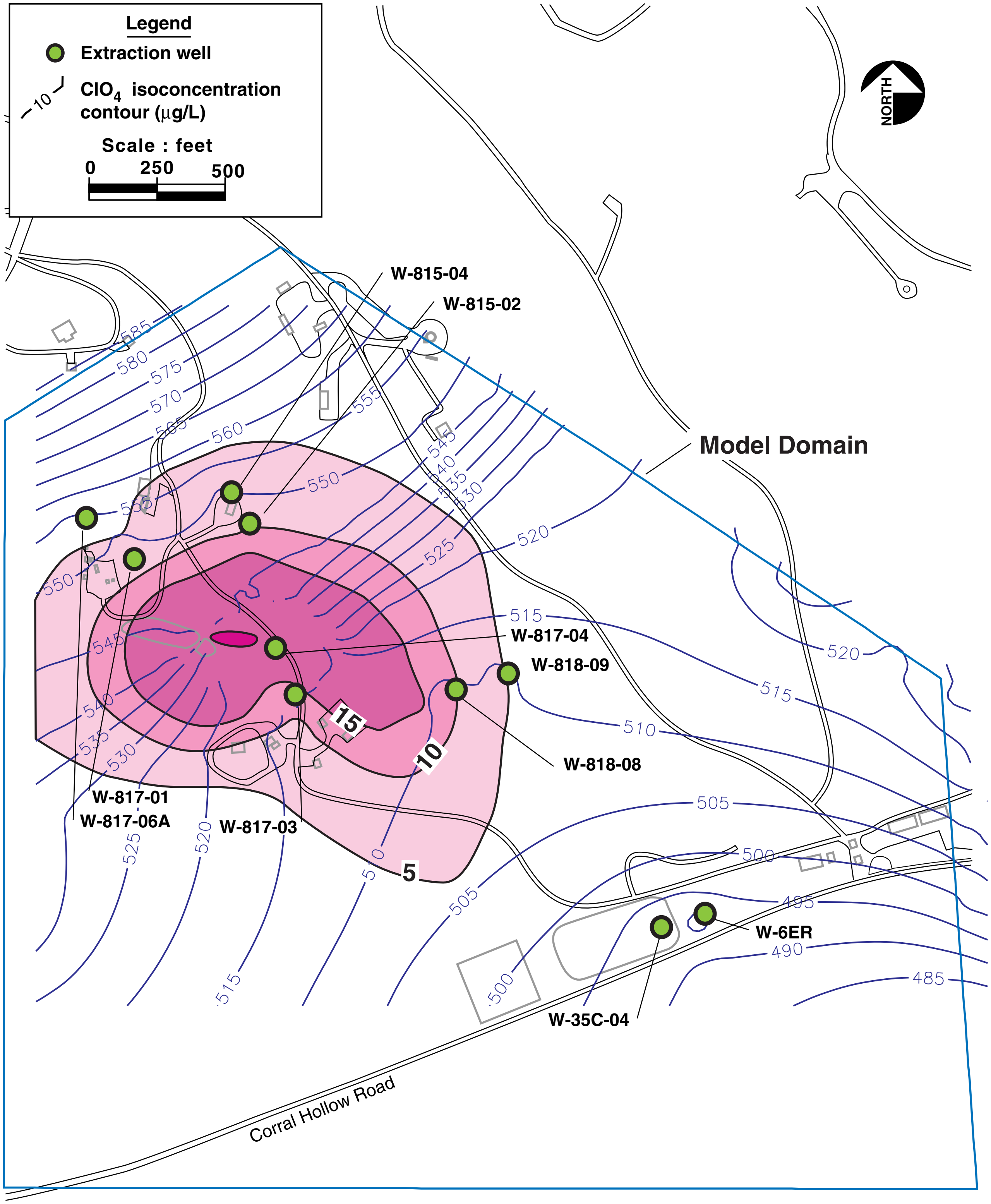

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Figure B-8. Figure showing isoconcentration contours for ClO_4 plume after simulating 25 years of pumping 10 extraction wells (see Table 2 for extraction flow rates).

Appendix C

Nitrate Study

Appendix C
Nitrate Study

C-1. Introduction

Nitrate is a dissolved constituent of ground water that can have both natural and anthropogenic sources. Ground water beneath Site 300 contains nitrate at concentrations exceeding the drinking water standard of 45 milligrams per liter (mg/L) [as nitrate (NO_3^-)]. A multi-disciplinary study was undertaken to determine the distribution of nitrate in soil and ground water beneath the site and estimate the relative contribution of natural versus anthropogenic sources to subsurface nitrate loading. This information is needed to determine background concentrations in ground water, set treatment facility effluent discharge limitations, and evaluate options, including monitored natural attenuation, for nitrate cleanup at Site 300. The data and interpretations presented here are intended as technical input to the regulatory decision-making process.

C-2. Hydrogeologic Setting

Ground water at Site 300 occurs in alluvial and bedrock aquifers. Bedrock aquifers occur under unconfined, confined, and flowing artesian conditions. The extent of saturation, potentiometric surface, and recharge/discharge locations for the $Tnbs_2$ bedrock aquifer in the High Explosives (HE) Process Area Operable Unit (OU) are shown in Figure C-1. The main discharge location for this aquifer is into the overlying alluvial aquifer, in the southeastern part of the HE Process area, where the bedrock aquifer subcrops beneath the alluvial aquifer.

A water-budget analysis was conducted to estimate natural recharge rates and on-site storage in the $Tnbs_2$ aquifer. Annual recharge was estimated to be 1.7E07 liters [1,730 cubic feet per day (cfd) or about 9 gallons per minute (gpm)], assuming 10% of the average annual precipitation (27 centimeters per year or 10.5 inches per year) recharges the aquifer through a catchment area of 7.2E06 ft^2. On-site storage was estimated to be 3.0E09 liters based on aquifer volumes calculated using EarthVision software.

C-3. Background Wells

The Site 300 database was reviewed to identify wells that are representative of natural, background conditions. The main criterion for identifying a background well was the absence of any anthropogenic chemicals. As shown in Figure C-2, 14 wells located throughout Site 300 met this condition. Data from these wells are presented in Table C-1; time-series plots of nitrate concentrations in these wells are presented in Figure C-3. Ten of the 14 background wells are screened in the Neroly Formation, two in the Cierbo Formation, one in Corral Hollow Creek Alluvium, and one in the Great Valley Sequence. Note that nitrate concentrations in the background wells range from less than 1 milligram per liter (mg/L) (as NO_3^-) to greater than the drinking water standard of 45 mg/L (as NO_3^-). These data suggest that there is no single value that represents natural background conditions.

C-4. Temporal and Spatial Distribution of Nitrate in Ground Water

Throughout Site 300, elevated nitrate levels (> 45 mg/L) occur in ground water located beneath known anthropogenic source areas and beneath areas where no sources have been identified or anthropogenic chemicals have been detected. In general, high nitrate concentrations (>100 mg/L) occur in the upper 50 to 100 feet (ft), beneath Building 834, 832 Canyon, and the HE Process Area OU (Fig. C-4). These high nitrate levels are usually associated with shallow, perched water-bearing zones that contain relatively small volumes of ground water. The nitrate mass in these perched zones is relatively small compared to the total mass of ground water nitrate beneath the site. In contrast, the $Tnbs_2$ aquifer contains relatively large quantities of dissolved nitrate (an estimated 100 metric tons) beneath the HE Process Area OU. A detailed study was conducted to evaluate the temporal and spatial distribution of nitrate in this aquifer with respect to known source areas. The spatial nitrate distribution and the distribution of dissolved oxygen in this aquifer are shown in Figures C-5 and C-6. Also shown on these maps are the locations of former HE wastewater disposal locations. Temporal variations of ground water nitrate are presented as a time-series plot in Figure C-7. Note that $Tnbs_2$ nitrate concentrations in recharge areas have remained fairly constant during the past 15 years, indicating a fairly continuous flux of nitrate to the ground water.

C-5. Nitrate Sources

Nitrate can be a natural or anthropogenic component of soil and ground water. Multiple natural and anthropogenic sources exist at Site 300 that could contribute to nitrate loading beneath the site. Natural sources include grassland biomass and geologic sources. Anthropogenic sources include septic systems and HE wastewater discharges. An exhaustive review of ground water nitrate data was conducted as part of this study to evaluate the relationship between known contaminant source areas and nitrate distribution. In addition, subsurface nitrate loading from different natural and anthropogenic sources was estimated to compare the relative contribution of each source to ground water nitrate. These estimates are presented in Section C-6, Mass Estimates.

C-5.1. Nitrate Cycling in the Environment

Nitrate cycling in the environment is a well-documented process (Jackson et al., 1988; Woodmansee, 1978; Woodmansee and Duncan, 1980; Kendall et al., 1998). As shown in Figure C-8, nitrate can be produced and transformed in the subsurface. Under certain conditions, organic nitrogen, which can be a component of recent plant detritus, geologically mature organic matter incorporated in aquifer sediment, or HE and HE transformation products, can be transformed to ammonium or nitrate in the subsurface. Seasonal accumulations of nitrogen in shallow soil (upper 30 centimeters) associated with native grass cycling represents a long-term source to subsurface nitrate loading and thus is available to leach to ground water during certain periods of the year. Under oxygen-depleted conditions (< 0.5 mg/L dissolved oxygen) and in the presence of an electron donor, anaerobic bacteria can transform nitrate into nitrogen (N_2) gas through a process known as denitrification, resulting in a net loss of nitrogen from the system.

C-5.2. Geologic Nitrogen

Nitrogen has been reported in all types of geologic materials including sedimentary, metamorphic, and igneous rocks (Holloway and Dahlgren, 1999). The main source of this nitrogen is organic matter deposited in sedimentary rocks. Elevated levels of geologic nitrogen have been detected in alluvial soils (Plio-Pleistocene Tulare Formation) along the west side of the San Joaquin Valley near Cantua Creek, and in ancient organic-rich shale deposits (late Cretaceous Panoche and Moreno Formations of the Great Valley Sequence) located in the upper reaches of the creek (Strathouse and Sposito, 1980). These deposits occur throughout the Diablo Range, including the Altamont Hills and Site 300. Strathouse and Sposito (1980) concluded that weathering, transport and deposition of organic nitrogen from upstream older deposits resulted in the secondary enrichment of younger alluvial soils with organic nitrogen. Over geologic time and under the appropriate conditions, organic nitrogen can be transformed into exchangeable nitrate and percolate into the ground water. At Site 300, concentrations exceeding 100 mg/L (as NO_3^-) have been detected in ground water from background well, NC7-50, which is screened in the late Cretaceous Great Valley Sequence.

In this study, soil leaching experiments were conducted using methods reported by Holloway (1999) to investigate the potential for the release of geologic nitrogen (as nitrate or ammonium) from Site 300 soil and aquifer sediment during weathering. These leaching experiments involved an initial hydrogen peroxide wash followed by application of potassium chloride (KCl) water to simulate weathering (Suefert, 2000). Eight soil samples were collected from areas where no anthropogenic chemicals had been detected. These samples were crushed, sieved, and placed in columns for leaching experiments. Most of the observed nitrate removal occurred during the initial peroxide wash, which was intended to break up organic matter aggregates. The greatest nitrate removal observed in the initial peroxide wash was 78 milligrams of nitrate per kilogram of soil sample (mg N/kg) for a Neroly sandstone, which represents 61% of the total organic nitrogen in that sample. Nitrate released by the initial 2M KCl water ranged from < 0.06 to 5.7 mg N/kg, but nitrate leached during the 30-, 60-, and 90-day KCl water leachings was below 0.06 mg N/kg for all eight samples. The average nitrate released from the initial KCl leachings (1.1 mg N/kg) was used to estimate the amount of exchangeable nitrate remaining in unsaturated soil and bedrock overlying the $Tnbs_2$ aquifer.

Significant ammonium was removed during the initial KCl wash for three of the samples (two Neroly sandstones and one Tps clay). The greatest amount of ammonium leached in the initial wash was 22 mg N/kg. More ammonium than nitrate was removed during the KCl leachings, but the greatest amount of ammonium leached at the 90-day sampling was 1.2 mg N/kg, observed for a Neroly siltstone/claystone sample.

The results of the soil leaching study indicate that significant quantities of exchangeable nitrate and ammonium exist in soil and unsaturated bedrock at Site 300. An average value of nitrate leached during these experiments and was used to estimate the amount of exchangeable nitrate remaining in the HE Process Area OU. This mass estimate is discussed in Section C-6.

C-5.3. Technical Operations

Since the late-1950s, Site 300 has been used to conduct a variety of experiments, including open-air detonation, involving high explosives (HE) chemicals such as RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine). About 150 tons of nitrogenous chemical explosives have been processed at Site 300 since that time. These chemicals were processed in a variety of ways including machining into shapedcharges in the HE Process Area OU. Wastewater is generated during machining operations because water is used as a coolant. Prior to 1985, waste liquids generated during machining operations were discharged to unlined disposal lagoons to photolytically degrade HE chemicals dissolved in the wastewater (Fig. C-9). Nitrate is one possible breakdown product of photolytic degradation of HE compounds such as RDX and TNT (2,4,6-trinitrotoluene).

Although chemical explosives like RDX have low aqueous solubility, some dissolution occurred during these machining operations. Estimates of HE wastewater discharge rates during this period range from 8,500 to 292,760 cubic feet per year (ft^3/year) (Carpenter, 1982; Raber, 1983; Carpenter et al., 1988). These discharges reportedly contained nitrate concentrations as high as 400 mg/L and HE compounds in the 1 to 3 mg/L range. The depth to ground water beneath these disposal lagoons ranges from 20 to 400 ft. Estimates of travel-time to reach the water table beneath these disposal lagoons ranges from 2 to 16 years (Raber, 1983). HE compounds were first detected in soil and ground water in 1988 during investigations required to support the permanent closure of the HE wastewater disposal lagoons (Carpenter et al., 1988).

In addition to HMX (cyclotetramethylene tetranitramine) and RDX, the site processed large quantities of the mock explosive, barium nitrate [$Ba(NO_3^-)_2$]. Barium nitrate has a very high aqueous solubility and subsurface mobility, in contrast to HMX and RDX which are much less soluble and tend to sorb to the rock matrix. Nitric acid was also used at the site and it was a likely component of the former wastewater discharges to the disposal lagoons. Notably, barium nitrate and nitric acid are direct sources of nitrate, whereas RDX, HMX, and other HE compounds must be transformed to generate nitrate.

Another release scenario for nitrogenous chemicals at Site 300 is through discharges to septic system leach fields. The majority of the buildings at Site 300 are equipped with a septic system; in many of the buildings, floor drains are also connected to septic systems. In the following section, estimates of nitrate mass for various natural and anthropogenic sources, including septic discharges, are presented.

C-6. Mass Estimates

A number of calculations were made to estimate and compare nitrate mass from different sources beneath the HE Process Area OU, including nitrate of geologic origin, septic system discharges, and plant biomass cycling. In addition, the mass of dissolved nitrate currently present in the $Tnbs_2$ aquifer beneath the HE Process Area OU was estimated. Due to subsurface heterogeneity and inherent uncertainty in these calculations, the estimates presented in Table C-2 are considered to be order-of-magnitude estimates.

Based on HE inventory records, about 1.5E05 kilograms (150 metric tons) of nitrogen-bearing chemicals have been processed at Site 300 since the late-1950s. The bulk of this mass was converted to gases such as nitrogen (N_2), carbon dioxide (CO_2), nitrous oxides (NO_X), and carbon monoxide (CO), when these explosive devices were detonated on the firing tables located in the northern part of Site 300 (Layton et al., 1986). A fraction of these nitrogen-bearing chemicals dissolved into the cooling water during machining operations and this wastewater was discharged into unlined disposal lagoons in the HE Process Area OU. The total amount of nitrate loading resulting from these operations is difficult to estimate because of the wide range in reported discharge rates at these facilities. Given this wide range (8,500 to 292,760 ft^3/year), the mass of nitrate in the discharge could account for 3 to 4%

percent of the total mass currently present in the underlying ground water to nearly 100% of this amount.

The Tnbs$_2$ aquifer contains an estimated 1.0E05 kilograms (about 100 metric tons) of dissolved nitrate beneath the HE Process Area OU. This estimate is based on recent (2nd quarter, 2001) nitrate concentration and water-level data; it was estimated using EarthVision.

The mass of exchangeable nitrate remaining in soil and bedrock overlying the Tnbs$_2$ aquifer was estimated using average initial KCl leaching values (4.8 mg NO_3^-/kg) obtained from the nitrate leaching study. The mass of unsaturated soil and bedrock (3.7E10 kg) overlying the Tnbs$_2$ aquifer recharge area was estimated using EarthVision. As presented in Table C-2, the mass of exchangeable nitrate was estimated to be 1.86E05 kg (about 186 metric tons).

Nitrate loading from seasonal plant biomass cycling was simulated using the numerical code, Century (Mikhailova et al., 2000; Metherall et al., 1993; Parton et al., 1993; Parton et al., 1988). Simulation results, including the total plant mass generated on a seasonal basis, total nitrogen contained in the plant material, and nitrate from plant biomass cycling during the past 30 years, are presented in Figures C-10 and C-11. As summarized in Table C-2, the total amount of nitrate leached to the ground water during this period is 11.8E03 kg (12 metric tons). Therefore, plant biomass appears to be a natural source of nitrate to ground water.

Nitrate loading from septic system leach fields in the HE Process Area OU was estimated using the Septic Systems Handbook (Kaplan, 1991). Nitrate loading from septic system discharges was estimated for a semi-arid environment assuming normal occupancy (30 workers) by HE Process Area OU personnel during a 40-year period. As presented in Table C-2, the total mass of untreated nitrate generated during this period is 1.6E04 kg (16 metric tons). This is a conservative estimate based on the assumption that each individual excretes about 50% of their annual input while at work.

C-7. Stable Isotope Analysis

Stable isotope ratios of nitrogen and oxygen (i.e., ?^{15}N and ?^{18}O, respectively) in nitrate can be used to investigate sources of nitrate and nitrate transformation processes in ground water (Kendall and McDonnell, 1998). Samples for stable isotope analysis were collected from 53 wells. Fifty of the wells are ground water monitor wells and three are background wells. Of the three background wells, two are screened in the Neroly Formation and one is screened in the Great Valley Sequence. In addition to ground water samples, two samples of potential source materials were prepared in the laboratory. One of the laboratory-prepared samples contained dilute 4 milliMolar (mM) nitric acid and the other contained a dilute solution of barium nitrate (mock explosive). The laboratory-prepared samples were submitted for isotope analysis because they represent anthropogenic chemicals that were used in technical operations at Site 300.

As shown in Figure C-12, stable isotopic signatures of nitrate (i.e., ?^{15}N and ?^{18}O values) revealed that all ground water samples from the site fall in the same general range as compiled literature values for soil nitrogen and septic waste. In contrast, nitric acid and barium nitrate exhibited markedly different stable isotope signatures than site ground water. Furthermore, denitrification would not lead to a convergence of the isotopic signatures in ground water with those of barium nitrate and nitric acid. [The denitrification trend with a 0.5 slope shown in Figure C-12 was empirically determined based on numerous studies (Kendall and McDonnell, 1998).] Thus, stable isotopic data suggest that these two potential anthropogenic sources of nitrate are highly unlikely to have contributed significantly to nitrate in Site 300 ground water.

C-8. Natural Attenuation via Denitrification

Figure C-13 presents ?^{15}N and ?^{18}O data for wells located along cross-section A-A'. Note that a linear-regression trend line fit to these data has a 0.5 slope, which is exactly the slope that would be expected as a result of denitrification. In addition to the 0.5 slope of the ?^{18}O/?^{15}N data, other evidence suggesting denitrification along this HE Process Area OU cross-section include the following: (a) low dissolved oxygen (DO) concentrations in the confined region of the $Tnbs_2$ aquifer where enriched ?^{15}N and ?^{18}O values are found, (b) low nitrate concentrations in the confined portion of the $Tnbs_2$ aquifer, and (c) the presence of excess nitrogen gas (N_2), the product of denitrification, in ground water with low nitrate concentrations in the confined portion of the $Tnbs_2$ aquifer. Thus, multiple lines of evidence, including hydrologic, geochemical, and stable isotope data, support natural attenuation of nitrate via denitrification in the confined portion of the $Tnbs_2$ aquifer beneath the HE Process Area OU.

C-9. Summary

The findings of the nitrate study are summarized below by category:

C-9.1. Background

1. There is no single, site-wide background value for nitrate.
2. Non-detectable concentrations of nitrate are not necessarily representative of background conditions, but depend on a number of factors, including depth, DO, recharge pathway, and lithology.
3. Nitrate concentrations in background wells range from < 1 to > 45 mg/L as NO_3^-.

C-9.2. Natural Sources

1. There is enough exchangeable nitrate (and ammonium) in the soil and bedrock to account for the mass of nitrate in the underlying ground water.
2. Plant biomass appears to be a natural source of nitrate to ground water

C-9.3. Anthropogenic Sources

1. There is more nitrate mass in the HE Process Area OU subsurface than can be attributed to anthropogenic sources.
2. Isotope data rule out the mock explosive, barium nitrate, and nitric acid as significant sources.
3. There are no obvious isotopic source signatures in ground water samples.

C-9.4. Processes

1. There is isotopic evidence for denitrification in the $Tnbs_2$ aquifer in the HE Process Area. The denitrification trend is driven largely by W-818-07, but it is supported by the detection of excess nitrogen (N_2) gas in the denitrified ground water.
2. Nitrate appears to be "self-remediating" in the $Tnbs_2$ aquifer in the HE Process Area due to conditions favorable for denitrification.

C-10. References

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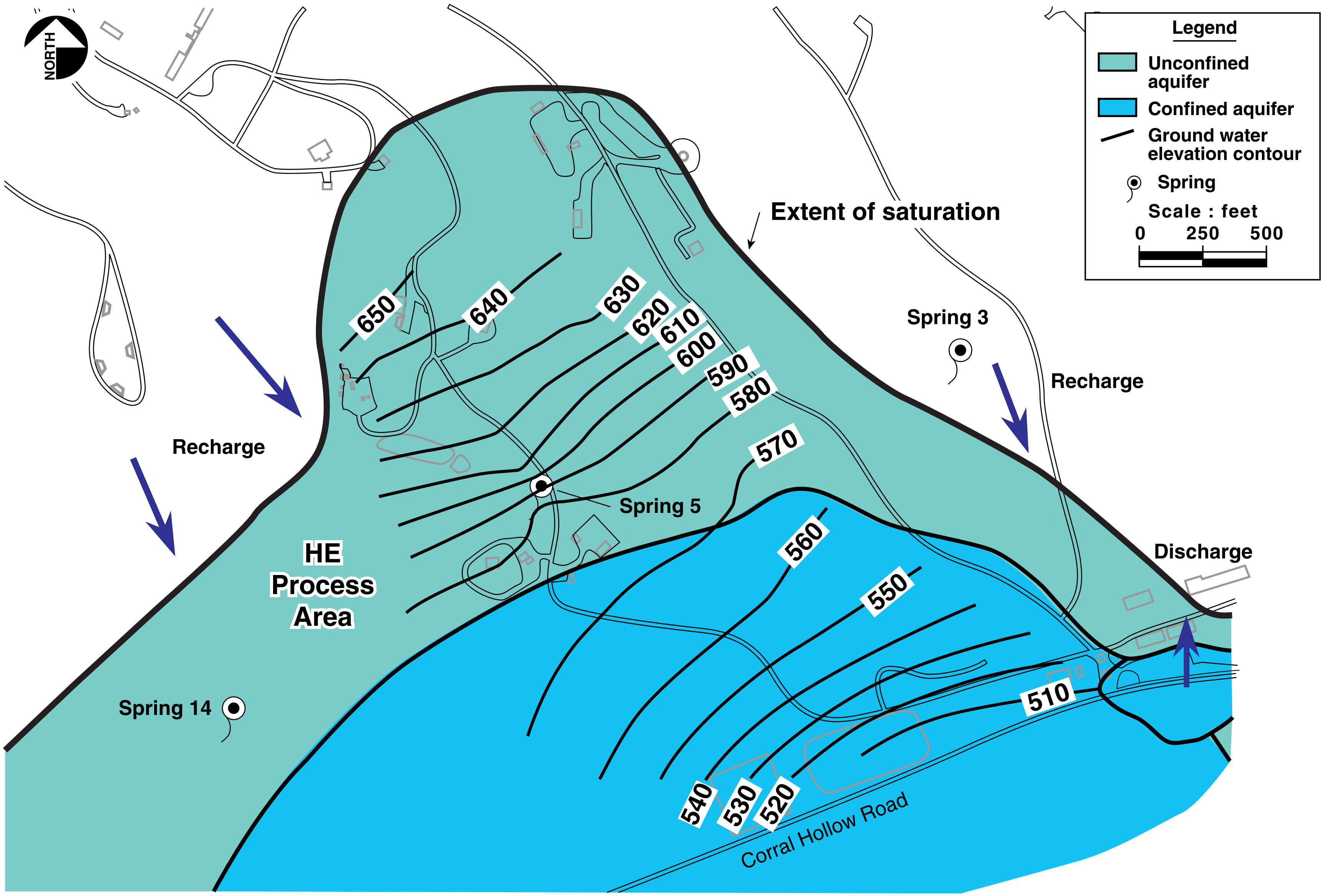

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Figure C-1. Subsurface map of the Tnbs$_2$ aquifer showing recharge/discharge areas, extent of saturation and ground water elevation contours.

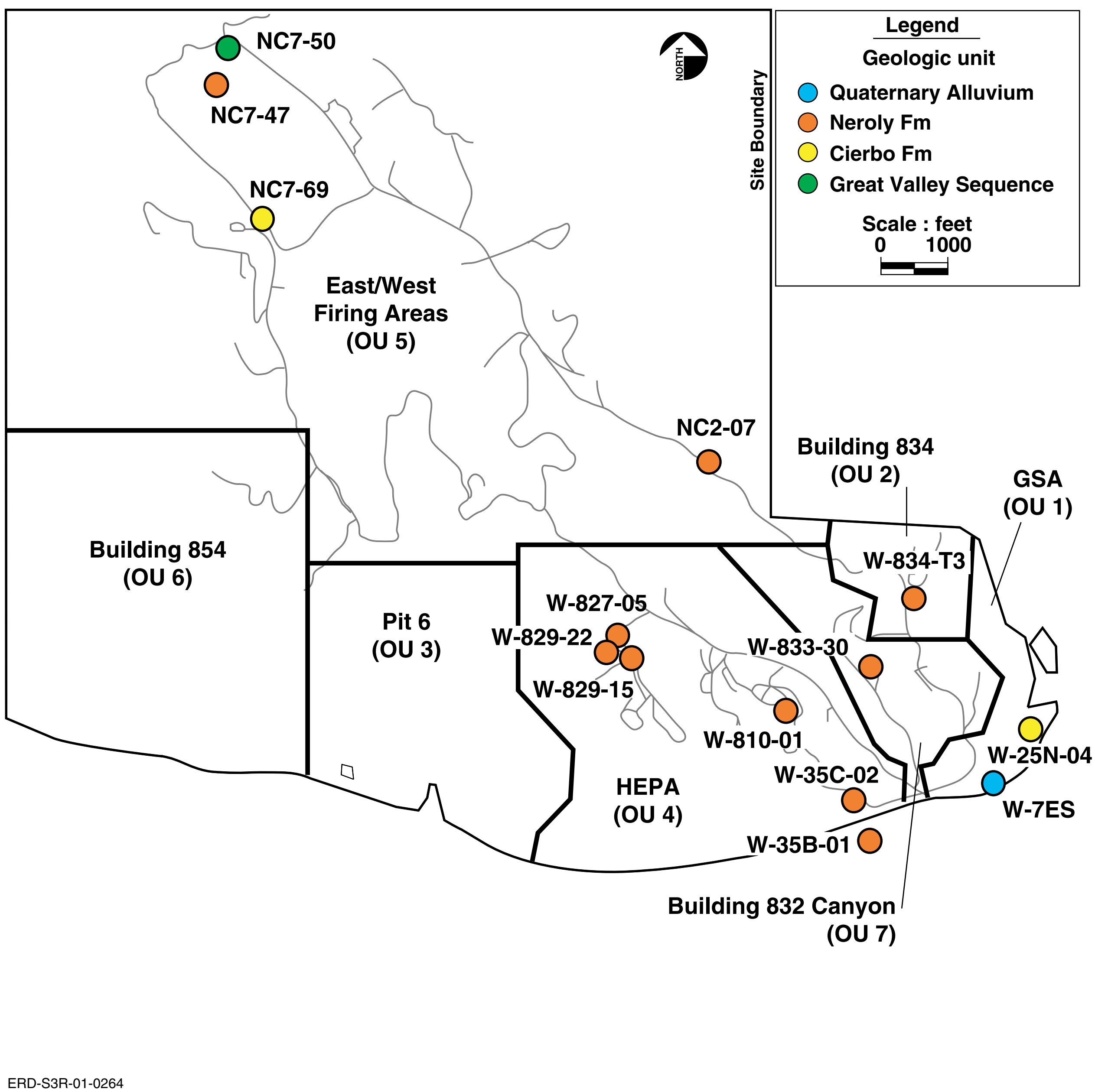

Figure C-2. Location of background wells at Site 300.

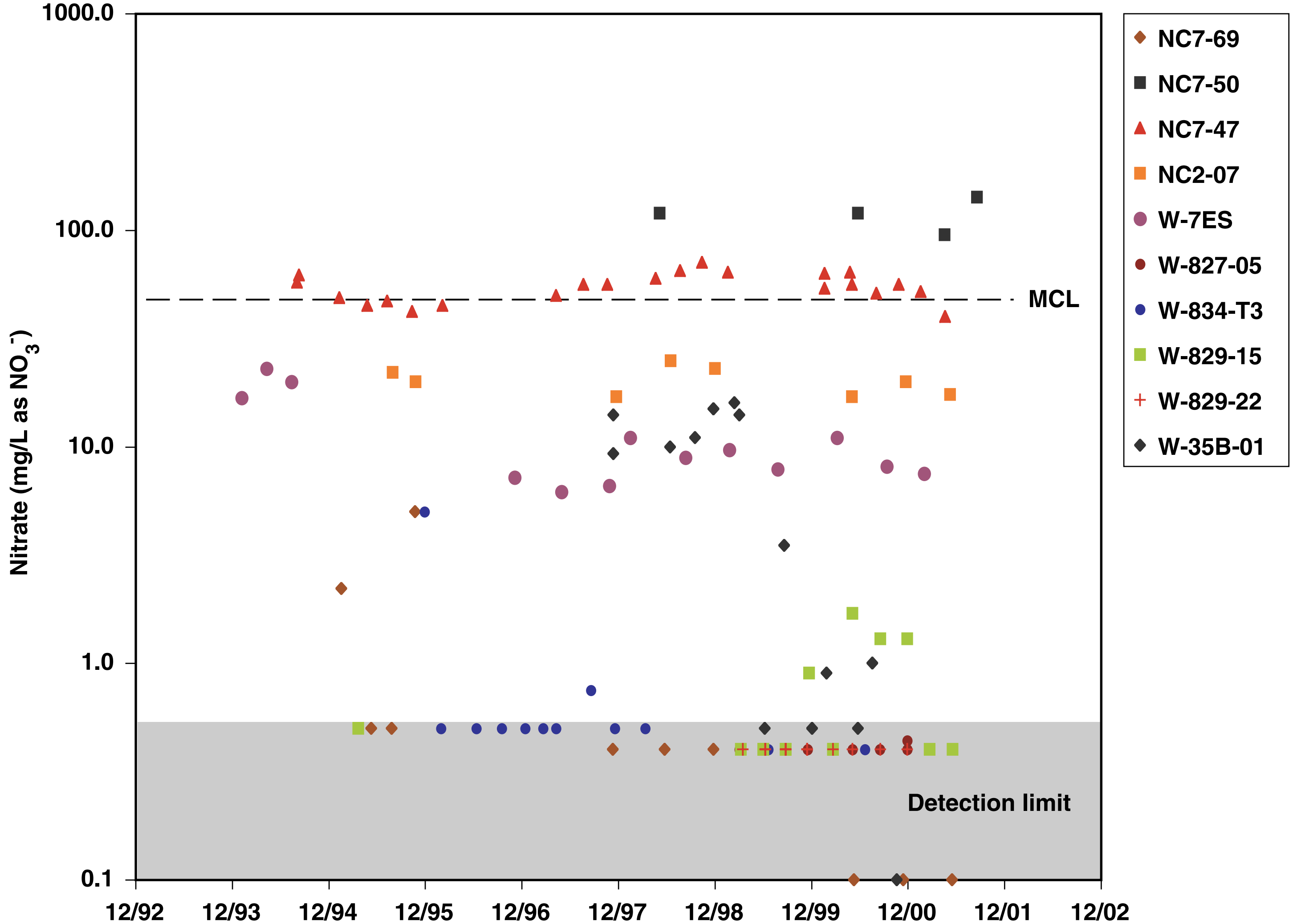

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Figure C-3. Time-series plots of nitrate concentrations in background wells at Site 300. Note: only background wells with 3 or more nitrate samples shown on plot.

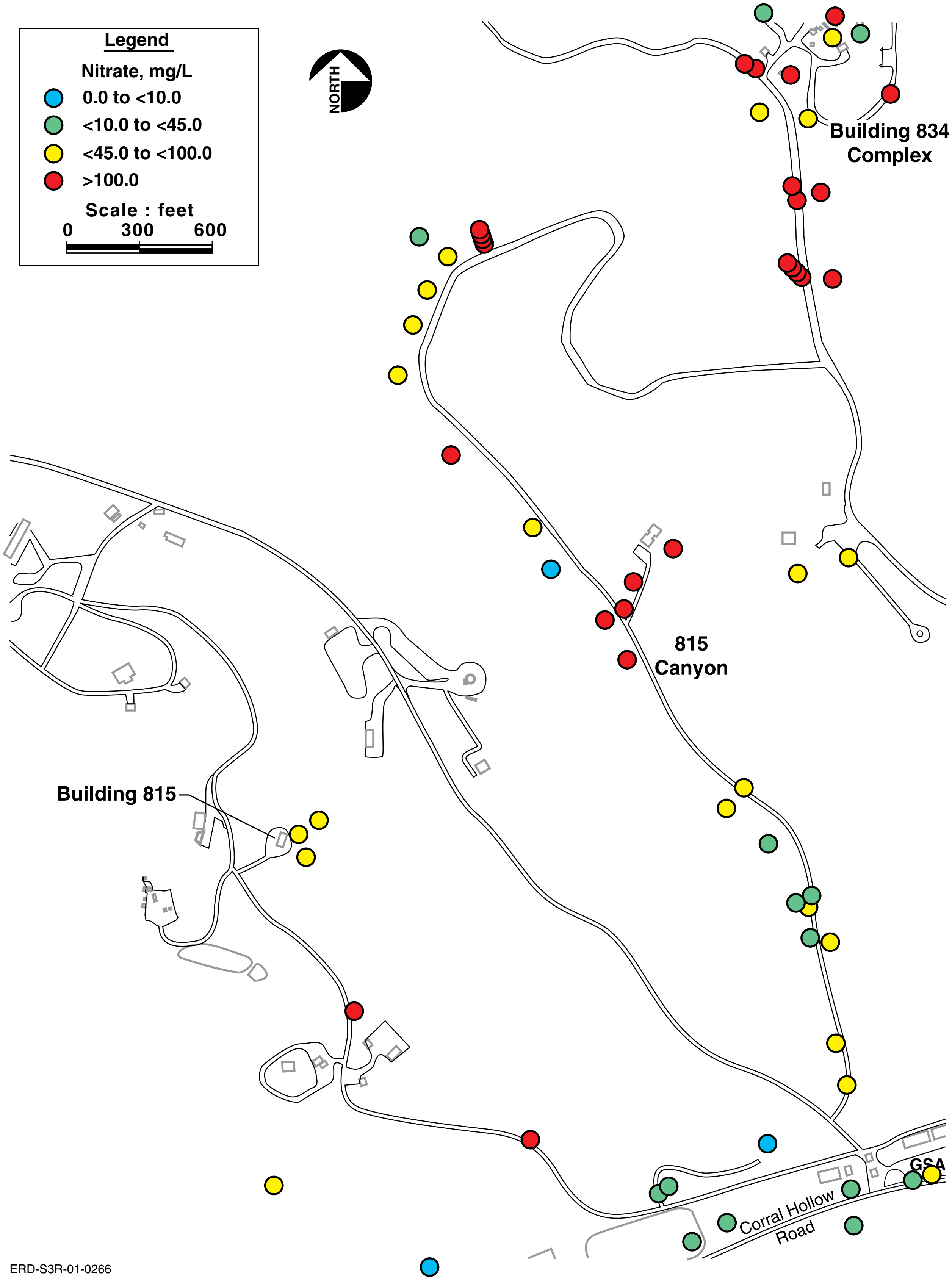

Figure C-4. Nitrate concentrations in ground water above 50 feet.

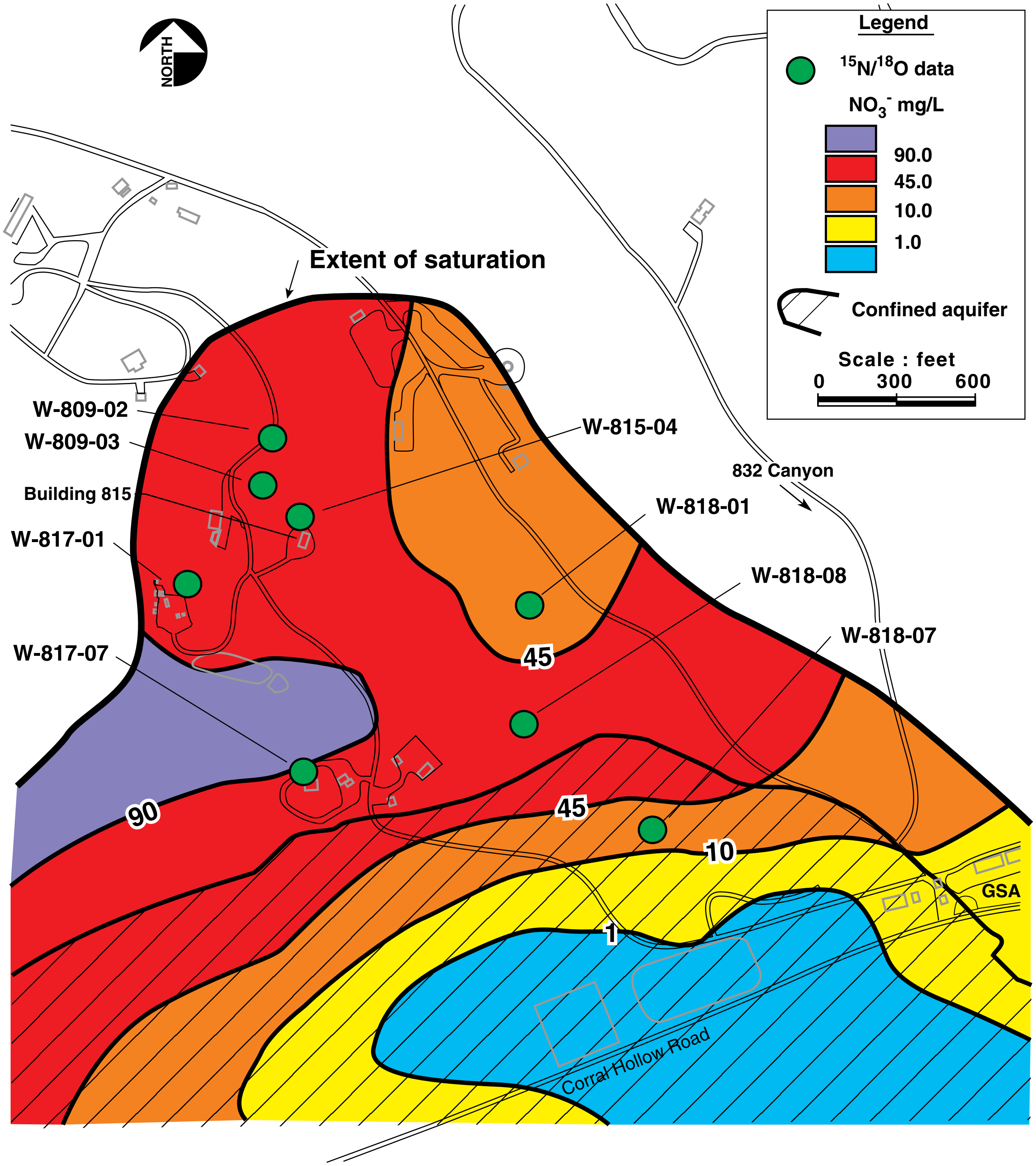

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Figure C-5. Nitrate concentrations in the $Tnbs_2$ aquifer.

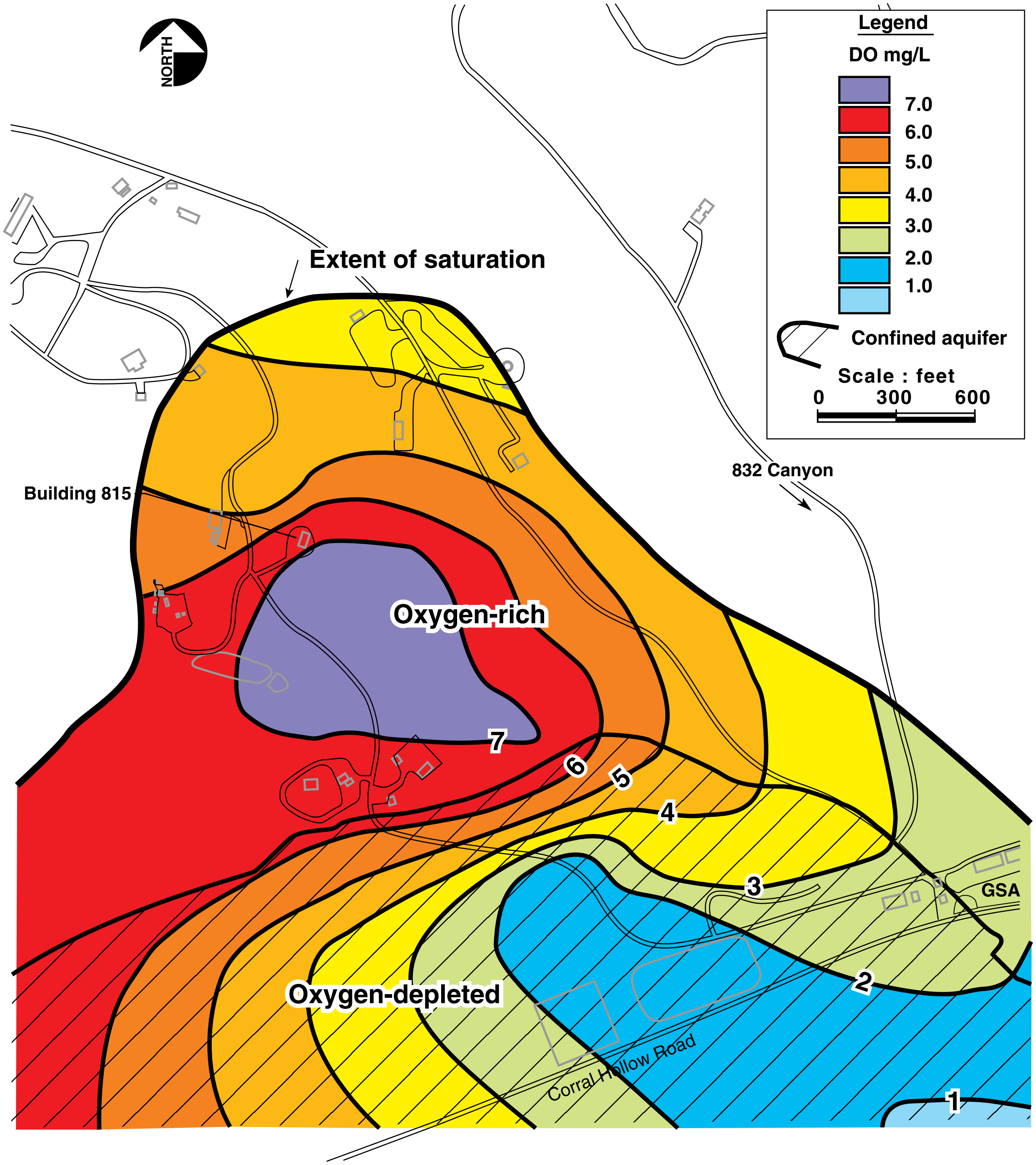

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Figure C-6. Dissolved oxygen in the Tnbs$_2$ aquifer.

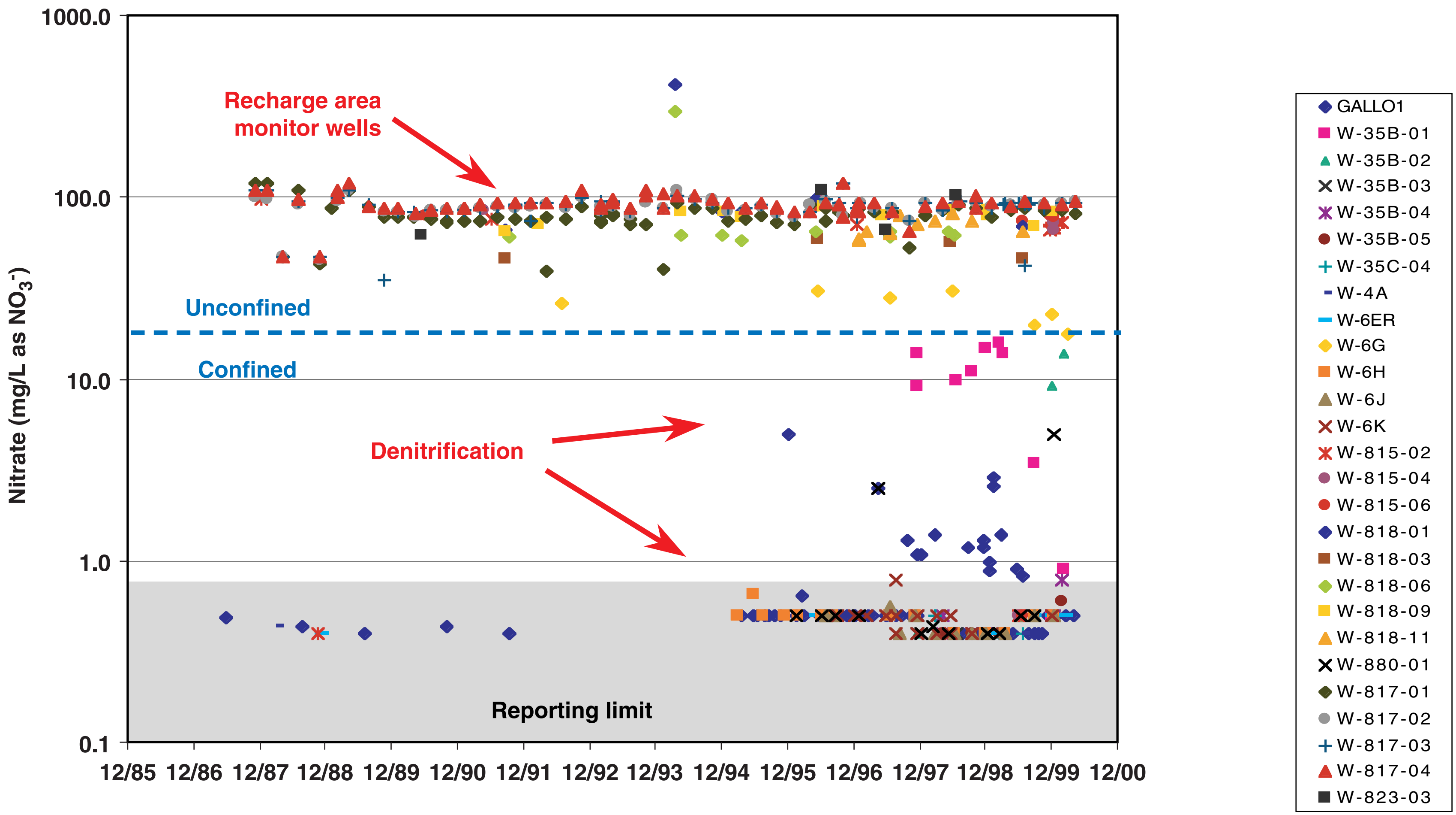

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Figure C-7. Time-series plots of ground water nitrate concentrations for $Tnbs_2$ aquifer wells on HE Process Area.

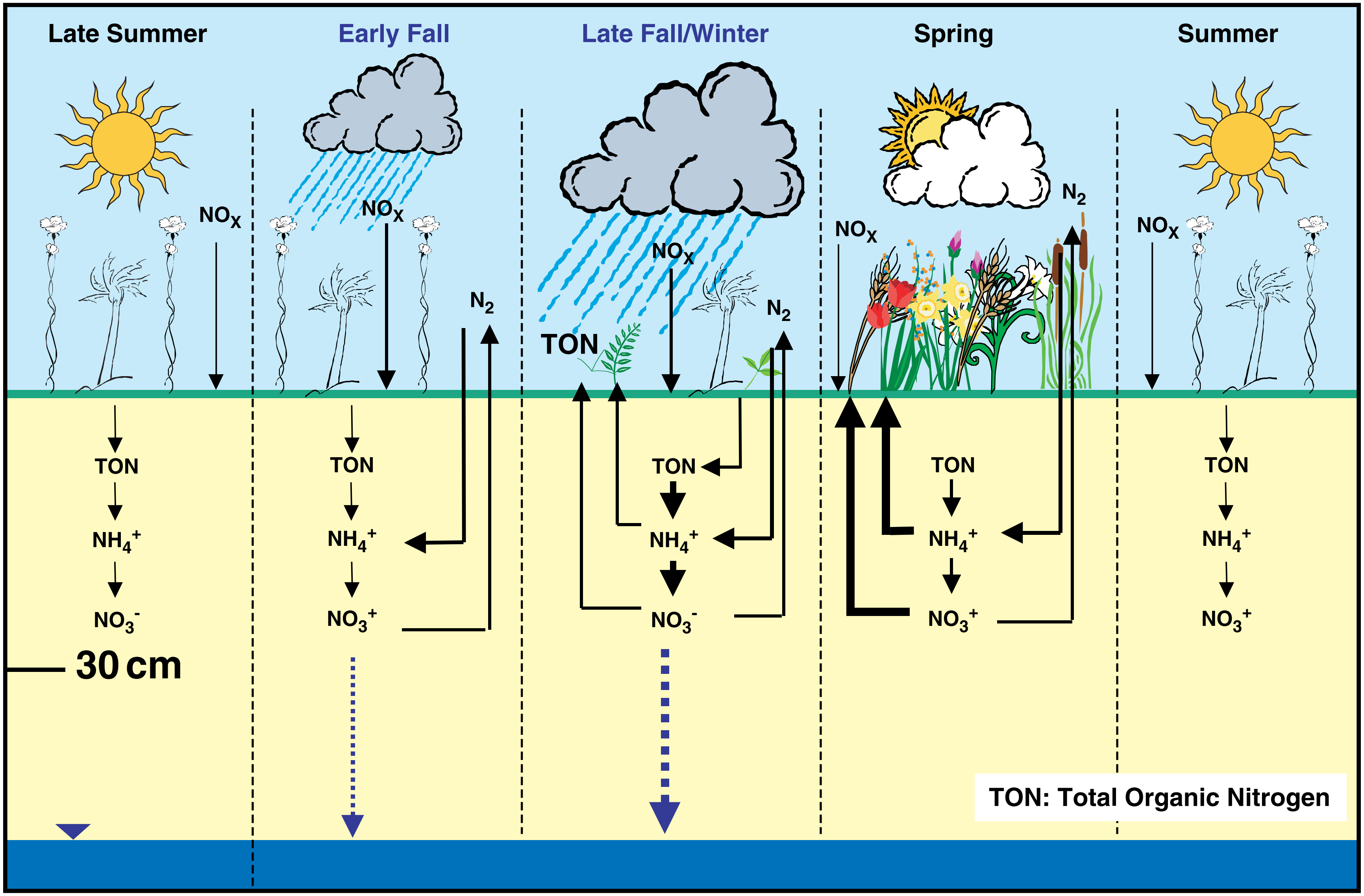

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Figure C-8. Nitrate cycling diagram.

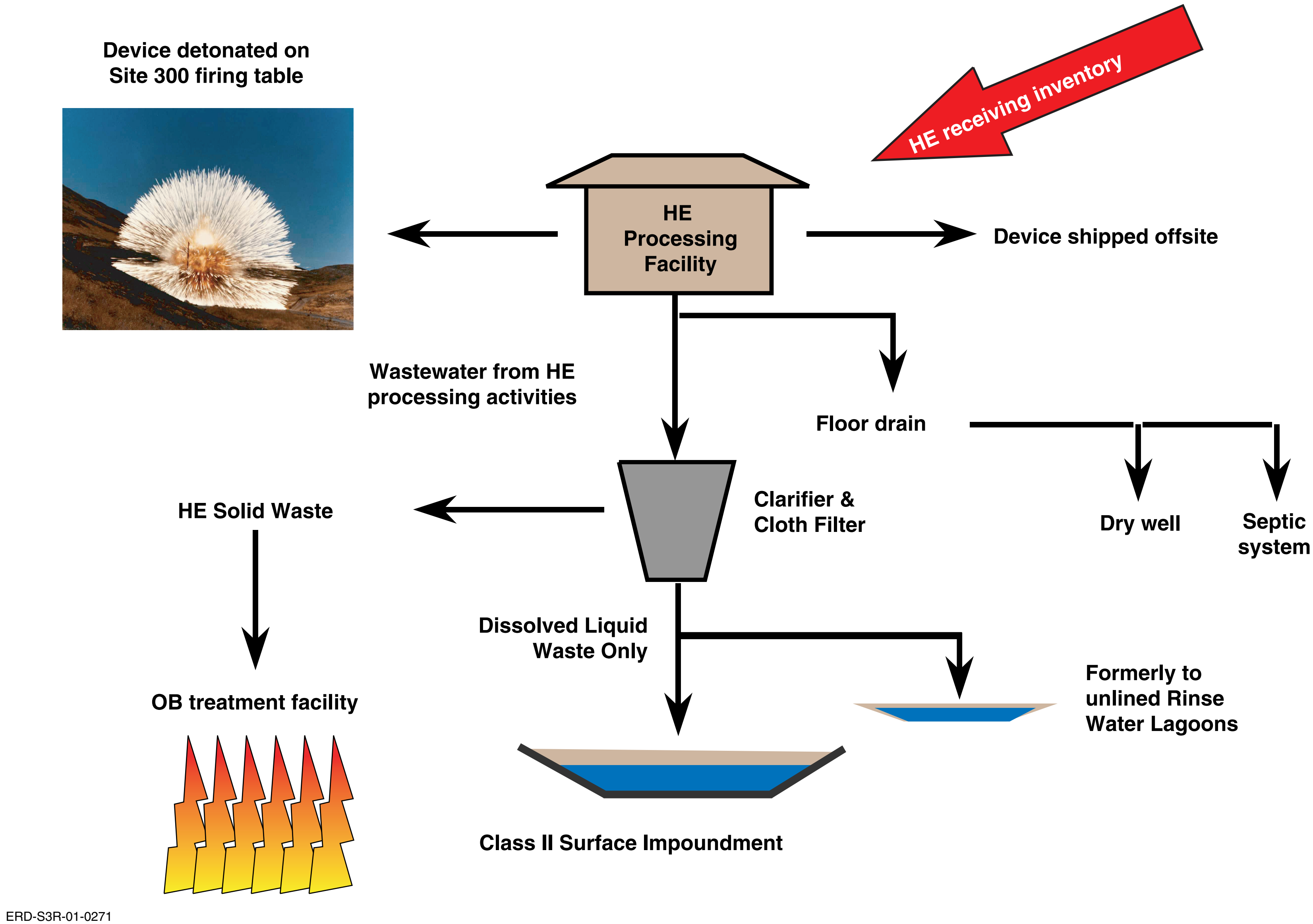
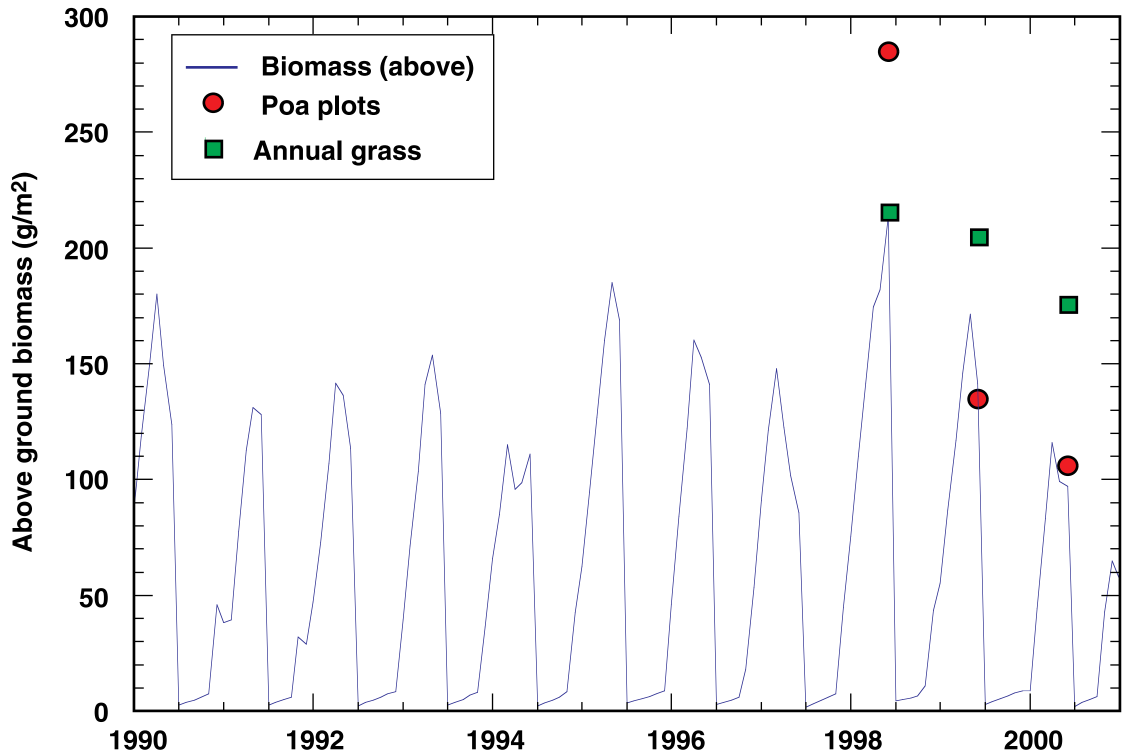


Figure C-9. Waste disposal process at the HE Process Area.



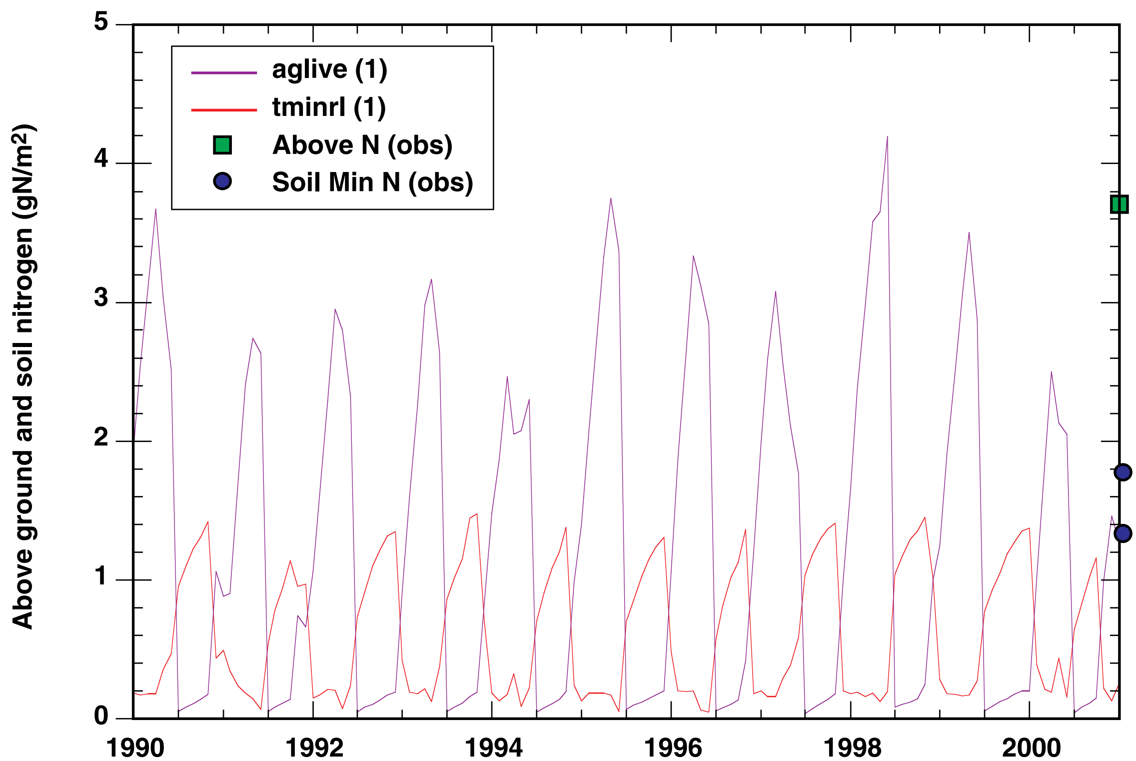


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Figure C-10. Total above-ground plant biomass and above-ground and soil nitrogen generated on a seasonal basis for the past 10 years based on Century model simulations (plotted points represent measured data from Site 300 for comparison).

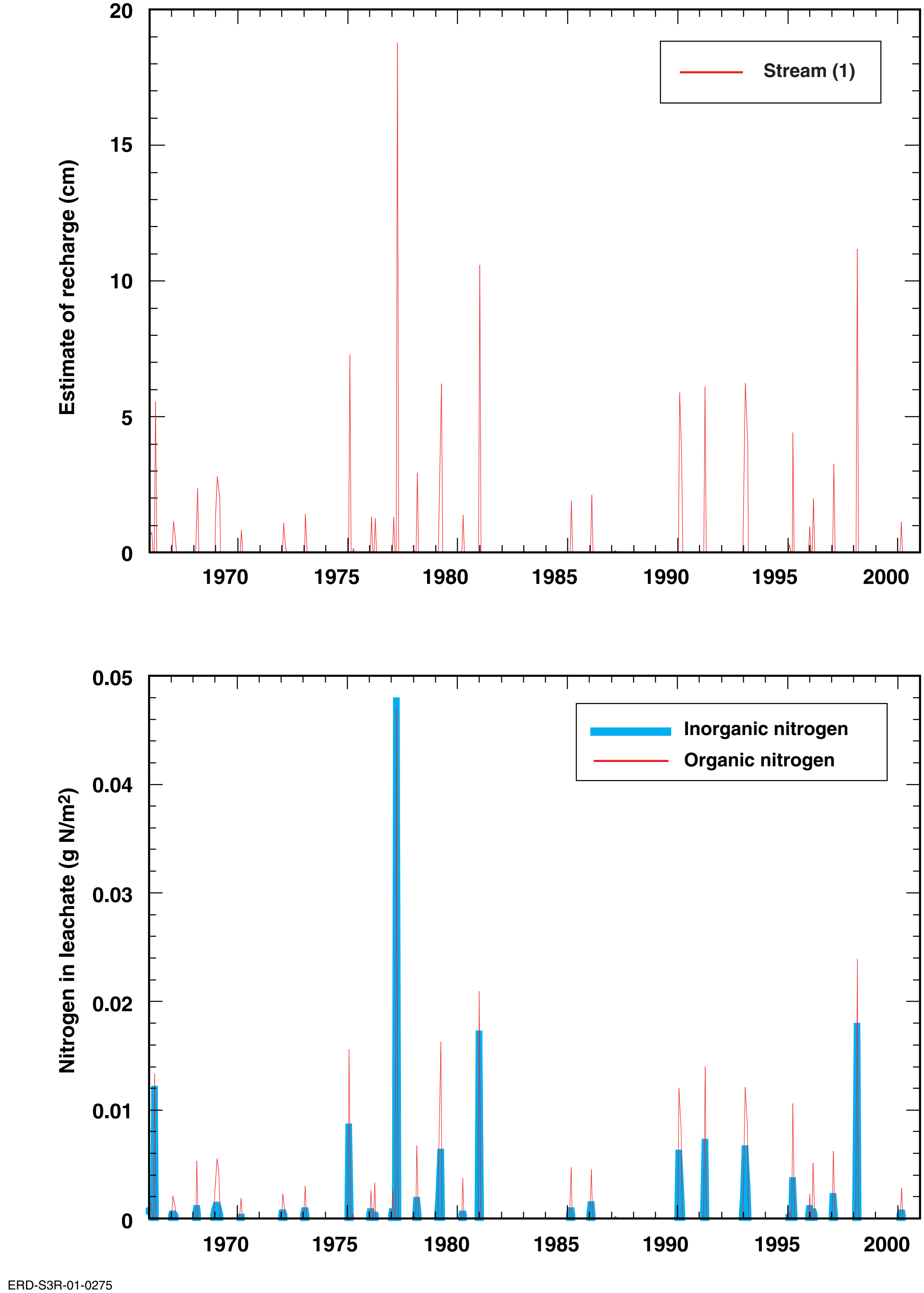

Figure C-11. Estimate of recharge and inorganic and organic nitrogen from plant biomass cycling during the past 30 years based on Century model simulations.

Source zones from Isotope Tracers in Catchment Hydrology,
C.Kendall and JJ McDonnell (Eds.) 1998

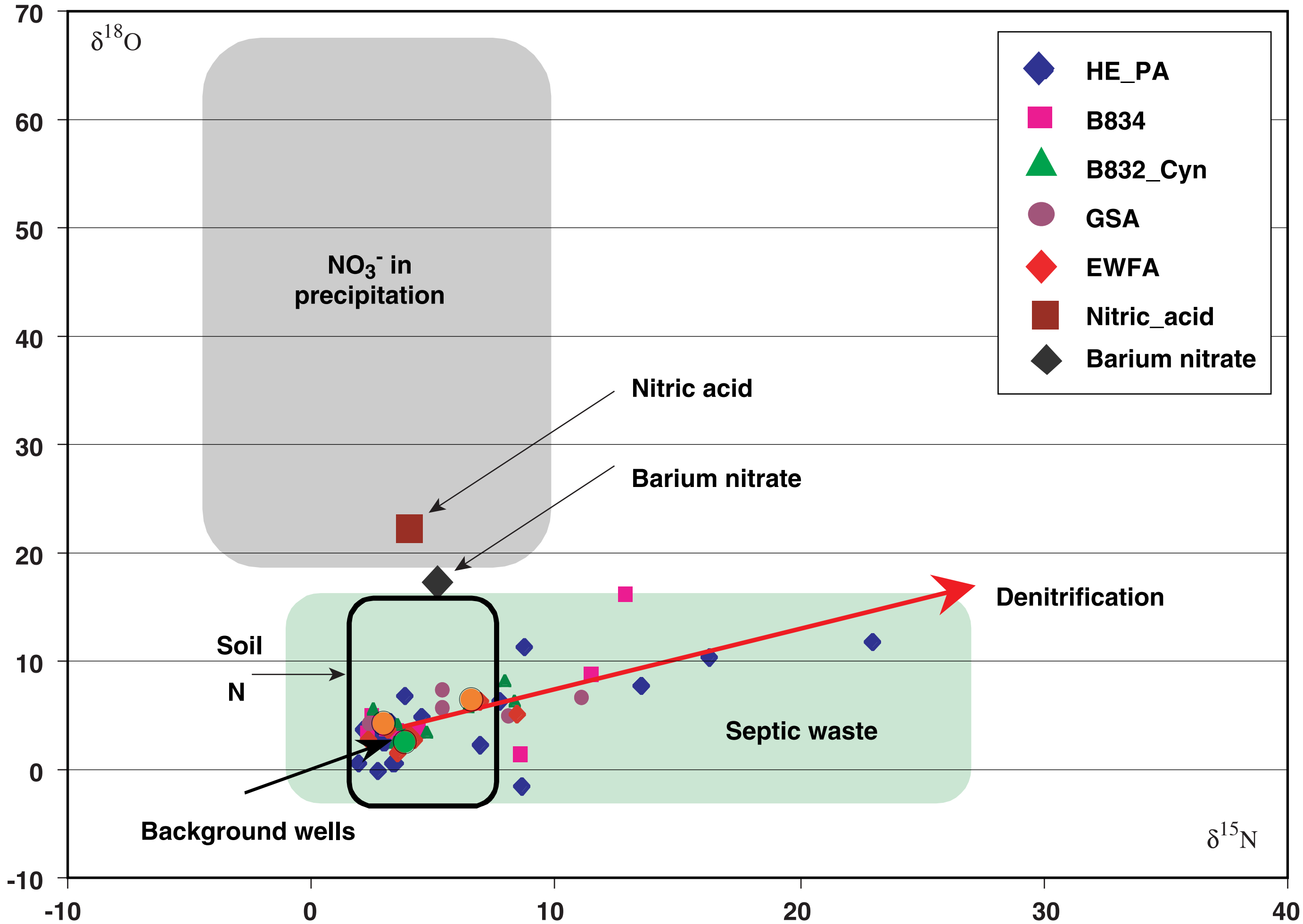

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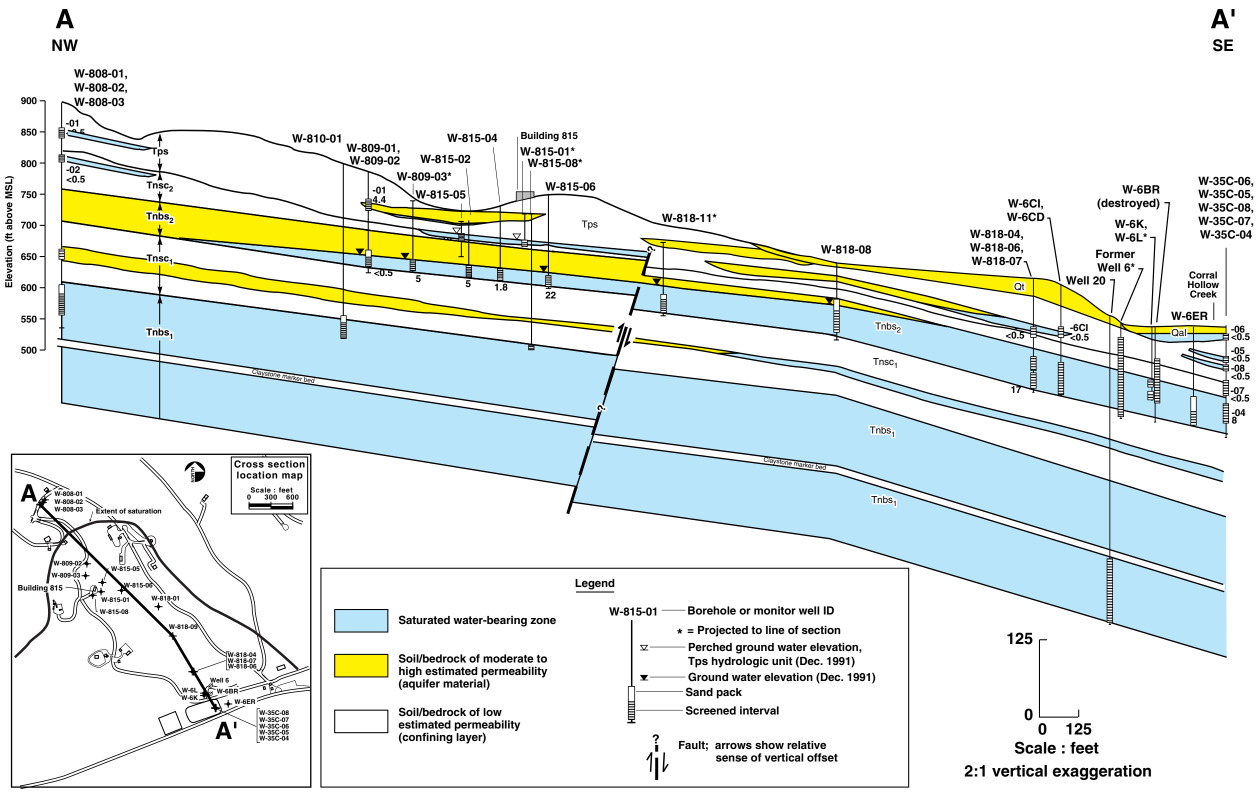
Figure C-12. Stable isotopic analysis of nitrate.



Hydrogeologic cross-section A-A'

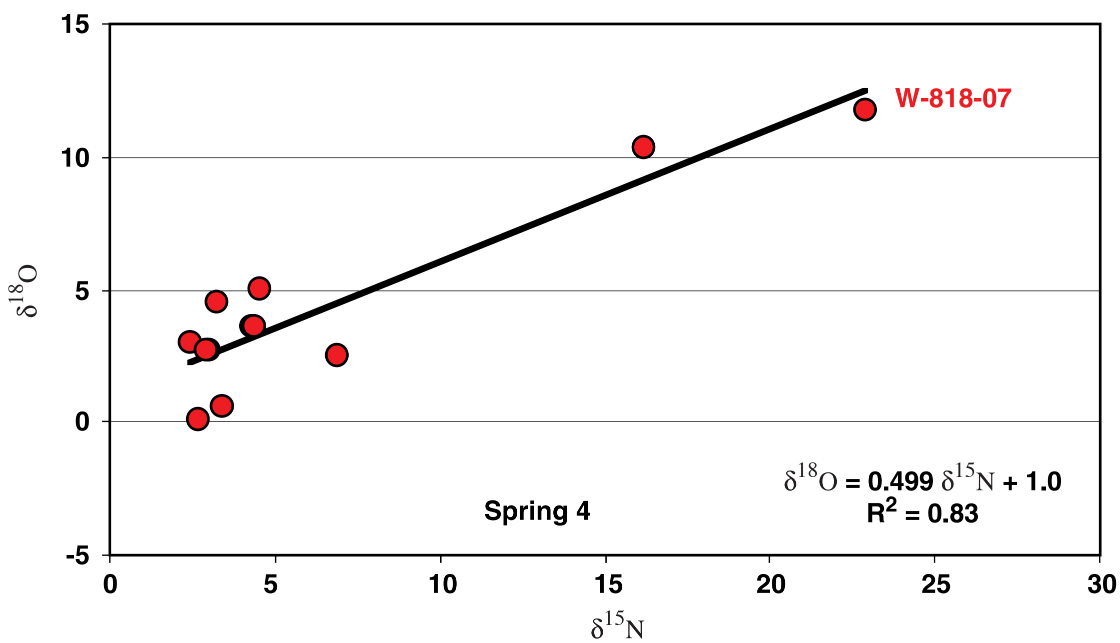


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Figure C-13. ^{15}N and ^{18}O data for wells located along cross section A-A'.

Table C-1. Selected chemistry for Site 300 background wells.

Well ID	Screen depth (ft bgs)	HSU	Nitrate (as NO_3^- mg/L)	Nitrite (as NO_2^- mg/L)	TCE (µg/L)	HMX (µg/L)	RDX (µg/L)	Perchlorate (µg/L)	Tritium (pCi/L)	Aluminum (mg/L)	Barium (mg/L)	Copper (mg/L)	Fluoride (mg/L)	DO (mg/L)	Eh mV	pH units	TDS mg/L
W-7ES	15–25	Qal	6.2–23.0 (14)[a]	<0.500	<0.500	–	–	–	–	<0.200	0.059	<0.050	0.33	7.6	60	7.7	870
W-35B-01	15.5–20.5	Qal	<0.1–16 (18)[a]	0.32	<0.500	<1.000	<1.000	<4.000	<95	<0.050	0.077	<0.010	0.27	–	–	7.7	1,030
NC2-07	91–101	Tnbs$_1$	17.4 –25.0 (11)[a]	–	<0.500	<1.000	<1.000	–	<100	<0.200	0.034	<0.010	0.4	6.2	84	7.8	560
NC7-47	54–64	Tnbs$_1$	11.0–71.0 (25)[a]	–	<0.500	<1.000	<1.000	<4.000	<100	<0.200	0.051	<0.010	0.63	7.2	128	8.2	410
W-35C-02	396.3–496.8	Tnbs$_1$	<0.4–2.4 (3)	–	<0.110	<20	<30	–	<100	<0.200	<0.5	<0.050	0.27	–	–	8.3	820
W-810-01	269.3–289.5	Tnbs$_1$	20 (1)[a]	<0.500	<0.500	<1.000	<0.71	<4.000	3.87	–	0.04	<0.020	–	1.1	-31	7.8	1,300
W-827-05	379.2–408.5	Tnbs$_1$	0.4 (13)[a]	0.102	<0.500	<5.000	<0.8	<4.000	5.34	–	<0.025	<0.010	0.27	–	–	8.0	1,600
W-829-15	382.2–392.2	Tnbs$_1$	<0.4–1.7 (15)[a]	1.6	<0.500	<5.000	<0.8	<4.000	<100	<0.050	0.056	<0.010	0.57	–	–	10.0	850
W-829-22	428–438	Tnbs$_1$	<0.4 (14)[a]	<0.065	<0.500	<5.000	<5.000	<4.000	<100	<0.050	<0.025	<0.010	0.67	–	–	8.4	650
W-833-30	294–314	Tnbs$_1$	<0.4–0.5 (9)[a]	<0.500	<0.500	<5.000	<0.75	<4.000	<130	–	<0.05	<0.050	–	–	–	7.7	460
W-834-T3	320.5–345	Tnbs$_1$	<0.4–2.9 (15)[a]	<0.02	<0.500	<0.050	<0.70	<4.000	–	<0.050	<0.025	<0.010	0.7	2.5	-36	6.6	444
NC7-69	126.1–146.1	Tmss	<0.1 (12)[a]	–	<0.500	<1.000	<1.00	–	<106	<0.200	0.025	<0.010	0.66	–	–	7.5	540
W-25N-04	290–339.2	Tmss	<0.4–2 (2)[a]	–	<0.500	–	–	–	–	–	–	<0.080	–	1.1	-181	8.5	1,500
NC7-50	90–95	GVS	32–160 (7)[a]	–	<0.500	–	–	<4.000	<100	<0.200	<0.025	<0.050	1.41	3.8	108	7.8	3,000

Notes:

– = No data available.
DO = Dissolved oxygen.
Eh = Oxidation reduction potential.
mV = Millivolts.
ft bgs = Feet below ground surface.
GVS = Great Valley Sequence.
HMX = Cyclotetramethylene tetranitramine.
HSU = Hydrostratigraphic unit.
ID = Identification.
µg/L = Micrograms per liter.
mg/L = Milligrams per liter.
pCi/L = Picocuries per liter.
pH = A measure of the acidity or alkalinity of an aqueous solution. pH is the negative logarithm of the hydrogen ion concentration in the solution.
Qal = Quaternary Alluvium.
RDX = Cyclo-1,3,5-trimethylene-2,4,6-trinitramine.
TCE = Trichloroethylene.
TDS = Total dissolved solids.
Tmss = Miocene Cierbo Formation.
Tnbs$_1$ = Miocene Neroly Formation – Lower Blue Sandstone aquifer.

[a] Number of nitrate samples.

Table C-2. HE Process Area nitrate mass comparison.

Type	Description	Mass (tons)	Mass estimate (kg)
Ground water	Nitrate mass in $Tnbs_2$ aquifer	100	90,718
Geologic	Exchangeable nitrate in soil within $Tnbs_2$ catchment	186	163,293
Plant biomass	Nitrate leached to ground water from plant biomass over 100 years	12	10,886
Sewage	Nitrate generated from sewage over 40 years	16	14,514
HE inventory	Total inventory of nitrogenous chemicals received at Site 300 (1955 to present)	150	136,077

Notes:

HE = High explosives.
Kg = Kilogram.
$Tnbs_2$ = Miocene Neroly Formation – Upper Blue Sandstone aquifer.

Appendix D

Construction Quality Assurance/ Quality Control Plan

Appendix D

Construction Quality Assurance/ Quality Control Plan

D-1. Introduction

This Quality Assurance/Quality Control (QA/QC) Plan has been developed in support of the construction and buildout of the High Explosives (HE) Process Area Operable Unit (OU) ground water extraction and treatment systems and extraction wellfield. Some of these facilities have already been constructed as part of the Building 815 Removal Action. As such, this plan will apply only to wellfield expansion and future construction of ground water treatment facilities.

The purpose of this plan is to define quality objectives and areas of responsibility in accordance with the requirements for the construction and buildout of LLNL extraction and treatment facilities. This plan has been developed to comply with Lawrence Livermore National Laboratory (LLNL) QA policy and to address the applicable elements of U.S. Department of Energy (DOE) Order 414.1A.

The QA/QC objectives are to:

- Assure excellence in construction design and implementation, and
- Provide the QA/QC requirements to meet all programmatic and institutional needs.

The QA/QC Plan provides confidence that these objectives will be achieved and that achievement will include due consideration for health, safety, property, and the environment.

D-2. QA/QC Processes and Procedures

Detailed QA/QC processes and procedures for construction activities are addressed in one or more of the following documents, which are incorporated by reference into this plan:

- U.S. Department of Energy (DOE) Order 414.1A, Quality Assurance Program (DOE, 1999).
- Lawrence Livermore National Laboratory (LLNL) Environmental Protection Department (EPD) Quality Assurance Management Plan (QAMP) (LLNL, 2001).
- LLNL Site 300 Environmental Restoration Project Quality Assurance Project Plan (QAPP) (Dibley, 1999).
- LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs) (Dibley and Depue, 2000).
- LLNL Construction Manager Manual - Subcontracted Construction Projects, Plant Engineering Department (LLNL, 1989).

- LLNL Construction Inspectors Policy and Procedure Manual, Plant Engineering Department (LLNL, 1990).

Table D-1 shows the 10 elements of the EPD QAMP, which implements DOE Order 414.1A, and their applicability to any future construction related activities for the HE Process Area OU ground water extraction and treatment systems. The Construction QA/QC Plan follows the Environmental Restoration Project QAPP approved by the U.S. Environmental Protection Agency (EPA).

D-3. Organization

This section documents the organizational structure, functional responsibilities, and lines of communication for those aspects of construction related activities for the HE Process Area OU ground water extraction and treatment systems that affect quality.

Figure D-1 shows the organizational structure for construction QA/QC activities. The descriptions below generally describe the QA/QC responsibilities of those involved in carrying out the QA/QC program for the construction of the HE Process Area OU ground water treatment systems. Project personnel as shown in Figure D-1 have the following responsibilities:

- The U.S. DOE is the Principal Responsible Party for Comprehensive, Environmental Response, Compensation and Liability Act (CERCLA) related activities at the LLNL Site 300. Environmental restoration activities at Site 300 are conducted by University of California staff in the LLNL Environmental Restoration Division (ERD), hereafter referred to as LLNL, under the direction of the DOE Site 300 Remedial Project Manager (RPM). The DOE RPM coordinates these activities through the U.S. Environmental Protection Agency, and California Department of Toxic Substances Control and the Regional Water Quality Control Board RPMs.
- The LLNL Environmental Protection Department (EPD) Quality Assurance Manager provides oversight and monitors QA related activities of divisions within the EPD, including ERD. The Quality Assurance Manager reports the results of quality verification to the EPD Department Head who, in turn, relays this information to DOE.
- The LLNL ERD Division Leader is responsible for implementing the EPD and ERD QA programs as it relates to activities in the division and ensuring that nonconforming conditions are promptly addressed and documented. The ERD Division Leader reports to both the EPD Department Head and to DOE.
- The LLNL ERD Site 300 Project Leader is responsible for ensuring that approved procedures related to QA are used during activities in the project and division and ensuring that nonconforming conditions are promptly addressed and documented. The Site 300 Project Leader issues the QA/QC plan and periodically reviews its implementation. The Site 300 Project Leader reports to the ERD Division Leader on QA conformance and other QA-related issues.
- The LLNL ERD Quality Assurance Implementation Coordinator is responsible for the development and implementation for the QA/QC plan, establishment and control of the applicable QA/QC requirements, 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 Quality Assurance Implementation Coordinator maintains direct communication and liaison with the EPD Quality Assurance Manager and has line authority through the ERD Division Leader for the implementation of the QA Program within the division.

- The LLNL Quality Assurance Engineer is responsible for providing direction to the Subproject Leader, Remediation Engineer, and Technician Supervisor in the selection and installation of the equipment and remediation systems to meet QA objectives and ensuring that construction meets design criteria specified in the design documents. The Quality Assurance Engineer reports directly to the Quality Assurance Implementation Coordinator on construction QA/QC related activities.

  The Quality Assurance Implementation Coordinator and Quality Assurance Engineer constitute the independent quality assurance reviewers as defined in the EPD Quality Assurance Management Plan. The Quality Assurance Management Plan requires that design/technical reviews are conducted by competent, independent reviewers other than those involved in the original design activity although they may be from the same organization. Additional QA audits of ERD activities are regularly conducted by DOE. The ERD Division Leader may assign an outside (non-LLNL), independent QA team as appropriate (i.e., when the necessary technical expertise to conduct design review is not available within the LLNL organization).

- The LLNL Subproject Leader is responsible for coordinating facility construction. The Subproject Leader reports directly to the Site 300 Project Leader.

- The LLNL Remediation Engineer is responsible for writing design criteria for equipment and flow rates to treat water, as well as providing oversight for construction activities. The Remediation Engineer is the equivalent to the Remedial Design Engineer. The Remediation Engineer reports to the Subproject Leader regarding facility design and construction.

- The LLNL Plant Engineering Project Manager (PEPM) is responsible for coordinating Plant Engineering activities, if any. The PEPM reports functionally during any assigned construction activities to the ERD Site 300 Project Leader and the Subproject Leader. The PEPM is Plant Engineering's primary contact with ERD for the assigned project. He/she is responsible for coordinating and executing the project assigned to him/her.

- The LLNL ERD Technician Supervisor is responsible for the supervision and oversight of day-to-day construction activities. The Technician Supervisor is the equivalent to the Remedial Action Constructor. The Technician Supervisor reports to the Subproject Leader regarding construction-related activities.

D-4. Training and Qualifications

Personnel supporting Environmental Restoration Projects are trained to ensure that they have the skills and knowledge necessary to perform their work assignments in a safe, competent, uniform, and environmentally sound manner. Technicians performing construction activities comply with the EPD's Training Management Plan, the Safety and Security Directorate Training

Implementation Plan, and the LLNL Training Program Manual. In addition to the regulatory driven training such as hazardous waste operations and emergency response certification, Superfund Amendments and Reauthorization Act/Occupational Safety and Health Administration (SARA/OSHA), and the Environment, Safety, and Health courses provided by LLNL, technicians also receive on-the-job training for their specific work tasks. All training is tracked and recorded by the EPD Training Section.

D-5. Quality Improvement

ERD technicians integrate quality improvement into all construction activities by communicating to management, per the requirements of SOP 4.12, Quality Improvement Forms, any unsafe practice or nonconforming item or process (e.g., faulty material, malfunctioning equipment, process defects, data irregularities, and deviations from standard operating procedures) that could potentially compromise worker safety or the activity's deliverable. The technicians also identify and communicate methods to improve quality or achieve greater efficiency of the treatment facilities or associated extraction system under construction.

D-6. Construction

D-6.1. Identification and Control of Items

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

The Technician Supervisor will request identification and inspection of items arriving at the construction site, when required. Acceptance of items or materials not in conformance with the design requirements shall be approved by the Project Manager and QA Engineer.

D-6.2. Inspection, Test, and Operating Status

The Technician Supervisor and Remediation Engineer shall maintain cognizance of incoming and stored materials and items and inspect or test them for conformance to requirements, as necessary. They shall tag rejected items to ensure that they are not inadvertently used.

Lockout tags shall be tied on electrical equipment, lifts and hoists, valves, etc. where such items (1) are unsafe to use, (2) are uncertified, or (3) may pose a risk to personnel working on the system.

D-6.3. Design Changes

If during the course of construction, design changes are necessary, these changes must be controlled in accordance with the following requirements:

- Changes to final designs, field changes, and nonconforming items dispositioned "use as is" or "repair" must be justified and must be subject to design control measures commensurate with those applied to the original design.
- Design control measures for changes must include provisions to ensure that the design analyses for the item are still valid.

- Changes must be approved by the same groups or organizations that reviewed and approved the original design documents.
- If a significant design change becomes necessary because of an incorrect original design, the design process and design verification methods and implementing procedures must be reviewed and modified, as appropriate. These design deficiencies must be documented according to the requirements provided using the organization's nonconformance reporting process.
- Field changes must be incorporated into the applicable design documents.
- Design changes that affect related implementing procedures or training programs must be communicated to the appropriate organizations.

D-6.4. Inspection

All construction work is subjected to inspection. The QA Engineer shall notify the Subproject Leader and Remediation Engineer if the work does not meet design criteria or quality requirements. After construction, the QA Engineer shall verify the accuracy of the as-built drawings to the final constructed facility.

D-7. Activation

D-7.1. System Check

Prior to operating the modified ground water treatment facility with contaminated ground water, a system check will be conducted to confirm the proper construction and operation of the treatment system. The following minimum requirements apply to this system check phase:

- A conformance inspection will be conducted to confirm that all equipment, piping, instrumentation, and control systems of the ground water treatment system have been installed according to the approved design. Any deficiencies in the ground water treatment system will be corrected.
- To confirm piping integrity, piping of the collection system and treatment system will be tested. Any leaks will be repaired.
- All instrumentation, control systems, and equipment will be inspected for malfunctions. All automatic controls, such as shutdown or alarm switches necessary for the operation of each treatment system phase, will be inspected for operational readiness prior to startup of that phase. Mechanical equipment, such as pumps and valves, required for the operation of the treatment phases, will be cycled or operated. Any functional deficiencies will be corrected.

D-7.2. Proof-of-System Check

After the system check has been conducted and any deficiencies corrected, a proof-of-system check will be conducted to ensure that the extraction wellfield and replacement treatment system will remove and treat contaminated ground water to meet regulatory effluent discharge limits. The proof-of-system check will consist of the following elements:

- The proof-of-system check will last long enough to demonstrate that contaminated ground water has been extracted from each extraction well and has been treated by the treatment system to meet effluent discharge limitations.
- Each of the new extraction wells will be pumped long enough to confirm that the ground water pumps and water level shutoff devices operate properly.
- The treated ground water will be analyzed for volatile organic compounds, RDX, nitrate, and perchlorate, as appropriate, after passing through the treatment system. (Not all of these contaminants will be contained in the influent to different treatment systems.)
- If analysis show that ground water concentrations are above the effluent discharge limitations, the ground water will receive further treatment until the concentrations reach regulatory standards.
- All treatment, transport, and disposal components (including pumps, valves, liquid level controllers, pipelines, flow meters, pressure gauges, etc.) will be inspected for leaks and/or malfunctions. In addition, the system's automatic controls will be inspected for operational readiness. All mechanical equipment will be operated under load to assure proper performance. Any deficiencies will be corrected.

D-7.3. Proof-of-System Monitoring

Proof-of-system monitoring will be conducted to characterize changes to the treatment system influent and effluent stream as a result of connecting new extraction wells, to determine the treatment efficiencies of new ground water treatment facilities, and to monitor the performance of the new extraction wells.

During the proof-of-system monitoring, the following analyses or measurements will be conducted:

- Total volume of water extracted from each new extraction well.
- Water levels in the new extraction wells.
- Total volume of water treated.
- Analysis of treatment system effluent samples for volatile organic compounds, RDX, nitrate, and perchlorate, as appropriate, as well as electrical conductivity, pH, and temperature. (Not all of contaminants will be contained in the influent to different treatment systems.)

The quality of the data generated as part of the proof-of-system testing will be assessed following the data quality assessment procedures outlined in Section 3.1.3 and Section 4 (Data Validation and Usability) of the ERD QAPP (Dibley, 1999).

D-7.4. Measuring and Testing Equipment Calibration and Verification

All Measuring and Test Equipment used in acceptance testing of electronic, monitoring, and interlock systems and items will be calibrated in accordance with the applicable LLNL or manufacturer's calibration manual. The individual conducting the test will be responsible for assuring that all test equipment is calibrated and within its certification period.

D-8. References

Dibley, V. (March 1999), *Environmental Restoration Division, Quality Assurance Project Plan, Livermore Site and Site 300 Environmental Restoration Projects*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-103160 Rev. 2).

Dibley V., and R. Depue (Eds.) (2000), *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)*, Lawrence Livermore National Laboratory, Livermore Calif. (UCRL-MA-109115 Rev. 8).

LLNL (July 2001), *Environmental Protection Department (EPD) Quality Assurance Management Plan (QAMP), Rev. 5.*, Lawrence Livermore National Laboratory, Livermore, Calif.

LLNL (1989), Construction Manager Manual - Subcontracted Construction Projects, Plant Engineering Department.

LLNL (1990), Construction Inspector's Policy and Procedure Manual, Plant Engineering Department.

U.S. DOE (1999), DOE Order 414.1A, Quality Assurance Program, Office of Nuclear Safety Policy and Standards.

Table D-1. Applicability of the EPD QAMP elements to the construction of HE Process Area OU ground water treatment systems and wellfield buildout.

EPD QAMP requirement	Title	Applicable ?
Element 1	EPD Quality Assurance Program Description	Yes
Element 2	Training and Qualification	Yes
Element 3	Quality Improvement	Yes
Element 4	Document and Records	Yes
Element 5	Work Processes	Yes
Element 6	Design Control	Yes
Element 7	Procurement	Yes
Element 8	Inspection and Acceptance Testing	Yes
Element 9	Management Assessment	Yes
Element 10	Independent Assessment	Yes

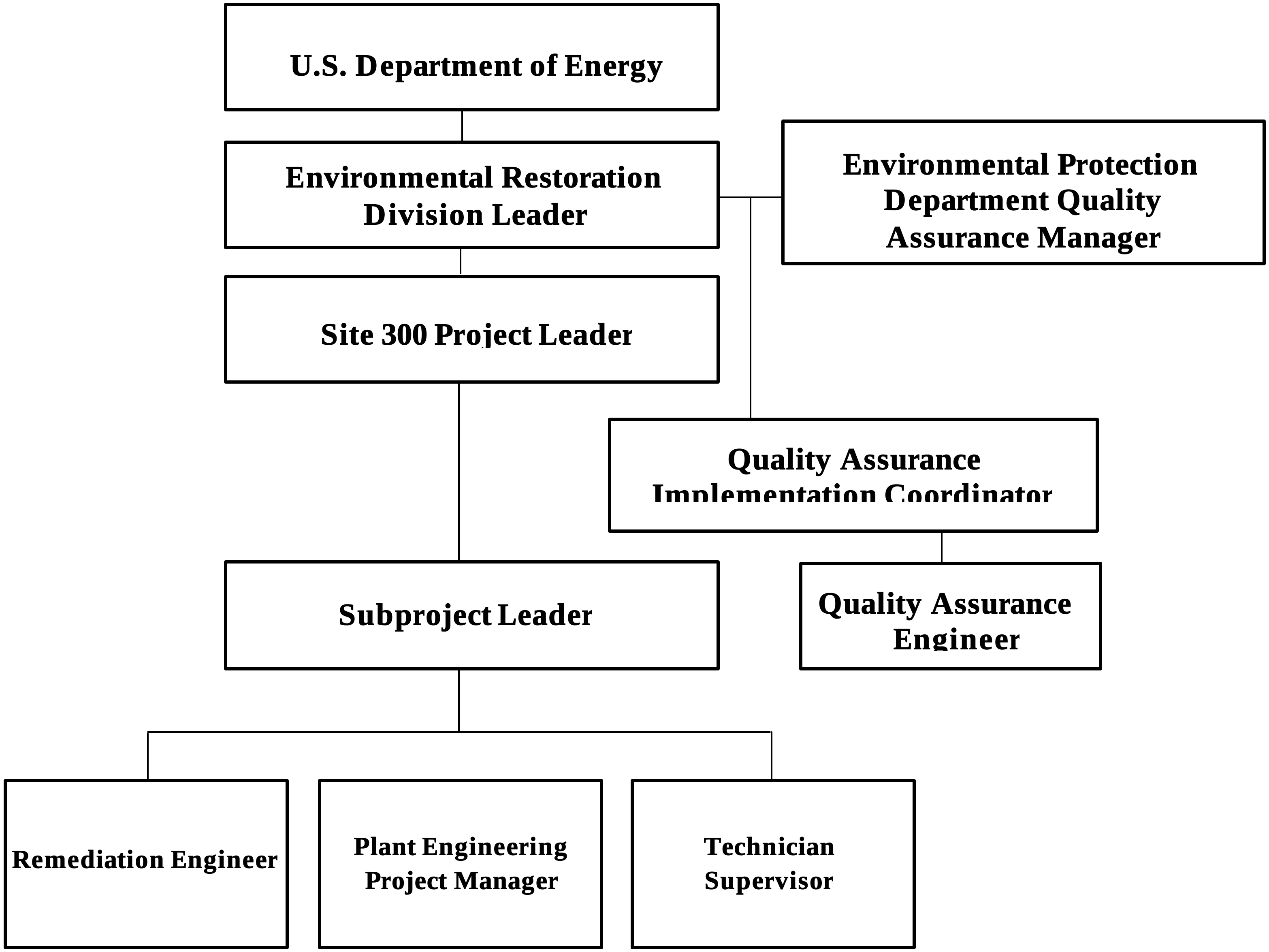

Figure D-1. Organizational structure for construction QA activities.

Appendix E

Construction Health and Safety Plan

Appendix E
Construction Health and Safety Plan

This Appendix contains the Construction Health and Safety Plan for the High Explosives (HE) Process Area Operable Unit (OU) Remedial Action.

E-1. Reason for Issue

Safety procedures are required to construct the HE Process Area OU remedial action. This Health and Safety Plan also serves as an administrative tool to summarize many of the requirements that are pertinent to the HE Process Area OU treatment facility construction. Some treatment facilities have already been constructed as part of the Building 815 Removal Action. This plan will apply only to wellfield expansion and future construction of ground water extraction and treatment facilities. Any potential health and safety hazards and the control of such hazards during construction are addressed in one or more of the following documents:

- Lawrence Livermore National Laboratory (LLNL) Environment, Safety, and Health Manual (LLNL, 2000).
- LLNL Environment, Safety, and Health Manual, Supplement 1.11 - Construction Subcontractor Safety Program (LLNL, 2000).
- LLNL Environmental Restoration Division (ERD) Site Safety Plan for Lawrence Livermore National Laboratory Comprehensive, Environmental Response, Compensation and Liability Act (CERCLA) Investigations at Site 300 (LLNL, 2000).

The requirements of the LLNL Environmental Safety and Health (ES&H) Manual are based on DOE's Integrated Safety Management System Principles and Work Smart Standards.

E-2. Work to be Done and Location of Activity

E-2.1. Location of Treatment Facilities

The HE Process Area OU is located in the southeast part of LLNL Site 300. Two ground water treatment facilities have already been constructed and are operating at present. One treatment facility (B815-SRC) is located in the Building 815 Source Area south of Building 815. A second treatment facility (B815-DSB) is located at the leading edge of the volatile organic compound (VOC) plume at the site boundary, west of the entrance to Site 300. Three additional treatment facilities are scheduled to be constructed as discussed in Section 3.4 of the Remedial Design report. One treatment facility, B817-SRC, will be installed in the immediate vicinity of Building 817. A second facility, B817-PRX, will be located approximately 880 feet (ft) southeast of Building 817 in the downgradient portion of the plume. A third treatment facility, B815-PRX will be located approximately 1,000 ft downgradient (southeast) of the Building 815 Source Area**.** Locations of the treatment facilities are shown in Figure 14 of the Remedial Design report.

E-2.2. Existing Treatment Facilities

The B815-DSB ground water extraction and treatment facility began operating in 1999 to prevent the offsite migration of trichloroethylene (TCE). At this facility, aqueous-phase GAC is used to remove VOCs from ground water extracted from two extraction wells located at the site boundary. Ground water from these wells currently contains only low concentrations [3 to 8 micrograms per liter (µg/L)] of TCE. RDX, nitrate, and perchlorate have not been detected in ground water extracted from these wells. The extraction wellfield for this facility will be expanded to include two additional extraction wells.

The B815-SRC ground water extraction and treatment facility began operating in 2000 to minimize the influence of pumping at the site boundary on the RDX plume and to begin VOC and RDX (cyclo-1,3,5-trimethylene-2,4,6-trinitramine) mass removal. At the B815-SRC facility, contaminated ground water is currently pumped from one extraction well. VOCs and the HE compound RDX are treated using aqueous-phase granular activated carbon (GAC) units. A bioreactor then removes nitrate and perchlorate from extracted ground water. An ion-exchange unit is then used as a "polishing" step to remove any perchlorate remaining in the water stream. It is planned to add three more extraction wells to this system's extraction wellfield.

Health and safety hazards and controls for the operation of these facilities are discussed in Appendix G (Operations and Maintenance Health and Safety Plan).

E-2.3. Future Treatment Facilities

The Remedial Design for the HE Process Area OU includes plans to install three additional ground water extraction and treatment facilities: B815-PRX, B817-SRC, and B817-PRX. These facilities will be used to reduce contaminant concentrations and remove mass at the HE rinsewater lagoon source areas and in the downgradient portions of the plume originating at Building 815. Each facility will treat contaminated ground water extracted from two to three wells.

Contaminants in ground water at the HE rinsewater lagoon source areas include VOCs, HE compounds, nitrate, and perchlorate. Extracted ground water will be treated using aqueous-phase GAC to remove VOCs and HE compounds. Nitrate and perchlorate in ground water will be treated using ion-exchange units.

Health and safety hazards and controls for the construction of these facilities are discussed in this Construction Health and Safety Plan.

E-3. Responsibilities

Ed Folsom, phone number (925) 422-0389, LLNL pager number 02892, and home phone number (925) 455-2715, is responsible for the safety of this operation and for assuring that all work is performed in conformance with this Health and Safety Plan. In the absence of the responsible individual, P.J. Lyra, phone number (925) 422-1830, LLNL pager number 05157, or Greg Santucci, phone number (925) 422-3089, LLNL pager number 06502, shall assume these responsibilities.

Any changes in construction activities that improve or do not significantly affect safety and environmental controls may be approved by the responsible individual(s) listed above, 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 Health and Safety Plan has been reviewed and approved, consistent with the LLNL Environmental Restoration Division review and approval process.

Before starting construction activities, the responsible individual shall verify and document that the operating personnel have read and understand the Health and Safety Plan, relevant Integration Work Sheets (IWSs), and associated LLNL ES&H Manual sections referenced in Section E-8.2.

E-4. Hazard Analysis

E-4.1. Noise Hazard

Irreversible hearing loss can occur due to long-term exposure to noise from operating heavy equipment and other construction activities. Noise can also aggravate pre-existing hypertension. The American Conference of Industrial Hygienists has established a standard of 85 dBA over an 8-hour day. Exposure to noise louder than 85 dBA is permitted, as long as the average exposure for the entire day is less than 85 dBA.

E-4.2. Electrical Hazard

A 480, 208/230, and 110 VAC electrical power supply is used to operate the HE Process Area OU ground water extraction and treatment systems. Electrical shock and injury may occur if personnel come into contact with exposed energized parts during servicing and maintenance activities.

E-4.3. Chemical Hazard

VOCs, consisting primarily of TCE, are or are expected to be contained in the extracted ground water treated in all the HE Process Area OU remediation systems. Concentrations of TCE in the treatment system influent are expected to range from 3 µg/L to 280 µg/L. TCE is listed as a potential carcinogen. Other VOCs have been periodically detected in ground water monitor wells in the HE Process Area OU including 1,1-dichloroethylene (DCE), cis-1,2-DCE, and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) which are not listed as carcinogenic substances. TCE, 1,1-DCE, and cis-1,2-DCE are kidney and liver toxins that may enter the body through inhalation, skin absorption, and/or ingestion. They are irritating to the eyes, nose, and throat and may affect the central nervous system. Freon 113 is a skin, eye, and throat irritant. It may enter the body through inhalation, skin absorption, and/or ingestion and affects the central nervous and cardiovascular systems.

The HE compound RDX is or is expected to be contained in extracted ground water treated in B815-SRC, B815-PRX, B817-SRC and B817-PRX at concentrations ranging from 6 µg/L to 120 µg/L. RDX is an explosive polynitramine commonly known by the British code name for Research Department Explosive. RDX is listed as a potential carcinogen. Although epidemiological studies have not been conducted, RDX has been reported to affect the central nervous system. HMX (cyclotetramethylene tetranitramine) (derived from High Melting

Explosives) is periodically detected in ground water monitor wells in the HE Process Area OU. HMX is an explosive polynitramine and is not listed as a carcinogenic substance. Studies indicate that HMX is a skin irritant and may be a neurotoxin based on animal studies.

Nitrate (as NO_3) is or is expected to be contained in extracted ground water treated in B815-SRC, B815-PRX, B817-SRC, and B817-PRX at concentrations ranging from 56 mg/L to 240 mg/L. Nitrate is non-carcinogenic but significant concentrations of nitrogen in drinking water has been linked to methemoglobinemia, or blue baby syndrome, a potentially fatal disease of infants.

Perchlorate is or is expected to be contained in extracted ground water treated in B815-SRC, B815-PRX, B817-SRC, and B817-PRX at concentrations ranging from 6 µg/L to 30 µg/L. The concerns surrounding perchlorate contamination involves its ability to inhibit iodide anion uptake by the thyroid. This results in decreased thyroid hormone production that can affect metabolism, growth, and development. Perchlorate is currently listed as non-carcinogenic however additional studies are being conducted to provide data to evaluate the potential for cancer risk.

E-4.4. Explosives Hazard

Although no explosives are used in environmental restoration activities, the treatment facilities are located in the HE Process Area OU. Within the HE Process Area OU, high explosives are mechanically pressed and machined into shaped detonation devises. The major hazards from explosives are personal injury and property damage caused by heat, blast, noise, fumes, and flying debris or projectiles from unintentional or inadequately controlled ignition or explosion of such materials.

E-4.5. Confined Space Hazard

A confined space is defined as an enclosed area that is large enough for an employee to enter and perform assigned work, has limited or restricted means of entry or exit, and is not designed for continuous human occupancy. If an ignition source is present in or introduced into an enclosed space that contains flammable gases, solvents, or dust, the atmosphere may burn or explode. Serious injury or death may result when the atmosphere contains even low concentrations of toxic gases.

E-4.6. Hand and Portable Power Tool Hazard

The Laboratory provides hand and portable tools that meet accepted national safety standards. However, these tools can still cause injury and must be properly used and maintained.

E-4.7. Working Alone Hazard

Working alone means performing any activity out of sight or communication for more than a few minutes at a time. For work on exposed energized electrical equipment, an individual is considered to be working alone if not within sight of someone else. The major danger in working alone is sustaining an illness or injury that precludes self-rescue.

E-4.8. Physical and Biological Hazards

Physical hazards associated with working at Site 300 include extreme temperatures with temperatures often exceeding 100º F in the summer. High air temperatures coupled with use of semi-permeable or impermeable protective clothing and/or strenuous physical activities have a high potential for inducing heat stress in workers. In addition, hazardous conditions may exist during lightning storms at Site 300. Biological hazards include rattlesnakes and insects (i.e., tarantulas, black widow spiders, scorpions, etc.).

E-4.9. Slip/Trip/Fall Hazards

The surfaces that operators stand or work on can be hazardous if not properly designed or maintained. Injuries can result from slips, trips, or falls on work surfaces. Work at heights or at elevated locations can also pose a fall hazard.

E-4.10. Material Handling Hazards

The hazards associated with improper material handling include being struck by a load, losing control of a load, physical overexertion, and exceeding equipment capacities. Such accidents can lead to injuries.

E-4.11. Mechanical Motion Hazards

A wide variety of mechanical motions and actions may present hazards to personnel. These can include the movement of rotating members, reciprocating arms, moving belts, meshing gears, cutting teeth, and any part that may cause impact or shear. These different types of hazardous mechanical motions and actions are basic in varying combinations to nearly all machines.

E-4.12. Hazards to Eyes

During construction activities, flying particles or objects can present a hazard to worker's eyes. The use of soldering or welding equipment also poses an eye hazard.

E-4.13. Fire Hazards

Soldering or welding of pipe connections may be necessary to connect pipeline to extraction wells or to the treatment facility. These hot-work activities present a fire hazard, particularly when performed in the more remote, grassy areas of the OU during the summer months when the grass is dry and highly ignitable.

In addition, vehicle travel off-road into grassy areas may be necessary during pipeline construction or hook-up. Hot engine and vehicle exhaust components may present a fire hazard when contacting high, dry grass or vegetation.

E-5. Hazard Control

Controls for the hazards identified in Section E-4 are based on selected sections of LLNL ES&H Manual, the Site Safety Plan for LLNL CERCLA Investigations at Site 300 (2000), and ERD IWSs #239 and #1960.

E-5.1. Noise Hazard Control

Based on previous experience, it is not anticipated that the noise level will be of concern during construction activities. However, sound levels will be monitored during any operation that may generate hazardous noise levels. Construction personnel will be required to wear noise protection when working within the noise hazard area, if required by LLNL Industrial Hygiene personnel. Engineered and/or administrative controls should also be implemented, as necessary, to limit noise and protect worker's hearing. The work supervisor shall provide workers affected by noise with earplugs or earmuffs as needed.

The facility operator is required to follow noise safety precautions outlined in the LLNL ES&H Manual, Section 10.08 "Hearing Conservation" and Supplement to 10.08.

E-5.2. Electrical Hazard Control

E-5.2.1. Access Control

Inadvertent contact with energized equipment is prevented by limiting access to the breaker switches. All breaker switches are contained in cabinets with keyed locks.

E-5.2.2. Electrical System Maintenance Safety Procedures

Only qualified electricians or electrical technicians perform activities on the electrical systems for the treatment facilities during construction work. These personnel will follow safety precautions as outlined in the LLNL ES&H Manual, Chapter 23, "Electrical Safety," and the Electronics Engineering Department–Electrical Safety Policy, LED-61-00-01-A1A. These personnel will also follow the LLNL Lockout and Tag program as defined in Chapter 26.13 of the LLNL ES&H Manual and IWS Safety Procedure #239 whenever any work is to be done that would expose them to energized equipment.

E-5.3. Chemical Hazard Control

Concentrations of contaminants in the treatment facility influent are generally several orders of magnitude lower than the recommended permissible exposure limits (PELs) or threshold limit values (TLVs) for these chemicals. Therefore, it is not anticipated that exposure levels in excess of PELs or TLVs will be encountered. However, precautions, such as use of personal protective equipment or clothing (i.e., gloves, safety glasses) should be taken to prevent exposure when potential contact with contaminated, untreated ground water is possible. In addition, to prevent the ingestion of hazardous materials, workers should wash their hands prior to eating, drinking, smoking, or using restroom facilities. The Material Safety Data Sheets for the chemical encountered in HE Process Area OU ground water are maintained at the technician's office at Site 300 and in the Site Safety Plan for LLNL CERCLA Investigations at Site 300 (2000).

E-5.4. Explosives Hazard Control

For safety and because of the sensitive and classified work performed in the HE Process Area OU, the Process Area is a "Special Limited" area. Access to the area is highly restricted by secondary fences and a security checkpoint. Workers must either have a Q-clearance or an Administrative Escort to enter the area. An L-Clearance allows admittance when escorted by a Q-cleared LLNL employee. All workers, regardless of clearance level, must obtain prior approval from the Special Area Access Requester to enter the HE Process Area OU. When remote operations occur in the HE Process Area OU, access to the area is restricted. Workers must also complete and follow the safety procedures covered in Course HS0095W "Site 300 Safety Orientation Training." This course contains information regarding signs, procedures, and controls used to minimize exposure to hazards related to Site 300 activities. Although no explosives are used in environmental restoration activities, it is imperative that workers follow the special safety and access requirements for the HE Process Area OU during construction activities in this area.

E-5.5. Confined Space Hazard Control

Confined space entries are not anticipated as part of construction activities in the HE Process Area OU at this time. However, construction personnel and technicians should be familiar with and perform all work in confined spaces in accordance with the LLNL ES&H Manual, Section 3, "Controls for Working in Confined Spaces." Technicians and construction personnel should contact Hazards Control Team #1 prior to entry in any confined space. A Confined Space permit is required for hazardous confined space work. Only qualified personnel with recent confined space training are permitted to work in confined spaces and are required to comply with the two-man rule.

E-5.6. Hand and Portable Tool Hazard Control

Facility technicians and construction personnel are responsible for selecting and using the proper tools for the job assigned and for wearing the appropriate personal protective equipment (i.e., safety glasses, etc.) when working with hand and portable tools. All hand and portable tools should be inspected prior to use to make sure they are not damaged and are in good-working condition. Any tool that is damaged or unfit for use should be immediately removed from service. Personnel are responsible for following the work safety standards outlined in LLNL ES&H Manual, Section 26.5.

E-5.7. Working Alone Hazard Control

When working alone on a non-hazardous activity, facility technicians and construction personnel will advise a co-worker or supervisor that they will be working alone and when they expect to return. For potentially hazardous activities, technicians will: (1) exercise prudent judgement whether or not to perform the activity alone, and (2) obtain prior authorization from work supervisor before beginning planned hazardous-work-alone operations to ensure that all hazards have been thoroughly evaluated from the perspective of working alone. Work supervisors are responsible for ensuring an IWS is prepared for activities classified as hazardous for working alone. Personnel are responsible for following the work safety standards outlined in

LLNL ES&H Manual, Section 26.12 and the Environmental Restoration Division Working Alone Guidelines (in ERD O&M Manual, Appendix L) for all work-alone activities.

E-5.8. Physical and Biological Hazard Control

During late spring and summer months, technicians and construction personnel should ingest fluids and evaluate their physical conditions regularly and break when necessary to avoid overheating. Work should be conducted in accordance with the LLNL ES&H Manual, Section 26.16. All personnel should follow procedures outlined in the Site 300 Lightning Procedures (S300 MGM-T-7) during a lightning alert at Site 300. A lightning alert means the weather conditions are potentially conducive to lightning. Lightning alerts are announced through the Site 300 communications systems. Employees and visitors must evacuate and remain outside explosives hazard zones until a lightning alert is cleared.

Technicians and construction personnel should inspect work areas for snakes and other biological hazards before commencing work. The use of high top work boots is recommended. Avoid biological hazards when possible; do not harass wildlife. Anyone who is bitten should be moved to a safe area and kept calm. Notify the Emergency Dispatch (911) immediately.

E-5.9. Slip/Trip/Fall Hazard Control

Work surfaces around the treatment facilities should be properly maintained at all times to prevent slips, trips, and falls. Maintenance includes assuring all spills and foreign materials (i.e., tools, excess equipment, etc.) are promptly removed, installing rubber or slip resistant mats at locations that may accumulate water, and ensuring that floor openings are equipped with adequate covers when worker exposure is possible. Any access to elevated locations or work at heights requires guardrails, an administrative control system, or fall protection devices. Personnel are responsible for following the work safety standards outlined in LLNL ES&H Manual, Sections 26.17 and 10.09.

E-5.10. Material Handling Hazard Control

When lifting or handling materials manually, operators should use methods that ensure personal safety and safety of the material being handled. Objects that are too heavy or bulky to handle safely should be moved using more than one person or mechanical lifting device. All material lifting or handling should be performed in accordance with the safety standards and procedures for lifting contained in the LLNL ES&H Manual, Section 29.3.

E-5.11. Mechanical Motion Hazard Control

Any machine part, function, or process which may cause injury shall either be guarded (physical barriers which prevent access to danger areas) or safeguarded (provided with devices which inhibit machine operation, to mitigate or eliminate danger areas).

Machine operators shall be trained in the proper use of equipment and associated guards/safeguards to protect themselves and others from machine-related hazards. Machine operators shall wear protective clothing or personal protective equipment as necessary whenever engineering controls are not available or are not fully capable of protecting personnel. At a minimum, safety shoes and safety glasses shall be worn by all personnel operating or working within close proximity of heavy machinery or equipment. When there is a potential for head injury, hard hats shall be worn.

E-5.12. Eye Hazard Control

Eye protection shall be provided and worn by technicians where flying particles or objects present a hazard. The minimum type of eye protection is a pair of safety glasses. Increased protection against flying particles is provided when safety glasses have side shields; side shields should be used in most cases. Special eye protection is required when operations such as welding or metal cutting with a torch or arc are performed.

Generally, the technician supervisor will select the eye protection that is appropriate for the type of work being conducted by the technician. Additional details for eye protection are contained in the LLNL ES&H Manual, Section 10.3.6.

E-5.13. Fire Hazard Control

As part of the LLNL program to control fire hazards, permits are required for welding, soldering, and other hot-work operations with a high fire potential. The permits are obtained from the LLNL Fire Department at Site 300. Construction areas shall be maintained in a fire-safe condition, including ensuring that the construction site is accessible to the Fire Department. Technicians will obtain fire permits for all soldering or welding work with a high fire potential. This work will be also be conducted in accordance with the requirements of the LLNL ES&H Manual, Section 25, LLNL Fire Protection Program Manual, and National Fire Protection Association (NFPA) 51 (Standard for Fire Prevention During Welding, Cutting, or Other Hot Work).

In addition, technicians must obtain approval to access any construction work site that requires off-pavement travel as defined by the LLNL “Restricted Off-Pavement Travel at Site 300” policy manual. Technicians planning to travel off-pavement must receive prior permission from the Site 300 Manager, the Functional Area Supervisor, and the CAS Operator and carry a trunked radio for communications. In addition, appropriate training is required for all personnel engaging in off-road travel at Site 300. Personnel should not park or drive through dry, tall grass. Technicians performing off-road travel during construction activities shall be familiar with the “Restricted Off-Pavement Travel at Site 300” manual (LLNL, 2001) and must be listed as ‘qualified personnel’ on IWS #1960 “Site 300 Restricted Travel to Perform ERD Activities.”

In case of fire, contact the LLNL Fire Department by dialing 911 or 925-447-6880 from a cellular phone.

E-6. Stop Work Procedures

LLNL’s stop-work procedure applies to all work done at the Laboratory. Activities that are imminently dangerous to workers, the public, or the environment shall be stopped immediately by any Laboratory employee, supplemental labor employee, or contractor. Each worker is empowered to stop work if there is a perceived unsafe or unapproved condition. “Stopping work” includes stabilizing an imminent danger situation to the extent that it can be left unattended for a prolonged period of time until the issue is resolved. The person requesting the work stoppage shall notify manager responsible for the work. The manager shall notify the area

ES&H Team and the Directorate ES&H Assurance Manager as soon as possible of this action. Informal stop work interventions to correct minor conditions (e.g., to remind workers to put on their hard hats, safety glasses etc.) do not require formal notification. Details of the Stop Work Process are included in the LLNL ES&H Manual, Section 1.7.

E-7. Emergency Response Procedures

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 and if trained appropriately, 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. The phone numbers of individuals to be notified in the event of an emergency during off-shift hours are posted at the HE Process Area OU treatment facilities. The LLNL ES&H Manual describes the emergency response procedures.

E-8. Applicable Documents

The following documents and/or sections thereof apply to safely performing construction activities at the HE Process Area OU and are incorporated into this Health and Safety Plan by reference.

E-8.1. Integration Work Sheet Safety Procedures #239 (Lockout and Tag Program for Institutional and PE Maintained Programmatic Equipment) and #1960 (Site 300 Restricted Travel to Perform ERD Activities)

E-8.2. LLNL Environment, Safety, and Health Manual Sections

Section 1.	LLNL ES&H Policies, General Worker Responsibilities, and Integrated Safety Management
Section 1.7.	Stop Work Procedures
Section 2.	Integrating ES&H into Laboratory Activities
Section 10.08	Hearing Protection
Section 21.	Chemicals
Section 21.3.5	Facilities and Equipment
Section 21.3.7	Handling Solid and Liquid Chemicals

Section 23.	Electrical Safety
Section 23.1	Introduction
Section 23.2	Hazards
Section 23.3	Controls for Electrical Work and Electrical Equipment
Section 23.4	Responsibilities
Section 23.5	Work Standards
Section 23.6	Resources for More Information
Appendix 23-B	Effects of Electrical Energy on Humans

E-8.3. LLNL Environment, Safety, and Health Manual, Supplement 1.11 - Construction Subcontractor Safety Program (LLNL, 2000).

E-8.4. LLNL Electronics Engineering Department—Electrical Safety Policy, LED-61-00-01-A1A

E-8.5. Site Safety Plan for LLNL CERCLA Investigations at Site 300, November 2000

E-8.6. LLNL Environment, Safety, and Health Manual Supplements

Section 10.08	Hearing Conservation
Section 11.07	Personnel Safety Interlocks
Section 26.13	LLNL Lockout and Tag Program

E-9. References

LLNL (2001) Restricted Off-Pavement Travel at Site 300, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-MI-144038).

LLNL (2000), LLNL Environment, Safety, and Health Manual.

LLNL (2000), LLNL Environment, Safety, and Health Manual, Supplement 1.11—Construction Subcontractor Safety Program.

LLNL (2000), Operations and Maintenance Manual Volume 1: Treatment Facility Quality Assurance and Documentation, Appendix L.

LLNL (2000), *Site Safety Plan for Lawrence Livermore National Laboratory CERCLA Investigations at Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-21172 Rev. 3).

LLNL (latest edition), *Fire Protection Program Manual*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-MA-116646).

Appendix F

Operations and Maintenance Quality Assurance/Quality Control Plan

Appendix F

Operations and Maintenance
Quality Assurance/Quality Control Plan

F-1. Introduction

This Quality Assurance/Quality Control (QA/QC) Plan has been developed in support of the Operations and Maintenance (O&M) for the High Explosives (HE) Process Area OU ground water extraction and treatment systems. The purpose of the plan is to define the quality objectives and areas of responsibility to operate and maintain these facilities. This plan meets the QA requirements of the U.S. Department of Energy (DOE) Order 414.1A, the Environmental Protection Department (EPD) Quality Assurance Management Plan (QAMP), (2001), and the Quality Assurance Project Plan (QAPP) for the Livermore Site and Site 300 Environmental Restoration Projects (1999).

F-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 the HE Process Area OU ground water treatment systems that affect quality.

Figure F-1 shows the organizational structure for QA/QC activities. The descriptions below generally describe the QA/QC responsibilities of those mainly involved in carrying out the QA/QC program for the O&M of the HE Process Area OU ground water treatment systems. The Lawrence Livermore National Laboratory (LLNL) Environmental Restoration Division (ERD) Site p300 Project Leader, the Quality Assurance Engineer, the Subproject Leader, and other individuals shown in Figure F-1 have the following responsibilities:

- The Site 300 Project Leader issues this QA/QC plan and periodically reviews its implementation. The Site 300 Project Leader may request an independent review or formal audit of the QA/QC program.
- The Quality Assurance Implementation Coordinator is responsible for the development and implementation of the QA/QC 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 Quality Assurance Engineer is responsible for providing direction in the O&M of remediation systems to meet QA/QC objectives.

- The Subproject Leader is responsible for overseeing facility startup and monitoring its performance and operations.
- The Remediation Engineer is responsible for providing technical direction in the O&M of treatment systems, reviewing and tracking failure of equipment and systems and determining the root cause of failures. The Remediation Engineer is also responsible for implementing the changes to the preventative maintenance schedule to reduce facility maintenance cost and downtime.
- The LLNL Plant Engineering Project Manager reports functionally during any assigned maintenance activities to the ERD Site 300 Project Leader and the Subproject Leader. The Plant Engineering Project Manager is Plant Engineering's primary contact with ERD for the assigned project. He/she coordinates and executes the project assigned to him/her. He/she is responsible for approving minor technical field design changes related to treatment facility modifications and/or O&M activities.
- The Technician Supervisor is responsible for the day-to-day supervision of the facility technicians who operate and maintain the treatment facilities. This includes scheduling required maintenance and ensuring completion in a timely fashion.
- The Treatment Facility Operator/Technician is responsible for the day-to-day operation and maintenance of the treatment facilities. This includes operating equipment, sampling, and performing maintenance to approved procedures, ensuring the measuring and testing equipment is properly calibrated and is of the proper type, range, and accuracy, reporting nonconformances or improvements, and reviewing facility data.
- State Certified Analytical Laboratories using EPA methods are responsible for providing independent chemical analytical results on water samples. For the HE Process Area OU ground water treatment systems, these samples are submitted as part of the monitoring program required by LLNL's discharge permits, in addition to operational testing samples collected prior to the official operation of a facility and routine samples taken to evaluate facility performance.

F-3. Quality Assurance Program

This section covers the objectives, quality goals, and the QA/QC elements. The procedures for implementation of QA/QC requirements are included in this plan, in the ERD Standard Operating Procedures (SOPs) (Dibley and Depue, 2000), the ERD O&M Manual for Site 300 Treatment Facilities, Volume I (2000), or in the HE Process Area OU ground water treatment system O&M manual (to be developed).

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

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

This QA/QC plan defines the process for providing confidence that these QA/QC objectives will be achieved and that achievement will include due consideration for health, safety, property, and the environment.

Table F-1 shows the 10 elements of the EPD QAMP, which implements DOE Order 414.1A, and their applicability to the operation and maintenance of HE Process Area OU ground water treatment systems.

The SOPs, the ERD O&M Manual for Site 300 Treatment Facilities, Volume I (2000), and the HE Process Area OU ground water treatment systems O&M manual (to be developed) provide the procedures to implement the applicable elements of the EPD QAMP. In addition, they include lists of the QA auditable records, including the responsible personnel, that are required to document compliance with the requirements of the EPD QAMP.

F-4. Training and Qualifications

ERD facility technicians may only perform work for which they are trained and qualified including the operation and maintenance of the HE Process Area OU treatment facilities. Untrained personnel may temporarily work under the supervision of a trained person until the required training is completed. The EPD Training Management Plan, the Safety and Security Directorate Training Implementation Plan, the LLNL Training Program Manual, and training questionnaires completed by supervisors dictate the training requirements for treatment facility personnel including course work and on-the-job training.

F-5. Quality Improvement

ERD facility technicians integrate quality improvement into all treatment facility O&M activities by communicating to management per the requirements of SOP 4.12, "Quality Improvement Forms," any unsafe practice or nonconforming item or process (e.g., faulty material, malfunctioning equipment, process defects, data irregularities, and deviations from standard operating procedures) that could potentially compromise worker safety, the activity's deliverable, or the compliance status of the facility. The technicians also identify and communicate methods to improve quality or achieve greater efficiency of the treatment facilities. These personnel also participate in facility assessments and operations meetings to address quality improvement issues.

F-6. Operations and Maintenance

F-6.1. Scope

The HE Process Area OU ground water treatment systems will be operated to treat ground water containing volatile organic compounds (VOCs), RDX, nitrate, and perchlorate. The water will be treated to meet the requirements specified by the Regional Water Quality Control Board (RWQCB). Therefore, O&M activities at this facility shall be controlled by quality procedures designed to meet these requirements.

F-6.2. Operations

F-6.2.1. General Operating Procedures

The Site 300 Project Leader is responsible for ensuring the quality of operations at these facilities. The Technician Supervisor is 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.

The treatment facilities have a required monitoring program as described in Appendix A. Water samples are collected and analyzed to monitor the performance of the ground water treatment systems in meeting Substantive Requirements for waste water discharge issued by the RWQCB. The Technician Supervisor is responsible for ensuring that the facility technicians are properly trained to collect these samples according to documented standard operating procedures. Samples generated as part of the treatment facility monitoring are assigned unique identifiers and documented traceability of these identifiers are maintained throughout the handling of the samples (the Chain-of-Custody process) and the data generated from measurements of the samples.

The HE Process Area OU ground water treatment systems have their own set of operating procedures. These procedures, which will be developed as part of the O&M manual, cover the different modes of operation including startup, shutdown, normal operation, safety considerations, and maintenance procedures.

Waste products (i.e., spent granular activated carbon with VOCs and RDX) that are generated as part of the treatment facility operation process are assigned unique identifiers and documented traceability of these identifiers is maintained throughout the handling of the samples (the Chain-of-Custody process). These waste products are turned over to LLNL's Hazardous Waste Management Division for shipment to an offsite Resource Conservation and Recovery Act (RCRA)-permitted regeneration or disposal facility.

F-6.2.2. Equipment Calibration and Verification

All measuring and test equipment used at the treatment facilities should be calibrated, maintained, and controlled per ERD Standard Operating Procedure 4.8 "Calibration/Verification and Maintenance of Measuring and Test Equipment" and the EPD QAMP, Section 5.5.5, to assure conformance with standards of known accuracy and traceability. Facility technicians are responsible for ensuring the calibration status of all data collection and monitoring equipment is current prior to use. The calibration status of this equipment will be identified and tracked in a Calibration/Maintenance Log.

F-6.2.3. Record Keeping

An operational logbook is kept at each facility. The logbook entries include the operating parameters of each system (i.e., temperature, pressure, etc.), the number and type of samples taken, maintenance performed on the system, and all adjustments made by the operators to the system.

In addition, the following QA records are generated by treatment facility activities:

- Chain-of Custodies.
- Analytical data.
- Instrument calibration and maintenance logbooks.
- Assessment reports and checklists.
- Course and On-the-Job Training completion records.
- Completed Quality Improvement Forms.
- Standard traceability certificates.

F-6.3. Maintenance

Two types of maintenance are performed at the HE Process Area OU ground water treatment systems:

- Preventive.
- Corrective.

F-6.3.1. Preventive Maintenance

Preventive maintenance is performed on those treatment facility components that need routine servicing and are part of systems related to quality. The preventive maintenance schedule is kept at the facility with the operations procedures. The Technician Supervisor is responsible for ensuring that preventive maintenance is scheduled and completed on schedule to minimize downtime. Maintenance will be performed by LLNL Plant Engineering and/or ERD personnel, and will follow the requirements set in the O&M manual to ensure the maintenance functions are performed as planned.

Table F-2 is a tentative schedule of the preventive maintenance for the HE Process Area OU ground water treatment systems.

F-6.3.2. 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. Using the graded approach, root cause analysis is performed when 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 logbook. Quality Improvement Forms are used to document component failures, root cause analysis, and preventive maintenance per SOP 4.12. As with preventive maintenance, corrective maintenance is performed by Plant Engineering personnel or ERD personnel in accordance with this QA/QC plan.

All corrective maintenance actions and their times of completion are recorded in the facility daily operations logs. 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 new component is noted. If successful, the system is allowed to resume normal operations. Startup sampling will be performed upon system restart, if necessary, in accordance with the requirements of the RWQCB Substantive Requirements for the HE Process Area OU ground water treatment system.

When the O&M manual for the HE Process Area OU ground water treatment systems is developed, it will indicate the required spare parts for system components that have relatively high risk of failure or a long lead time for procurement. These components are to be maintained onsite to prevent extended shutdown of the treatment system.

F-6.3.3. Maintenance Support

Maintenance support activities including the identification and control of O&M materials, inspection and testing of treatment facilities, monitoring of operating status, control of processes, and control of measuring and test equipment, will be implemented as outlined in the HE Process Area OU ground water treatment systems O&M manual (to be developed).

F-7. Assessment Tools

ERD performs QA/Management self-assessments of the treatment facilities triennially. These assessments review treatment facility activities to QA and ES&H requirements and procedures. A member of the ERD management team participates on the assessment team to identify, correct, and prevent management problems that hinder the achievement of ERD's objectives. ERD uses the results of the assessments performed by internal and external organizations to assess the performance of treatment facility activities. Additional information on assessment tools can be found in the ERD Quality Assurance Project Plan (1999) and the EPD QAMP (2001).

F-8. References

Dibley, V. (March 1999), *Environmental Restoration Division, Quality Assurance Project Plan, Livermore Site and Site 300 Environmental Restoration Projects,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-103160 Rev. 2).

Dibley, V., and R. Depue (Eds.) (2000), *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs),* Lawrence Livermore National Laboratory Livermore, Calif. (UCRLMA-109115 Rev. 8).

LLNL (July 2001), Environmental Protection Department (EPD) *Quality Assurance Management Plan (QAMP), Rev. 5*, Lawrence Livermore National Laboratory, Livermore, Calif.

LLNL (March 2000), *Environmental Restoration Division, Operations and Maintenance Manual, Volume 1: Treatment Facility Quality Assurance and Documentation, Rev. 1*, Lawrence Livermore National Laboratory, Livermore, Calif.

U.S. DOE (1999), DOE Order 414.1A, Quality Assurance Program, Office of Nuclear Safety Policy and Standards.

Table F-1. Applicability of the EPD QAMP elements to the operation and maintenance of the HE Process Area OU ground water extraction and treatment systems.

EPD QAMP requirement	Title	Applicable ?
Element 1	EPD Quality Assurance Program Description	Yes
Element 2	Training and Qualification	Yes
Element 3	Quality Improvement	Yes
Element 4	Document and Records	Yes
Element 5	Work Processes	Yes
Element 6	Design Control	Yes
Element 7	Procurement	Yes
Element 8	Inspection and Acceptance Testing	Yes
Element 9	Management Assessment	Yes
Element 10	Independent Assessment	Yes

Table F-2. Preventive maintenance for the HE Process Area OU ground water extraction and treatment systems.

Action	Frequency/comments
Inspect variable speed submersible pump	Annually
Check aqueous-phase granular activated carbon (GAC) units and associated piping	Weekly
Check bioreactor units and associated piping[a]	Weekly
Check ion exchange units and associated piping[a]	Weekly
Check discharge lines	Weekly
Monitor pump controller	Weekly
Monitor level sensors	Weekly
Monitor pressure indicator	Weekly
Monitor pH meter	Weekly
Monitor flow indicator	Weekly
Inspect miscellaneous hoses, seals, fittings, etc.	Weekly
Perform preventive maintenance for wellhead demister	Annually
Perform preventive maintenance for well pumps	Quarterly
Perform preventive maintenance for temperature sensors	Annually
Perform preventive maintenance for temperature indicators	Annually
Check electrical breakers and disconnects[b]	Annually
Inspect sampling ports	Before use
Clean organic debris from area surrounding the building	As needed

[a] Where unit is present as part of treatment train of the facility.

[b] All electrical system maintenance to be performed by a qualified electrician or electrical technician.

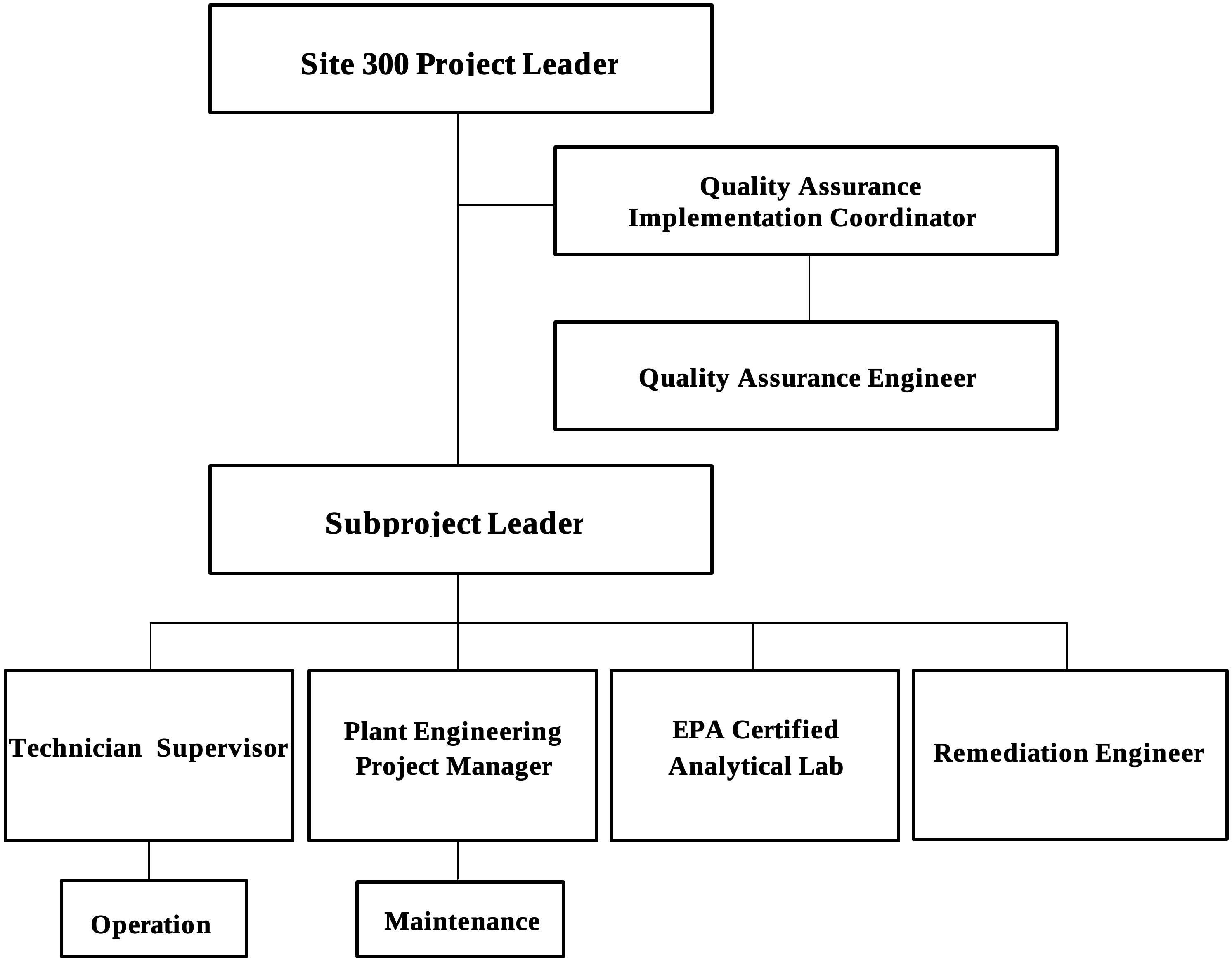

Figure F-1. Organizational chart for O&M QA/QC for the HE Process Area treatment facilities.

Appendix G

Operations and Maintenance Health and Safety Plan

Appendix G

Operations and Maintenance Health and Safety Plan

This Appendix contains the Operations and Maintenance (O&M) Health and Safety Plan for the High Explosives (HE) Process Area Operable Unit (OU) ground water extraction and treatment facilities.

G-1. Reason for Issue

Safety procedures are required to operate and maintain the ground water extraction and treatment systems for the HE Process Area OU. This Health and Safety Plan also serves as an administrative tool to summarize many of the requirements of the Lawrence Livermore National Laboratory (LLNL) Environment, Safety, and Health (ES&H) Manual (LLNL, 2000), and Site Safety Plan for LLNL Site 300 (LLNL, 2000), that are pertinent to the HE Process Area OU treatment facility O&M. The requirements of the LLNL ES&H Manual are based on Department of Energy's (DOE's) Integrated Safety Management System Principles and Work Smart Standards.

G-2. Work to be Done and Location of Activity

G-2.1. Location of Treatment Facilities

The HE Process Area OU is located in the southeast part of LLNL Site 300. Two ground water treatment facilities have already been constructed and are operating at present. One treatment facility (B815-SRC) is located in the Building 815 Source Area south of Building 815. A second treatment facility (B815-DSB) is located at the leading edge of the volatile organic compound (VOC) plume at the site boundary, west of the entrance to Site 300. Three additional treatment facilities are scheduled to be constructed as discussed in Section 3.4 of the Remedial Design report. One treatment facility, B817-SRC, will be installed in the immediate vicinity of Building 817. A second facility, B817-PRX, will be located approximately 880 ft southeast of Building 817 in the downgradient portion of the plume. A third treatment facility, B815-PRX will be located approximately 1,000 ft downgradient (southeast) of the Building 815 Source Area. Locations of the treatment facilities are shown in Figure 14 of the Remedial Design report.

G-2.2. Treatment Objectives and Methods

The treatment systems in the HE Process Area OU are used to remove VOCs, nitrate, perchlorate, and in some locations, RDX, from ground water to meet Substantive Requirements for discharge of treated water issued by the Regional Water Quality Control Board. Contaminated ground water will be pumped from extraction wells utilizing submersible pumps.

Flow to the treatment facilities is not expected to exceed 5 gallons per minute per facility. Aqueous-phase granular activated carbon (GAC) will be used to remove volatile organic compounds (VOCs) and RDX from the extracted ground water. Ion-exchange units will then treat nitrate and perchlorate where it is present in the treatment facility influent. At the B815-SRC treatment facility, a bioreactor is also used after the aqueous-phase GAC to remove nitrate from ground water.

G-2.3. Particulate Filtration

Extracted ground water from HE Process Area OU wellfields pass through four 25-micron filters that have differential pressure gauges across them in the range of 0 to 25 pounds per square inch (psi). This filtration process is designed to remove particulates from ground water that could reduce treatment system efficiency.

G-2.4. Ground Water Treatment Process

The B815-DSB ground water extraction and treatment facility began operating in 1999 to prevent the offsite migration of trichloroethylene (TCE). At this facility, aqueous-phase GAC is used to remove VOCs from ground water extracted from two extraction wells located at the site boundary. Ground water from these wells currently contains only low concentrations [3 to 8 micrograms per liter (µg/L)] of TCE. RDX, nitrate, and perchlorate have not been detected in ground water extracted from these wells. The extraction wellfield for this facility will be expanded to include two additional extraction wells

The B815-SRC ground water extraction and treatment facility began operating in 2000 to minimize the influence of pumping at the site boundary on the RDX plume and to begin VOC and RDX mass removal. At the B815-SRC facility, contaminated ground water is currently pumped from one extraction well. However, the extraction wellfield will be expanded to include three additional extraction wells. VOCs and the HE compound RDX are treated using aqueous-phase GAC units. A bioreactor then removes nitrate and perchlorate from extracted ground water. An ion-exchange unit is then used as a “polishing” step to remove any perchlorate remaining in the water stream.

The Remedial Design for the HE Process Area OU includes plans to install three additional ground water extraction and treatment facilities: B815-PRX, B817-SRC, and B817-PRX. These facilities will be used to reduce contaminant concentrations and remove mass at the HE rinsewater lagoon source areas and in the downgradient portions of the plume originating at Building 815. Each facility will treat contaminated ground water extracted from two to three wells.

Contaminants in ground water at the HE rinsewater lagoon source areas include VOCs, RDX, nitrate, and perchlorate. Extracted ground water will be treated using aqueous-phase GAC to remove VOCs and RDX. Nitrate and perchlorate in ground water will be treated using ion-exchange units.

G-2.5. Discharge of Treated Ground Water

Treated ground water from most of the treatment systems (B815-SRC, B815-PRX, B817-SRC, and B817-PRX) in HE Process Area OU is or will be discharged through misting towers. Treatment facility effluent sprayed from the misting towers typically will form a cloud of water vapor that quickly evaporates. Nitrate is or is expected to be present in these treatment facility's effluent and is discharged via misting towers. The amount of nitrate released during misting operations is not significant enough to cause detectable increases in nitrate deposition rates downwind of the facility. Therefore, misting of nitrate-containing treatment facility effluent is not expected to impact local ground water quality. The treated effluent from the B815-DSB treatment facility is discharged to an infiltration trench.

G-3. Responsibilities

Ed Folsom, phone number (925) 422-0389, LLNL pager number 02892, and home phone number (925) 455-2715, is responsible for the safety of this operation and for assuring that all work is performed in conformance with this Health and Safety Plan and applicable sections of the LLNL ES&H Manual, Environmental Protection Handbook, and the Site Safety Plan for Comprehensive, Environmental Response, Compensation and Liability Act (CERCLA) Investigations at LLNL Site 300. In the absence of the responsible individual, P.J. Lyra, phone number (925) 422-1830, LLNL pager number 05157, or Greg Santucci, phone number (925) 422-3089, LLNL pager number 06502, shall assume these responsibilities.

Any changes in operations that improve or do not significantly affect safety and environmental controls may be approved by the responsible individual(s) listed above, and the LLNL 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 Health and Safety Plan has been reviewed and approved, consistent with the LLNL Environmental Restoration Division (ERD) review and approval process.

Before starting operation, the responsible individual shall verify and document that the operating personnel have read and understand the Health and Safety Plan, relevant Integration Work Sheets (IWSs), and associated LLNL ES&H Manual sections referenced in Section G-5 below.

G-4. Hazard Analysis

A Preliminary Hazard Analysis of the Site 300 treatment facilities was conducted by LLNL Hazards Control. The Hazards Control team classified the ERD treatment facilities as "excluded" facilities. An excluded facility is a facility that is not designated by DOE as a nuclear facility or by LLNL as a high-, moderate-, or low-hazard non-nuclear facility. Excluded facilities do not require Facility Safety Procedures. However, a number of hazards are associated with work at the HE Process Area OU as described below.

G-4.1. Electrical Hazard

A 480, 208/230, and 110 VAC electrical power supply is used to operate the HE Process Area OU ground water extraction and treatment systems. Electrical shock and injury may occur if personnel come into contact with exposed energized parts during servicing and maintenance activities.

G-4.2. Seismic Hazard

Personnel may be injured during an earthquake due to falling equipment or missile hazards (equipment or materials moving energetically due to seismic forces).

G-4.3. Chemical Hazard

VOCs, consisting primarily of TCE, are contained in the extracted ground water treated in all the HE Process Area OU remediation systems. Concentrations of TCE in the treatment system influent are expected to range from 3 µg/L to 280 µg/L. TCE is listed as a potential carcinogen. Other VOCs have been periodically detected in ground water monitor wells in the HE Process Area OU including 1,1-dichloroethylene (DCE), cis-1,2-DCE, and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) which are not listed as carcinogenic substances. TCE, 1,1-DCE, and cis-1,2-DCE are kidney and liver toxins that may enter the body through inhalation, skin absorption, and/or ingestion. They are irritating to the eyes, nose, and throat and may affect the central nervous system. Freon 113 is a skin, eye, and throat irritant. It may enter the body through inhalation, skin absorption, and/or ingestion and affects the central nervous and cardiovascular systems.

The HE compound RDX is or is expected to be contained in extracted ground water treated in B815-SRC, B815-PRX, B817-SRC and B817-PRX at concentrations ranging from 6 µg/L to 120 µg/L. RDX is an explosive polynitramine commonly known by the British code name for Research Department Explosive. RDX is listed as a potential carcinogen. Although epidemiological studies have not been conducted, RDX has been reported to affect the central nervous system. HMX (derived from High Melting Explosives) is periodically detected in ground water monitor wells in the HE Process Area OU. HMX is an explosive polynitramine and is not listed as a carcinogenic substance. Studies indicate that HMX is a skin irritant and may be a neurotoxin based on animal studies

Nitrate (as NO_3) is or is expected to be contained in extracted ground water treated in B815-SRC, B815-PRX, B817-SRC, and B817-PRX at concentrations ranging from 56 mg/L to 240 mg/L. Nitrate is non-carcinogenic but significant concentrations of nitrogen in drinking water have been linked to methemoglobinemia, or blue baby syndrome, a potentially fatal disease of infants.

Perchlorate is or is expected to be contained in extracted ground water treated in B815-SRC, B815-PRX, B817-SRC, and B817-PRX at concentrations ranging from 6 µg/L to 30 µg/L. The concerns surrounding perchlorate contamination involves its ability to inhibit iodide anion uptake by the thyroid. This results in decreased thyroid hormone production that can affect metabolism, growth, and development. Perchlorate is currently listed as non-carcinogenic however additional studies are being conducted to provide data to evaluate the potential for cancer risk.

G-4.4. Explosives Hazard

Although no explosives are used in environmental restoration activities, the treatment facilities are located in the HE Process Area OU. Within the HE Process Area OU, high explosives are mechanically pressed and machined into shaped detonation devises. The major hazards from explosives are personal injury and property damage caused by heat, blast, noise, fumes, and flying debris or projectiles from unintentional or inadequately controlled ignition or explosion of such materials.

G-4.5. Confined Space Hazard

A confined space is defined as an enclosed area that is large enough for an employee to enter and perform assigned work, has limited or restricted means of entry or exit, and is not designed for continuous human occupancy. If an ignition source is present in or introduced into an enclosed space that contains flammable gases, solvents, or dust, the atmosphere may burn or explode. Serious injury or death may result when the atmosphere contains even low concentrations of toxic gases.

G-4.6. Hand and Portable Power Tool Hazard

The Laboratory provides hand and portable tools that meet accepted national safety standards. However, these tools can still cause injury and must be properly used and maintained.

G-4.7. Working Alone Hazard

Working alone means performing any activity out of sight or communication for more than a few minutes at a time. For work on exposed energized electrical equipment, an individual is considered to be working alone if not within sight of someone else. The major danger in working alone is sustaining an illness or injury that precludes self-rescue.

G-4.8. Physical and Biological Hazards

Physical hazards associated with working at Site 300 include extreme temperatures with temperatures often exceeding 100° F in the summer. High air temperatures coupled with use of semi-permeable or impermeable protective clothing and/or strenuous physical activities have a high potential for inducing heat stress in workers. In addition, hazardous conditions may exist during lightning storms at Site 300. Biological hazards include rattlesnakes and insects (i.e., tarantulas, black widow spiders, scorpions, etc.).

G-4.9. Slip/Trip/Fall Hazards

The surfaces that operators stand or work on can be hazardous if not properly designed or maintained. Injuries can result from slips, trips, or falls on work surfaces. Work at heights or at elevated locations can also pose a fall hazard.

G-4.10. Material Handling Hazards

The hazards associated with improper material handling include being struck by a load, losing control of a load, physical overexertion, and exceeding equipment capacities. Such accidents can lead to injuries.

G-4.11. Mechanical Motion Hazards

A wide variety of mechanical motions and actions may present hazards to personnel. These can include the movement of rotating members, reciprocating arms, moving belts, meshing gears, cutting teeth, and any part that may cause impact or shear. These different types of hazardous mechanical motions and actions are basic in varying combinations to nearly all machines.

G-4.12. Fire Hazards

Vehicle travel off-road into grassy areas may be necessary during pipeline and/or well maintenance. Hot engine and vehicle exhaust components may present a fire hazard when contacting high, dry grass or vegetation.

G-5. Hazard Control

Controls for the hazards identified in Section G-4 are based on selected sections of LLNL ES&H Manual, the Site Safety Plan for LLNL CERCLA Investigations at Site 300 (2000), and ERD Integration Work Sheets (IWSs) #239, #1265, and #1960.

G-5.1. Electrical Hazard Control

G-5.1.1. Access Control

Inadvertent contact with energized equipment is prevented by limiting access to the breaker switches. All breaker switches are contained in cabinets with keyed locks.

G-5.1.2. Electrical System Maintenance Safety Procedures

Only qualified electricians or electrical technicians perform maintenance activities on the electrical systems for the treatment facilities. These personnel will follow safety precautions as outlined in the LLNL ES&H Manual, Chapter 23, "Electrical Safety," and the Electronics Engineering Department–Electrical Safety Policy, LED-61-00-01-A1A. These personnel will also follow the LLNL Lockout and Tag program as defined in Chapter 26.13 of the LLNL ES&H Manual and IWS Safety Procedure #239 whenever any work is to be done that would expose them to energized equipment.

G-5.2. Seismic Hazard Control

Equipment will remain securely bolted to concrete pads to avoid damage and injury during an earthquake. To preclude injury from missile hazards (equipment or materials moving energetically due to seismic forces), any equipment or materials stored at a height of 5 ft or more shall be seismically restrained.

G-5.3. Chemical Hazard Control

Concentrations of contaminants in the treatment facility influent are generally several orders of magnitude lower than the recommended permissible exposure limits (PELs) or threshold limit values (TLVs) for these chemicals. Therefore, it is not anticipated that exposure levels in excess of PELs or TLVs will be encountered. However, precautions, such as use of personal protective equipment or clothing (i.e., gloves, safety glasses) should be taken to prevent exposure when potential contact with contaminated, untreated ground water is possible. In addition, to prevent the ingestion of hazardous materials, workers should wash their hands prior to eating, drinking, smoking, or using restroom facilities. The Material Safety Data Sheets for the chemical encountered in HE Process Area OU ground water are maintained at the technician's office at Site 300 and in the Site Safety Plan for LLNL CERCLA Investigations at Site 300 (2000).

G-5.4. Explosives Hazard Control

For safety and because of the sensitive and classified work performed in the HE Process Area OU, the Process Area is a "Special Limited" area. Access to the area is highly restricted by secondary fences and a security checkpoint. Workers must either have a Q-clearance or an Administrative Escort to enter the area. An L-Clearance allows admittance when escorted by a Q-cleared LLNL employee. All workers, regardless of clearance level, must obtain prior approval from the Special Area Access Requester to enter the HE Process Area OU. When remote operations occur in the HE Process Area OU, access to the area is restricted. Workers must also complete and follow the safety procedures covered in Course HS0095W "Site 300 Safety Orientation Training." This course contains information regarding signs, procedures, and controls used to minimize exposure to hazards related to Site 300 activities. Although no explosives are used in environmental restoration activities, it is imperative that workers follow the special safety and access requirements for the HE Process Area OU during treatment facility O&M activities.

G-5.5. Confined Space Hazard Control

Confined space entries are occasionally performed at the HE Process Area OU treatment facilities as part of the facility O&M. Facility operators and technicians should be familiar with and perform all work in confined spaces in accordance with the LLNL ES&H Manual, Section 3, "Controls for Working in Confined Spaces." Technicians should contact Hazards Control Team #1 prior to entry in any confined space. A Confined Space permit is required for hazardous confined space work. Only qualified personnel with recent confined space training are permitted to work in confined spaces and are required to comply with the two-man rule.

G-5.6. Hand and Portable Tool Hazard Control

Facility technicians are responsible for selecting and using the proper tools for the job assigned and for wearing the appropriate personal protective equipment (i.e., safety glasses, etc.) when working with hand and portable tools. All hand and portable tools should be inspected prior to use to make sure they are not damaged and are in good-working condition. Any tool that is damaged or unfit for use should be immediately removed from service. Personnel are responsible for following the work safety standards outlined in LLNL ES&H Manual, Section 26.5.

G-5.7. Working Alone Hazard Control

When working alone on a non-hazardous activity, facility technicians will advise a co-worker or supervisor that they will be working alone and when they expect to return. For potentially hazardous activities, technicians will: (1) exercise prudent judgement whether or not to perform the activity alone, and (2) obtain prior authorization from work supervisor before beginning planned hazardous-work-alone operations to ensure that all hazards have been thoroughly evaluated from the perspective of working alone. Work supervisors are responsible for ensuring an IWS is prepared for activities classified as hazardous for working alone. Personnel are responsible for following the work safety standards outlined in LLNL ES&H Manual, Section 26.12 and the Environmental Restoration Division Working Alone Guidelines (in ERD O&M Manual, Appendix F) for all work-alone activities.

G-5.8. Physical and Biological Hazard Control

During late spring and summer months, technicians should ingest fluids and evaluate their physical conditions regularly and break when necessary to avoid overheating. Work should be conducted in accordance with the LLNL ES&H Manual, Section 26.16. All personnel should follow procedures outlined in the Site 300 Lightning Procedures (S300 MGM-T-7) during a lightning alert at Site 300. A lightning alert means the weather conditions are potentially conducive to lightning. Lightning alerts are announced through the Site 300 communications systems. Employees and visitors must evacuate and remain outside explosives hazard zones until a lightning alert is cleared.

Technicians should inspect work areas for snakes and other biological hazards before commencing work. The use of high top work boots is recommended. Avoid biological hazards when possible; do not harass wildlife. Anyone who is bitten should be moved to a safe area and kept calm. Notify the Emergency Dispatch (911) immediately.

G-5.9. Slip/Trip/Fall Hazard Control

Work surfaces around the treatment facilities should be properly maintained at all times to prevent slips, trips, and falls. Maintenance includes assuring all spills and foreign materials (i.e., tools, excess equipment, etc.) are promptly removed, installing rubber or slip resistant mats at locations that may accumulate water, and ensuring that floor openings are equipped with adequate covers when worker exposure is possible. Any access to elevated locations or work at heights requires guardrails, an administrative control system, or fall protection devices.

Personnel are responsible for following the work safety standards outlined in LLNL ES&H Manual, Sections 26.17 and 10.09.

G-5.10. Material Handling Hazard Control

When lifting or handling materials manually, operators should use methods that ensure personal safety and safety of the material being handled. Objects that are too heavy or bulky to handle safely should be moved using more than one person or mechanical lifting device. All material lifting or handling should be performed in accordance with the safety standards and procedures for lifting contained in the LLNL ES&H Manual, Section 29.3.

G-5.11. Mechanical Motion Hazard Control

Any machine part, function, or process which may cause injury shall either be guarded (physical barriers which prevent access to danger areas) or safeguarded (provided with devices which inhibit machine operation, to mitigate or eliminate danger areas).

Machine operators shall be trained in the proper use of equipment and associated guards/safeguards to protect themselves and others from machine-related hazards. Machine operators shall wear protective clothing or personal protective equipment as necessary whenever engineering controls are not available or are not fully capable of protecting personnel. At a minimum, safety shoes and safety glasses shall be worn by all personnel operating or working within close proximity of heavy machinery or equipment. When there is a potential for head injury, hard hats shall be worn.

G-5.12. Fire Hazard Control

Technicians must obtain approval to access any wellfield maintenance work site that requires off-pavement travel as defined by the LLNL "Restricted Off-Pavement Travel at Site 300" policy manual. Technicians planning to travel off-pavement must receive prior permission from the Site 300 Manager, the Functional Area Supervisor, and the CAS Operator and carry a trunked radio for communications. In addition, appropriate training is required for all personnel engaging in off-road travel at Site 300. Personnel should not park or drive through dry, tall grass. Technicians performing off-road travel during O&M activities shall be familiar with and must be listed as 'qualified personnel' on IWS #1960 "Site 300 Restricted Travel to Perform ERD Activities", as well as the "Restricted Off-Pavement Travel at Site 300" manual (LLNL, 2001).

In case of fire, contact the LLNL Fire Department by dialing 911 or 925-447-6880 from a cellular phone.

G-6. Environmental Concerns and Controls

G-6.1. Ground Water Extraction and Treatment Systems

Concern: Discharge of untreated ground water.

Controls:

- Interlocks shut off the system and the flow of air and water if physical damage to the treatment system occurs.
- Scheduled sampling per waste discharge permit monitors treated ground water discharge.
- Facility operator inspects the system periodically.

G-7. Training

G-7.1. Basic Facility Operator Courses

The following courses are required for all HE Process Area OU treatment facility operators:

- HS-0039—SARA/OSHA Training (40-hour course with yearly refreshers).
- HS-0001—New Employee Safety Orientation.
- HS-1620—Standard First Aid (First Aid Certification valid for 2 years).
- HS-5300—Back Care Workshop.
- HS-5605 – Driving the Site 300 Trails.
- HS-5606W – LLNL Radio Course.
- HS-0095— Site 300 Safety.
- HS-2080—Site 300 Explosives Safety Training for Crafts, Protective Services, and Fire Personnel.

G-7.2. Selective Training Courses

The following courses may be required when they apply to the tasks assigned to the facility operator:

- HS-0006—Hazardous Waste Handling Practices (refresher training required annually).
- HS-4150—Confined Space Entry.
- HS-4240—Chemical Safety.
- HS-5220—Electrical Safety (required every 5 years).
- HS-5245—Lockout and Tag Procedure (refresher training required every 5 years).

G-7.3. Training Responsibilities and Documentation

Training courses identified in this section do not qualify a person to operate the treatment equipment and treatment systems located in HE Process Area OU. Only the responsible individual(s) identified in Section G-3 of this Health and Safety Plan will determine if and when a person is qualified to operate the treatment facilities. Once qualified, the technician supervisor records that the technician has been qualified as a treatment facility operator.

The responsible individual, or designee, shall ensure that all required training (including on-the-job training if applicable) is completed and documented in the LLNL Repository of Completed Courses. Untrained personnel may work under the supervision of a trained person until the required training is completed.

G-8. Maintenance

Items requiring periodic maintenance do not impact the safety of the operation. Interlocks shall be tested annually.

G-9. Quality Assurance

O&M activities at the HE Process Area OU treatment facilities shall be controlled by quality procedures designed to meet ground water treatment and discharge requirements specified in the waste discharge permits for ground water. Controls to prevent the discharge of untreated ground water and meet quality objectives include:

- Annual interlock function checks shall be performed by the Facility Electronics Staff or Plant Engineering Electronic Engineering Staff. Test documentation shall be maintained by the Facility Electronics Supervisor, or designee.
- Scheduled weekly, monthly, quarterly, and annual sampling of water to ensure compliance and quality.
- Treatment facility-related analytical data will be reviewed by the Quality Assurance Coordinator or designee to ensure the data meets quality objectives.

G-10. Emergency Response Procedures

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. The phone numbers of individuals to be notified in the event of an emergency during off-shift hours are posted at the HE Process Area OU treatment facilities. The LLNL ES&H Manual describes the emergency response procedures.

G-11. Applicable Documents

The following documents and/or sections thereof apply to the safe operation of the HE Process Area OU treatment facilities and are incorporated into this Health and Safety Plan by reference.

G-11.1. Treatment Facility Operating Manual for the HE Process Area OU ground water treatment facilities (to be produced)

G-11.2. Integration Work Sheet Safety Procedures #239 (Lockout and Tag Program for Institutional and PE Maintained Programmatic Equipment), #1265 Ground Water and Soil Vapor Treatment Facility Operations at Site 300, and #1960 (Site 300 Restricted Travel to Perform ERD Activities)

G-11.3. LLNL Environment, Safety, and Health Manual Sections

Section 1.	LLNL ES&H Policies, General Worker Responsibilities, and Integrated Safety Management
Section 2.	Integrating ES&H into Laboratory Activities
Section 10.08	Hearing Protection
Section 21.	Chemicals
Section 21.3.5	Facilities and Equipment
Section 21.3.7	Handling Solid and Liquid Chemicals
Section 23.	Electrical Safety
Section 23.1	Introduction
Section 23.2	Hazards
Section 23.3	Controls for Electrical Work and Electrical Equipment
Section 23.4	Responsibilities
Section 23.5	Work Standards
Section 23.6	Resources for More Information
Appendix 23-B	Effects of Electrical Energy on Humans

G-11.4. LLNL Electronics Engineering Department—Electrical Safety Policy, LED-61-00-01-A1A

G-11.5. Site Safety Plan for LLNL CERCLA Investigations at Site 300, November 2000

G-11.6. LLNL Environment, Safety, and Health Manual Supplements

Section 10.08	Hearing Conservation
Section 11.07	Personnel Safety Interlocks
Section 26.13	LLNL Lockout and Tag Program

G-12. References

LLNL (2001) Restricted Off-Pavement Travel at Site 300, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-MI-144038).

LLNL (2000), LLNL Environment, Safety, and Health Manual.

LLNL (2000), *Site Safety Plan for Lawrence Livermore National Laboratory CERCLA Investigations at Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-21172 Rev. 3).

Acronyms and Abbreviations

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1,2-DCE	1,2-dichloroethylene
2-D	two-dimensional
3-D	three-dimensional
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AVI	active vacuum induced
AWS	American Welding Society
$Ba(NO_3)_2$	barium nitrate
bgs	below ground surface
BTU	Bio Treatment Unit
CO	carbon monoxide
CO_2	carbon dioxide
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfd	cubic feet per day
CFR	Code of Federal Regulations
cm	centimeter
CMP	Compliance Monitoring Program
CO	carbon dioxide
COC	Contaminants of Concern
DSB	Distal site boundary
DHS	Department of Health and Safety
DO	dissolved oxygen
DOE	U.S. Department of Energy
DOL	Department of Labor
DOT	Department of Transportation
DSB	Distal site boundary
DTSC	California Department of Toxic Substances Control
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
EPD	Environmental Protection Department
ERD	Environmental Restoration Division
ES&H	Environmental Safety & Health
FFA	Federal Facility Agreement
ft	feet, foot
ft/s	feet per seconds
ft^2	square feet
ft^3/yr	cubic feet per year

FY	Fiscal Year
GAC	granular activated carbon
gal	gallon(s)
gpd	gallons per day
gpm	gallons per minute
GTU	GAC Treatment Unit
HE	High explosives
HMX	cyclotetramethylene tetranitramine
hp	horsepower
HSU	hydrostratigraphic unit
HWAA	Hazard Waste Accumulation Area
HWMD	Hazardous Waste Management Division
Hz	hertz
ICBO	International Conference of Building Officials (ICBO)
ID	identification
in.	inch
Inf Tr	infiltration trench
I/O	input/output
IX	ion exchange
IWS	Integration Work Sheet
K	hydraulic conductivity
KCl	potassium chloride
kg	kilograms
lb	pound(s)
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
mA	milliamp
µg/L	micrograms per liter
mi^2	square miles
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mgN/kg	milligram of nitrate per kilogram of soil sample
MW	monitor well
NFPA	National Fire Protection Association
N_2	nitrogen
ND	not detected
NRTL	Nationally Recognized Testing Laboratory
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
OU	operable unit
Ph	Phase
P&ID	piping and instrumentation diagram
ppm_v	parts per million per volume
PEL(s)	permissible exposure limits
PEST	parameter automated estimation tool
PEPM	Plant Engineering Project Leader
PRG	Preliminary Remediation Goal
PRX	proximal
psi	pounds per square inch
PVC	polyvinyl chloride
PVDF	polyvinylidene flouride
QA	quality assurance
Qal	Quaternary Alluvium

QAMP	Quality Assurance Management Plan
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
QC	quality control
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RDX	cyclo-1,3,5-trimethylene-2,4,6-trinitramine
RDWP	Remedial Design Work Plan
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager
RWQCB	California Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
SCADA	Supervisory Control and Data Acquisition
sec	second(s)
SOP	Standard Operating Procedure
SRC	source
STLC	Soluble Threshold Limit Concentration
STU	Solar-powered Treatment Unit
SVS	soil vapor survey
SWFS	Site-Wide Feasibility Study
SWRI	Site-Wide Remedial Investigation
TCE	trichloroethylene
TDS	total dissolved solids
TKEBS	tetrakis (2-ethylbutoxy) silane
TLVs	threshold limit values
$Tnbs_1$	Miocene Neroly Formation - Lower Blue Sandstone Member
$Tnbs_2$	Miocene Neroly Formation - Middle Blue Sandstone Member
$Tnsc_1$	Miocene Neroly Formation - Middle Siltstone/Claystone Member
$Tnsc_2$	Miocene Neroly Formation - Middle Siltstone/Claystone Member
TNT	trinitrotoluene
Tps	Pliocene nonmarine unit
Tpsg	Pliocene nonmarine unit (gravel facies)
TVOC	total volatile organic compound
UCRL	University of California Radiation Laboratory
yd	yard(s)
VOC	volatile organic compound
V p-p	volts peak to peak
VDC	volts direct current