U.S. Department of Energy
Oakland Operations Office, Oakland, California 94612

Lawrence Livermore National Laboratory
University of California, Livermore, California 94550

UCRL-AR-144104

Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300

Authors:

R. Ferry[1]
W. Daily
L. Ferry
G. Aarons[2]
V. Madrid
J. Valett[2]
Z. Demir[2]

Contributors:

R. Depue
K. Heyward

November 2001

[1]Pentacore Resources, Livermore, California
[2]Weiss Associates, Emeryville, California

Environmental Protection Department
Environmental Restoration Division

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Approval and Concurrence for the Five-Year Review for the General Services Area at Lawrence Livermore National Laboratory Site 300

Prepared by:

The United States Department of Energy
Oakland Operations Office
Oakland, California

Approved:

Roy Kearns 11-16-01

Roy Kearns Date
Site 300 Remedial Project Manager
U.S. Department of Energy
Oakland Operations Office

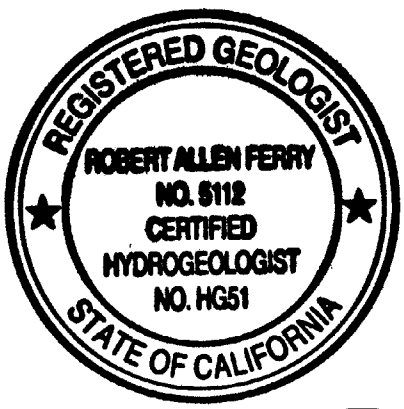
Concurrence:

Michela Actuy (Acting) 11-20-01

Daniel A. Meer Date
Chief, Federal Facilities Cleanup Branch
U.S. Environmental Protection Agency
Region IX

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.



11/29/01

Robert A. Ferry Date
California Registered Geologist
No. 5112
License expires: July 31, 2003
California Certified Hydrogeologist
No. HG51
License expires: July 31, 2003

Five-Year Review Summary Form

Site Identification		
Site name: Lawrence Livermore National Laboratory Site 300, General Services Area Operable Unit		
EPA ID: CA 2890090002		
Region: IX	State: California	City/County: San Joaquin/Alameda
Site Status		
NPL status: Final		
Remediation status: Operating		
Multiple OUs: Yes	Construction completion date: To be determined	
Has the site been put into reuse: No		
Review Status		
Reviewing agency: U.S. Department of Energy		
Author name: Robert A. Ferry		
Author title: Principal	Author affiliation: Pentacore Resources, LLC	
Review period: February 1997 to June 2001		
Date(s) of site inspection: Not applicable		
Type of review: DOE Policy		
Review number: 1		
Triggering action: Final Record of Decision for the General Services Area OU		
Triggering action date: February 5, 1997		
Due date: February 5, 2002		

Five-Year Review Summary Form (continued)

Deficiencies:

No deficiencies in the remedy were identified during the five-year review process.

Recommendations and Follow-up Actions:

The following recommendations were developed during the five-year review process:

- A high priority should be given to optimizing ground water and soil vapor extraction well placement and pumping rates to maximize contaminant capture within the existing wellfields and shorten the time required to reach cleanup standards.
- Additional ground water extraction wells located north of Building 875 should be considered. Although VOC concentrations in ground water in this area are relatively low (maximum of 46 µg/L), the lateral extent of this plume is limited and ground water extraction may accelerate achievement of cleanup standards throughout the GSA.
- Contaminants in the regional aquifer in the central GSA should be closely monitored, but extraction should be considered only if data indicate that the current declining concentration trend does not continue.
- In the eastern GSA, DOE should consider the possibility of undetected VOC mass if ground water remediation does not continue its current progress toward achieving cleanup standards.

If DOE and the regulatory agencies agree to incorporate any or all of these recommendations, implementation milestones can be added to the schedule in the Federal Facility Agreement for Site 300, and/or administered less formally by inclusion in the minutes of the Remedial Project Manager's monthly meetings.

No other follow-up actions were identified related to this five-year review.

Protectiveness Statement:

The Health and Safety Plan and the Contingency Plan are in place, sufficient to control risks, and properly implemented. Ground water and soil vapor extraction and treatment are effectively controlling the migration of contaminants, and are reducing contaminant concentrations in the subsurface as needed to meet cleanup standards in the time frame anticipated at the time of the ROD. Institutional controls are in place to prevent use of contaminated ground water. Thus, the remedy for the GSA OU is protective of human health and the environment.

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1. Introduction

The United States Department of Energy (DOE) has conducted a five-year review of the remedial actions implemented at the General Services Area (GSA) operable unit (OU) at Lawrence Livermore National Laboratory (LLNL) Site 300. DOE is the lead agency for environmental restoration at LLNL. The review documented in this report was conducted from January 2001 through May 2001. Parties providing analyses in support of the review include:

- U.S. DOE, Oakland Operations Office.
- LLNL, Environmental Restoration Division.
- Pentacore Resources, LLC.
- Weiss Associates.

The purpose of five-year reviews is to determine whether the remedy at the site is, or is expected to be, protective of human health and the environment. The methods, findings, and conclusions of the reviews are documented in five-year review reports. In addition, the five-year review reports identify deficiencies found during the review, if any, and present recommendations to address them. The format and content of this document is consistent with recent draft guidance issued by DOE (DOE, 2000a) and the U.S. Environmental Protection Agency (EPA) (EPA, 1999).

This is the first five-year review for the GSA OU. Although not required by statute, this review is considered a policy review because the remedial action will allow for unlimited use and unrestricted exposure upon completion, but will take longer than five years to complete. In accordance with DOE policy, the triggering action for this review is the date of actual remedial action onsite construction, assumed to be the signature date, February 5, 1997, of the Final Record of Decision (ROD) for the GSA OU (DOE, 1997). DOE has not yet performed five-year reviews for other OUs at Site 300.

The background and description of the GSA OU are presented in Section 3. The following paragraphs include the descriptions and status of other environmental restoration activities at Site 300. Many of these areas and OUs were included in the Interim Site-Wide ROD for Site 300 (DOE, 2001).

Building 834 OU - The Building 834 facilities have been in use since the late 1950s for experiments involving thermal cycling of weapons components. From 1962 to 1978, intermittent spills and piping leaks resulted in contamination of the subsurface with trichloroethylene (TCE) and silicone oils. Nitrate contamination in ground water results from septic-system effluent but may also have natural sources. Ground water and soil vapor extraction and treatment began in 1986 as treatability studies. Cleanup continued under an Interim ROD for the OU and later under the Interim Site-Wide ROD for Site 300. DOE has periodically modified and expanded the extraction wellfield and upgraded the treatment facilities, and is conducting treatability studies to evaluate *in situ* biodegradation.

Pit 6 Landfill OU - From 1964 to 1973, waste was buried in nine unlined trenches and animal pits at the Pit 6 Landfill. Contaminants in the subsurface include volatile organic

compounds (VOCs), tritium, nitrate, and perchlorate. In 1971, DOE excavated portions of the waste contaminated with depleted uranium. In 1997, a landfill cap was installed as a removal action to prevent infiltrating precipitation from further leaching contaminants from the waste. Because of decreasing TCE concentrations in ground water, the presence of TCE degradation products, and the short half-life of tritium (12.3 years), the selected interim remedy for TCE and tritium at the Pit 6 Landfill is monitored natural attenuation. DOE is evaluating the source, extent, and natural degradation of perchlorate and nitrate. The interim remedy for these contaminants in ground water is continued monitoring.

High Explosives Process Area OU - Surface spills from 1958 to 1986 resulted in the release of VOCs at the former Building 815 steam plant. High-explosive compounds, nitrate, and perchlorate are present in the subsurface and are attributed to wastewater discharges to former unlined rinsewater lagoons. The High Explosives Burn Pits were capped in 1998. In 1999, DOE implemented a removal action to perform ground water extraction at the site boundary to prevent the TCE plume from migrating offsite. Treatability studies are underway near Building 815 to assess high explosive, nitrate, and perchlorate treatment technologies. The selected interim remedy for this OU includes continued ground water extraction and treatment.

Building 850 Firing Table - High-explosives experiments have been conducted at the Building 850 Firing Table since 1958. Tritium was used in these experiments, primarily between 1963 and 1978. As a result of the dispersal of test assembly debris during explosions, surface soil was contaminated with metals, polychlorinated biphenyls (PCBs), dioxins, furans, high-explosive compounds, and depleted uranium. Leaching from firing table debris has resulted in tritium and depleted uranium contamination in subsurface soil and ground water. Nitrate has also been identified in ground water. PCB-contaminated shrapnel and debris was removed from the area around the firing table in 1998. The selected remedy for the Building 850 area includes excavation of the contaminated surface soil and a nearby sand pile as a final remedy and monitored natural attenuation of tritium in ground water as an interim remedy.

Pit 7 Landfill Complex - The Pit 3, 4, 5, and 7 Landfills are collectively designated the Pit 7 Landfill Complex. Firing table debris containing tritium, depleted uranium, and metals was placed in the pits in the 1950s through the 1980s. The Pit 4 and 7 Landfills were capped in 1992. Ongoing releases of contaminants to ground water are occurring. DOE is continuing to characterize the area and is preparing an area-specific Remedial Investigation/Feasibility Study.

Pit 2 Landfill - The Pit 2 Landfill was used from 1956 to 1960 to dispose of firing table debris and gravel. No unacceptable risk or hazard to human health or ecological receptors has been associated with the Pit 2 Landfill, and there is no evidence of any release from the landfill. The selected interim remedy for the Pit 2 Landfill is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill.

Building 854 OU - TCE was released to soil and ground water through leaks and discharges of heat-exchange fluid, primarily between 1967 and 1984. Other contaminants in ground water include nitrate and perchlorate. Some TCE-contaminated soil was excavated in 1983. Treatability studies to assess VOC, nitrate, and perchlorate extraction and treatment are underway. The selected interim remedy for this OU includes ground water and soil vapor extraction and treatment.

Building 832 Canyon OU - TCE was released to soil and ground water through leaks and discharges of heat-exchange fluid at Buildings 830 and 832 between the late 1950s and 1985. Nitrate and perchlorate are also present in ground water. In 1999, DOE began a treatability study to evaluate ground water and soil vapor extraction at Building 832. Two other treatability studies are underway in the downgradient portion of the VOC plume to: (1) evaluate the optimum locations of ground water extraction wells to inhibit offsite migration of contaminants, and (2) test the effectiveness of iron filings (zero-valent iron) in removing VOCs from extracted ground water. The selected interim remedy for this OU includes continued soil vapor and ground water extraction and treatment.

Building 801 Dry Well and the Pit 8 Landfill - Waste fluid was discharged to a dry well located adjacent to Building 801D from the late 1950s to 1984, resulting in minor subsurface VOC contamination. The Pit 8 Landfill was used to dispose of debris from the Building 801 Firing Table until an earthen cover was installed in 1974. There is no evidence of a contaminant release from the landfill. The selected interim remedy for this area is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill.

Building 833 - TCE was used as a heat-exchange fluid in the Building 833 area from 1959 to 1982 and was released through spills and rinsewater disposal, resulting in minor VOC contamination of the shallow soil/bedrock and perched ground water. The selected interim remedy for this area is continued monitoring.

Building 845 Firing Table and Pit 9 Landfill - High-explosives experiments were conducted at the Building 845 Firing Table from 1958 to 1963. Leaching from firing table debris resulted in minor contamination of subsurface soil with depleted uranium and high-explosive compounds. No ground water contamination has been detected. The Pit 9 Landfill was used to dispose of firing table debris generated at the Building 845 Firing Table. The debris buried in the pit may contain tritium, uranium, and/or high-explosive compounds. However, there is no evidence of a contaminant release from the Pit 9 Landfill. No unacceptable risk or hazard was identified in either area. The selected interim remedy for this area is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill.

Building 851 Firing Table – The Building 851 Firing Table has been used for high-explosives research since 1982. These experiments resulted in minor VOC, depleted uranium, metals, and high-explosives contamination in soil and ground water. No unacceptable risk or hazard was identified in this area. The selected interim remedy for this area is continued monitoring.

Advanced Test Accelerator (Building 865) - Solvents were used at this facility, and Freon-113 has been detected in the subsurface. DOE is planning to conduct further site characterization.

Building 812 – This facility has been in use since the 1960s. Gravel from the firing table was pushed into an adjacent ravine or to the side of the table. Depleted uranium has been detected in soil and further characterization is planned.

Sandia Test Facility - From about 1959 to 1960, Sandia National Laboratories (Livermore) operated a small, temporary firing table at Site 300. The facility consisted of a portable building

with other structures built into the hillside and surrounded by sandbags. The facility may have been used to test or store high explosives. DOE is planning to investigate this area.

2. Site Chronology

The following chronology summarizes important events relevant to environmental restoration in the GSA OU:

1960s/1970s	Solvents discharged to dry wells in the GSA, contaminated shop debris buried in eastern GSA, and discharges at the Building 879 Steam-Cleaning/Sink facility occurred.
1970s/1980s	Solvent spills from drum rack occurred.
1982	Site investigations began.
1990	LLNL Site 300 placed on the National Priorities List.
1991	Ground water remediation began in the eastern GSA as a removal action.
1992	Federal Facility Agreement for Site 300 signed.
1993	Ground water remediation began in the central GSA as a removal action.
1994	Soil vapor extraction began in the central GSA as a removal action.
1994	Site-Wide Remedial Investigation report issued.
1995	Feasibility Study for the GSA OU issued.
1996	Proposed Plan for the GSA OU issued.
1997	Record of Decision for the GSA OU signed.
1997	Remedial actions started.
1998	Remedial Design document for the GSA OU issued.

3. Background

3.1. Physical Characteristics

LLNL Site 300 is a U.S. DOE experimental test facility operated by the University of California. It is located in the eastern Altamont Hills 17 miles east of Livermore, California (Figure 1). At Site 300, DOE conducts research, development, and testing associated with high-explosive materials. During previous Site 300 operations, a number of contaminants were released to the environment. These releases occurred primarily from spills, leaking pipes, leaching from unlined landfills and pits, high-explosive test detonations, and disposal of waste fluids in lagoons and dry wells (sumps).

The GSA OU is located in the southeast corner of Site 300 (Figure 1). Within the GSA are a number of craft shops, storage buildings, and offices that support the research being conducted at

Site 300. The GSA has been separated into the central GSA and the eastern GSA based on differences in hydrogeology and the distribution of environmental contaminants. The majority of structures are located in the central GSA. The eastern GSA contains a sewage treatment and adjacent overflow ponds. The offsite area adjacent to the GSA is sparsely populated and used for agriculture. The nearest major population center (Tracy, California) is 8.5 miles to the northeast.

Three distinct hydrogeologic units have been identified beneath the GSA. Figure 2 is conceptual hydrogeologic cross-section through the GSA. In the central GSA, the surface sediments typically consist of unconsolidated valley-fill and terrace alluvium extending to a depth of approximately 15 to 30 ft below ground surface (bgs). Beneath the alluvium is a sandstone bedrock layer approximately 25 ft in thickness. Unconfined ground water occurs in the alluvium and sandstone and is referred to as the "shallow aquifer." The depth to ground water is 10 to 20 ft bgs, and in the shallow aquifer ground water flows toward the south and east at a velocity of 0.05 to 0.10 ft/day. A potentiometric surface elevation contour map for the shallow aquifer in the central GSA is presented as Figure 3. A silty claystone aquitard underlies the shallow aquifer, separating it from a deeper, laterally-extensive sandstone regional aquifer. The regional aquifer is separated into upper and lower units by an easily identifiable claystone marker bed. Ground water velocity in the regional aquifer is approximately 0.3 feet per day.

The hydrogeology in the eastern GSA is similar, except that the claystone aquitard and overlying shallow sandstone units are absent and ground water in the alluvium is in direct contact with the underlying regional aquifer. Due to the presence of low-permeability layers within the regional aquifer, the ground water in the alluvium and bedrock above these confining layers is considered a single aquifer (the alluvial/shallow bedrock aquifer). In the eastern GSA, the hydraulic conductivity of the alluvium is significantly greater than in the central GSA. The depth to ground water is 10 to 15 ft bgs, and ground water flow in the alluvial aquifer is toward the east and north at a velocity of 0.5 to 3 feet per day. A potentiometric surface elevation contour map for the alluvial and shallow bedrock aquifer in the eastern GSA is presented as Figure 4.

There are no environmentally sensitive areas on Site 300 property within the GSA OU. However, the California Department of Fish and Game operates an ecological preserve immediately northeast of the GSA along Corral Hollow Creek. Administrative controls are in place to minimize any potential detrimental impacts on the preserve from the GSA cleanup, including managing of ground water treatment system discharges to prevent surface water from reaching the preserve during the summer months.

3.2. Land and Resource Use

Prior to DOE establishing Site 300 as remote testing facility in 1955, the area was used for cattle grazing. Site 300 is currently an operating facility, and will remain under DOE control for the reasonably anticipated future. There is no known planned modification or proposed development of the offsite land adjacent to the GSA. Current offsite land use near the GSA includes cattle grazing, private residences, and an ecological preserve. Offsite, several private water-supply wells are in use, but all supply wells at risk from contamination from the GSA have either been sealed or are being regularly monitored.

3.3. History of Contamination

The eight confirmed contaminant release sites in the GSA are shown on Figure 5 and listed below:

1. The Building 879 Steam-Cleaning/Sink facility.
2. Former dry well 875-S1.
3. Former dry well 875-S2.
4. A decommissioned solvent drum rack and underground solvent retention tank.
5. Former dry well 872-S.
6. Former dry well 873-S.
7. A former debris burial trench west of the sewage treatment pond in the central GSA.
8. Several former debris burial trenches north of the sewage treatment overflow pond in the eastern GSA.

Solvents containing VOCs were commonly used as degreasing agents in craft shops in the central GSA. Rinse water from these operations was disposed of in dry wells. Typically, the dry wells in the central GSA were gravel-filled pits 3 to 4 feet deep and 2 feet across. The dry wells were used until 1982 and were all excavated in 1983–1984.

In the eastern GSA, various types of debris were disposed of in debris burial trenches during the 1960s and 1970s. Some of this debris was contaminated with small quantities of VOCs. Trenching of the debris burial area, interviews with former and present employees, and examination of aerial photographs indicate that the trenches contain primarily metal, ceramic, and glass debris from the craft shops.

3.4. Initial Response

DOE began environmental investigations in the GSA in 1982. Since then, almost 100 monitor wells have been installed to characterize the vertical and horizontal extent of contamination throughout the GSA and to measure ground water elevations. Other site characterization methods included soil sampling, soil vapor surveys, hydraulic testing, colloidal borescope investigations, and geophysical surveys. Test pits were also used to determine the extent of burial trenches and contamination in the eastern GSA.

Pre-ROD remediation activities at the GSA included:

- Excavating and backfilling all dry wells.
- Sealing and abandoning impacted or threatened water-supply wells.
- Removal actions to begin ground water and soil vapor extraction and treatment.

3.5. Contaminants

The primary contaminant found in ground water and soil at the GSA is TCE, comprising approximately 90% of the total VOCs. TCE is volatile, denser than water, and tends to sorb to soil. TCE is a suspected human carcinogen. Other VOCs detected in the GSA include tetrachloroethylene (PCE), 1,2-dichloroethylene (1,2-DCE), 1,1-dichloroethylene (1,1-DCE), 1,1,1-trichloroethane (1,1-TCA), acetone, benzene, bromodichloromethane, chloroform, ethylbenzene, Freon 113, toluene, and xylenes.

In the central GSA, the highest preremediation concentration of TCE in soil was 360 milligrams per kilogram (mg/kg), detected below the Building 875 dry wells. The preremediation concentration of total VOCs in ground water was approximately 272,000 micrograms per liter (µg/L). Globules of TCE (a Dense Non-Aqueous Phase Liquid, or DNAPL) were observed in some ground water samples. The baseline human health risk assessment conducted in 1991 estimated a maximum excess carcinogenic risk of 7×10^{-2} if ground water from a hypothetical water-supply well located at the site boundary near the Building 875 dry wells were to be ingested over a 70-yr period (risk values below 10^{-6} are considered protective). The corresponding noncarcinogenic hazard index was 560 (hazard indices below 1 are considered protective). The baseline risk assessment also estimated an excess cancer risk to onsite workers from TCE vapors migrating into Building 875 of 1×10^{-5}.

In the eastern GSA, the highest preremediation concentration of total VOCs detected in shallow ground water near the debris burial trench at the eastern GSA was approximately 100 µg/L. Prior to the start of remediation, the plume of TCE in ground water exceeding the Maximum Contaminant Level (MCL) of 5 µg/L extended approximately 4,200 feet offsite. The 1991 baseline human health risk assessment estimated an excess carcinogenic risk of 5×10^{-5} for ingesting ground water from a hypothetical water-supply well located at the site boundary near the debris burial trench. The risk associated with potential use of contaminated ground water at two offsite wells (CDF-1 and SR-1) was approximately 10^{-5}. Very low concentrations of VOCs (maximum of 0.017 mg/kg) have been detected in the vadose zone beneath the debris trenches in the eastern GSA. No unacceptable risk or hazard was associated with potential exposure to VOCs in surface or subsurface soil.

4. Remedial Actions

4.1. Remedy Selection

The remedies selected for the GSA OU are intended to achieve the following Remedial Action Objectives:

<u>Protection of Human Health:</u>

- Prevent human ingestion of the ground water containing VOC concentrations (single carcinogen) above the State and Federal drinking water MCLs, a cumulative excess cancer risk (all carcinogens) greater than 10^{-6}, and a cumulative hazard index (all noncarcinogens) greater than 1.

- Prevent human inhalation of VOCs in vapor in concentrations above those that pose an excess cancer risk of 10^{-6}.

Protection of the Environment:

- Restore water quality, at a minimum, to water quality objectives that are protective of beneficial uses (i.e., MCLs).

The cleanup standard for ground water in the GSA OU is to reduce VOC concentrations to MCLs in all impacted ground water. VOCs in the vadose (unsaturated) zone will be remediated to the extent technically and economically feasible to minimize further degradation of the ground water by contaminants in the vadose zone. The vadose zone cleanup will be completed when it is demonstrated that: (1) VOCs remaining in the vadose zone no longer cause concentrations in the leachate to exceed the ground water cleanup standards, based on an interpretation of soil vapor data using an appropriate vadose zone model, and (2) VOCs have been removed to the extent technically and economically feasible to meet the ground water cleanup levels sooner, more cost-effectively, and more reliably. Another cleanup standard is to mitigate the excess cancer risk from inhalation of indoor air within Building 875 caused by VOCs migrating into the building from the subsurface.

The remedies for the GSA were selected based on their capacity to contain contaminant sources, prevent further plume migration, remove contaminant mass from the subsurface, and protect human health and the environment both onsite and offsite. In the remedial design phase, DOE considered hydrogeologic factors, contaminant characteristics, available remedial technologies, and effective performance monitoring techniques. The selected remedy for the GSA consists of:

- Ground water extraction and treatment in the central GSA.
- Soil vapor extraction and treatment at the Building 875 dry well area in the central GSA.
- Ground water extraction and treatment in the eastern GSA.
- Regular ground water and soil vapor monitoring.
- Institutional controls, such as access/land-use restrictions and measures to prevent use of contaminated ground water.

4.2. Remedy Implementation

Sections 4.2.1 and 4.2.2 present a summary of the actions DOE has taken to implement the selected remedy in the GSA OU, and also describe any significant modifications to the remedy since the Final ROD (DOE, 1997) and Remedial Design (Rueth et al., 1998) documents for the GSA OU. Information on the performance of the remedy is included in Section 6.4, as is information on the current concentration and distribution of contamination.

4.2.1. Central GSA

4.2.1.1. Ground Water

Ground water cleanup began in the central GSA in 1993 using four extraction wells at the Building 875 dry well release area. The ROD and Remedial Design documents included plans to evaluate expansion of the shallow aquifer ground water extraction wellfield to include other contaminant sources and the downgradient extent of the VOC plume. Three extraction wells were added in 1999 (the Phase I wellfield expansion). Two of these extraction wells were installed at the Building 872 and Building 873 dry well VOC release sites (wells W-872-02 and W-873-07, respectively). The third well (W-7O) was installed hydraulically downgradient from the Building 875 dry well release area. DOE presented a Phase II wellfield expansion work plan in 2000. With regulatory concurrence, the Phase II plan screened out six potential extraction wells that had been included in the remedial design (W-873-06, W-7S, W-7F, W-7T, W-7Q, and W-875-03), due to low contaminant concentrations and/or low well yields, and proposed installing one additional shallow aquifer extraction well (W-7R), if needed in the future. However, data obtained since 2000 has caused DOE to begin the process of re-evaluating the future configuration of the wellfield with the objective of optimizing contaminant mass removal and improving migration control. Once this evaluation is complete, DOE will present a revised wellfield configuration to the regulatory agencies that will include any additional extraction wells necessary to achieve ground water cleanup standards.

Currently, contaminated ground water is extracted from the shallow aquifer using seven wells each producing 0.5 to 7 gallons per minute (gpm). The current treatment configuration includes particulate filtration, air stripping to remove VOCs from extracted water, granular activated carbon (GAC) to treat vapor effluent from the air stripper, and discharge to the ground surface using irrigation sprinklers.

Active remediation of the regional aquifer by extraction from well W-7P was included as part of the selected remedy in the GSA ROD and scheduled to be implemented as part of the 2000 Phase II wellfield expansion, but DOE has since re-evaluated the contaminant hydrogeology in this part of the central GSA and is no longer considering extracting from the regional aquifer because:

1. The maximum VOC concentration in the regional aquifer has decreased from a historic maximum of 63 µg/L to 12 µg/L at present. This is attributed to a reestablishment of the naturally-occurring upward hydraulic gradient since several nearby water-supply wells were sealed in the early 1990s. Past pumping from these wells reversed the natural gradient and caused VOCs to be drawn downward into the regional aquifer where the regional aquifer is hydraulically connected with the shallow aquifer (i.e., where the intervening aquitard is absent). The upward gradient is now causing VOCs in the regional aquifer to migrate upward into the overlying shallow aquifer in the alluvium (the original source of contamination to the regional aquifer). Removing VOCs from the shallow aquifer in this area is an important part of DOE's overall cleanup strategy for the GSA and will be addressed in the overall re-evaluation of the GSA wellfield.

2. Extracting ground water from the regional aquifer would very likely cause additional VOCs to migrate downward into that aquifer from the overlying, more highly contaminated shallow aquifer.

3. The mass of VOCs in the regional aquifer is relatively small (0.01 kg).

Contaminant concentrations in the regional aquifer will continue to be closely monitored, and DOE will reconsider extraction if concentrations do not continue to decline. DOE has not yet obtained regulatory approval for this modification to the wellfield configuration, but will present the results of the wellfield evaluation and any proposed modifications for regulatory concurrence.

4.2.1.2. Vadose Zone

In 1994, DOE began soil vapor extraction at the Building 875 dry well contaminant source area as a removal action. The soil vapor extraction wellfield and treatment system described in the GSA ROD and Remedial Design documents is fully implemented. Seven wells are used either to extract soil vapor or as passive air inlet wells. Simultaneous ground water extraction in the vicinity lowers the elevation of the ground water surface and maximizes the volume of unsaturated soil influenced by vapor extraction. Extracted vapors are treated with vapor-phase GAC and discharged to the atmosphere. The current treatment configuration includes a de-misting chamber, a regenerative blower, and four 140-lb vapor-phase GAC vessels arranged in series.

4.2.2. Eastern GSA

DOE began ground water remediation at the eastern GSA in 1991 as a removal action and continued as a remedial action after the GSA ROD. An offsite ground water extraction and treatment facility was included in the remedial design. However, since the existing extraction configuration has been extremely successful in controlling offsite contaminant migration, this offsite facility was determined not to be needed. TCE concentration in the area of the proposed facility is low (5-6 µg/L) and decreasing. The regulatory agencies concurred with the decision not to install this facility.

Currently, contaminated ground water is extracted from the alluvial aquifer using three wells yielding 15 gpm each. Initially, air sparging was used to treat extracted ground water, but a treatability study conducted in 1995-1996 indicated that treatment using aqueous-phase GAC was a simpler and more efficient technology at the site, and a GAC system was installed in 1997. The current treatment configuration includes particulate filtration, contaminant adsorption by aqueous-phase GAC using three 1,000-lb vessels arranged in series, and surface discharge to Corral Hollow Creek.

4.3. System Operations/Operation and Maintenance

In general, the three extraction and treatment systems are operating as designed and no significant operations, performance, maintenance, or cost issues were identified during the review. All required documentation is in place, and treatment system operations and maintenance (O&M) activities are consistent with established procedures and protocols.

O&M procedures are contained in the following documents:

- Health and Safety Plan, Quality Assurance/Quality Control Plan, Compliance Monitoring Plan, and Contingency Plan for the GSA OU, contained within the Remedial Design document (Rueth et al., 1998).
- Operations and Maintenance Manual, Volume VI: Central General Services Area Vapor and Ground Water Treatment Facilities (LLNL, 2000).
- Eastern GSA Treatment Facility Operations Checklist (LLNL, 1999).
- Central GSA: Substantive Requirements and the Monitoring and Reporting Program issued by the California Regional Water Quality Control Board (CRWQCB) and the Permit to Operate issued by the San Joaquin Valley Unified Air Pollution Control District.
- Eastern GSA: National Pollutant Discharge Elimination System (NPDES) Waste Discharge Requirements (No. CA 0082651) and Standard Provisions and Reporting Requirements issued by the CRWQCB.

Monitoring and optimizing the performance and efficiency of the three extraction and treatment systems comprises a large portion of the O&M activities. Extracted ground water is sampled at multiple points during the treatment process to ensure compliance with discharge requirements. Treatment system parameters such as pressure, flow, and temperature are recorded daily to anticipate potential mechanical problems. Monitor and extraction wells are sampled regularly. Quarterly reports submitted to the regulatory agencies document all analytic results, O&M activities, and system performance data.

The major O&M activity at the central GSA ground water treatment facility is to ensure maximum operating efficiency of the air stripper. The internal air pressure within the air stripper is closely monitored. When this pressure reaches a pre-determined point (indicating buildup of scaling within the packing elements) the system is overhauled to ensure maximum efficiency of VOC removal from extracted ground water. Other O&M activities include injecting anti-scaling compounds, removing iron oxide buildup, maintaining remote computer access and data collection capabilities, protecting the unit from freezing in cold weather, and periodically replacing spent vapor-phase GAC.

The major O&M activities at the central GSA soil vapor treatment facility are monitoring the performance of the system and replacing spent vapor-phase GAC. The vapors treated by the primary GAC vessel (the first of four in series) are tested regularly for VOC breakthrough. When breakthrough occurs in the effluent of the primary vessel, the effluent of the secondary vessel is tested until breakthrough occurs. Upon VOC breakthrough from the secondary vessel, both the primary and secondary GAC vessels are replaced. Other O&M issues include ensuring the temperature within the GAC drums remains within the optimal range and optimizing the performance of the soil vapor extraction and ambient air injection wells.

DOE's major O&M activity at the eastern GSA ground water treatment facility is replacing the 3,000 lbs of aqueous-phase GAC. The extracted ground water treated by the primary GAC vessel (the first of three in series) is sampled and analyzed regularly for VOCs. When VOCs break through the primary vessel, the effluent of the secondary vessel is tested until breakthrough occurs. Upon breakthrough from the secondary vessel, the GAC in both the primary and secondary vessels is replaced.

The two treatment systems in the central GSA have consistently operated in compliance with all permits and requirements. The eastern GSA treatment system has also been in compliance with the exception of one occasion in 2000 when discharge limits were slightly exceeded. However, the cause was quickly identified and appropriate corrective action was taken (replacement of aqueous-phase GAC). No regulatory action was taken.

The budgeted and actual costs associated with the management, investigation, testing, modeling, design, construction, and O&M of the environmental remediation activities within the GSA are tracked closely. The GSA OU has consistently operated within the allocated budget. The current construction and O&M cost of the GSA treatment facilities is approximately $500,000 per year. Figure 6 shows the budgeted and actual cost of the GSA cleanup from 1995 to the present.

5. Five-Year Review Process

The five-year review of the GSA OU at LLNL Site 300 was led by Mr. Roy Kearns, Site 300 Remedial Project Manager for the DOE-Oakland Operations Office. The following team members assisted in the review:

- Robert Ferry, Principal Hydrogeologist, Pentacore Resources, LLC.
- William Daily, Engineer, LLNL.
- Leslie Ferry, Deputy Project Leader, LLNL.
- Vic Madrid, Environmental Scientist, LLNL.
- Gerard Aarons, Geologist, Weiss Associates.
- John Valett, Geologist, Weiss Associates.
- Zafer Demir, Project Geologist, Weiss Associates.

This five-year review consisted of examining relevant project documents and site data:

- Final Site-Wide Remedial Investigation for Lawrence Livermore National Laboratory Site 300 (Webster-Scholten et al., 1994).
- Final Feasibility Study for the General Services Area at Lawrence Livermore National Laboratory Site 300 (Rueth and Berry, 1995).
- Proposed Plan for Remediation of the Lawrence Livermore National Laboratory Site 300 General Services Area (DOE, 1996).
- Final Record of Decision for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300 (DOE, 1997).
- Cost and Performance Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300 (Ferry, 1997).
- Remedial Design Document for the General Services Area Treatment Facilities, Lawrence Livermore National Laboratory Site 300 (Rueth et al., 1998).

- Building 875 Inhalation Risk Mitigation Evaluation at the Central GSA at Lawrence Livermore National Laboratory Site 300 (DOE, 2000b).
- Eastern GSA Treatment Facility Operations Checklist (LLNL, 1999).
- Operations and Maintenance Manual, Volume VI: Central General Services Area Vapor and Ground Water Treatment Facilities (LLNL, 2000).

This five-year review evaluated subsurface contaminant concentration and remediation system performance data collected through calendar year 2000.

A notice informing the public that this five-year review was in progress was placed in the Tracy Press on September 5, 2001. The completed report is available in the information repositories in the Visitor's Center at the LLNL Livermore Site and at the Tracy Public Library. Notice of its completion will be placed in the Tracy Press and local contacts will be notified by letter. A brief summary of this report will be distributed to members of the community.

6. Five-Year Review Findings

6.1. Interviews and Site Inspection

Interviews or a site inspection are not required for sites with an ongoing presence. "Ongoing presence" means that either the U.S. EPA, the State, or another agency is the lead agency for the site and that the lead agency is involved in and knowledgeable of site activities, issues, concerns, and status. Specifically, there should be regular activity at the site, evidenced by continuing response work that is overseen by the continued presence of the lead agency or regular inspections by the lead agency.

Because the cleanup at the GSA falls within the definition of "ongoing presence" neither interviews nor a site inspection were required.

6.2. Changes in Cleanup Standards and To Be Considered Requirements

There have been no changes in location-, chemical-, or action-specific requirements since the ROD was signed in 1997.

6.3. Changes in Exposure Pathways, Toxicity, and Other Contaminant Characteristics

There have been no changes in exposure pathways, toxicity, and other contaminant characteristics since the ROD was signed in 1997.

6.4. Data Review

The effectiveness and protectiveness of the remedy for the GSA OU was assessed primarily by reviewing contaminant concentration reduction and mass removal data. In general, ground

water and soil vapor extraction have been very successful in removing contamination from the subsurface.

In the following sections, DOE has included estimates of the preremediation mass of contaminants in the subsurface, and compared these values to the mass of contaminants removed by ground water and soil vapor extraction. The estimates of VOC mass removal by the three extraction and treatment systems are considered to be relatively accurate. The estimates of the preremediation mass of contaminants in the subsurface have a much greater degree of uncertainty and are given as range of values, assuming an uncertainty of ±30% as calculated from sensitivity analyses. The comparison of preremediation mass to that removed through extraction should not be used as the basis for decision-making regarding the performance of the remedy. The cleanup standards established in the GSA ROD are defined solely on the basis of subsurface contaminant concentrations.

6.4.1. Central GSA

6.4.1.1. Ground Water

The original mass of VOCs estimated to have been present in the ground water in the central GSA prior to the beginning of extraction (1993) was 25-47 kg. Since then, 11.1 kg of VOCs have been removed by ground water extraction, representing 24-44% of the original mass. Over 5.4 million gallons of contaminated ground water have been extracted and treated. TCE comprises approximately 90% of the extracted VOCs, PCE 5%, and other VOCs (Freon 113, 1,1-DCE, and 1,2-DCE) make up the remainder. The cumulative mass of VOCs extracted over time is shown on Figure 7. Figure 8 shows the mass of VOCs extracted each quarter since 1993. There has been a general decline in the rate of mass removal since remediation began. Mass removal is typically highest between January and July, when more ground water is available as a result of the infiltration of winter precipitation. Currently, approximately 1 kg of VOCs are extracted in ground water each year. Future mass removal rates are extremely difficult to predict because: (1) removal efficiency varies as a result of fluctuating ground water elevation and contaminant concentration, (2) changes in extraction well configuration affect removal rate, and (3) the mass removal rate will continue to decline as VOCs are removed from high-permeability sediments and diffuse slowly out of fine-grained materials. The maximum VOC concentration in ground water treatment system influent has decreased from 10,800 µg/L in 1993 to 100 µg/L in 2000, as shown on Figure 9.

Prior to remediation, the maximum total VOC concentration in ground water was approximately 272,000 µg/L, compared to the current (2000) maximum of 1,600 µg/L. Figure 10 is an isoconcentration contour map of total VOCs in the shallow aquifer in the central GSA constructed using 2000 data, and also shows the maximum historic VOC concentration for each well. VOC concentrations have decreased throughout the contaminant plume. The number of wells in the shallow aquifer in which VOC concentrations exceed the MCL cleanup standard has decreased from 28 to 19.

The results of a capture zone analysis for the existing ground water extraction wells in the central GSA are shown on Figure 11. The capture zones were calculated from measured ground water elevation data and are not time-dependent. This analysis shows that the capture zones

include the primary contaminant release locations and areas of highest VOC concentration, preventing further migration of contaminants away from these areas.

Low concentrations of VOCs are present in the upper portion of the regional bedrock aquifer, as shown on Figure 12. The VOC concentration in the regional aquifer has decreased from a historic maximum of 63 µg/L to 12 µg/L. The number of wells in the regional aquifer in which VOC concentrations exceed the MCL cleanup standard has decreased from 7 to 1. No offsite wells completed in the regional aquifer show contamination exceeding MCLs. DOE is not planning to extract ground water from the regional aquifer, as discussed in Section 4.2.1.

Without additional actions, it is expected that future compliance with ground water cleanup standards will be achieved, but this may be accelerated by optimizing the configuration of the extraction well network. The performance of the selected remedy in the central GSA is generally consistent with modeling performed in the Remedial Design phase that estimated the time to reach cleanup standards would be approximately 30 years (i.e., by 2027).

6.4.1.2. Vadose Zone

Soil vapor extraction has been significantly more effective than ground water extraction in removing VOC mass from the subsurface. The original mass of VOCs estimated to have been present in the vadose zone in the central GSA prior to the beginning of extraction (1994) was 73-136 kg. Since then, 61.2_kg of VOCs have been removed by soil vapor extraction, representing 43-84% of the original mass. The extracted VOCs are comprised almost exclusively of TCE. The cumulative mass of VOCs extracted over time is shown on Figure 7. Figure 8 shows the mass of VOCs extracted each quarter since 1994. The rate of mass removal is extremely variable, possibly as a result of: (1) temporal permeability variations in the subsurface caused by changes in vadose zone moisture content, (2) seasonal changes in the thickness of the vadose zone from fluctuating ground water levels, and/or (3) changes in the VOC concentration in extracted soil vapor as the extraction and air injection well configuration is changed. Currently, approximately 2.7 kg of VOCs are extracted in soil vapor each year. The future rate of VOC mass removal by soil vapor extraction is even more difficult to predict than that for ground water extraction.

The maximum VOC concentration in soil vapor treatment system influent has decreased from 450 parts per million by volume ($ppm_{v/v}$) in 1994 to 3 $ppm_{v/v}$ in 2000, as shown on Figure 9. The initial sharp decline in VOC concentration is followed by a slower decrease in contaminant concentrations, indicating that the removal of contaminants has become limited by the rate at which the remaining VOCs can desorb into the ground water or volatilize into soil vapor.

Soil vapor extraction has contributed to reducing the excess human health risk due to inhalation of VOC vapors migrating into Building 875. The estimated excess risk prior to remediation was 1×10^{-5}. In 2000, the risk estimate was recalculated to be 9.5×10^{-7}. This revised estimate considered, among other factors, the reduced concentration of TCE in soil vapor near the building (DOE, 2000b). Inhalation risk within Building 875 is no longer of concern.

No additional action is expected to be required to achieve vadose zone cleanup standards. The performance of the selected remedy is generally consistent with modeling performed in the Remedial Design phase that estimated the time to reach cleanup standards would be approximately 10 years (i.e., by 2008).

6.4.2. Eastern GSA

The original mass of VOCs estimated to have been present in the ground water in the eastern GSA prior to the beginning of extraction (1991) was 0.5-2.3 kg. Since then, approximately 6.2_kg of VOCs have been removed by ground water extraction. The mass of VOCs extracted exceeds the preremediation estimate because: (1) ground water with higher VOC concentration than is represented by samples from monitor wells is present, resulting in an artificially low estimate of initial mass, and/or (2) undetected VOC mass is present in the vadose zone, although site characterization indicated that the VOC concentrations in unsaturated soil and bedrock are extremely low.

Over 171 million gallons of contaminated ground water have been extracted and treated. The extracted VOCs are comprised almost exclusively of TCE. The cumulative mass of VOCs extracted over time is shown on Figure 7. Figure 8 shows the mass of VOCs extracted each quarter since 1991. There has been a general decline in the rate of mass removal since remediation began. Mass removal is relatively consistent throughout the year. Currently, approximately 0.24 kg of VOCs are extracted in ground water each year. The maximum VOC concentration in ground water treatment system influent has decreased from 63 µg/L in 1992 to 3 µg/L in 2000, as shown on Figure 9.

Ground water extraction has contributed significantly to reducing the extent of ground water contamination. The length of the TCE plume in ground water at concentrations exceeding detection limits (typically 0.5 µg/L) has been reduced from 4,200 ft to 1,700 ft, and the length of the plume exceeding the 5 µg/L MCL has decreased from 4,200 ft to 600 ft. The number of wells in which VOC concentrations exceed the MCL cleanup standard has decreased from 18 to 5, including only one offsite well. Prior to remediation, the maximum total VOC concentration in ground water was approximately 100 µg/L, compared to the current (2000) maximum of 8.7 µg/L. Figure 13 is an isoconcentration contour map of total VOCs in the shallow aquifer in the eastern GSA constructed using 2000 data, and also shows the maximum historic VOC concentration for each well. VOC concentrations have decreased throughout the contaminant plume. Figure 14 is a set of time-series maps showing changes in the extent and concentration of VOCs in ground water in the eastern GSA.

The results of a capture zone analysis for the existing ground water extraction wells in the eastern GSA are shown on Figure 15. The capture zones were calculated from measured ground water elevation data and are not time-dependent. This analysis, combined with contaminant concentration data from downgradient wells, indicates that the three extraction wells are effectively mitigating offsite migration of VOCs and extracting water from the areas of highest remaining contamination.

No additional action is expected to be required to achieve cleanup standards. The performance of the selected remedy in the eastern GSA is generally consistent with modeling performed in the Remedial Design phase that estimated the time to reach cleanup standards would be approximately 10 years (i.e., by 2008).

7. Assessment

The protectiveness of the remedy was assessed by determining if:

- The remedy is protective of human health and the environment.
- The remedy is functioning as intended at the time of the decision documents.
- The assumptions used in the decision-making process are still valid.

This five-year review determined that the remedy for the GSA OU was indeed protective and effective, based on the following:

- Ground water and soil vapor extraction are effectively reducing contaminant concentrations in the subsurface. In the central GSA, the current maximum VOC concentrations in both ground water and soil vapor have decreased by over two orders of magnitude. VOC concentrations throughout the ground water plume have declined. In the eastern GSA, the extent of VOCs in ground water has been greatly reduced, and very little ground water is now contaminated at concentrations exceeding MCLs.
- DOE has removed a total of 78.5 kg of VOCs from the subsurface in the GSA OU. This represents 42-79% of the estimated preremediation mass of total VOCs present in the subsurface. Mass removal rates are declining for both ground water and soil vapor as contaminants are removed from more permeable subsurface sediment and diffuse slowly from low-permeability materials.
- Soil vapor extraction at the Building 875 release site has contributed to reducing the human health risk due to inhalation of TCE vapors within nearby Building 875 to a level that is not of further concern.
- The overall performance of the selected remedy in the GSA OU is consistent with expectations at the time the ROD was signed. The extraction and treatment systems are performing as designed and will continue to be operated and optimized.
- System operation procedures are consistent with requirements.
- Costs have been consistently below budget and are decreasing.
- No early indicators of potential remedy failure were identified.
- All required institutional controls are in place and no current or planned changes in land use at the site suggest that they are not effective.
- The Contingency Plan and the Health and Safety Plan are in place, sufficient to control risks, and properly implemented.
- There have been no changes in location-, chemical-, or action-specific requirements since the ROD for the GSA OU was signed in 1997, nor have there been changes in exposure pathways, toxicity, and other contaminant characteristics.
- There have been no changes in risk assessment methodologies that could call the protectiveness of the remedy into question.

8. Deficiencies

No deficiencies in the remedy were identified during the five-year review process.

9. Recommendations and Follow-Up Actions

The following recommendations were developed during the five-year review process:

- A high priority should be given to optimizing ground water and soil vapor extraction well placement and pumping rates to maximize contaminant capture within the existing wellfields and shorten the time required to reach cleanup standards.
- Additional ground water extraction wells located north of Building 875 should be considered. Although VOC concentrations in ground water in this area are relatively low (maximum of 46 µg/L), the lateral extent of this plume is limited and ground water extraction may accelerate achievement of cleanup standards throughout the GSA.
- Contaminants in the regional aquifer in the central GSA should be closely monitored, but extraction should be considered only if data indicate that the current declining concentration trend does not continue.
- In the eastern GSA, DOE should consider the possibility of undetected VOC mass if ground water remediation does not continue its current progress toward achieving cleanup standards.

If DOE and the regulatory agencies agree to incorporate any or all of these recommendations, implementation milestones can be added to the schedule in the Federal Facility Agreement for Site 300, and/or administered less formally by inclusion in the minutes of the Remedial Project Manager's monthly meetings.

No other follow-up actions were identified related to this five-year review.

10. Protectiveness Statement

The Health and Safety Plan and the Contingency Plan are in place, sufficient to control risks, and properly implemented. Ground water and soil vapor extraction and treatment are effectively controlling the migration of contaminants, and are reducing contaminant concentrations in the subsurface as needed to meet cleanup standards in the time frame anticipated at the time of the ROD. Institutional controls are in place to prevent use of contaminated ground water. Thus, the remedy for the GSA OU is protective of human health and the environment.

11. Next Review

The next policy review will be conducted within five years of the signature date of this report.

12. References

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Figures

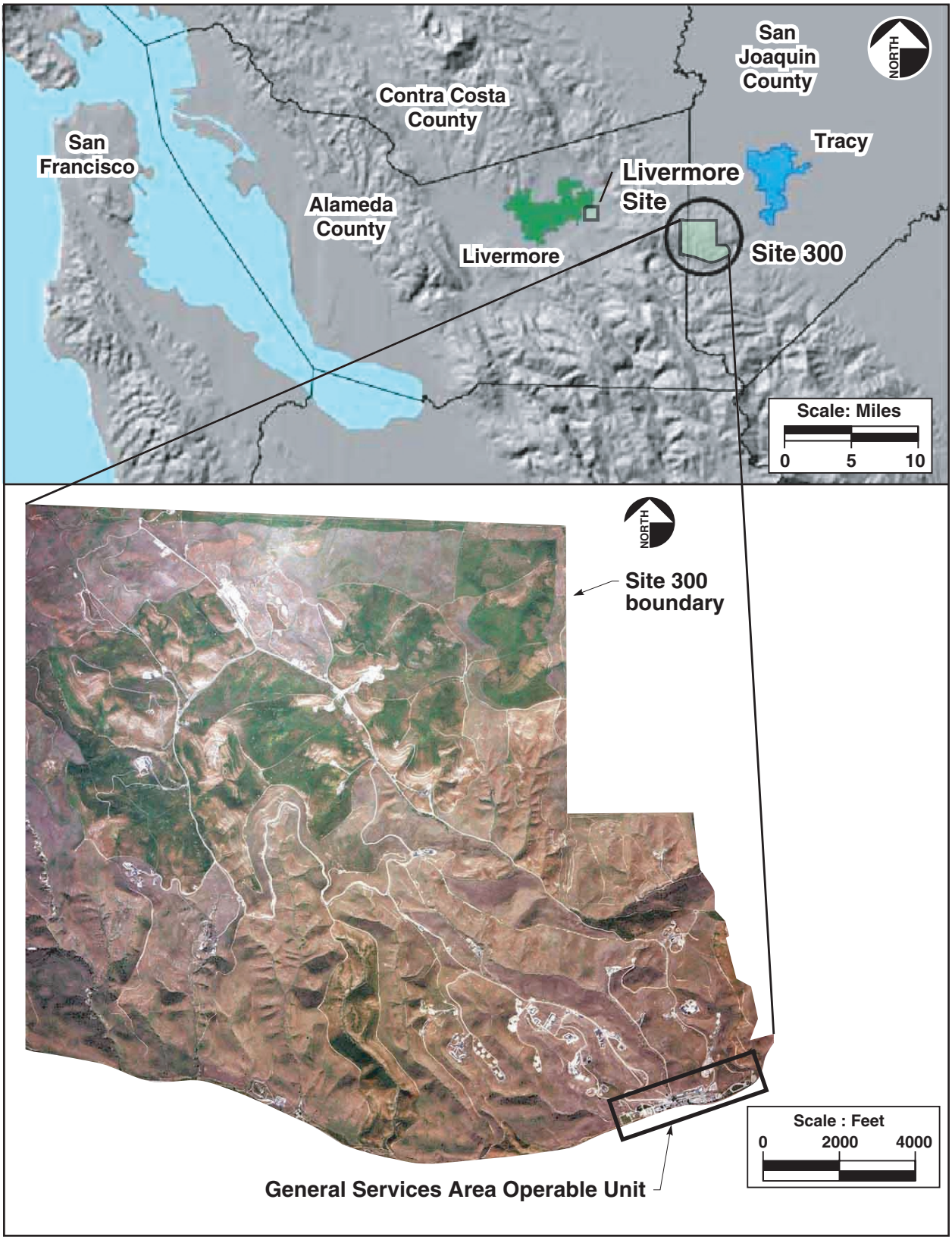

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Figure 1. Locations of LLNL Site 300 and the GSA OU.

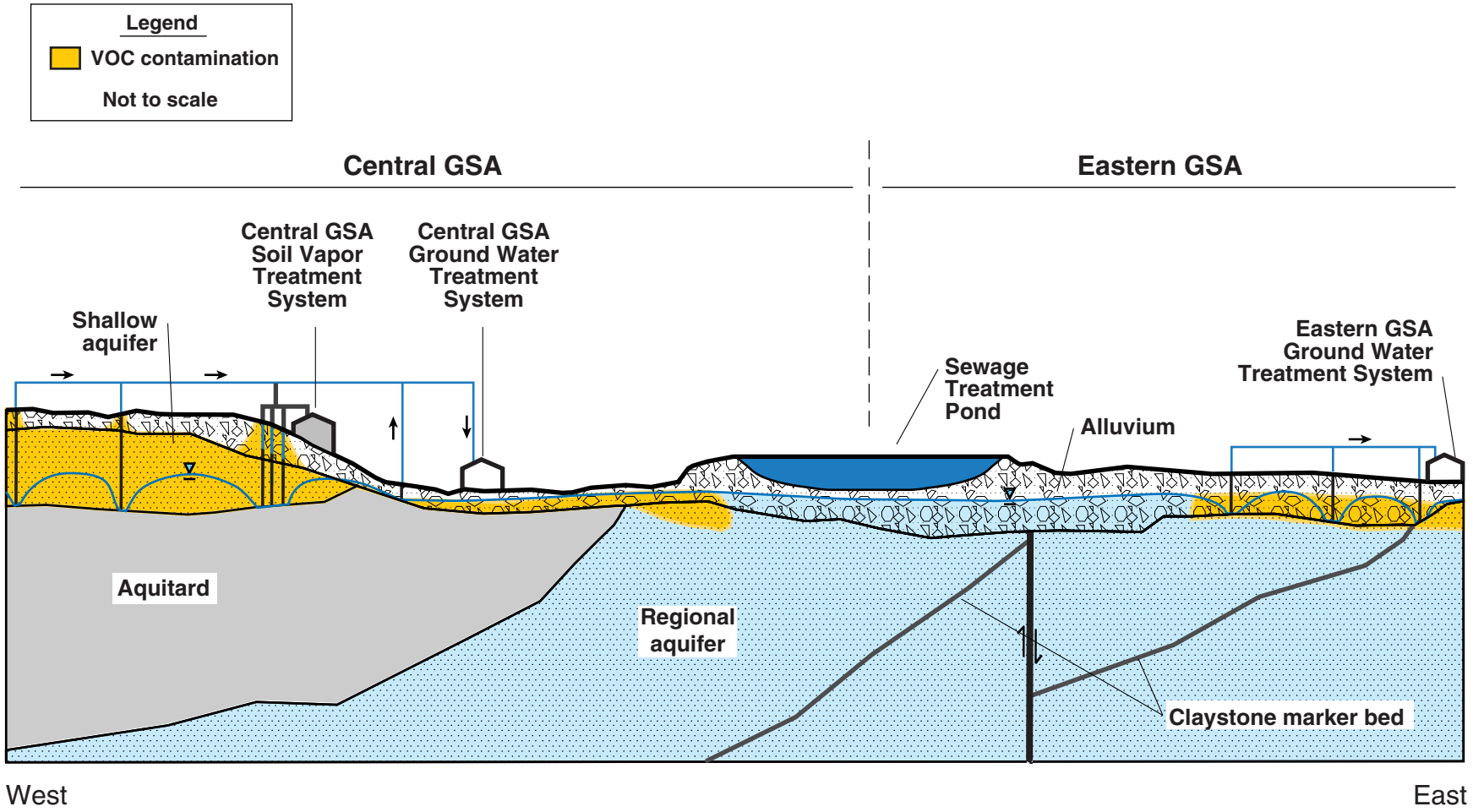

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Figure 2. Conceptual hydrogeologic cross-section of the GSA.

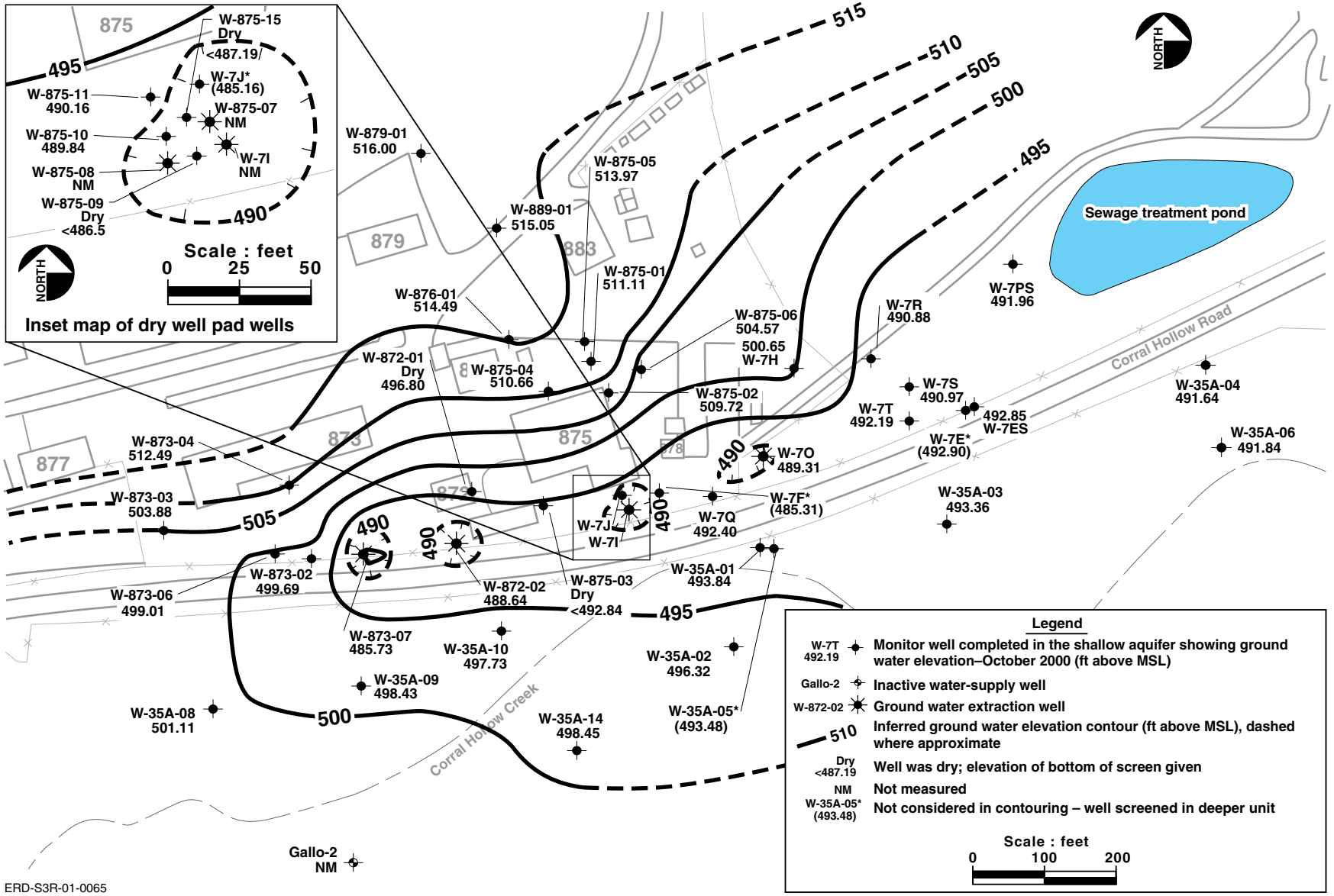

Figure 3. Potentiometric surface of the shallow aquifer in the central GSA (4th quarter 2000).

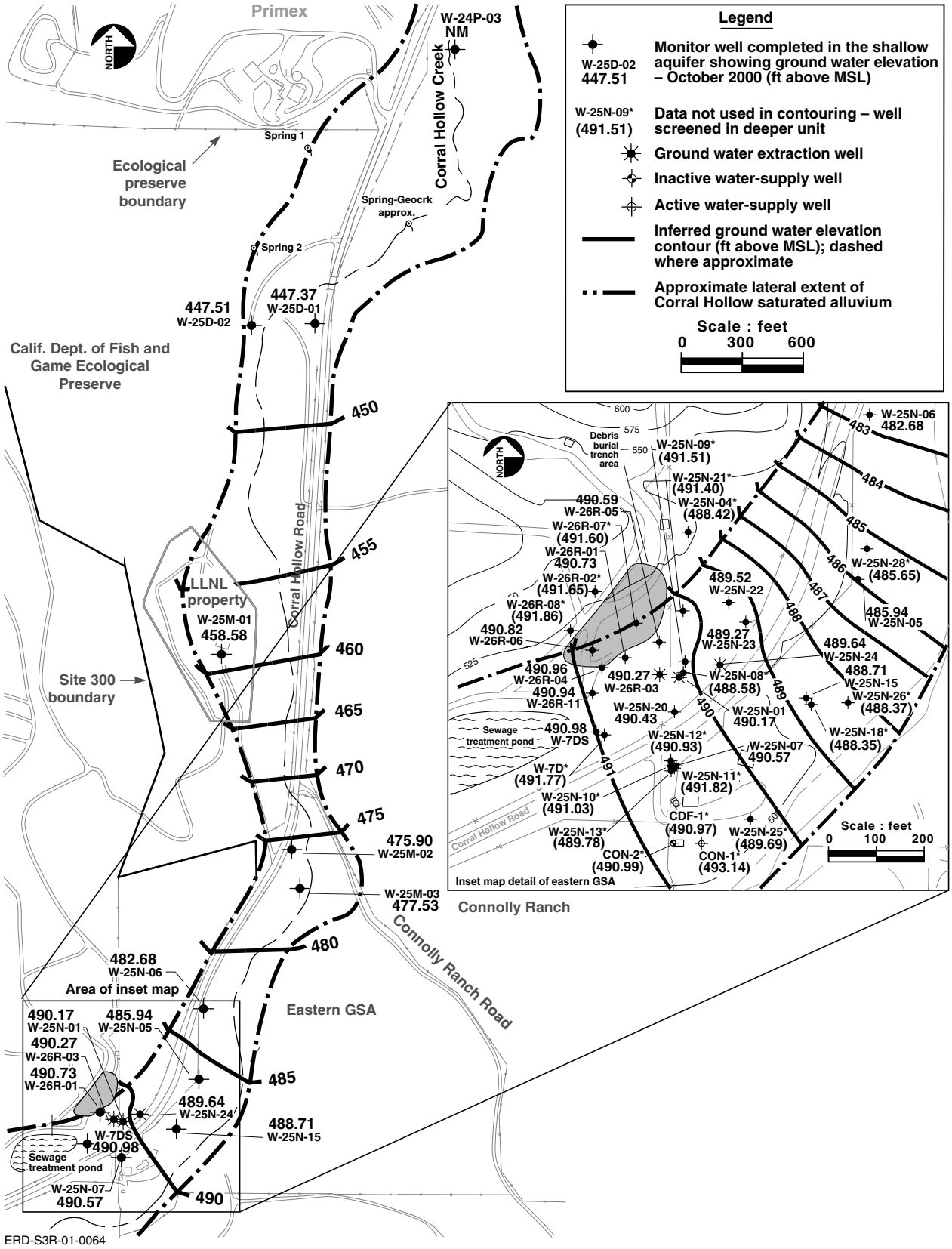

Figure 4. Potentiometric surface map of the alluvial and shallow bedrock aquifer in the eastern GSA.

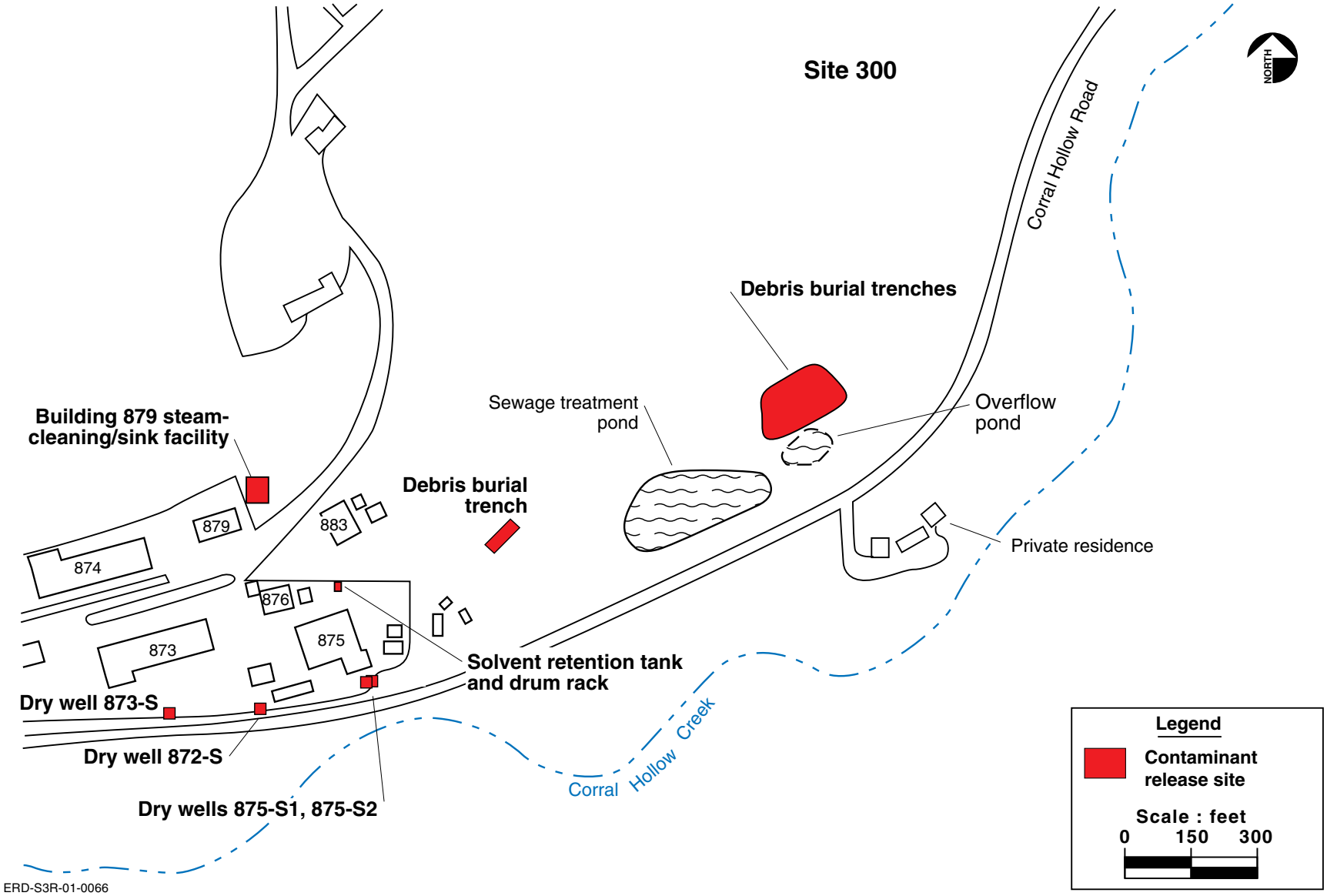

Figure 5. Contaminant release sites in the GSA.

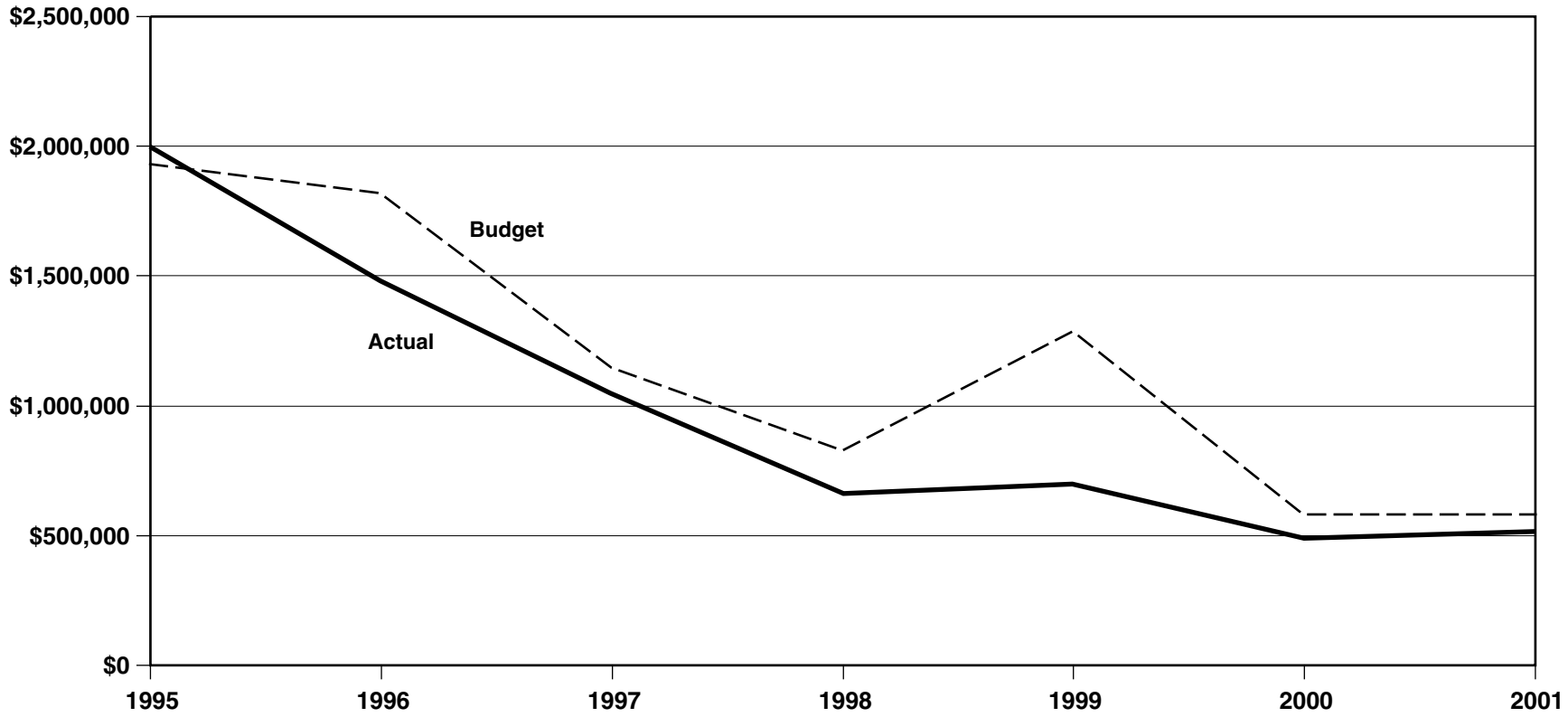

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Figure 6. Budgeted and actual costs for the GSA OU.

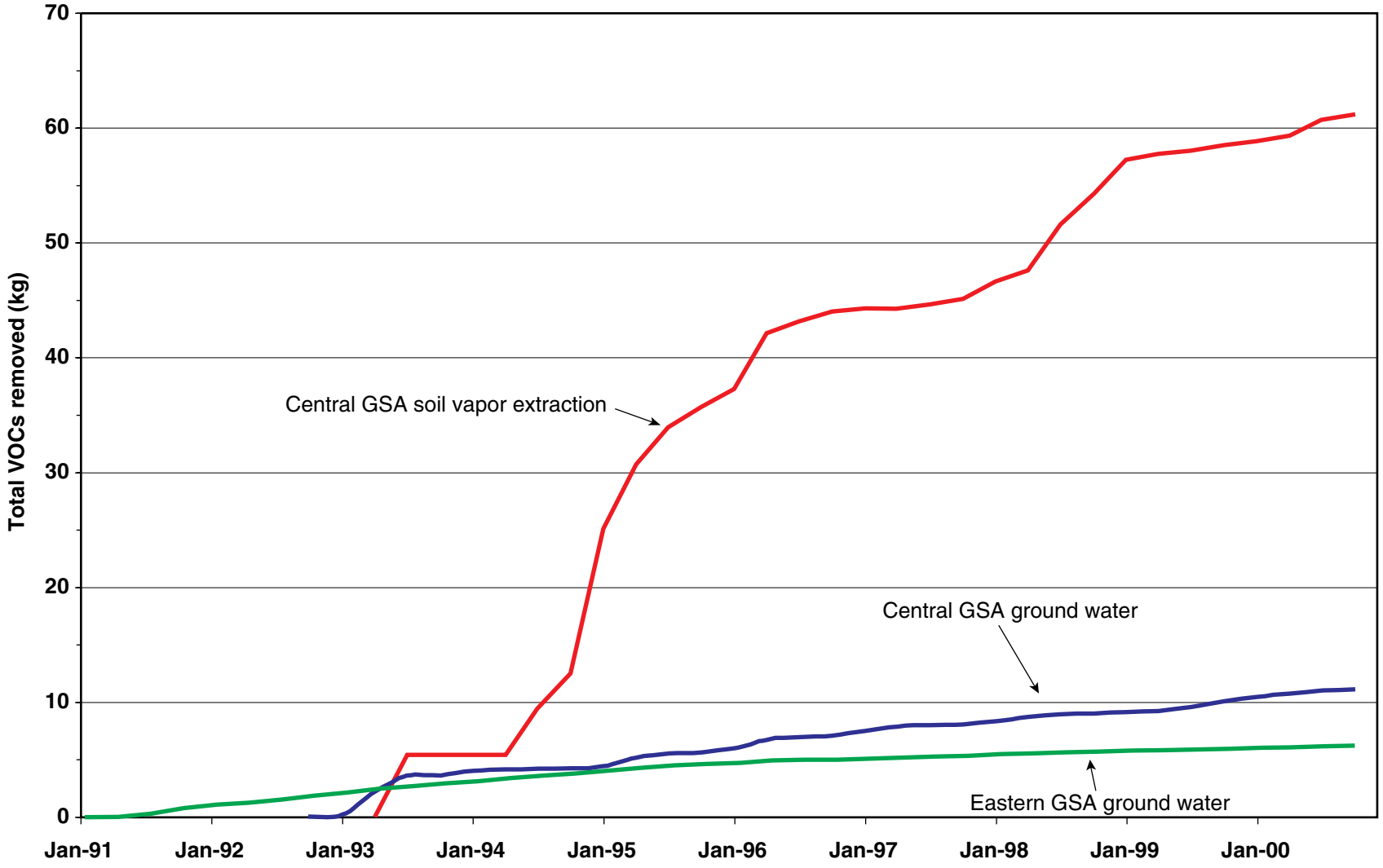

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Figure 7. Cumulative mass of total VOCs removed from ground water and soil vapor in the GSA.

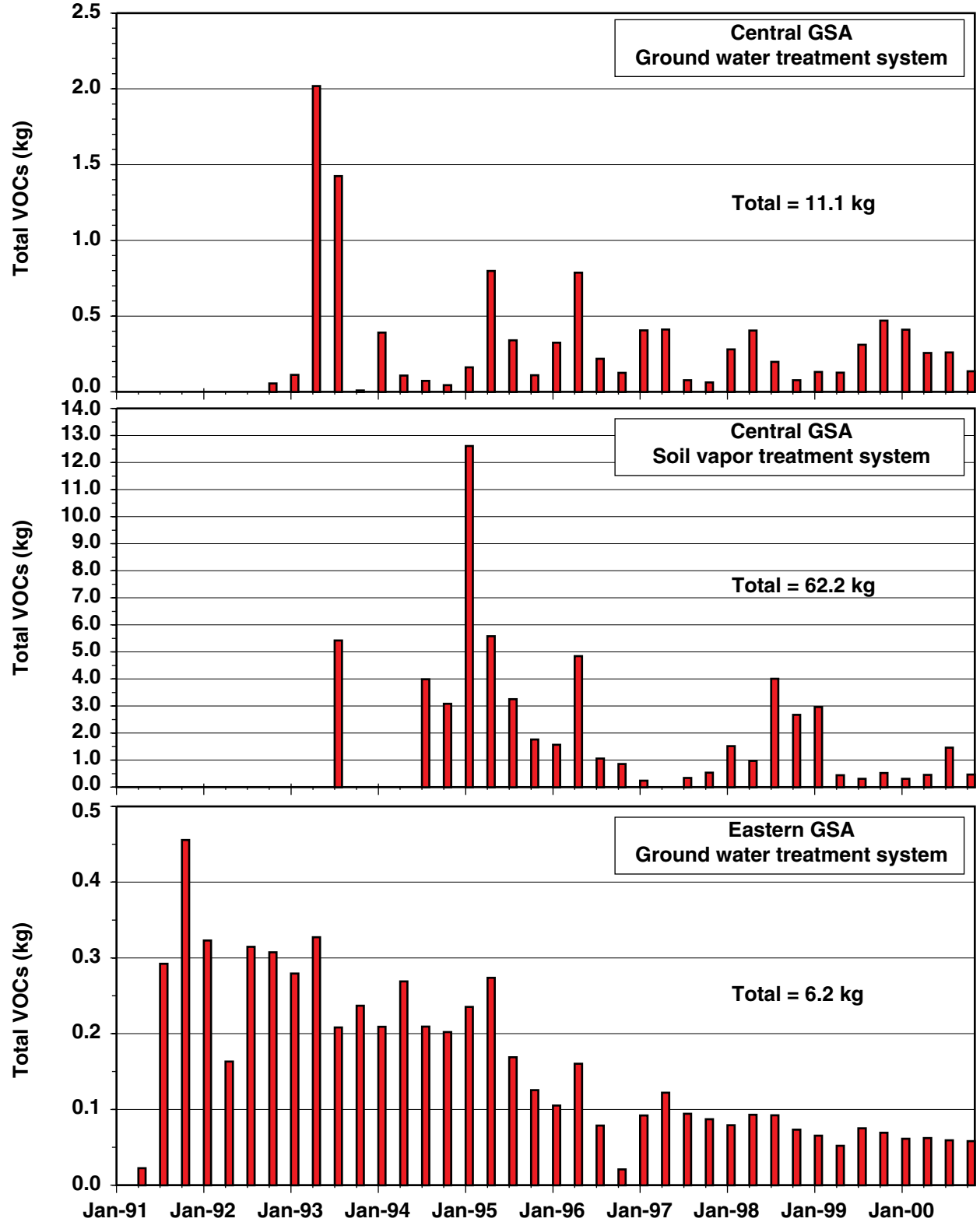

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Figure 8. Total VOC mass removal by quarter in the GSA OU.

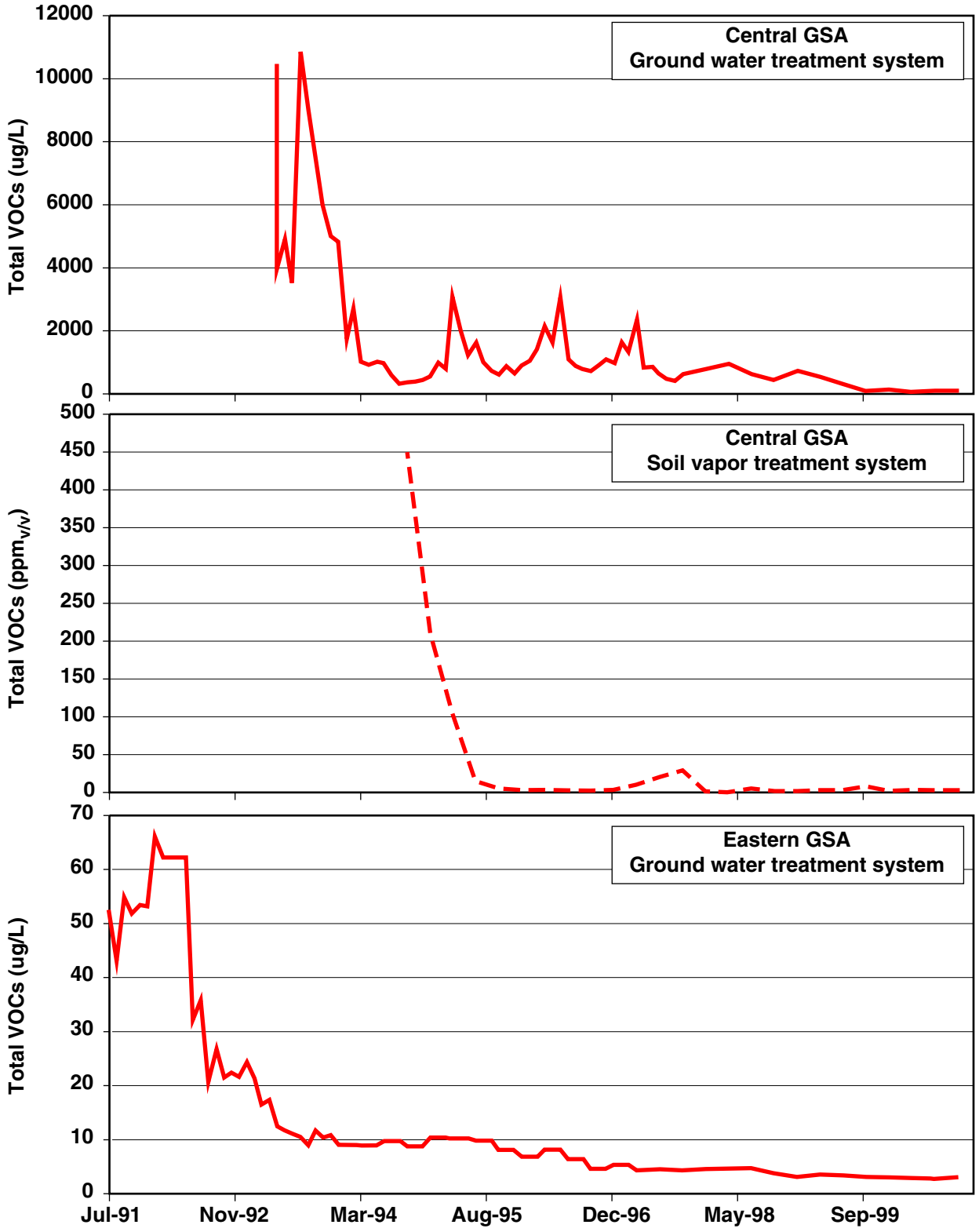

Figure 9. Historic maximum total VOC concentrations in treatment system influent in the GSA.

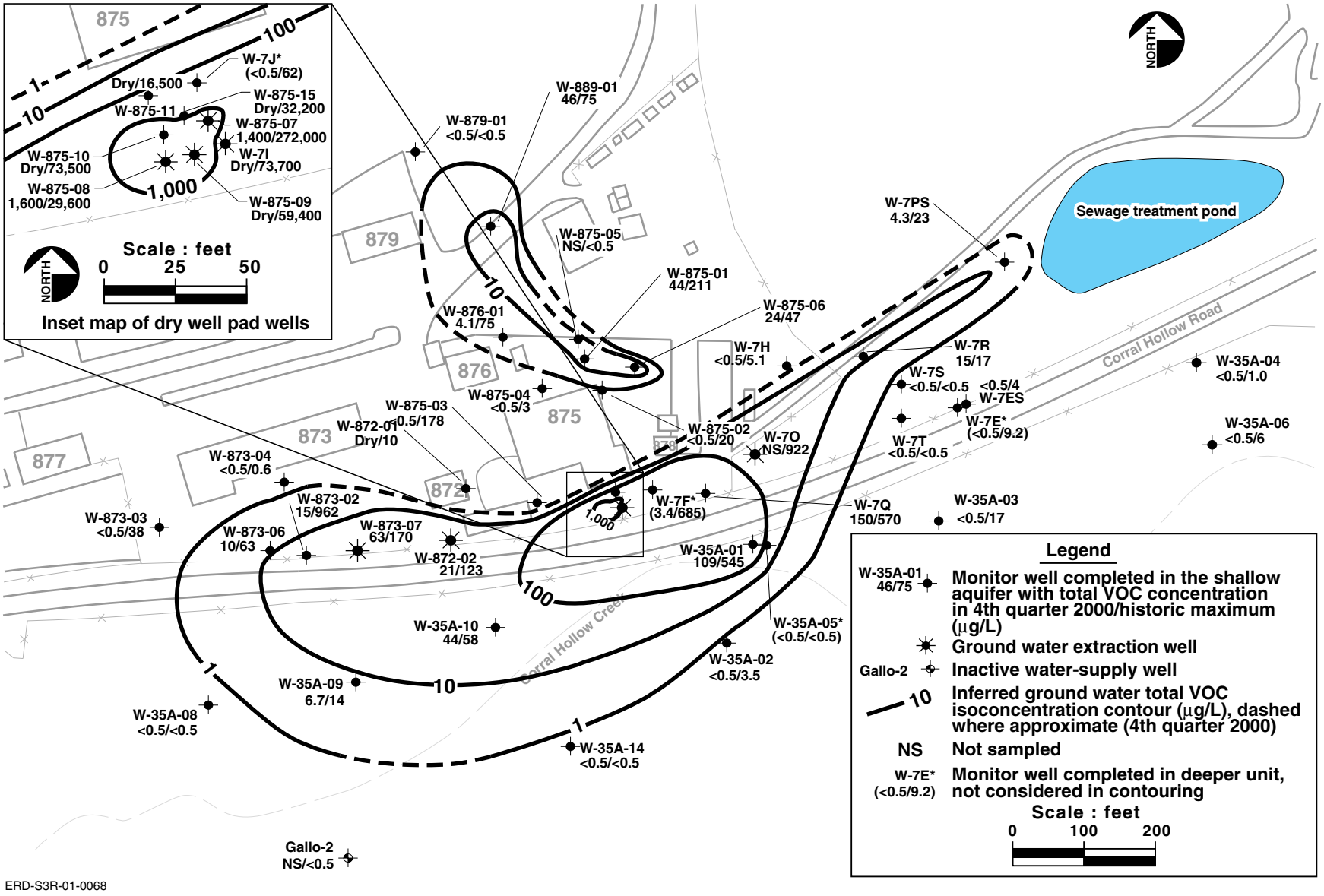

Figure 10. Total VOC concentrations in ground water in the shallow aquifer in the central GSA.

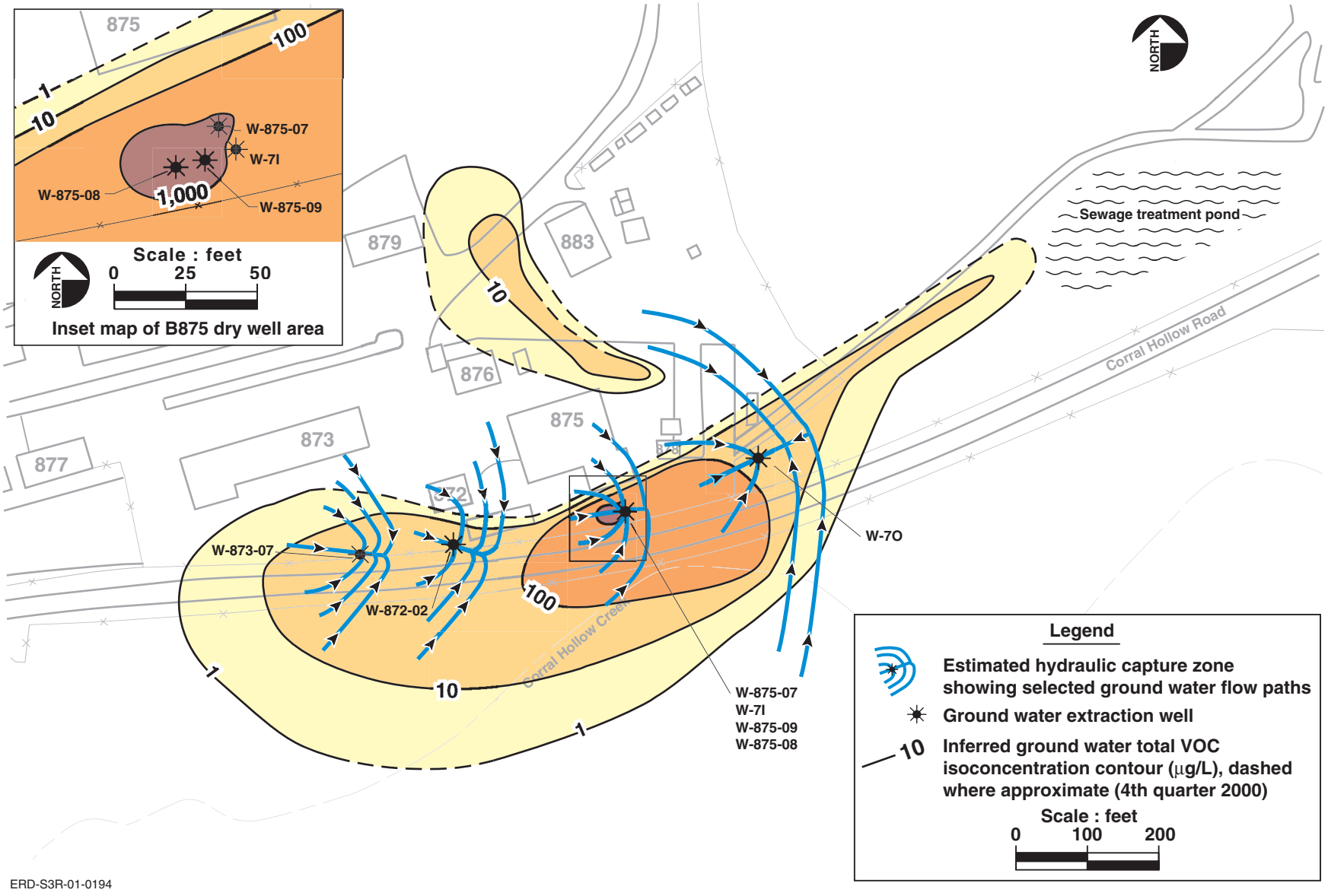

Figure 11. Ground water capture in the central GSA.

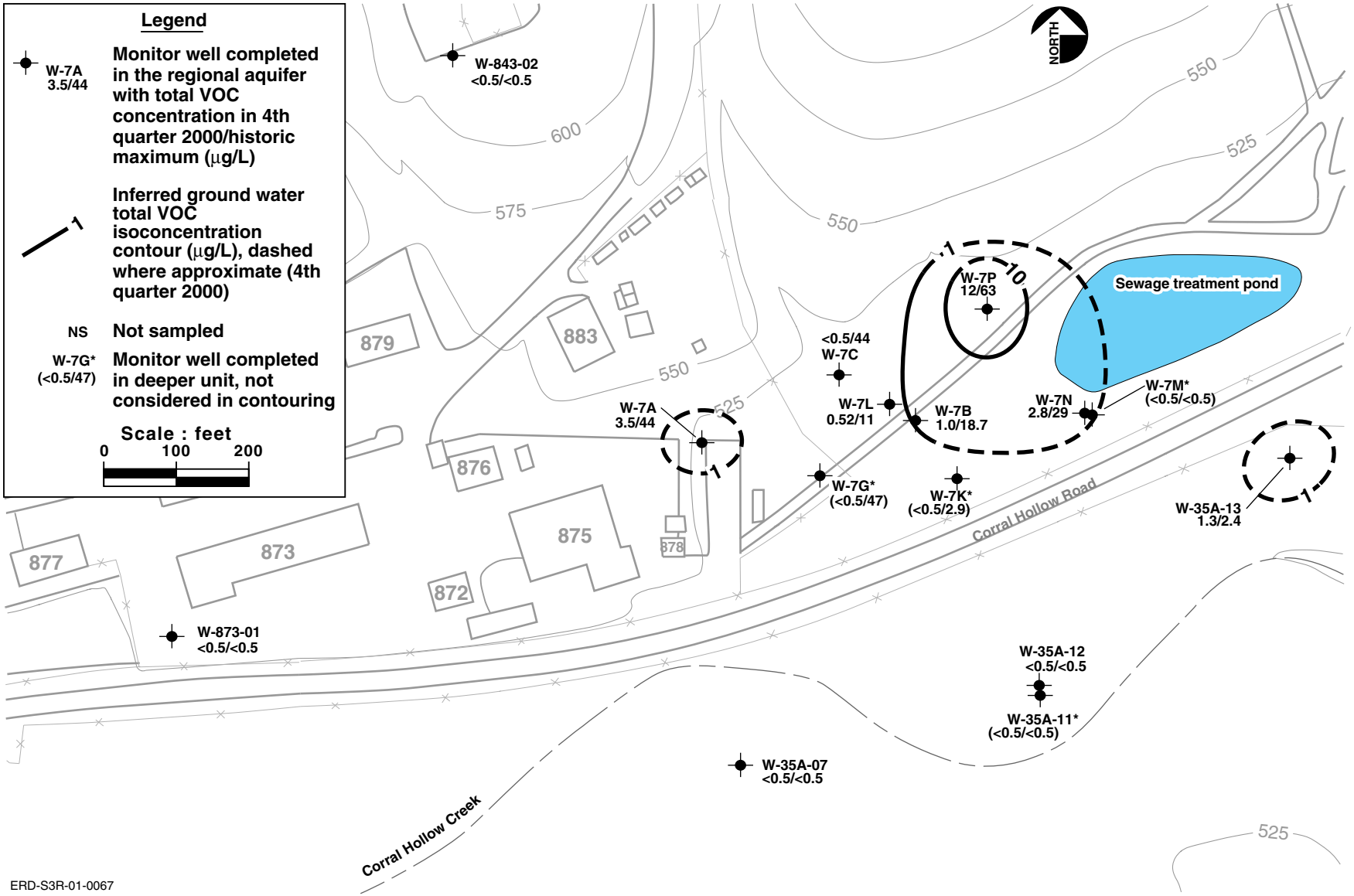

Figure 12. Total VOC concentrations in ground water in the regional aquifer above the claystone marker bed in the central GSA.

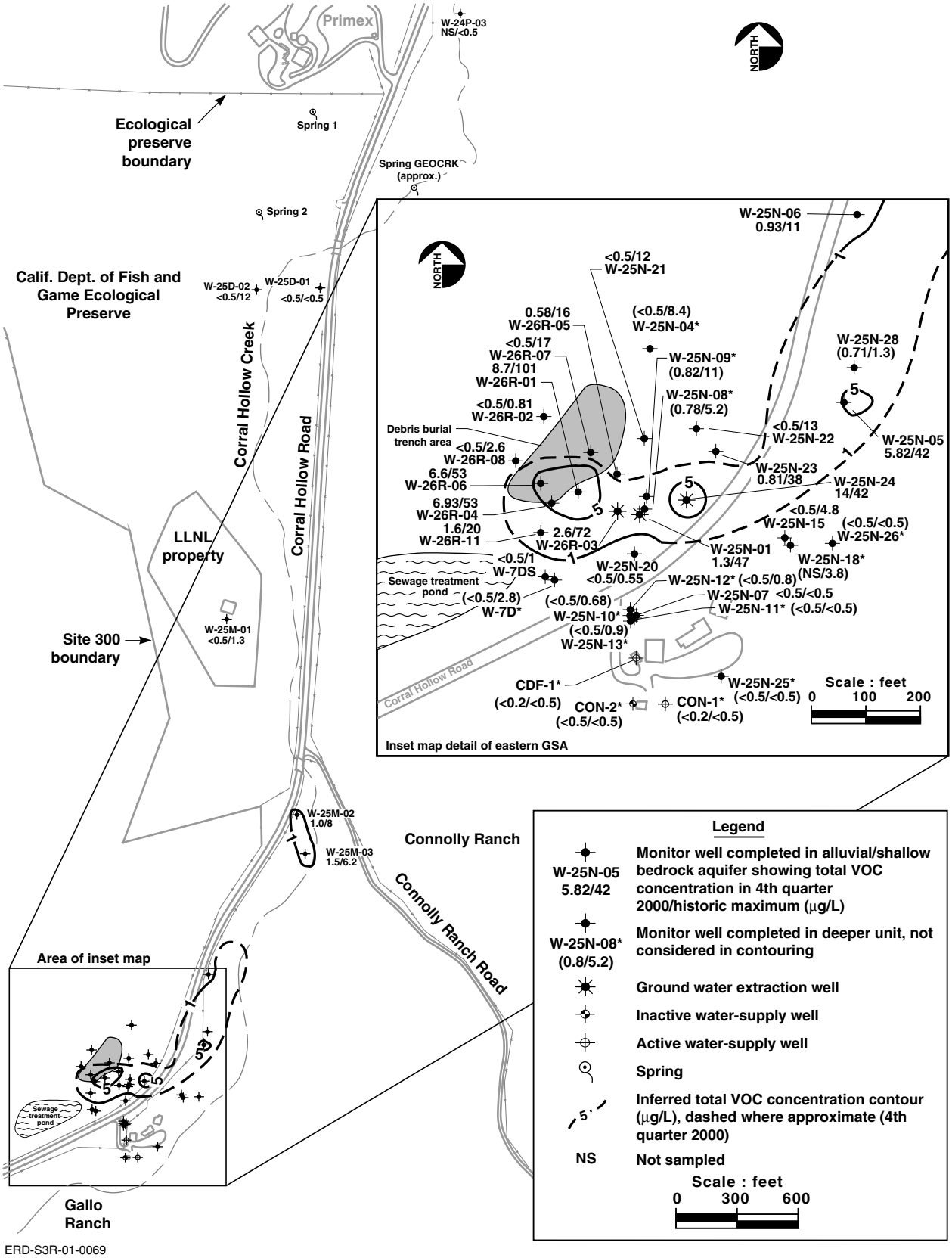

Figure 13. Total VOC concentrations in ground water in the eastern GSA and vicinity.

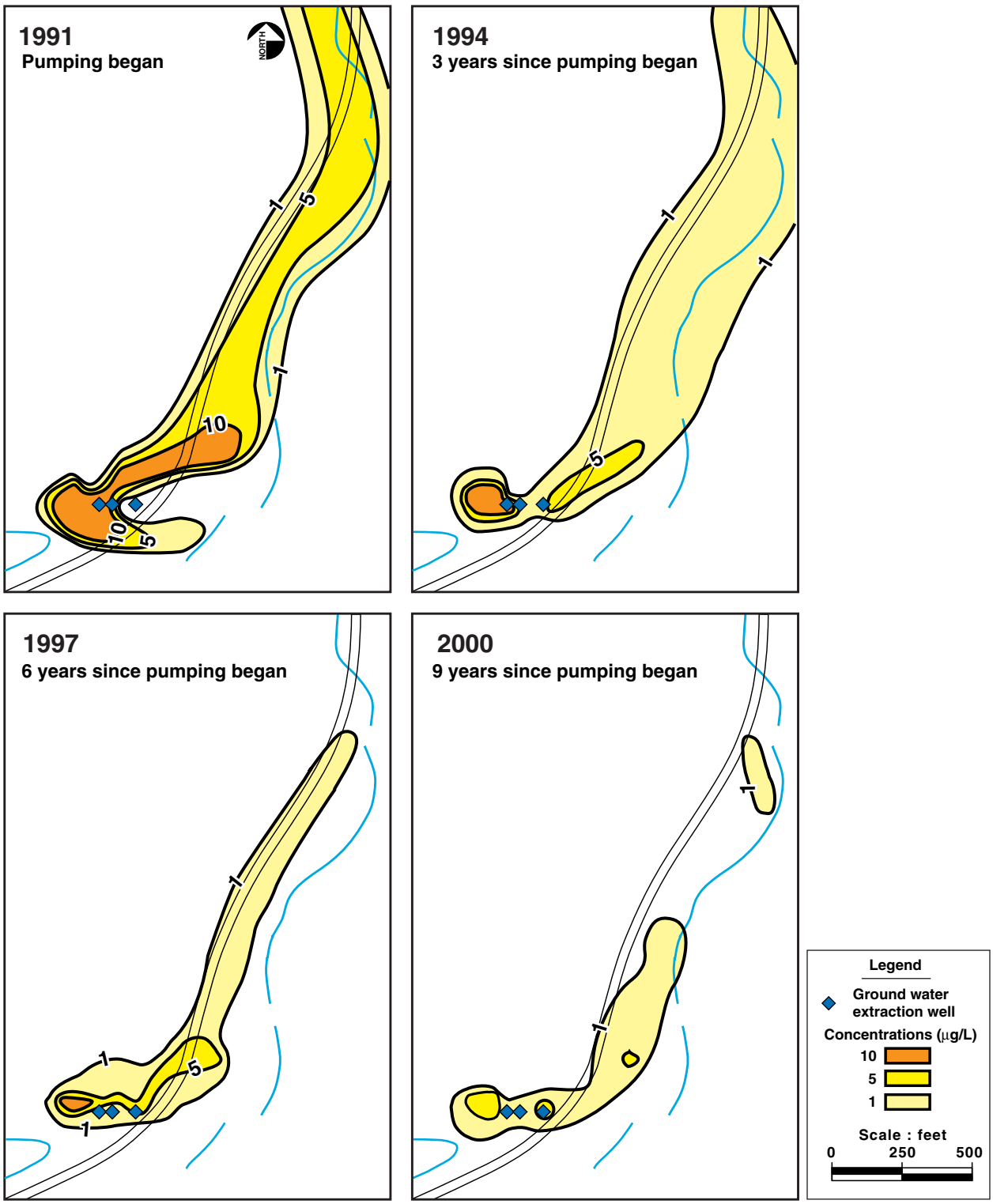

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Figure 14. Time-series isoconcentration maps of total VOCs in ground water in the eastern GSA.

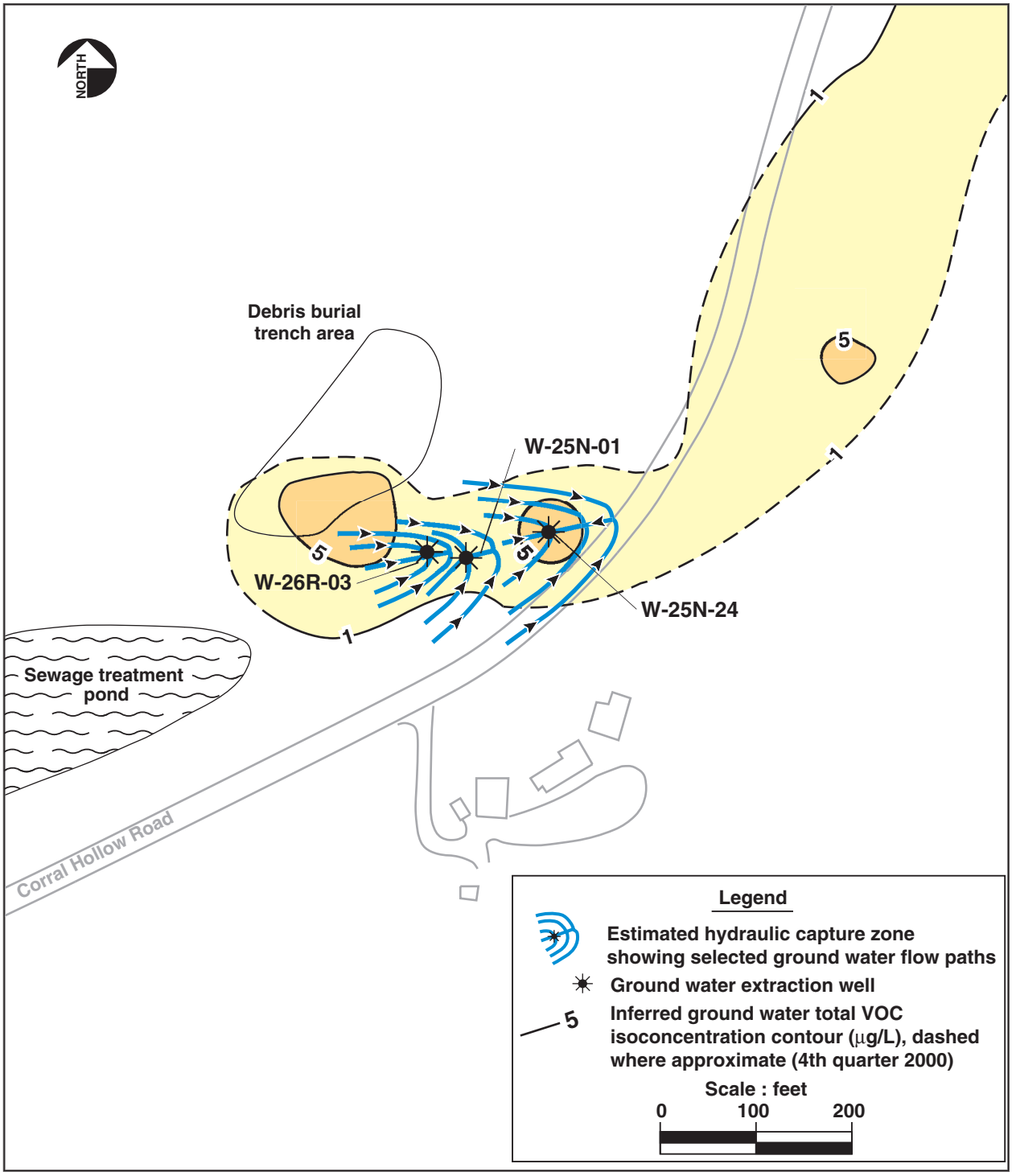

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Figure 15. Ground water capture in the eastern GSA.