STELLAR ENVIRONMENTAL SOLUTIONS
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TRANSMITTAL MEMORANDUM

TO: ALAMEDA COUNTY HEALTH CARE SERVICES AGENCY
DEPT. OF ENVIRONMENTAL HEALTH
HAZARDOUS MATERIALS DIVISION
1131 HARBOR BAY PKWY, SUITE 250
ALAMEDA, CA 94502

DATE: 11/17/00

ATTENTION: SCOTT SEERY

FILE: SES-2000-46

SUBJECT: REDWOOD REGIONAL PARK FUEL LEAK SITE

WE ARE SENDING: (≤) HEREWITH ≤ UNDER SEPARATE COVER
(≤) VIA MAIL ≤ VIA

THE FOLLOWING: SITE FEASIBILITY STUDY REPORT (OCT 2000)

≤ AS REQUESTED ≤ FOR YOUR APPROVAL
≤ FOR REVIEW (≤) FOR YOUR USE
≤ FOR SIGNATURE ≤ FOR YOUR FILES

COPIES TO: K. BURGER (EBRPD)
M. RUGG (FISH & GAME)
R. BREWER (REGIONAL BOARD)

BY: Bruce Rucker BMR

★ Stellar Environmental Solutions

2198 Sixth Street, Suite 201. Berkeley, CA 94710
Tel: (510) 644-3123 • Fax: (510) 644-3859

Geoscience & Engineering Consulting

October 20, 2000

Mr. Scott O. Seery – Hazardous Materials Specialist
Alameda County Health Care Services Agency
Environmental Protection
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502

Subject: Feasibity Study Report for Redwood Regional Park Service Yard Site, Oakland, California

Dear Mr. Seery:

Enclosed is the Stellar Environmental Solutions (SES) Feasibility Study Report for the underground fuel storage tank (UFST) site located at the Redwood Regional Park Service Yard Site, 7867 Redwood Road, Oakland, California. This project is being conducted for the East Bay Regional Park District (District) and follows previous site investigation and remediation activities conducted since 1993 associated with former leaking underground fuel storage tanks. The key regulatory agencies for this investigation are Alameda County Health Care Services Agency – Environmental Protection (ACHCSA), California Regional Water Quality Control Board (Board) and California Department of Fish and Game (CDFG).

This report evaluates the monitoring and investigation data collected to date, screens potential remedial actions against regulatory-mandated feasibility study criteria, and ranks the viable technologies to meet the remediation goals. If you have any questions regarding this report, please contact Mr. Ken Burger of the District or contact us directly at (510) 644-3123.

Sincerely,

Bruce M. Rucker, R.G., R.E.A
Project Manager

Richard S. Makdisi, R.G., R.E.A.,
Principal Geochemist

REGISTERED GEOLOGIST
BRUCE M. RUCKER
No. 6814
Exp. 9/01
STATE OF CALIFORNIA

cc: Michael Rugg, California Department of Fish and Game
Chuck Headlee, Regional Board
Ken Burger, East Bay Regional Park District

SITE FEASIBILITY STUDY REPORT

REDWOOD REGIONAL PARK SERVICE YARD
OAKLAND, CALIFORNIA

Prepared For:

EAST BAY REGIONAL PARK DISTRICT
OAKLAND, CALIFORNIA

Prepared By:

STELLAR ENVIRONMENTAL SOLUTIONS
2198 SIXTH STREET
BERKELEY, CALIFORNIA 94710

October 20, 2000

Project No. 2000-46

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EXECUTIVE SUMMARY

Stellar Environmental Solutions (SES) was retained by East Bay Regional Park District (District) to conduct continued site investigations at the Redwood Regional Park Service Yard fuel leak site at 7867 Redwood Road, Oakland, Alameda County. Tasks conducted since the previous (April 2000) SES report included the second of two instream bioassessment events per California Department of Fish and Game protocols and one groundwater and surface water monitoring event. This scope was designed to provide continued data on groundwater and surface water contamination, and to evaluate impacts from the groundwater plume on aquatic organisms in Redwood Creek.

The site has undergone site investigations and remediation since 1993 to address the subsurface contamination caused by leakage from one or more of the two former underground fuel storage tanks (UFSTs) that contained gasoline and diesel fuel. The UFSTs and the majority of source area contaminated soil were removed in 1993. An estimated volume of 850 CY of petroleum-contaminated soil with concentrations above 1,000 mg/Kg is estimated to be left in place in the area of the original excavation, as well as downgradient along the pathway of the plume. Most of the residual contaminated soil exists in the capillary fringe up to 150 feet downgradient of the former UFSTs, resulting from the sorption of fuel constituents from contaminated groundwater onto capillary fringe soils during periods of high groundwater elevation. This soil contamination will be a long-term source of groundwater contamination as it desorbs and contributes to the groundwater over time.

Groundwater and surface water sampling conducted since November 1994 (16 events) has shown an overall trend of decreasing contaminant concentrations—including gasoline, diesel, BTEX and MTBE in the two groundwater wells within the footprint of the contaminant plume. Site groundwater contaminants historically (and recently) detected in excess of drinking water standards include benzene, ethylbenzene, total xylenes, and MTBE. Fuel TPH has also been detected, but there are no drinking water standards for TPH fuels (as gasoline, diesel, motor oil, etc).

Discharge of contaminated groundwater into Redwood Creek, approximately 150 feet downgradient of the former UFST source area, has been documented. The leading edge of the plume daylighting in the upgradient creek bank is approximately 30 feet wide. The results of the two instream bioassessment events in Redwood Creek documented no impacts to aquatic organisms.

The area of the plume with total petroleum hydrocarbon (TPH) concentrations greater than 10,000 µg/L is estimated to be 60 feet wide by 100 feet long, and begins approximately 30 feet downgradient of the source area, suggesting that the plume is becoming "disconnected" from the former UFST source area. Significantly greater groundwater contamination detected in the April 1999 subsurface investigation suggest that downgradient well MW-4 is not located directly along the plume's longitudinal axis. Site data also suggest that there is a substantial mass of groundwater contamination upgradient of the parking lot's downgradient edge, which will continue to migrate toward Redwood Creek, and that future impacts to Redwood Creek from contaminated groundwater discharge may be worse than at present.

Natural attenuation is indicated to be occurring at the site, mainly at the plume margins and former source area. Natural attenuation is likely minimal in the higher concentration portion along the centerline of the plume due to limited oxygen content, suggesting that natural attenuation has not been, and will not be in the future, sufficient to mitigate impacts to the creek.

The lead regulatory agency providing oversight for the site is the Alameda County Health Care Services Agency (ACHCSA). The California Department of Fish and Game (CDFG) has also taken an active interest in the potential impact to Redwood Creek and requested the instream bioassessment. While it is unlikely that site groundwater would be used as a drinking water source, drinking water standards can be applied by regulators as cleanup standards. CDFG code stipulates a policy of zero discharge of petroleum to surface waters, unless it can be demonstrated that remediation is infeasible and that instream biota are not affected.

Following the District's and regulators' review of the April 2000 SES report, a meeting was called by ACHCSA in July 2000; the meeting resulted in a written request that this Feasibility Study Report be completed to evaluate potential remedies, and that two additional groundwater monitoring wells be installed and added to the site monitoring program (a workplan for the well installations has been submitted concurrently with this Feasibility Study Report).

This report presents the results of the Feasibility Study to mitigate the plume from continued discharge into Redwood Creek. Background data are mostly incorporated by reference to previous reports in order to minimize repetition. An initial screening was conducted to identify the three most viable alternatives, which include: monitor natural attenuation (MNA); install a cutoff/barrier wall with an inboard trench to extract groundwater; and in situ treatment through the injection of ORC™. The three viable alternatives were evaluated against the following six criteria:

- Long-term effectiveness and permanence;
- Reduction in toxicity, mobility, and volume;

- Short-term effectiveness;
- Implementability;
- Cost; and
- Regulatory and community acceptance.

Based on these criteria, ORC™ injection was judged to be the most viable remedy.

PROPOSED ACTIONS

The District proposes to implement the following actions to address regulatory concerns:

- Discuss the conclusions of this Feasibility Study with the regulators to obtain their concurrence.
- Obtain regulatory agency concurrence on the SES workplan for additional groundwater monitoring well installations, and implement that workplan.
- Implement the recommended ORC™ injection remedy selected in the Feasibility Study.
- Continue the established program of quarterly surface water and groundwater monitoring to evaluate the effectiveness of the remedy.

1.0 INTRODUCTION

PROJECT BACKGROUND

The subject property is the East Bay Regional Park District (District) Redwood Regional Park Service Yard located at 7867 Redwood Road in Oakland, Alameda County, California. The site has undergone site investigations and remediation since 1993 to address the subsurface contamination caused by leakage from one or more of two former underground fuel storage tanks (UFSTs) that contained gasoline and diesel fuel. The Alameda County Health Care Services Agency (ACHCSA) has provided regulatory oversight of the investigation since its inception.

KEY OBJECTIVES AND SCOPE OF WORK

The principal program objectives of the current work were delineated in the SES proposal of August 2000, which was designed to meet ACHCSA's requirements (outlined in their August 2000 letter), to complete an appropriate feasibility study and design a remedy to stop or minimize the discharge of the existing hydrocarbon plume into Redwood Creek. **The key objectives of this feasibility study and remedial action assessment were to:**

- Review the site data collected since the April 1999 Assessment report, including the recent September 2000 groundwater and surface water monitoring event to see if there are any substantive chages in the assessment of the geometry of the site contamination and pathways of migration into the senstive reeceptor, Redwood Creek.
- Assess the regulatory considerations as a preamble to the feasibility study
- Complete a feasibility study of viable remedies and rank them against the feasibility criteria of ong-term effectiveness and permanence; reduction in toxicity, mobility, and volume; short-term effectiveness; implementability; cost; and regulatory and community acceptance.
- Make recommendations for further action.

The SES June 1999 report provided a full discussion of previous site remediation and investigations, site geology and hydrogeology, residual site contamination, a conceptual model for contaminant fate and transport, and an evaluation of hydrochemical trends and plume stability (SES, 1999b).

This report specifically discusses the findings of the work conducted since the June 1999 report, and summarizes previous findings where applicable.

SITE DESCRIPTION

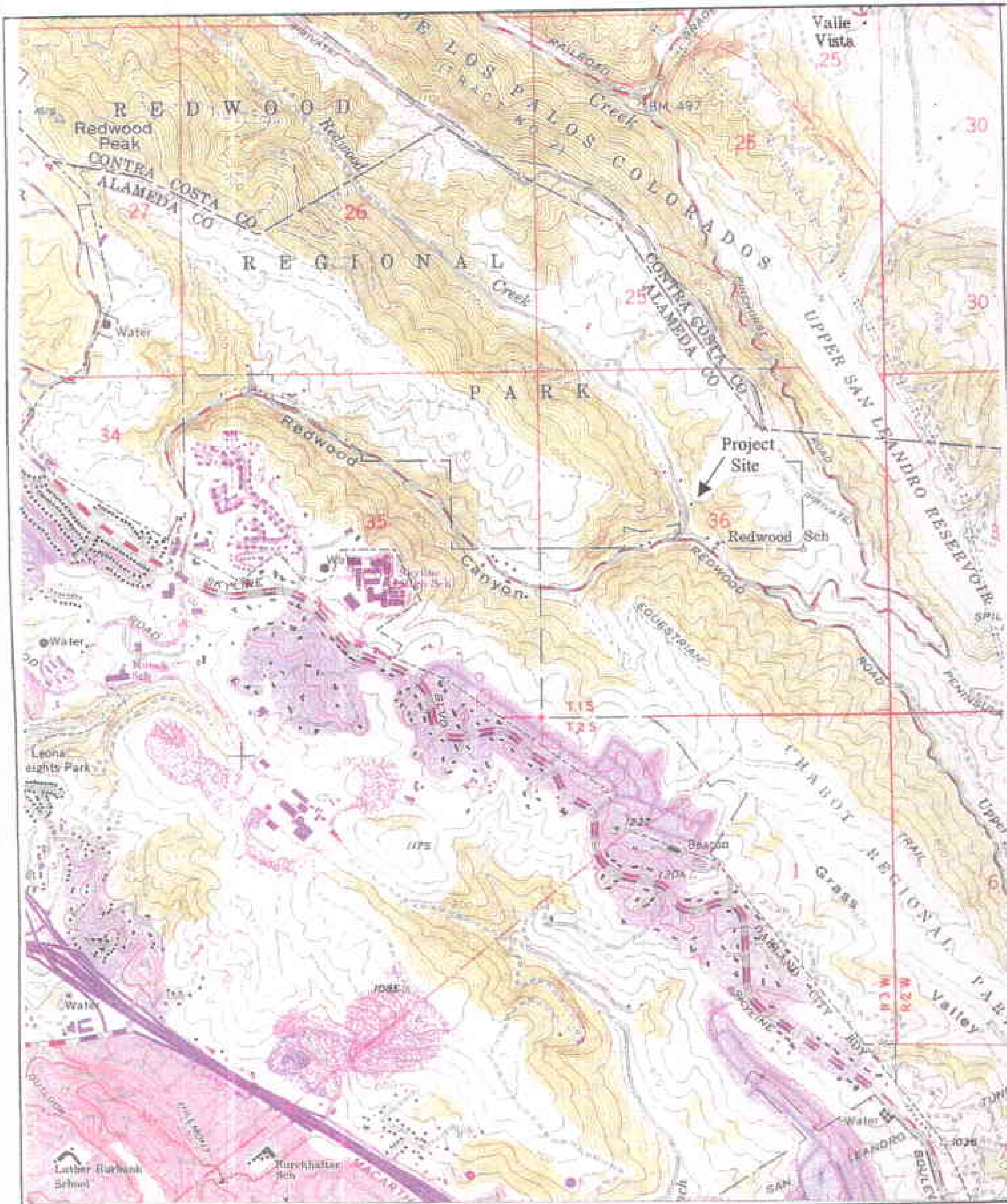
The project site is located at 7867 Redwood Road in Oakland, Alameda County, California. Figure 1 shows the location of the project site. The site slopes to the west, from an elevation of approximately 564 feet above mean sea level (amsl) at the eastern edge of the service yard to approximately 545 feet amsl at Redwood Creek, which approximately defines the western edge of the project site as regards this investigation. Figure 2 is a site plan.

The project site is a service yard for Redwood Regional Park, which utilized two UFSTs (one 2,000-gallon diesel fuel and one 5,000-gallon unleaded gasoline) from the mid-1960s to 1993. Figure 2 shows the location of the former UFSTs. Both UFSTs were reportedly installed between 1965 and 1968 (Parsons, 1993a). The 5,000-gallon steel UFST contained unleaded gasoline, and was reportedly a converted channel buoy purchased from the Navy (Parsons, 1993a). The tanks and piping underwent integrity testing in 1984, 1986, 1988, and 1989. The unleaded gasoline UFST system failed the 1988 and 1989 tests (Parsons, 1993a).

SITE INVESTIGATION AND REMEDIATION HISTORY

Site remediation and characterization activities have been conducted since 1993, beginning with removal of the UFSTs. A more detailed discussion is provided in the SES June 1999 report. Appendix A contains tabular summaries of historical soil, groundwater, and surface water analytical results, and site maps showing sample locations and key analytical results. A complete listing of previous site investigation and remediation reports is included in the References section (Section 9.0). The following phases of work have been conducted:

- The two UFSTs were removed in April 1993.
- Approximately 600 cubic yards of contaminated soil in the vicinity of the UFSTs were excavated for offsite disposal in April 1993, with a total excavation surface area of approximately 5,000 square feet and a maximum depth of approximately 25 feet (soil excavation activities were halted due to the potential for slope instability, the presence of significant facility constraints (roads and buildings), and the infiltration of spring water into the excavation).
- Excavation confirmation soil sampling was conducted in June 1993, and confirmed elevated levels of TPH-gasoline range (TPHg); TPH-diesel range (TPHd); and benzene, toluene,



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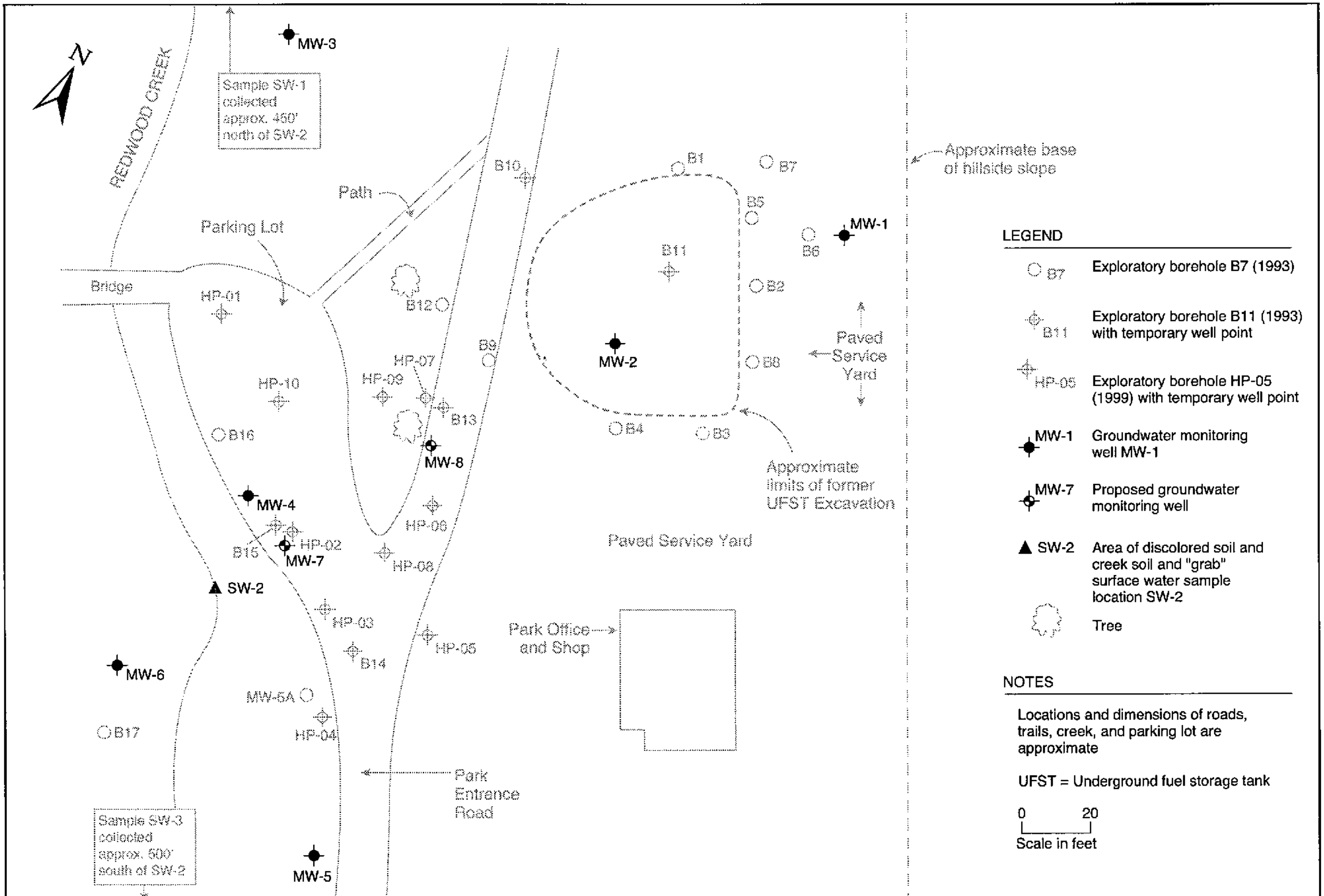
U.S.G.S. TOPOGRAPHIC MAP SHOWING SITE LOCATION

Redwood Regional Park Service Yard Oakland, Alameda County, California	By: MJC	NOVEMBER 1997	Stellar Environmental Solutions Geoscience & Engineering Consulting
	Figure 1		



2000-46-04

Stellar Environmental Solutions
Geoscience & Engineering Consulting

SITE PLAN AND HISTORICAL SAMPLING LOCATIONS
Redwood Regional Park Service Yard, Oakland, CA

Figure 2

by: MJC | OCTOBER 2000

ethylbenzene, and total xylenes (BTEX); lead was not detected, and methyl *tertiary*-butyl ether (MTBE) was not analyzed for.

- An initial site characterization was conducted in September and October 1993 in the vicinity of the former UFST excavation to evaluate the nature, magnitude, and extent of soil and groundwater contamination. Seventeen 17 exploratory boreholes were drilled, five of which were converted to temporary well points. No significant soil contamination was detected in soil boreholes immediately north, south, or east of the former UFST remedial excavation. Fuels in soil were detected in soil boreholes up to 90 feet southwest of the former UFST excavation, and groundwater contamination was found to extend from the source area downgradient to just upgradient of Redwood Creek (Parsons, 1993c).

- A site characterization was conducted in April 1999 to fill data gaps about the extent of residual hydrocarbon contamination downgradient of the former tank area, evaluate impacts from the groundwater plume on aquatic organisms in Redwood Creek, and develop a conceptual model of the plume migration and evolution (SES 1999a and 1999b). Eleven exploratory boreholes were drilled, from which soil samples and grab-groundwater samples were collected for laboratory analysis. The data refined the lateral limits of the groundwater plume—which extends a distance of approximately 150 feet from the former tank area to the creek—with concentrations above 10,000 µg/L TPH occurring over a distance of 100 feet and a width of approximately 55 feet (beginning approximately 30 feet from the tank area); this suggest that the plume is becoming disconnected from the source area. The data also indicated that natural attenuation is likely occurring on the margins of the plume, but is not sufficient to fully attenuate contamination within the axis of the plume prior to its discharge to the creek.

- A total of 16 groundwater monitoring, sampling, and analysis events have been conducted on an approximately quarterly frequency since November 1994, which have defined the lateral extent of groundwater contamination. Installation and monitoring of two additional wells has been requested by ACHCSA and will likely be conducted in the first quarter of 2001.

- Fourteen surface water sampling events have been collected in Redwood Creek since 1994 to evaluate impacts of site contamination on that surface water body. Surface water sampling, creek bank soil sampling, and visual observations have confirmed that contaminated groundwater discharges to the creek, that detected surface water contamination at the discharge area is diluted to non-detectable levels within several hundred feet downstream, and that naturally-occurring algae appear to be utilizing the petroleum as a carbon source.

■ Two instream bioassessment events were conducted in April 1999 and January 2000 to evaluate potential impacts to stream biota associated with the site contamination. No impacts to stream biota were documented.

Before the August 2000 letter from ACACHCSA, historical ACHCSA-approved revisions or inputs to the groundwater sampling program have included: 1) discontinuing hydrochemical sampling and analysis in wells MW-1, MW-3, MW-5, and MW-6; 2) discontinuing creek surface water sampling at upstream location SW-1; and 3) reducing the frequency of creek surface water sampling from quarterly to semi-annually (ACHCSA, 1996).

2.0 PHYSICAL SETTING

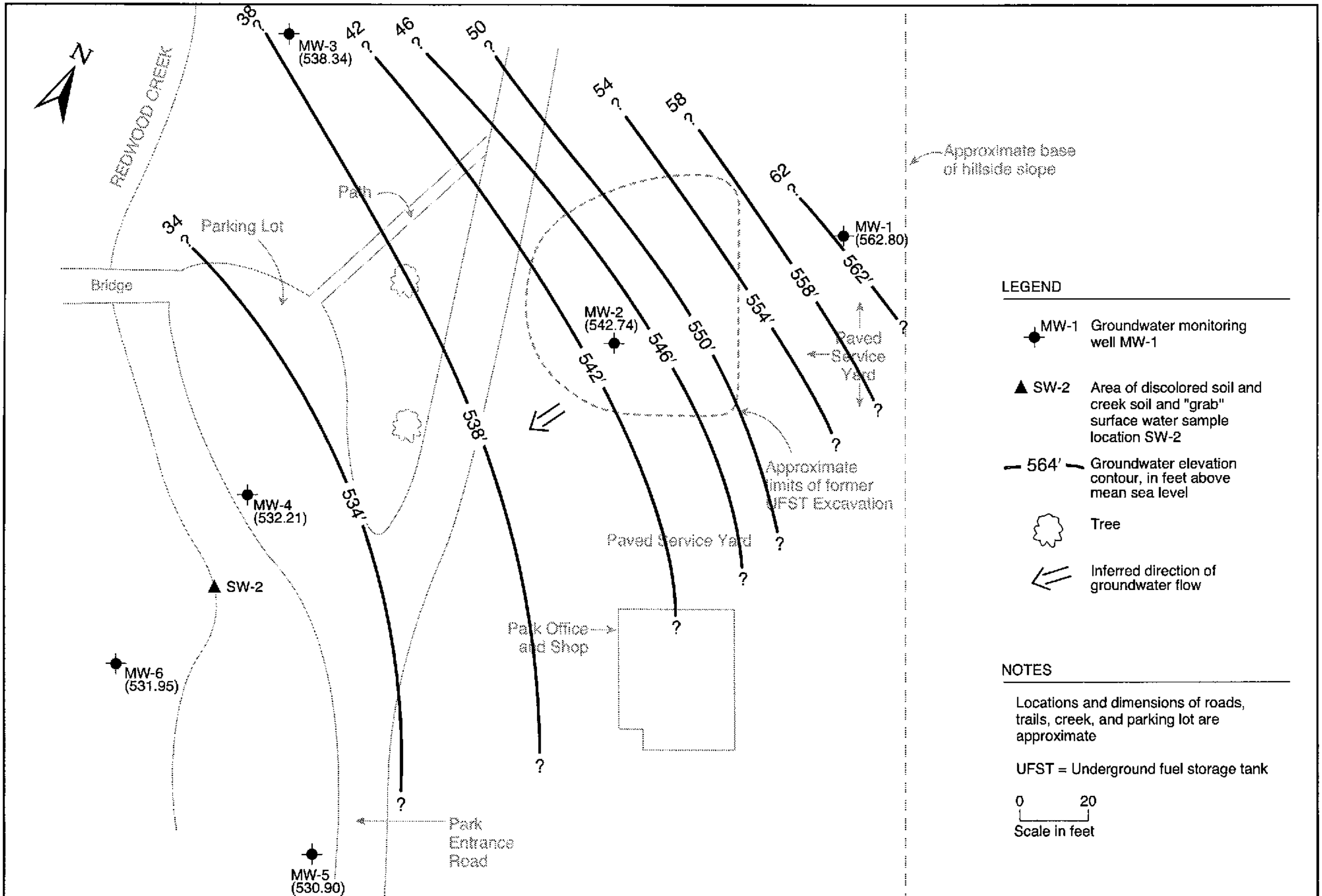
The following is a brief summary of the site hydrogeologic conditions based on geologic logging and water level measurements historically collected at the site to provide a sufficient technical setting for the feasibility study. A more detailed discussion of these data are presented in the SES June 1999 report.

Shallow soil stratigraphy consists of a surficial 3- to 10-foot thick clayey silt unit underlain by a 5- to 15-foot thick silty clay unit. In all monitoring well boreholes, a 5- to 10-foot thick clayey coarse-grained sand and clayey gravel unit was encountered that laterally grades to a clay or silty clay. This unit overlies a weathered siltstone at the base of the observed soil profile. Soils in the vicinity of MW-1 are inferred to be landslide debris.

Groundwater at the site occurs under unconfined and semi-confined conditions at a depth of 12.5 to 19 feet bgs, corresponding to the top of the clayey, silty sand-gravel zone. Local perched water zones have been observed well above the top of the capillary fringe. Local groundwater flow direction has been consistently measured as northeast to southwest. Figure 3 is a groundwater elevation map constructed from the September 2000 monitoring well static water levels. The groundwater gradient is relatively steep—approximately 2 feet per foot—between well MW-1 and the former UFST source area, resulting from the topography and the highly disturbed nature of sediments in the landslide debris. Downgradient from the UFST source area, well MW-2 and Redwood Creek, the groundwater gradient is approximately 0.1 feet per foot.

Site-specific empirical data (using the estimated time for UFST-sourced contamination to reach Redwood Creek) suggests a conservative estimate of groundwater velocity within the aquifer material at 7 to 10 feet per year, with the rate of movement within the clay rich zones being substantially less.

Redwood Creek borders the site to the west, and is a seasonal creek known for the occurrence of rainbow trout. Creek flow in the vicinity of the site shows significant seasonal variation with little to no flow during the summer and fall dry season, and vigorous flow with depths to 1 foot during the winter and spring wet season. The creek is a gaining stream (i.e., it is recharged by groundwater) in the vicinity of the site and discharges into Upper San Leandro Reservoir, located approximately 1 mile southeast of the site.



Stellar Environmental Solutions Geoscience & Engineering Consulting	**GROUNDWATER ELEVATION MAP–SEPTEMBER 28, 2000** **Redwood Regional Park Service Yard, Oakland, CA**	**Figure 3** by: MJC — OCTOBER 2000

2000-46-02

3.0 DISTRIBUTION AND PERSISTENCE OF CONTAMINATION & REGULATORY CONSIDERATIONS

This section summarizes historical site investigation data, and updates trend analyses based on the recently collected September 2000 data. Current distribution of soil and groundwater contamination (and natural attenuation indicators) based on the 1999-2000 subsurface investigations is presented. The recent September 2000 groundwater and surface monitoring event has been submitted under separate cover (SES, 2000a). A full discussion of the contaminant distribution and transport conceptual model was presented in the SES June 1999 report (SES 1999b). Appendix A contains historical soil, groundwater, and surface water analytical data.

RESIDUAL SOIL CONTAMINANT DISTRIBUTION IN SOURCE AREA

Previous (1993 and 1994) investigation data documented the extent and magnitude of contamination in the former UFST source area. While the 1993 remedial action resulted in the removal of approximately 600 cubic yards (CY) of TPH-contaminated soil, an estimated 20 to 100 CY of TPH-contaminated soil remains at the source area. This area is now completely paved, and would be expected to act as a continued source to groundwater contamination only during seasonal periods of high groundwater elevations. The residual soil contamination in the former source area is generally not considered a significant input based on the relatively low volume of the residual contamination and the distance from the area to the former source to the downgradient sensitive receptor, Redwood Creek.

DOWNGRADIENT SOIL CONTAMINANT DISTRIBUTION

The magnitude and extent of soil contamination downgradient of the former UFST source area has been well defined by historical and recent (April-May 1999) borehole analytical results, and has shown that soil contamination beyond the source area is confined to the capillary fringe and does not extend downgradient across Redwood Creek. The zone of soil contaminated above 1,000 mg/kg TPH (TPHg + TPHd) is lenticular shaped, extends approximately 150 feet from the center of the former UFST source area to Redwood Creek, varies in width from approximately 20 to 40 feet (approximate average of 30 feet), and is widest approximately halfway between the source area and the creek. The thickness of this zone varies from 3 to 8 feet, and averages approximately 4.5 feet over the length of the zone. This corresponds to an approximate volume of 850 cubic yards.

GROUNDWATER CONTAMINATION DISTRIBUTION

The magnitude and extent of groundwater contamination has been well defined by historical investigations, and shows the following:

- TPHg concentrations are significantly greater than TPHd concentrations, and BTEX and MTBE constituents generally show the same geometric distribution as the TPHg.
- Maximum total TPH (TPHg + TPHd) contamination in groundwater (approximately 300,000 µg/L) is located at the downgradient edge of the plume near MW-4, just upgradient of Redwood Creek, and total TPH concentrations decrease along the plume axis closer to the source area. Significant total TPH concentrations (approximately 47,000 µg/L to 70,000 µg/L) were detected in 1999 upgradient boreholes up to 60 feet upgradient of MW-4, suggesting a substantial mass of groundwater contamination that will continue to migrate downgradient toward the creek. This is the location at which a new monitoring well will be installed (to determine the centerline of the plume, and thus the highest contamination).
- Groundwater contamination above 10,000 µg/L TPH (TPHg + TPHd) comprises an elliptical plume that extends approximately 100 feet from the downgradient edge of the former UFST source area to Redwood Creek, and is approximately 60 feet wide (total of 6,000 square feet). The leading edge of the plume at the Redwood Creek interface appears to be about 30 feet wide. A smaller zone (approximately 200 square feet) with TPH contamination above 100,000 µg/L is located in the immediate vicinity of borehole HP-02 at the leading edge of the plume. This area with the potential for over 100,000 µg/L will also be explored during the upcoming monitoring well installations.

CREEK SURFACE WATER CONTAMINATION

As discussed in the June 1999 report, TPH and aromatic hydrocarbons have been historically detected at the SW-2 location where contaminated groundwater discharges to Redwood Creek. During periods of low creek flow contaminated (discolored) soil is evident in the creek bank, providing empirical evidence of the capillary fringe zone of residual contaminated soil. Historical contaminant concentrations in creek surface water samples are several orders of magnitude below immediately upgradient groundwater samples, probably due to the immediate dilution of the discharge into the creek.

The last two surface water samples at location SW-2 (in December 1999 and September 2000) were near or above the previous historical maximum for all site contaminants at that location for their respective time of sampling. The December 1999 concentrations of 1,300 µg/L TPHg, 250 µg/L TPHd, and 85 µg/L total BTEX are the maximum detected in the 14 monitoring events at SW-2.

The September 2000 monitoring at SW-2 showed lower concentrations than those in December 1999, but higher than some concentrations reflecting the dry season. This supports the hypothesis that a "slug" of groundwater contamination greater than that measured in site monitoring wells is moving toward the discharge area, and that contaminant discharge from groundwater to surface water could be on an increasing trend.

PROJECTED FUTURE TRENDS

As discussed in detail in the June 1999 report, the majority of contaminated soil in the UFST source area was removed, with the exception of small pockets of TPH-contaminated soil that could not be removed due to its proximity to landslide deposits. The continued decrease in groundwater concentrations at source area well MW-2 confirms that the contaminant plume is in the process of "disconnecting" from the source area; however, long-term source area contributions will continue to some degree as long as groundwater is in contact with contaminated soil and is allowed to migrate downgradient. The distribution of the residual TPH soil within the capillary fringe along the length of the 150-foot long plume makes it practically and economically burdensome to remove.

It is well documented in the literature (LLNL, 1995; McAllister and Chiang, 1994) that natural attenuation of petroleum hydrocarbons is a viable mechanism for stabilization and ultimate reduction of plume size; site data suggest that attenuation is indeed occurring on the fringes of the plume. However, the site data also suggest that attenuation is muted in the centerline of the plume due to the elevated contaminant concentrations and the short distance between the former source area and the creek. Potential remedies to address this have been articulated in the following alternatives analyses which included MNA alone, a barrier wall with extraction trench/treatment system and enhanced MNA though the application of oxygen-releasing compounds.

REGULATORY CONSIDERATIONS

The Applicable Relevant and Appropriate Regulations (ARARs) for this site are presented here to give a regulatory context to the problem before presenting the interpretation of findings and consideration of remedial action. The ARARs generally should be considered in the light of the following:

- There is a significant volume of residual petroleum and aromatic hydrocarbon contamination in the former UFST source area and in the capillary fringe extending approximately 150 downgradient to Redwood Creek. This contaminated soil will continue to be a long-term source of groundwater contamination. However, given the site conditions, remediation of this contaminated soil by excavation and offsite disposal is neither practical nor cost-effective.

- Groundwater contamination is currently greatest at or near the downgradient edge of the site, adjacent to Redwood Creek. Groundwater daylights at the base of the slope within the creek during the low flow period in summer, and site contaminants have been sporadically detected in creek surface water at a localized point of groundwater discharge.
- Site groundwater is not utilized for drinking water. Redwood Creek flows to Upper San Leandro Reservoir, a municipal water supply; however, downstream creek surface water samples have never contained concentrations of concern as a result of the dilution effect from the stream. Human health risk associated with site contamination would be limited to short-term exposure to contaminated surface water.
- Redwood Creek is a protected trout stream, and discharge of contaminated groundwater should be evaluated in the context of impacts to benthic invertebrates as indicator of the overall riparian environment.
- The lead regulatory agency for the site investigation is the Alameda County Health Care Services Agency (ACHSA). The ACHSA is a Local Oversight Program (LOP) to the Regional Board, and provides its own oversight until some resolution such as site closure is agreed upon, at which time it sends its recommendation to the RWQCB for approval of the closure. The California Department of Fish and Game (CDFG) has communicated their concerns directly to ACHCSA as regards potential impacts to Redwood Creek.

The following subsections present potentially applicable criteria for evaluating site contamination in soil, groundwater, and surface water, and compare site contamination to the relevant criteria.

SOIL CONTAMINATION

Cleanup and Further Assessment Criteria

Regulatory agencies can require remediation of petroleum-contaminated soil if they deem its impact to be significant. The evaluation of impacts can take numerous forms, from the general adoption of a non-degradational standpoint to the need to demonstrate definitive human health or ecological impacts of significance. Generally, the first regulatory assessment evaluates if the contamination is hazardous, which would be the case for hydrocarbons that are ignitable or toxic, and/or if residual soil contamination contributes to groundwater and/or surface water contamination resulting in unacceptable impacts. In this case, the soils are not considered hazardous but they will contribute some input to groundwater over time.

Comparison of Site Data to Regulatory Criteria

Sufficient site characterization has been conducted to confirm the extent and magnitude of residual soil contamination, and that this will be an ongoing source of groundwater contamination. However, the residual soil is located in areas around the former source where it could not be excavated initially due to site constraints and in the capillary fringe zone where it cannot be effectively removed without completing a highly impractical excavation. Thus, for the purpose of the feasibility study, the residual soil contamination is left in place and will be remediated over time by natural attenuation with additional assistance by in-situ remediation that may be implemented in the area of the relatively high concentration plume.

GROUNDWATER CONTAMINATION

Cleanup and Further Assessment Criteria

There are several potentially applicable standards for groundwater contamination: all are drinking water standards and include:

- Federal and California primary and secondary Maximum Contaminant Levels (MCLs) and MCL goals;
- California Department of Health Services (DHS) action levels (ALs) for toxicity, taste, and odor; and
- California Environmental Protection Agency (Cal/EPA) Applied Action Levels (AALs).

The standard that can be applied by the lead regulatory is the strictest of any applicable State or federal standards, and these can be used as cleanup goals. Table 1 summarizes the groundwater quality criteria, and recent maximum site concentrations, and includes only the California and federal MCLs which are generally the most stringent of the drinking water standards. The majority of the groundwater quality standards are human health risk-based, and apply to groundwater that is a drinking water source; however, drinking water standards can be applied to sites where groundwater is not a drinking water source. Cleanup action level criteria can be determined by natural geo-chemical conditions at a site. For example, where an existing aquifer has a sustained yield of less than 200 gallons per day or the electrical conductivity is greater than 5,000 μmhos/cm, the California State Water Resources Control Board (SWRCB) considers the aquifer not usable as a potential public water supply. Historical groundwater monitoring data indicate that the site groundwater conditions meet the criteria for a potential public water supply, and therefore drinking water standards could be applied as cleanup standards.

TABLE 1
SURFACE AND GROUND WATER QUALITY CRITERIA FOR DETECTED CONTAMINANTS

Analyte	Groundwater Regulatory Limit (µg/L)	Maximum Detected Groundwater Concentration & Date [a] (µg/L)	Surface Water Regulatory Limit (µg/L)	Maximum Historical Detected Surface Water Concentration [b] (µg/L) Number of Samples/ Number of Exceedances
TPH-gasoline	No limit established	**54,000 – 2/99**	No limit established	**1,300**
TPH-diesel	No limit established	**270,000 – 2/99**	No limit established	**250**
Benzene	1 (Ca MCL-Prim) 71 (IRIS-H20)	**1,700 – 2/99**	 0.34 (WQO-DW) 21 (WQO-Other) 21 (IRIS-H20+Org) 71 (IRIS-H20) 130 (EPA Tier II)	**13** 6/ 14 0 / 14 0 / 14 0 / 14 0 /14
Toluene	40 (fed MCL-Sec-Prop) 1,000 (fed MCL-Prim-Prop) 200,000 (IRIS-H20)	**110 – 2/99**	 9.8 (EPA Tier II) 6,800 (IRIS-H20+Org) 200,000 (IRIS-H20)	**1.0** 0 / 14 0 / 14 0 / 14
Ethylbenzene	30 (fed MCL-Sec-Prop) 680 (Ca MCL-Prim) 29,000 (IRIS-H20)	**2,800 – 2/99**	 7.3 (EPA Tier II) 3,100 (IRIS-H20+Org) 29,000 (IRIS-H20)	**47** 2 / 14 0 / 14 0 / 14
Total Xylenes	20 (fed MCL-Sec-Prop) 1,750 (Ca MCL-Prim)	**11,000 – 2/99**	 13 (EPA Tier II)	**27** 1 / 14
MTBE	5 (Ca MCL-Sec-Pro) 14 (Ca MCL-Prim-Pro)	**260 – 2/99**	No limit established	**2.3**

Notes:

[a] Concentrations detected since February 1998 in site monitoring wells or temporary well points.

[b] Concentrations detected since 1993 in Redwood Creek.

Ca MCL-Prim = State of California Primary Maximum Contaminant Level for drinking water.

Ca MCL-Sec-Prop = State of California Secondary Maximum Contaminant Level (proposed) for drinking water.

EPA Tier II = USEPA Tier II values from Proposed Water Quality Guidance for the Great Lakes System, 1993.

Fed MCL-Prim-Prop = Federal Primary MCL (proposed); Fed MCL-Sec-Prop = Federal Secondary MCL (proposed).

WQO - DW= California State Water Resources Control Board (SWRCB) Water Quality Objective for inland surface waters that are potential drinking water sources.

WQO – Other = SWRCB Water Quality Objective for inland surface waters that are not potential drinking water sources.

IRIS-H20 = Environmental Protection Agency Integrated Risk Information System - concentration at which there is a human carcinogenicity risk of 10E-6 or less for consumption of water only.

IRIS-H20+Org = Environmental Protection Agency Integrated Risk Information System - concentration at which there is a human carcinogenicity risk of 10E-6 or less for consumption of water only.

MISSING

- USEPA Ecotox Chronic FW
- CTR
- RWQCBSF AWQC

SEE: August 2000 Interim Final RBSLs guidance document

There are no published numerical groundwater quality standards for TPH. This is because TPH is a complex mixture of dozens of individual compounds that varies by commercial grade; therefore, each mixture behaves differently as regards toxicity, transport, and fate. TPH is specifically regulated under the RWQCB general "nondegradation of beneficial use" policy (RWQCB, 1992), which essentially is a zero-discharge policy.

Site-specific groundwater cleanup standards (especially for TPH) can be calculated using the now common risk-based corrective action (RBCA) modeling approach that determines acceptable levels of residual soil and groundwater contamination that are protective of specified downgradient health risk or ecological receptors. Because of the documented discharge of contaminated groundwater into Redwood Creek, the immediate concern of ACHCSA and CDFG is potential impacts to Redwood Creek resulting from groundwater discharge. It is likely that these agencies will require, at a minimum, that groundwater contamination concentrations not exceed those that pose unacceptable impacts to Redwood Creek, as discussed in the following paragraphs.

Comparison of Site Data to Regulatory Criteria

Maximum fuel concentrations detected in site groundwater samples during the 1999-2000 timeframe of groundwater monitoring and temporary well point sampling in excess of published regulatory agency ARARs for groundwater include:

- Benzene (1,700 µg/L): Exceeds the California Primary MCL and IRIS human health criteria. and USEPA Ecotox Chronic FW
- Toluene (110 µg/L): Exceeds the proposed Federal Secondary MCL.
- Ethylbenzene (2,800 µg/L): Exceeds the California and Federal MCLs. and USEPA Ecotox Chronic FW
- Total xylenes (11,000 µg/L): Exceeds the California and Federal MCLs. and USDOE PRG
- MTBE (260 µg/L): Exceeds the proposed MCLs.
- TPH - RWQCBSF (1998)

As noted previously, greater groundwater contaminant concentrations are inferred to exist in the central portion of the groundwater plume between historical sampling locations.

SURFACE WATER CONTAMINATION

Regulatory Criteria

While the ACHCSA and RWQCB both have a non-degradation policy stipulating that known discharges of contaminants to sensitive aquatic receptors are prohibited, there are only a few published sources of numerical criteria. These are shown in Table 1 as "action levels" and guidance criteria for surface water quality, including:

- USEPA Integrated Risk Information System (IRIS) values for consumption of aquatic organisms and/or water (human health risk-based).
- SWRCB Water Quality Objectives (WQOs) for inland surface waters (SWRCB, 1991) (aquatic toxicity-based and calculated base on a 30-day average of sample concentrations).
- Oak Ridge National Laboratory (ORNL) Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota (ORNL, 1996) (aquatic toxicity-based); Table 1 presents the most stringent of the "benchmark" screening values, which are the USEPA Tier II water quality guidance criteria.

As for groundwater, there are no numerical criteria published for TPH in fresh (non-saline) surface water. There is inherent technical difficulty in determining point-of-discharge concentrations in surface water due to immediate dilution effects, and due to the uncertainty of the geometry and dynamics of the creek-groundwater interface. Therefore, it is possible that regulatory agencies could utilize immediately upgradient groundwater concentrations as representative of worst-case surface water concentrations. A more technically defensible and rigorous approach is to calculate site-specific target levels by conducting aquatic toxicity bioassay testing, the next more intensive step beyond the CDFG bioassessment procedure which approximates the minimum threshold conditions at which the benthic macroinvertebrate community shows impacts.

In addition to numerical criteria, the RWQCB publishes beneficial uses for various surface water bodies, which are used to establish water quality criteria and discharge prohibitions (RWQCB, 1992). There are no listed direct beneficial uses for Redwood Creek, but the existing fish ladder within 30 feet of the area where the plume intermittently daylights indicates the creek to be a sensitive receptor. There are listed beneficial uses for Upper San Leandro Reservoir [located approximately 4,000 feet south (downstream) of the project site], into which Redwood Creek flows. Existing beneficial uses for Upper San Leandro Reservoir include: water contact recreation; municipal and domestic supply; warm and cold fresh water habitats; wildlife habitat; and fish spawning. Potential beneficial uses include non-contact water recreation.

The CDFG has a "zero discharge" policy that prohibits petroleum discharge into waters of the state [Fish and Game Code Section 5650(a)(1)]. The code allows a discharge if the following two criteria are met: 1) it is infeasible to completely remove the petroleum; and 2) release is not adversely affecting the instream biota. Adverse effects include acute and chronic toxicity, as well as reproductive effects on fish and invertebrates. As discussed in Section 3.0, SES retained the CDFG Water Pollution Control Laboratory (WPCL) to implement its protocol for conducting instream bioassessments to evaluate impacts to aquatic life. The results of the bioassessment can be used directly by CDFG to determine if unacceptable impacts to the creek are occurring.

Comparison of Site Data to Criteria

No site-sourced contaminants have been detected in excess of regulatory numerical criteria in site creek water samples during the previous year of creek water monitoring. The only contaminants that have been historically detected in creek water samples in excess of published regulatory agency ARARs for surface water are:

- ***Benzene.*** Detected in 6 out of the 14 surface watering monitoring events since February 1995, all at location SW-2 near the contaminated groundwater discharge, at concentrations ranging from 1.9 to 13 μg/L, which exceed the 0.34 μg/L WQO for inland surface waters that are potential drinking water sources. (Note: the samples analyzed do not represent an average concentration over a 30-day period, upon which the WQO is based, and therefore are not directly comparable to the WQO.)
- ***Ethylbenzene.*** Detected in 2 of the 14 events, both at location SW-2 near the contaminated groundwater discharge, at concentrations ranging from 19 to 47 μg/L, which exceed the 7.3 μg/L EPA Tier II value for aquatic toxicity.
- ***Total Xylenes.*** Detected in 1 of the 14 events, at location SW-2 near the contaminated groundwater discharge, at a concentration of 27 μg/L, which exceeds the 13 μg/L EPA Tier II value for aquatic toxicity.

As discussed in previous reports, including the SES June 1999 report, the results of the CDFG WPCL instream bioassessment indicated no adverse impacts to benthic macroinvertebrate communities at the site.

4.0 IDENTIFICATION AND SCREENING OF FEASIBLE REMEDIATION TECHNOLOGIES

CURRENT CONDITIONS AND REMEDIAL ACTION OBJECTIVE

Current conditions include a 30- to 60-foot wide groundwater fuel plume in the approximately 20-foot long area between the downgradient edge of the parking area and Redwood Creek, a steep vegetated hillside slope with no vehicle access. There is no reasonably cost-effective method for remediating contamination within this zone. A substantial mass of groundwater and capillary fringe soil contamination is located upgradient of that zone, primarily under the parking lot. Based on the current plume configuration and hydraulic regime, we infer that groundwater contamination equaling or exceeding current site maxima could persist at the downgradient plume limits (adjacent to Redwood Creek) for at least several years. A significant site constraint is the relatively short distance between the current inferred center of contaminant mass and Redwood Creek, which precludes installation of an effective "trigger" monitoring well system between the plume and the creek.

The overall remedial action objective for the EBPD Redwood Creek site is to arrest the migration of the hydrocarbon plume from daylighting downgradient in Redwood Creek. While the discharge has been occurring for some time, the site data suggests that a higher concentration portion of the plume is moving closer to the Creek and this part of the plume needs to be mitigated. Any selected remedy must satisfy the regulatory agencies that the site contamination will be appropriately mitigated. Three viable remedies have been selected for further feasibility analyses after screening out a number of other possible but less attractive candidates. Remediation must address the overall protection of human health and the environment and compliance with Applicable or Appropriate and Relevant Criteria (ARARs). In addition, it should address the following six criteria: yes

- Long-term effectiveness and permanence;
- Reduction in toxicity, mobility, and volume;
- Short-term effectiveness;
- Implementability;
- Cost; and

- Regulatory and community acceptance.

The question of long-term effectiveness addresses the magnitude of risks resulting from the residual soil hydrocarbons left in place, and the adequacy and reliability of controls. Other critical questions assessed are the likelihood of meeting performance specifications, type of long-term management, monitoring and necessary maintenance, difficulties and uncertainties of the long-term operation and maintenance, confidence in the remedial system's ability to handle potential problems, and assessment of the remedy effectiveness. Remediation should be evaluated for reducing the toxicity, mobility, and/or volume of the contaminants. For short-term effectiveness, remediation should also address protection of the community, protection of workers, environmental impacts, and time required to reach cleanup objectives. The implementability evaluation includes ease of implementation.

SOIL REMEDATION CONSIDERATIONS

No direct soil remediation is being proposed because the soil contamination at the source area has long since been remediated and the residual coil contamination is located in a relatively thin zone between 2 and 4 feet thick beneath an overburden of 10 feet or more of soil. Direct excavation and removal is thus infeasible as it would require an extensive excavation resulting in the destruction of mature surface flora. However, some of the alternatives to treat the groundwater discussed below have an ancillary benefit of also reducing soil contamination concentrations by introducing conditions that favor more rapid biodegradation.

GROUNDWATER REMEDIATION ALTERNATIVES

Three viable remediation remedy alternatives are considered for this feasibility analysis. All three have been demonstrated to be technically effective at other sites. Each alternative is evaluated for its overall protection of health and the environment, and compliance with ARARs; impact on long-term and short-term effectiveness; reduction of chromium mobility, toxicity and volume; and implementability and cost. Each alternative is compared to the criteria and discussed. All the alternatives are summarized in Table 2. Table 3 shows a summary comparison of the alternatives against the criteria.

Briefly, the three groundwater remediation alternatives considered are:

1. Monitoring of Natural Attenuation
2. Cuttoff Wall Barrier with Groundwater Pump & Treat
3. In Situ oxygen releasing compound (ORC™) Treatment

Table 2
Remedial Technology Feasibility Criteria

ASSESSMENT CRITERIA	ALTERNATIVE 1 Monitor Natural Attenuation of TPH	ALTERNATIVE 2 Cuttoff Wall and Trench Groundwater Pump & Treat	ALTERNATIVE 3 In Situ ORC™ Treatment
1. Long-term Effectiveness and Permanence			
Magnitude of Residual Risk Onsite	Significant: TPH will continue to migrate to Redwood Creek and will likely > in concentration.	Minor: The egroundwater pump & treat system discharge is expected to keep up with recharge.	Minor, although it may take up to two years (2 injections) to significantly reduce concentrations
Adequacy and Reliability of Controls	No engineered controls are required.	May or may not achieve hydraulic control, depending on lithologic constaints.	Will need 2 injections of slurry; inspection wells needed to measure resultant contaminant reduction
2. Reduction of Toxicity, Mobility and Volume			
	Toxicity will increase over time as soil contamination feeds plume and slug of high concentration moves towards Redwood Creek.	Contaminant mobility is reduced. Groundwater removal will reduce the volume of contaminants. Toxicity reduction by mass removal	Contaminant mobility is reduced through ORC™ and treatment. Groundwater treatment will reduce the volume of contaminants and toxicity is reduced through enhanced biodegradation
3. Short-term Effectiveness			
Time Until Remedial Action Objectives are Achieved	Remedial action objectives of containing plume will not be achieved. MCLs at creek interface may be eventually achieved in the long term.	Compliance criteria for groundwater at the site would be accelerated but MCLs at site will not be achieved. MCLs at creek inteface will eventually be achieved.	Compliance criteria for groundwater at the site would be accelerated but MCLs at site will not be achieved. MCLs at creek interface will eventually be achieved.
Protection of Community During Remedial Action	Community not protected with potential downgradient exposures in event people walk in creek	No risk to community.	No risk to community.
Protection of Workers During Remedial Action	No risk to personnel conducting groundwater monitoring.	No risk to personnel installing remedy and groundwater extraction/monitoring.	No risk to personnel conducting ORC™ injection/ treatment.

Table 2 *continued*

ASSESSMENT CRITERIA	ALTERNATIVE 1 Monitor Natural Attenuation of TPH	ALTERNATIVE 2 Cuttoff Wall and Trench Groundwater Pump & Treat	ALTERNATIVE 3 In Situ ORC™ Treatment
3. Short-term Effectiveness *continued*			
Environmental Protection	Plume would continue to migrate and attenuate, with high concentrations.	Long-term localized contamination above MCLs for benzene.	Long-term localized contamination above MCLs for benzene.
4. Implementability			
Technical Feasibility	Feasible.	Groundwater treatment can be implemented.	Groundwater treatment can be implemented.
Administrative Feasibility	No permits necessary.	Utility connections must be established and permits must be obtained.	Required permits must be obtained.
5. Cost			
Capital Cost	0	$200,000 [a]	$90,000 [b]
Operation and Maintenance as discussed	$50,000 [c]	$100,000 [d]	$40,000 [e]
Restoration/Closure	$25,000	$50,000	$25,000
TOTAL	$75,000	$350,000	$155, 000
6. Regulatory and Community Acceptance			
	Unacceptable	Acceptable	Acceptable

Notes:

[a] Cost estimates assumes utility tie-in back to the corporation yard.

[b] Two separate injection events with injection points at 9 foot centers across projected plume footprint.

[c] 5 years of MNA at $10,000/year; including all reporting.

[d] 5 years of extraction includng all reporting.

[e] 3 years of of injection including effectivenss assessment and reporting.

MONITORING OF NATURAL ATTENUATION

Description

Monitoring Natural Attenuation (MNA) is the "do nothing" alternative that, as a result of the demonstrated degradability of petroleum hydrocarbons by naturally occurring mechanisms, has been found to be a viable option for addressing many hydrocarbon plumes, replacing the need for active remediation, when there are no sensitive receptors that could be impacted before the natural attenuation reduces the concentrations to acceptable levels. Specifically, biodegradation of petroleum hydrocarbons in groundwater has a significant role in creating a stable plume, minimizing groundwater plume configuration and concentrations over time (Lawrence Livermore National Laboratory, 1995). Hydrocarbon biodegradation and presence of a stable plume are the basis for application of risk-based methodologies in support of site closure (RWQCB, 1996).

A single round of biodegradation-indicator (bio-indicator) parameters was collected at the site in April 1999 in site wells and temporary well points, and additional natural attenuation analyses were conducted in the December 1999 and September 2000 groundwater monitoring events. The limited site data suggest that natural attenuation is occurring on the fringes of the plume, but that attenuation is muted in the centerline of the plume and is insufficient to prevent discharge of contaminated water to the creek.

Long-term Effectiveness and Permanence

Long-term effectiveness is considered poor to fair. Effectiveness is poor in being able to stop the short-term impacts to the Redwood Creek that will likely continue given the close proximity of the high concentration area of the plume to Redwood Creek. The effectiveness is judged fair in the upgradient area where the UST was removed. Natural biodegradation in areas with sufficient oxygen is expected in the permeable excavation backfill zone. The margins of the plume will likewise have good natural attenuation. However, the areas with relatively high (> 5,000 mg/kg TPH or > 10 mg/L TPH could resist biodegradation because insufficient oxygen would be available.

Reduction in Toxicity, Mobility, and Volume

Reduction in toxicity will occur slowly over the long term, via diffusion of the more toxic BTEX compounds. The mobility will not be directly affected by natural attenuation, except that the reductions provide for less contaminant mass to move through the plume over time. Over the long term, the volume will decrease as the disconnected plume migrates downgradient into the Creek.

Short-term Effectiveness

Natural attenuation does not provide any viable short term effectiveness in reducing the contaminant mass.

Implementability

The MNA is easiest to implement in that there are no additional requirements other than the additional wells required to complete more extensive monitoring of the areas of concern—as is true for all the alternatives.

Cost

Cost of the MNA associated quarterly monitoring is approximately $10,000 annually.

Regulatory and Community Acceptance

MNA is not currently likely to be considered an acceptable remedy, due to the increase in concentrations and potential for continuing higher TPH concentrations to discharge into Redwood Creek as the plume continues to migrate downgradient.

CUTTOFF WALL BARRIER WITH INTERCEPTOR TRENCH AND GROUNDWATER PUMP & TREAT

Description

To reduce the flow of groundwater to Redwood Creek, a heavy vinyl sheet pile barrier with interlocking joints would be driven to a depth of approximately 12 feet bgs in the area immediately east of MW-4. This would create a physical barrier to groundwater flow, thereby preventing the plume from moving downgradient into the creek. Because groundwater would back up behind this barrier, low flow extraction of the groundwater could be achieved with a well point installed within the middle of an interceptor trench measuring 3 by 30 feet. Water treatment would be by liquid-phase carbon adsorption. Treated water would be disposed of via a national Pollution Discharge Elimination System (NPDES) permit to the creek.

The sheet pile cutoff wall alternative is designed to establish hydraulic control to the northeast where the plume originates. It is expected that the groundwater would collect in the trench after backing up against the barrier. Activation of a low flow rate (estimated at 1 gpm or less) in the well installed within the trench should control the backup given the low groundwater velocity estimated for the site area.

Long-term Effectiveness and Permanence

The potential effectiveness of the sheet pile cutoff wall with trench and extraction well alternative is good. The barrier wall has excellent predictable hydraulic performance and a long service life. However, the groundwater pumping rate could vary depending on the seasonal recharge. The location of a relatively small 1,000-pound carbon unit could be located adjacent to the wells or back at the Redwood Creek corporation yard, although placing it back at the yard would necessitate a more powerful pump.

Reduction in Toxicity, Mobility, and Volume

An immediate reduction of mobility and volume of the plume migrating to Redwood Creek would occur due to the barrier and the groundwater treatment would result in toxicity reduction. However, site constraints (the steep slope) do not allow for this remedy to be located between the well MW-4 and Redwood Creek—so a small portion of the plume will not be affected by the remedy.

Short-term Effectiveness

The cutoff barrier and associated groundwater extraction would be effective immediately upon implementation.

Implementability

This implementability of this remedy is considered fair. It is feasible to implement relatively quickly, but has some site constraints, including the area being an open dirt parking area with no utility support (electrical and plumbing needed for the remedy would have to be tied back to the Corporation Yard). The vinyl sheet pile barrier could be installed to the desired depth of 25 feet bgs. The location of the carbon unit would need to be worked out with the District to assure no interference with other park missions.

Cost

The estimated capital cost of this alternative is approximately $180,000. The operations and maintenance cost for the estimated 5-year period is $50,000. This cost may be assumed to be accurate to approximately 25 percent.

Regulatory and Community Acceptance

Regulatory acceptance of this alternative is expected. Community acceptance would likely occur as well, but this alternative will have a disruptive aspect to the use of the parking area used for hikers.

IN SITU ORC™ TREATMENT

Description

A series of 37 Geoprobe™ bores are proposed to be drilled in a grid pattern separated by about 10 feet for the purpose of injecting the ORC™ to both reduce the concentration and mobility of the hydrocarbon plume. A second series of up to 20 injection points would then be used after evaluating the effectiveness of the initial injection and delineating residual hot spot areas. The location of the bores will be placed both in a line parallel to Redwood Creek (perpendicular to the plume, near its leading edge) and parallel to the plume along the center line where the highest concentrations are expected to be.

The exact location of the injection points will be modified based on results from the new well data to be collected in the coming months. All injection points will be advanced 18 feet bgs. Using an average TPH concentration of 20 mg/L for the last year, the manufacturer recommends that approximately 50 pounds of ORC™ be mixed into a slurry with about 10 gallons of clean water, and pressure injected into each of the 26 points. The ORC™ is released into the groundwater—and capillary fridge—at an approximate ratio of 3 pounds magnesium hydroxide to 1 pound of hydrocarbons. Typically, two applications are required, and each application is effective for 6 to 9 months. The first application should result in significant reduction in hydrocarbon mass. After evaluating the extent of any remaining hot spots, the second application will be used to target the remaining areas of concern.

Long-term Effectiveness and Permanence

The effectiveness of the ORC™ slurry remediation action alternative is judged to be fair to good. While it is considered effective in reducing the dissolved hydrocarbon concentrations, it does not restrict groundwater flow. Most sites are characteristically anaerobic—as is this one—such that the introduction of supplemental oxygen increases the rate of aerobic biodegradation. Data obtained from the manufacturer indicates that over 80 percent of the hydrocarbons mass can be reduced within 9 months under ideal conditions. The low permeability soils at the Redwood Creek site will likely reduce the effectiveness, but pressure injection should allow for good distribution of the ORC™ through the less transmissive soil and provide effective reductions at the hotspots upgradient of the ORC™ injection points.

Reduction in Toxicity, Mobility, and Volume

The ORC™ injection should be effective in reducing the toxicity of the plume by accelerating the biodegradation significantly within the first 6 month or so. The mobility of the plume will likewise be reduced in the area upgradient of the injection point grid that parallels Redwood Creek and in the grid area perpendicular to the creek to focus on the highest concentration area of the plume moving down towards the creek. The volume of dissolved hydrocarbons within the treatment area will likely be reduced within the first 6 to 9 months by 50 percent of more—according to the manufacturer's data. However, site constraints (a steep slope) do not allow for the injection of the ORC™ between well MW-4 and Redwood Creek, so a small portion of the plume will not be affected by the remedy.

Short-term Effectiveness

Accelerated biodegradation of the hydrocarbons begins immediately to some degree; thus, some short-term benefit exists. However, it will take a number of months to evaluate the effectiveness of the injection of the ORC™ and measure the mass reductions achieved.

Implementability

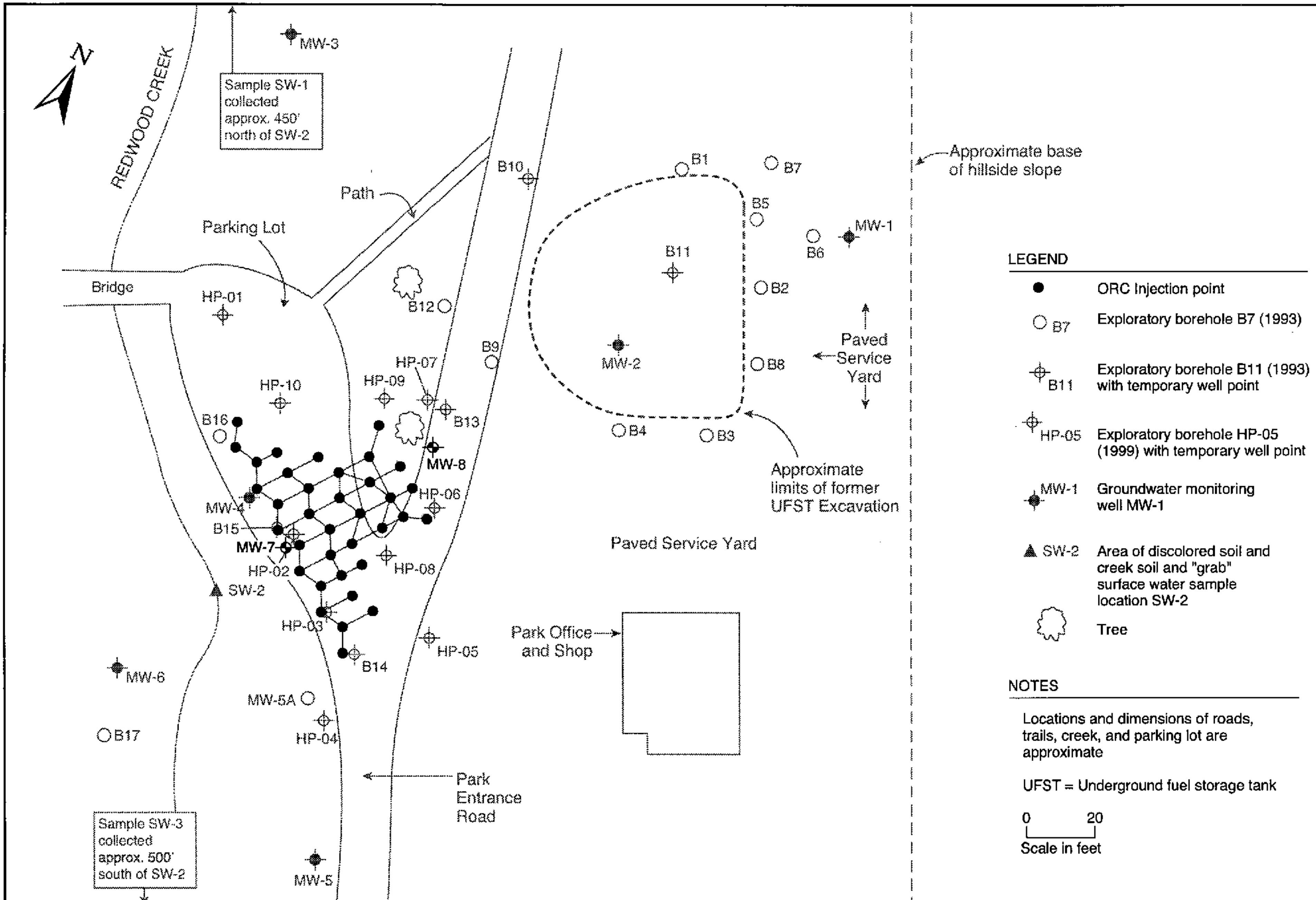
Implementation of this alternative requires the injection of ORC™ in up to 57 injection points in two discrete events over a 1-year period. The first and primary ORC™ injection event of 37 points is shown in Figure 4. The ORC™ loading per borehole will be approximately 120 pounds which is computed based on the conservative assumptions of the site maxima data using the manufacturers computation spread sheet. The second injection event that estimated up to 20 additional injection points will be located based on the effectiveness monitoring after the first event. Each borehole will be pressure injected with the ORC™ slurry to a depth of approximately 25 feet bgs across up to 15 feet of saturated zone. Above the capillary fridge the boreholes will be filled with bentonite/Portland cement grout to the surface. Based on site conditions—including no utilities—the implementability of this option is rated good because it can be rapidly installed and begins working immediately.

Cost

The estimated in-situ remedy cost (the injection of ORC™ in two events) of this alternative is approximately $75,000. The reporting, remedy effectiveness monitoring and maintenance cost for the estimated 2-year period is $40,000. This cost may be assumed accurate to approximately 25 percent.

Regulatory and Community Acceptance

Regulatory and community acceptance is expected for this proposed remedy.



Stellar Environmental Solutions Geoscience & Engineering Consulting	PROPOSED LAYOUT OF ORC REMEDY Redwood Regional Park Service Yard, Oakland, CA	Figure 4 by: MJC — OCTOBER 2000

2000-46-06

Table 3
Summary of Comparison of Screening Technologies to Feasibility Criteria

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility and Volume	Short-term Effectiveness	Implementability	$Cost
1. Monitor Natural Attenuation	Passed	Failed	Failed	Failed	Failed	P	$75,000
2. Wall & GW Pump & Treat	Passed	Passed	Passed	Passed	Passed	Passed	$350,000
3. In Situ ORC™ Treatment	Passed	Passed	Passed	Passed	Passed	Passed	$155,000

Notes:

* Over 5-year period.

5.0 SUMMARY, CONCLUSIONS AND PROPOSED ACTIONS

SUMMARY AND CONCLUSIONS

- The conclusions and recommendations presented in this section are based on previous investigation and remediation reports, field investigation descriptions, analytical results, and interpretations delineated and developed in the body of this report. Interpretations are based on data collected by previous investigators between 1993 and February 1998, and on the results of the SES field investigations conducted between September 1998 and September 2000.

- The site utilized two UFSTs (diesel and gasoline) that were excavated and removed from the site in 1993, along with 600 CYof contaminated soil. An estimated volume of 850 CY of petroleum-contaminated soil with concentrations above 1,000 mg/Kg is estimated to be left in place in the area of the original excavation, as well as downgradient along the pathway of the plume. Most of the residual contaminated soil exists in the capillary fringe up to 150 feet downgradient of the former UFSTs, resulting from the sorption of fuel constituents from contaminated groundwater onto capillary fringe soils during periods of high groundwater elevation. This soil contamination will be a long-term source of groundwater contamination.

- Groundwater sampling conducted on an approximately quarterly frequency since November 1994 (16 events) has shown an overall decreasing concentration trend in groundwater contaminants—including gasoline, diesel, and BTEX. MTBE was detected in both the source area and the downgradient monitoring wells when it was analyzed for the first time in September 1998.

- Near-maximum historical groundwater contaminant concentrations were detected in February 1998, coinciding with unusually heavy rains and correspondingly high groundwater elevations, which likely desorbed capillary fringe soil contamination into groundwater. However, maximum concentrations at the downgradient Redwood Creek surface water sampling point SW-2 occurred in December 1999, suggesting that the higher concentration portions of the plume are continuing to migate to the creek.

- Recent (December 1999 and Septmber 2000) groundwater analytical data showed maximum concentrations of most analytes detected in downgradient well MW-4, suggesting that the center of mass of the contaminant groundwater plume has moved from the UFST source area and beyond well MW-2.

- Synthesis of all site soil and groundwater data shows that the groundwater contaminant plume with TPH concentrations greater than 10,000 µg/L is up to 60 feet wide by 100 feet long, and begins approximately 30 feet downgradient of the source area, suggesting that the plume is becoming "disconnected" from the former UFST source area. The leading edge of the plume daylighting in the creek banks is approximately 30 feet wide.

- Site groundwater and surface water contaminants historically (and recently) detected in excess of drinking water standards include one or more of the following: benzene, ethylbenzene, total xylenes, and MTBE.

- Significantly greater groundwater contamination detected in the April 1999 subsurface investigation relative to previous data suggest that MW-4 is not located directly along the plume's longitudinal axis. The recent data also suggest that there is a substantial mass of groundwater contamination upgradient of the parking lot's downgradient edge, which will continue to migrate toward Redwood Creek, and that future impacts to Redwood Creek from contaminated groundwater discharge may be worse than at present. There is no practical or cost-effective remedy for addressing that portion of capillary fringe soil and groundwater contamination in the approximately 20-foot wide zone between the downgradient edge of the site parking lot and the creek. Continued impacts to the creek from residual site contamination upgradient of that area could be mitigated by either hydraulic containment methods, or more cost-effectively by injection of oxygen-releasing compound into closely spaced boreholes within the zone of contamination, to stimulate biodegradation.

- Natural attenuation is indicated to be occuring at the site, mainly at the plume margins and former source area. Natural attenuation is likely muted in the higher concentration portion along the centerline of the plume due to limited oxygen content, suggesting that natural attenuation has not and in the future will not be sufficient to mitigate impacts to the creek.

- The CDFG code stipulates a policy of zero discharge of petroleum to surface waters, unless it can be demonstrated that complete removal of the petroleum is infeasible and that instream biota are not affected. The results of the initial two stream bioassessment events (April and December 1999) indicate no contaminant-sourced impacts to the benthic macroinvertebrate community in Redwood Creek. Additional bioassessment events are warranted only if groundwater and/or surface water analytical results indicate a potential for significantly discharge of petroleum to the creek.

- Three feasibility study alternatives—Monitoring Natural Attenuation, Barrier Wall with Extrcation Trench, and ORC™ Injections—were evelauated against six criteria. The ranking of the alternatives shows the ORC™ Injection to be the prefered remedy.

PROPOSED ACTIONS

Based on the available data and the August 2000 letter from ACHCSA, The District proposes to implement the following actions to address regulatory concerns:

- Discuss the conclusions of this Feasibility Study with the regulators to obtain their concurrence.
- Obtain regulatory agency concurrence on the SES workplan for additional groundwater monitoring well installations, and implement that workplan. ✓ done
- Implement the recommended ORC™ injection remedy selected in the Feasibility Study.
- Continue the established program of quarterly surface water and groundwater monitoring to evaluate the effectiveness of the remedy.

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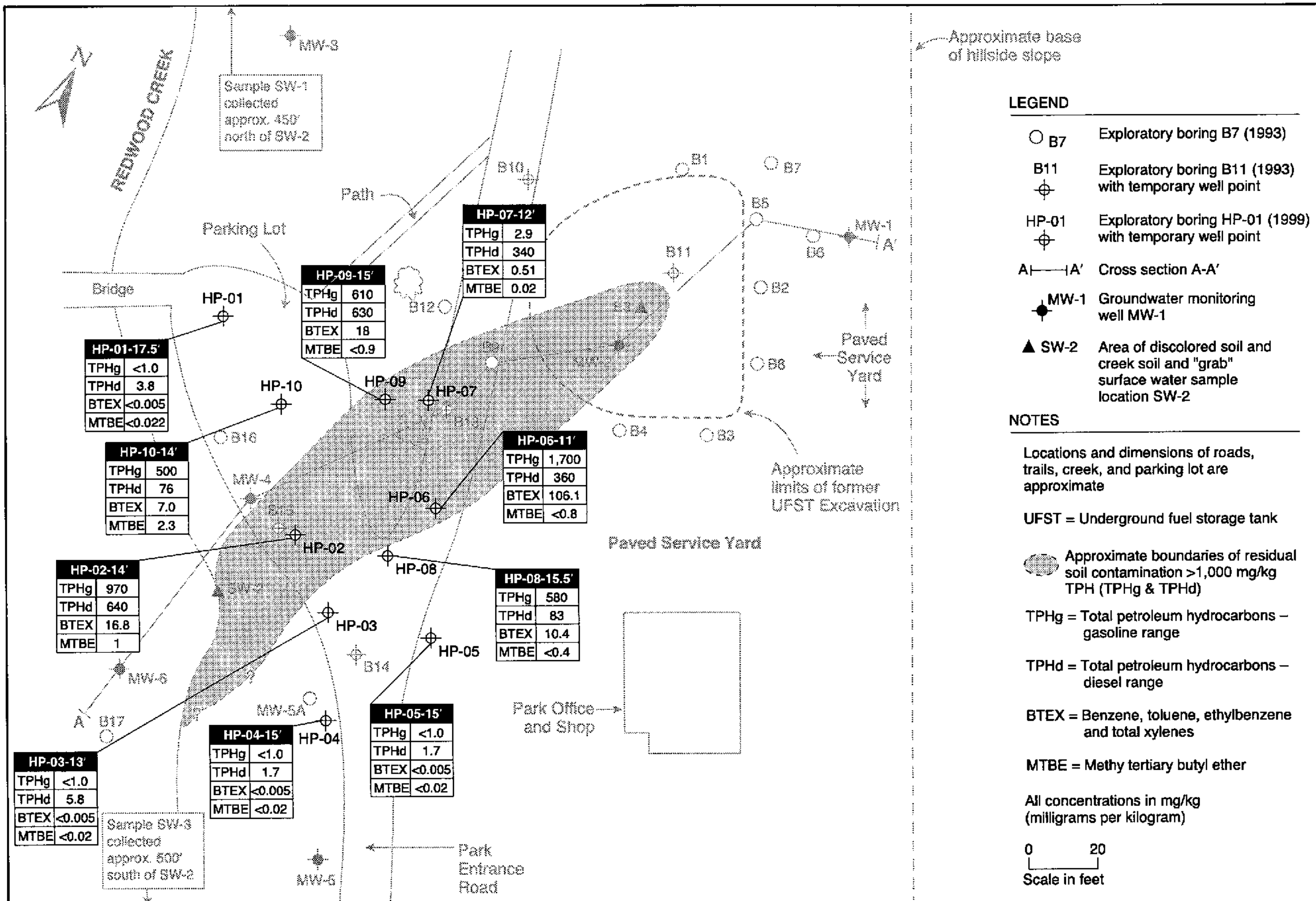
10.0 LIMITATIONS

This report has been prepared for the exclusive use of East Bay Regional Park District and their authorized representatives and the Regulators. No reliance on this report shall be made by anyone other than the client and regulators for whom it was prepared.

The findings and conclusions presented in this report are based on the review of previous investigators' findings at the site as well as site activities conducted by SES since September 1998. This report provides neither a certification nor guarantee that the property is free of hazardous substance contamination. This report has been prepared in accordance with generally accepted methodologies and standards of practice of the area. The SES personnel who performed this limited remedial investigation are qualified to perform such investigations and have accurately reported the information available but cannot attest to the validity of that information. No warranty, expressed or implied, is made as to the findings, conclusions and recommendations included in the report.

The findings of this report are valid as of the present. Site conditions may change with the passage of time, natural processes or human intervention, which can invalidate the findings and conclusions presented in this report. As such, this report should be considered a reflection of the current site conditions as based on the investigation and remediation completed.



Stellar Environmental Solutions

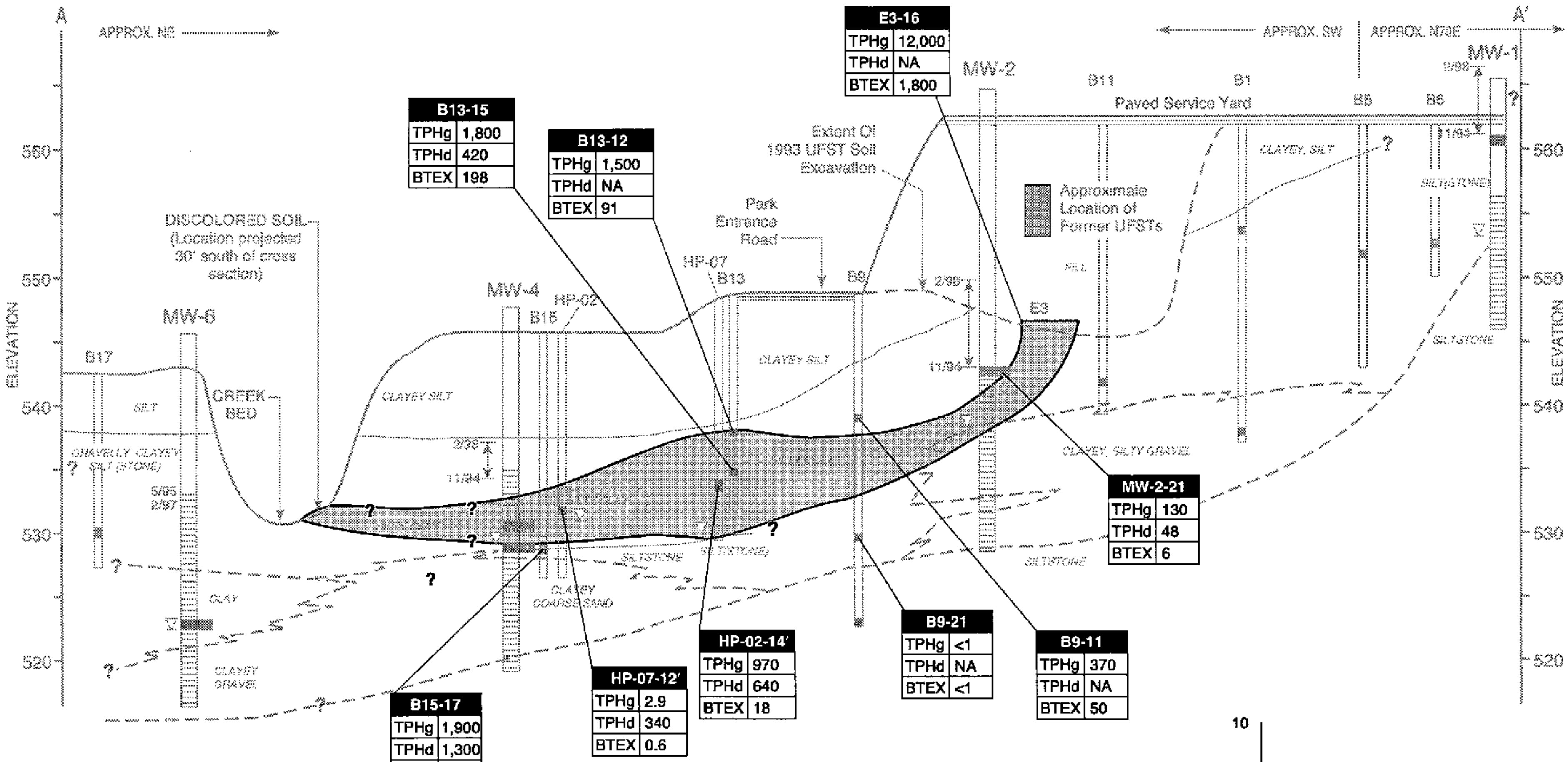
Geoscience & Engineering Consulting

April 1999 Borehole Soil Analytical Results and Plan View of Residual Soil Contamination Redwood Regional Park Service Yard, Oakland, CA

by: MJC

MAY 1999

99012-16-a



LEGEND

- B1 Exploratory Boring B1
- Location of soil sample collected for laboratory analysis
- ∇ First encountered groundwater during drilling (4/99)
- Approximate boundaries of residual capillary fringe contaminated soil >1000 mg/kg TPH (TPHg & TPHd)
- MW-1 Monitoring Well MW-1
- Location of soil sample collected for laboratory analysis
- Well screen interval
- 4/99–11/94 Range of static water levels measured between November 1994 and April 1999 showing dates of measured maxima and minima

NOTES

Locations and dimensions of roads, trails and parking lot are approximate

UFST = Underground fuel storage tank

NA = Not analyzed

UFSTs not drawn to scale

All elevations surveyed by EBRPD relative to United States Geological Survey (USGS) Survey Benchmark No. JHF-49 and are expressed as feet above mean sea level (MSL)

Well casing and boring widths not to scale

Some borings projected into cross section (see Figure 2)

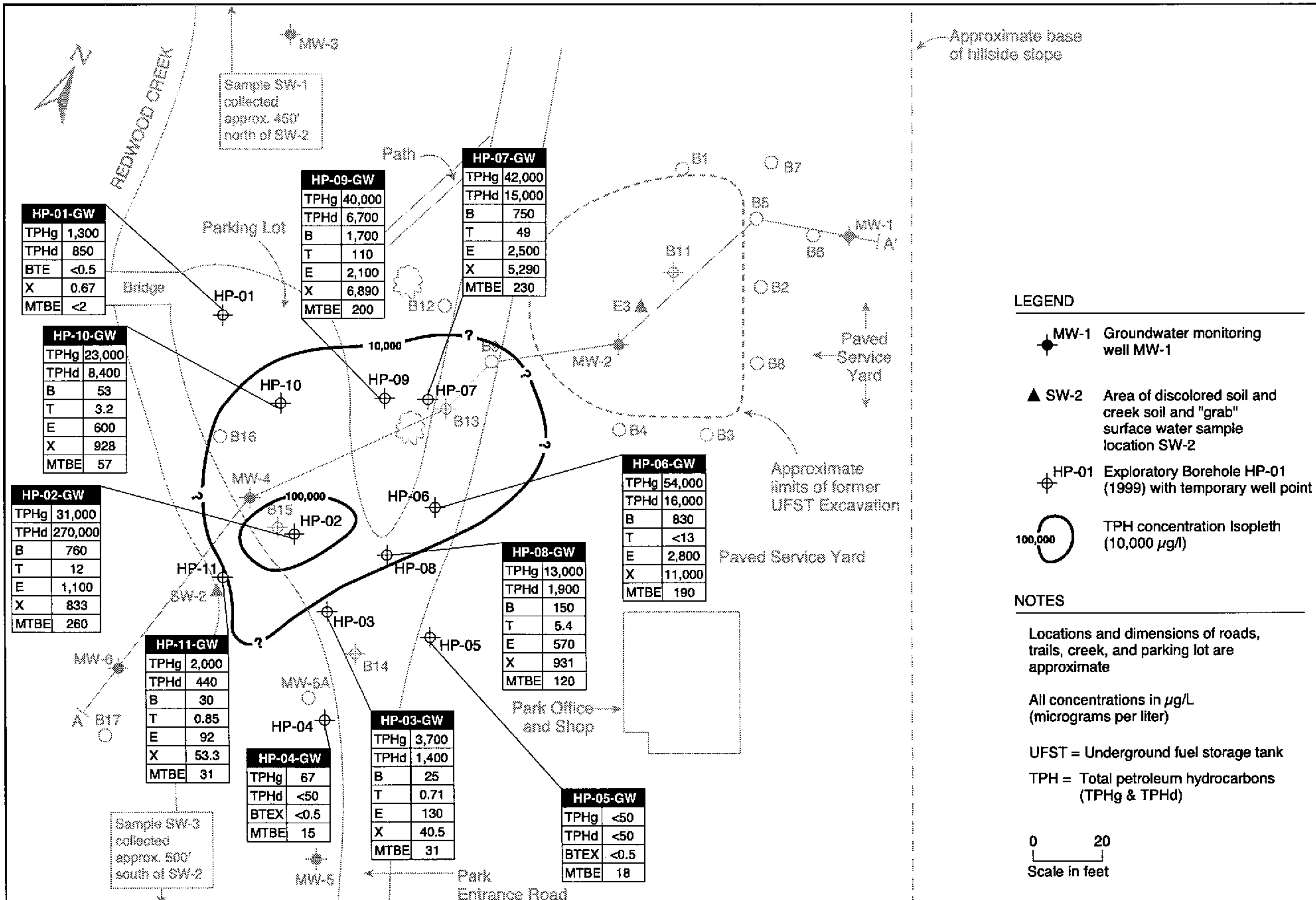
Stellar Environmental Solutions

Geoscience & Engineering Consulting

Cross Section Showing Residual Soil Contamination Redwood Regional Park Service Yard, Oakland, CA

by: MJC | MAY 1999

99012-17



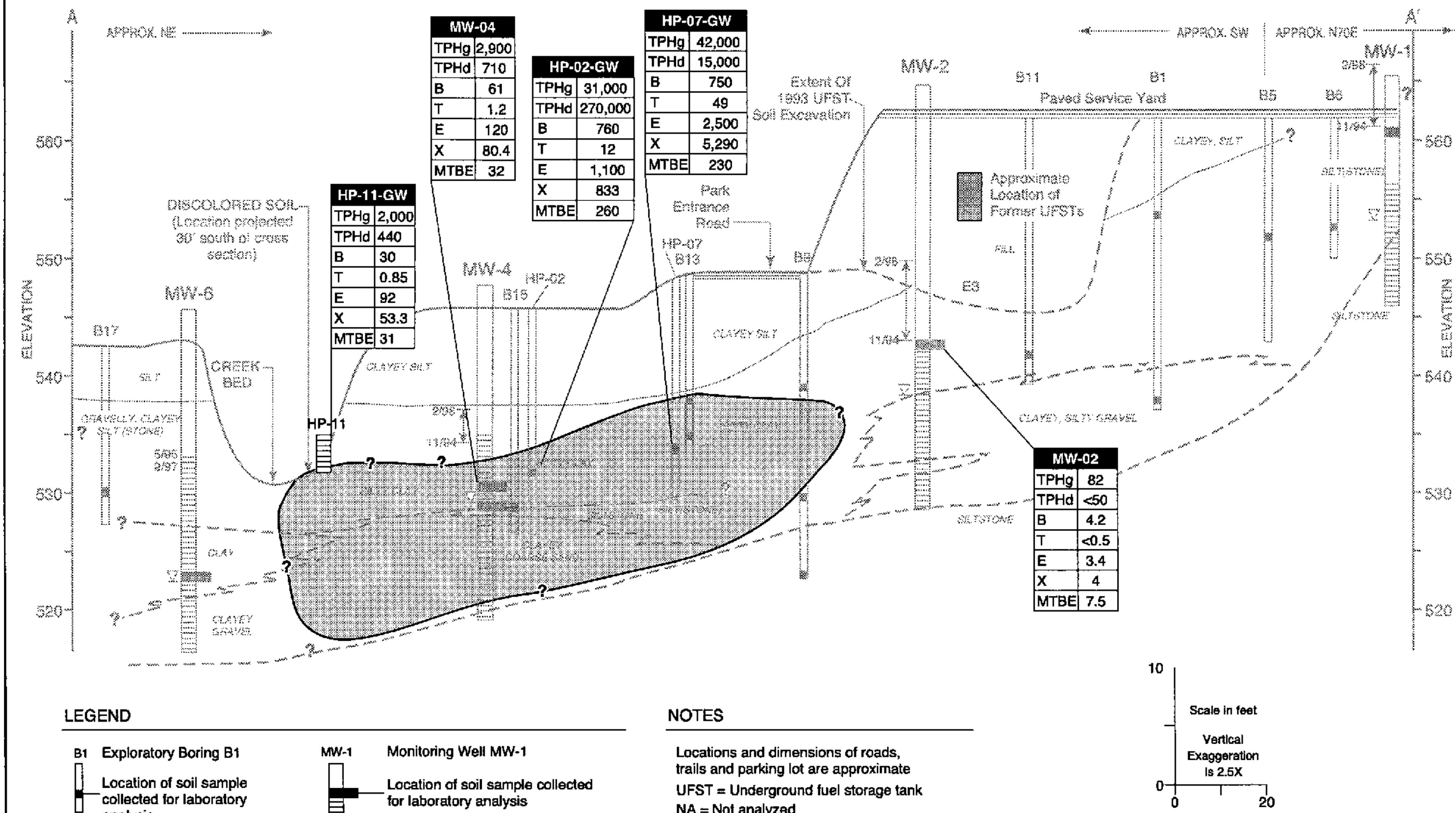
Stellar Environmental Solutions

Geoscience & Engineering Consulting

April 1999 Borehole Groundwater Analytical Results and Plan View of Groundwater Contamination Redwood Regional Park Service Yard, Oakland, CA

by: MJC | MAY 1999

99012-18-a



LEGEND

- B1 Exploratory Boring B1
- Location of soil sample collected for laboratory analysis
- ∇ First encountered groundwater during drilling (4/99)
- Approximate boundaries of groundwater contamination >10,000 µg/L TPH (TPHg & TPHd)
- MW-1 Monitoring Well MW-1
- Location of soil sample collected for laboratory analysis
- Well screen interval
- 4/99 – 11/94 Range of static water levels measured between November 1994 and April 1999 showing dates of measured maxima and minima

NOTES

Locations and dimensions of roads, trails and parking lot are approximate

UFST = Underground fuel storage tank

NA = Not analyzed

UFSTs not drawn to scale

All elevations surveyed by EBRPD relative to United States Geological Survey (USGS) Survey Benchmark No. JHF-49 and are expressed as feet above mean sea level (MSL)

Well casing and boring widths not to scale

Some borings projected into cross section (see Figure 2)

Stellar Environmental Solutions

Geoscience & Engineering Consulting

Cross Section Showing Groundwater Contamination Redwood Regional Park Service Yard, Oakland, CA

by: MJC

MAY 1999

99012-19

Table A.1
Summary of Historical Soil Sample Analytical Results
Redwood Regional Park Service Yard
Oakland, California

Sample I.D.	Depth (ft bgs)	Concentrations in mg/kg					
		TPHg	TPHd/k	Benzene	Toluene	Ethyl-benzene	Total Xylenes
UFST Excavation Confirmation Samples – May & June 1993 (*indicates soil at that location was removed)							
DT-1*	10	NA	**4**	< 0.005	< 0.005	< 0.005	< 0.005
DT-2*	10	NA	**3**	< 0.005	< 0.005	< 0.005	< 0.005
GT-1*	12	**800**	NA	**6.3**	**43**	**18**	**94**
GT-2	12	**2,200**	NA	**19**	**120**	**45**	**250**
E1-17	17	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
E2-16	16	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
E3-16	16	**12,000**	NA	**80**	**390**	**230**	**1,100**
E4-13	13	**6**	NA	**0.37**	**0.006**	**0.1**	**0.1**
E5-7.5	7.5	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
Exploratory Borehole Samples – September and October 1994							
B1-11	11	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B1-27	27	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B2-11	11	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B2-15	15	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B3-12	12	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B3-18	18	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B4-18	18	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B4-23	23	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B5-11	11	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B7-12	12	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B8-4	4	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B8-10	10	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B9-11	11	**370**	NA	**1.7**	**7.9**	**6.9**	**34**
B9-21	21	< 1	NA	**0.1**	**0.011**	**0.017**	**0.069**
B9-28	28	< 1	NA	< 0.005	**0.033**	**0.035**	**0.14**
B10-6	6	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005

Sample I.D.	Depth (ft bgs)	Concentrations in mg/kg					
		TPHg	TPHd/k	Benzene	Toluene	Ethyl-benzene	Total Xylenes
B10-21	21	< 1	**7**	< 0.005	< 0.005	< 0.005	< 0.005
B11-11.5	11.5	< 1	< 2	**0.021**	< 0.005	< 0.005	< 0.005
B12-14.5	14.5	**150**	NA	**0.24**	**0.44**	**1.7**	**4.6**
B12-15	15	**77**	NA	**0.15**	**0.24**	**0.9**	**2.7**
B12-21	21	**97**	NA	**0.46**	**1.2**	**2**	**5.4**
B13-12	12	**1,500**	NA	< 0.4	< 0.4	**13**	**78**
B13-15	15	**1,800**	**420**	**8.8**	**39**	**30**	**120**
B14-18	18	**210**	**50**	**0.017**	**0.1**	**0.34**	**0.63**
B15-17	17	**1,900**	**1,300**	**1.1**	**0.8**	**9.1**	**14**
B16-17.5	17.5	**50**	NA	< 0.1	< 0.1	**0.2**	**0.2**
B17-12.5	12.5	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
Monitoring Well Installation Borehole Samples – October 1994							
MW1-5	5	< 1	**3**	< 0.005	< 0.005	< 0.005	< 0.005
MW-21	21	**130**	**48**	**0.31**	**0.18**	**1.3**	**4.4**
MW3-10	10	< 1	**3**	< 0.005	< 0.005	< 0.005	< 0.005
MW3-25	25	< 1	**5**	< 0.005	< 0.005	< 0.005	< 0.005
MW4-15.5	15.5	**22**	**4**	< 0.005	**0.038**	< 0.005	**0.49**
MW4-16.5	16.5	**10**	**43**	< 0.005	**0.009**	**0.11**	**0.21**
MW5A-15	15	**570**	**200**	< 0.005	**1.1**	**1.9**	**2.9**
MW5-15	15	< 1	**2**	< 0.005	< 0.005	< 0.005	< 0.005
MW6-19	19	< 1	**2**	< 0.005	< 0.005	< 0.005	< 0.005
Exploratory Borehole Samples - April 1999							
HP-01-17.5'	17.5'	< 1.0	**3.8**	< 0.005	< 0.005	< 0.005	< 0.005
HP-02-14'	14'	**970**	**640**	**1.3**	**1.3**	**5.5**	**8.7**
HP-03-13'	13'	< 1.0	**5.8**	< 0.005	< 0.005	< 0.005	< 0.005
HP-04-15'	15'	< 1.0	**1.7**	< 0.005	< 0.005	< 0.005	< 0.005
HP-05-15'	15'	< 1.0	**4.3**	< 0.005	< 0.005	< 0.005	< 0.005
HP-06-11'	11'	**1,700**	**360**	**1.4**	**2.7**	**21**	**81**
HP-07-12'	12'	**2.9**	**340**	**0.028**	< 0.005	**0.13**	**0.347**
HP-08-15.5'	15.5'	**580**	**83**	< 0.1	**1.0**	**4.7**	**4.7**
HP-09-15'	15'	**610**	**630**	**1.5**	**1.5**	**3.8**	**11.2**

Sample I.D.	Depth (ft bgs)	Concentrations in mg/kg					
		TPHg	TPHd/k	Benzene	Toluene	Ethyl-benzene	Total Xylenes
HP-10-14'	14'	**500**	**76**	**0.19**	**1.6**	**2.0**	**3.21**

Notes:

TPHg – Total petroleum hydrocarbons – gasoline range (equivalent to total volatile hydrocarbons)

TPHd/k – Total petroleum hydrocarbons – diesel/kerosene ranges (equivalent to total extractable hydrocarbons)

NA = Not Analyzed

mg/kg = milligrams per kilogram (equivalent to parts per million – ppm)

TABLE A.2

HISTORICAL GROUNDWATER MONITORING WELLS ANALYTICAL RESULTS

REDWOOD REGIONAL PARK SERVICE YARD, OAKLAND, CALIFORNIA

(wells MW-1,MW-3 and MW-6 not sampled after August 1995 based on absence of detected contamination)

(all concentrations in µg/L, equivalent to parts per billion [ppb])

Well MW-2									
Event	**Date**	**TPHg**	**TPHd**	**Benzene**	**Toluene**	**Ethylbenzene**	**Total Xylenes**	**Total BTEX**	**MTBE**
1	Nov-94	**66**	*< 50*	**3.4**	*< 0.5*	*< 0.5*	**0.9**	**4.3**	*NA*
2	Feb-95	**89**	*< 50*	**18**	**2.4**	**1.7**	**7.5**	**29.6**	*NA*
3	May-95	*< 50*	*< 50*	**3.9**	*< 0.5*	**1.6**	**2.5**	**8**	*NA*
4	Aug-95	*< 50*	*< 50*	**5.7**	*< 0.5*	*< 0.5*	*< 0.5*	**5.7**	*NA*
5	May-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
6	Aug-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
7	Dec-96	*< 50*	*< 50*	**6.3**	*< 0.5*	**1.6**	*< 0.5*	**7.9**	*NA*
8	Feb-97	*< 50*	*< 50*	**0.69**	*< 0.5*	**0.55**	*< 0.5*	**1.24**	*NA*
9	May-97	**67**	*< 50*	**8.9**	*< 0.5*	**5.1**	*< 1.0*	**14**	*NA*
10	Aug-97	*< 50*	*< 50*	**4.5**	*< 0.5*	**1.1**	*< 0.5*	**5.6**	*NA*
11	Dec-97	**61**	*< 50*	**21**	*< 0.5*	**6.5**	**3.9**	**31.4**	*NA*
12	Feb-98	**2,000**	**200**	**270**	**92**	**150**	**600**	**1,112**	*NA*
13	Sep-98	*< 50*	*<50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	**7**
14	Apr-99	**82**	**710**	**4.2**	*< 0.5*	**3.4**	**4**	**11.6**	**7.5**
15	Dec-99	**57**	*<50*	**20**	**0.61**	**5.9**	*<0.5*	**26.5**	**4.5**
16	Sep-00	*< 50*	*<50*	**0.72**	*< 0.5*	*< 0.5*	*< 0.5*	**0.7**	**7.9**

NA = Not Analyzed for this constituent

TABLE A.2 (continued)

Well MW-4									
Event	Date	TPHg	TPHd	Benzene	Toluene	Ethylbenzene	Total Xylenes	Total BTEX	MTBE
1	Nov-94	2,600	230	120	4.8	150	88	363	NA
2	Feb-95	11,000	330	420	17	440	460	1,337	NA
3	May-95	7,200	440	300	13	390	330	1,033	NA
4	Aug-95	1,800	240	65	6.8	89	66.5	227	NA
5	May-96	1,100	140	51	< 0.5	< 0.5	47	98	NA
6	Aug-96	3,700	120	63	2	200	144	409	NA
7	Dec-96	2,700	240	19	< 0.5	130	92.9	242	NA
8	Feb-97	3,300	< 50	120	1.0	150	102.5	374	NA
9	May-97	490	< 50	2.6	6.7	6.4	6.7	22	NA
10	Aug-97	1,900	150	8.6	3.5	78	52.6	143	NA
11	Dec-97	1,000	84	4.6	2.7	61	54.2	123	NA
12	Feb-98	5,300	340	110	24	320	402	856	NA
13	Sep-98	1,800	<50	8.9	< 0.5	68	26.9	104	23
14	Apr-99	2,900	710	61	1.2	120	80.4	263	32
15	Dec-99	1,000	430	4	2	26	13.9	45.9	<2.0
16	Sep-00	570	380	< 0.5	< 0.5	16	4.1	20.1	2.4

NA = Not Analyzed for this constituent

TABLE A.2 (continued)

Well MW-5									
Event	**Date**	**TPHg**	**TPHd**	**Benzene**	**Toluene**	**Ethylbenzene**	**Total Xylenes**	**Total BTEX**	**MTBE**
1	Nov-94	**50**	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
2	Feb-95	**70**	*< 50*	**0.6**	*< 0.5*	*< 0.5*	*< 0.5*	**0.6**	*NA*
3	May-95	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
4	Aug-95	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
5	May-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
6	Aug-96	**80**	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
7	Dec-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
8	Feb-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
9	May-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
10	Aug-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
11	Dec-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
12	Feb-98	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
13	Sep-98	*< 50*	*<50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*< 2*
Groundwater monitoring in this well discontinued with Alameda County Health Care Services Agency approval									

NA = Not Analyzed for this constituent

TABLE A.3

HISTORICAL SURFACE WATER ANALYTICAL RESULTS

REDWOOD REGIONAL PARK SERVICE YARD, OAKLAND, CALIFORNIA

(all concentrations in µg/L, equivalent to parts per billion [ppb])

Sampling Location SW-1 (Upstream of Contaminated Groundwater Discharge Location SW-2)									
Event	**Date**	**TPHg**	**TPHd**	**Benzene**	**Toluene**	**Ethylbenzene**	**Total Xylenes**	**Total BTEX**	**MTBE**
1	Feb-94	**50**	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
2	May-95	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
3	May-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
4	Aug-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
5	Dec-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
6	Feb-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
7	Aug-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
8	Dec-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
9	Feb-98	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
10	Sep-98	*< 50*	*<50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*< 2*
11	Apr-99	*< 50*	*<50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*< 2*
Samplingat this location discontinued after April 1999.									

NA = Not Analyzed for this constituent

TABLE A.3 (continued)

Sampling Location SW-2 (Area of Contaminated Groundwater Discharge)									
Event	**Date**	**TPHg**	**TPHd**	**Benzene**	**Toluene**	**Ethylbenzene**	**Total Xylenes**	**Total BTEX**	**MTBE**
1	Feb-94	**130**	*< 50*	**1.9**	*< 0.5*	**4.4**	**3.2**	**9.5**	*NA*
2	May-95	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
3	Aug-95	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
4	May-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
5	Aug-96	**200**	*< 50*	**7.5**	*< 0.5*	**5.4**	*< 0.5*	**12.9**	*NA*
6	Dec-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
7	Feb-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
8	Aug-97	**350**	**130**	**13**	**0.89**	**19**	**10.7**	**43.6**	*NA*
9	Dec-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
10	Feb-98	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
11	Sep-98	*< 50*	*<50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	< 2
11	Apr-99	**81**	*<50*	**2.0**	*< 0.5*	**2.5**	**1.3**	**5.8**	**2.3**
13	Dec-99	**1,300**	**250**	**10.0**	**1.0**	**47**	**27**	**85.0**	**2.2**
14	Sep-00	**160**	**100**	**2.1**	*< 0.5*	**5.2**	**1.9**	**9.2**	**3.4**

NA = Not Analyzed for this constituent

TABLE A.3 (continued)

Sampling Location SW-3 (Downstream of Contaminated Groundwater Discharge Location SW-2)									
Event	Date	TPHg	TPHd	Benzene	Toluene	Ethylbenzene	Total Xylenes	Total BTEX	MTBE
1	May-95	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
2	Aug-95	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
3	May-96	*< 50*	**74**	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
4	Aug-96	**69**	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
5	Dec-96	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
6	Feb-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
7	Aug-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
8	Dec-97	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
9	Feb-98	*< 50*	*< 50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	*NA*
10	Sep-98	*< 50*	*<50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	< 2
11	Apr-99	*< 50*	*<50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	< 2
12	Dec-99	*< 50*	*<50*	*< 0.5*	*< 0.5*	*< 0.5*	*< 0.5*	—	< 2
13	Sep-00	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	—	*NS*

NS = Not Sampled (no surface water present during sampling event)
NA = Not Analyzed for this constituent