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Alameda County  
Environmental Health

October 27, 2011

Ms. Barbara Jakub  
Alameda County Health Care Services Agency  
1131 Harbor Bay Parkway, Suite 250  
Alameda, CA 94502-6577

**Subject: Work Plan, Magnesium Sulfate Infiltration, Feasibility Study**  
**Site: 76 Service Station No. 5325**  
**3220 Lakeshore Avenue**  
**Oakland, California**  
**Fuel Leak Case No. RO0000229**

Dear Ms. Jakub;

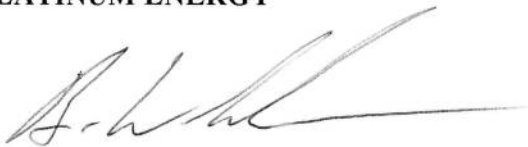
I declare under penalty of perjury that to the best of my knowledge the information and/or recommendations contained in the attached report is/are true and correct.

If you have any questions or need additional information, please call:

Brian Whalen  
Platinum Energy  
30343 Canwood Street, Suite 200  
Agoura Hills, California 91301  
Tel: (818) 206-5704  
Fax: (818) 206-5721  
bwhalen@platinum-energy.com

Sincerely,

**PLATINUM ENERGY**



**BRIAN WHALEN**

Attachment

# Work Plan

## *Magnesium Sulfate Infiltration Feasibility Study*

*76 Service Station No. 5325  
3220 Lakeshore Avenue  
Oakland, CA*

*Alameda County Health Care Services Agency  
Fuel Leak Case No. RO0000229*

*San Francisco Bay Regional Water Quality  
Control Board  
No. 01-1588*

*GeoTracker Global ID No. T0600101463*

*Antea Group Project No. I40255325  
October 27, 2011*

*Prepared for:*  
**Ms. Barbara J. Jakub, P.G.**  
Alameda County  
Environmental Health  
1131 Harbor Bay Parkway,  
Suite 250  
Alameda, CA 94502

*Prepared by:*  
**Antea™Group**  
11050 White Rock Road  
Suite 110  
Rancho Cordova, CA 95670  
+1 800 477 7411

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# Work Plan

## *Magnesium Sulfate Infiltration Feasibility Study 76 Service Station No. 5325*

### 1.0 INTRODUCTION

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Antea Group, has prepared this work plan proposing the infiltration of magnesium sulfate ( $MgSO_4$ ) using monitoring wells U-1 and U-2 for the purpose of remediating the petroleum hydrocarbon impacted groundwater beneath the site located at 3220 Lakeshore Avenue, Oakland, California (**Figure 1**). These two monitoring wells were chosen based on the most recent groundwater analytical results (June 2011). Currently, these two monitoring wells are the most impacted by petroleum hydrocarbons.

#### 1.1 Site Description

The site is located on the southeast corner of the intersection of Lakeshore Avenue and Lake Park Avenue in Oakland, California (**Figure 1**). The site is bounded to the north by Lakeshore Avenue; to the west and southwest by Lake Park Avenue; to the southeast by a supermarket parking lot; and to the east by a pharmacy. Station facilities include service station building with one service bay, three fuel dispenser islands, and two 12,000-gallon double-wall fiberglass gasoline underground storage tanks (USTs) (**Figure 2**).

#### 1.2 Previous Assessment

May 1990 Three exploratory soil borings were advanced adjacent to the UST complex to depths ranging from 10 to 12.5 feet below ground surface (bgs). Soil samples were analyzed for total petroleum hydrocarbons as gasoline (TPHg) and benzene, toluene, ethylbenzene, and xylenes (BTEX). The samples contained TPHg concentrations ranging from 2 to 7,500 parts per million (ppm) and benzene concentrations ranging from 0.14 to 13 ppm.

June 1990 Two 10,000-gallon gasoline USTs, one 550-gallon waste oil UST, and related product dispensers were replaced. Soil samples from the UST excavation sidewalls and bottom and product line trenches were reported to contain TPHg and benzene at concentrations ranging from 12 to 2,800 ppm and 0.008 to 11 ppm, respectively. Approximately 250 cubic yards of soil and backfill material were aerated onsite to reduce concentrations to below 100 ppm TPHg, then transported to an appropriate soil disposal facility. Groundwater was encountered at approximately 7.5 feet bgs.

September 1990 Monitoring wells U-1, U-2, and U-3 were installed. TPHg was reported in soil samples collected from the capillary fringe in well borings U-1 and U-2 at levels of 110 and 480 ppm, respectively. Benzene was reported in the soil sample from well boring U-1 at a level of 4.5 ppm. Petroleum hydrocarbons were below the laboratory's indicated reporting limit in soil or groundwater samples from U-3. Groundwater samples collected from monitoring wells U-1 and U-2 were reported to contain 690 and 38 parts per billion (ppb) TPHg and 780 and 27 ppb benzene, respectively.

June 1990 Monitoring wells U-4, U-5, and U-6 were installed. TPHg and benzene were detected in the capillary fringe soil sample collected from boring U-5 at levels of 400 ppm and 1.9 ppm, respectively. TPHg and benzene were below the laboratory's indicated reporting limits in soil samples collected from borings U-4 and U-6. Groundwater levels stabilized at depths between 8.8 and 9.2 feet bgs.

November 1996 One 550-gallon waste-oil UST was removed and the product lines and dispensers were replaced. A soil sample collected from the sidewall of the waste oil UST excavation contained 1.5 ppm total petroleum hydrocarbons as diesel (TPHd) and 78 ppm total oil and grease (TOG). TPHg, benzene, methyl tertiary butyl ether (MTBE), halogenated volatile organic compounds (HVOCs), and semi-volatile organic compounds (SVOCs) were below the laboratory's indicated reporting limits. Product line trench excavation and over excavation samples were reported to contain petroleum hydrocarbon levels ranging from below the laboratory's indicated reporting limit to 880 ppm of TPHg, below the laboratory's indicated reporting limit to 3.6 ppm of benzene, and below the laboratory's indicated reporting limit to 23 ppm of MTBE. Approximately 276 tons of excavated soil was transported to an appropriate disposal facility.

June 1997 Two exploratory borings (U-D and U-E) and one UST observation well were installed. U-D was advanced offsite on Lakeshore Avenue. TPHg, BTEX, and MTBE were reported in one or all of the soil samples collected at the capillary fringe from the soil borings. TPHg and MTBE were reported at a maximum of 450 ppm and 1.1 ppm, respectively, in U-D.

October 2003 Site environmental consulting responsibilities were transferred to TRC.

April 2006 Three ozone sparge wells (C-1 through C-3) were installed by TRC in the vicinity of monitoring well U-2 for the purpose of an ozone pilot study. Total purgeable petroleum hydrocarbons (TPPH) were reported at a maximum of 4,600 milligrams per kilograms (mg/kg) in the five feet below grade (fbg) soil sample collected from C-1.

June through August 2006 A 3-month ozone sparge event was completed on sparge points C-1 through C-3 located in the vicinity of monitoring well U-2 using a mobile ozone sparge treatment system.

October 2007 Site environmental consulting responsibilities were transferred to Delta Consultants.

January 2011 Delta Consultants rebranded to Antea Group.

### **1.3 Sensitive Receptors**

Lake Merritt is located approximately 0.3 miles down-gradient of the site. No domestic water wells are located within a one mile distance of the site.

### **1.4 Geo-Hydrologic Setting**

The site is located in the Santa Clara Valley Groundwater Basin, East Bay Plain Subbasin. The site is underlain by estuarine deposits consisting primarily of unconsolidated clay and silt rich in organic material.

Based on previous investigations, the site is underlain by clay and silt to depths of approximately 25 feet bgs. Discontinuous units of sand and gravel are observed beneath the site at varying depths. The water-bearing unit is composed of sand and silt and is encountered at depths ranging from 6 to 17 feet bgs.

Currently, six groundwater monitoring wells (U-1 through U-6) are purged and sampled on a semi-annual basis during the second and fourth quarters at the site. During the most recent groundwater monitoring event (June 2011), groundwater was reported between 5.12 and 11.15 feet below top of casing (BTOC) in the site monitoring wells. The location of the monitoring wells is shown on **Figure 2**.

The groundwater flow direction as indicated from data collected during the semi-annual groundwater monitoring and sampling event is predominately to the northwest with an average gradient of 0.024 foot per foot (ft/ft). Historical groundwater flow directions are shown on **Figure 3**. The June 3, 2011 Groundwater Elevation Contour Map is presented as **Figure 4**.

## **2.0 REMEDIAL METHOD ASSESSMENT**

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### **2.1 Historical Remedial Summary**

June 1990 Approximately 250 cubic yards of soil and backfill material were removed from the tank pit excavation and product line trenches and transported to an appropriate disposal facility.

November 1996 Approximately 276 tons of soil removed from a waste-oil UST excavation was transported to an appropriate disposal facility.

1997 Free product skimmers were placed in monitoring wells U-1 and U-2 to remove the free product in these two monitoring wells.

April 1999 A calculated 167.44 pounds of petroleum hydrocarbons were removed during a 6 day Dual Phase Extraction (DPE) event.

June through August 2006 A 3-month ozone sparge event was completed on sparge points C-1 through C-3 located in the vicinity of monitoring well U-2 using a mobile ozone sparge treatment system. Approximately 17.5 pounds of ozone were injected into the subsurface during the pilot test.

### **2.2 Sulfate in the Hydrocarbons Biodegradation Process**

Recent case studies show that, in anaerobic conditions, microbes utilize sulfate as a terminal electron acceptor in the process of hydrocarbon biodegradation in groundwater. Although other terminal-electron accepting processes (TEAPs) may occur simultaneously during hydrocarbon degradation (with the utilization of nitrite/nitrate, manganese, iron, and oxygen), data suggests that sulfate reduction may be the most important TEAP in the active reduction of hydrocarbons (Dale R. Van Stempvoort, James Armstrong, and Bernhard Mayer, 2007).

Situations where dissolved BTEX plumes show significantly depleted concentrations of sulfate, typically <10 milligrams per Liter (mg/L), within the plume core, as well as slightly depleted sulfate on the plume fringe, and an elevated sulfate concentration (consistent with background concentrations) in uncontaminated areas just beyond the plume edge, suggest that anaerobic sulfate reduction is occurring (Lyle Bruce, Jim Cuthbertson, Arati Kolhatkar, J. Scott Ziegler, and Brent Graves, 2007).

A 2001 study conducted by Dale R. Van Stempvoort, et al., concluded that the periodic replenishment of sulfate, resulting from infiltration of snowmelt (carrying dissolved sulfate from soils) through the vadose zone and into the aquifer, played a key role in the biodegradation of petroleum hydrocarbons.

### **2.3 Site Sulfate and Iron Conditions**

During the June 2011 groundwater sampling event conducted at the site, sulfate concentrations ranged from <1.0 milligrams per liter (mg/L) (U-1) to 79.3 mg/L (U-4). At this site, the lowest reported sulfate concentrations are at the core of the plume (U-1 and U-2) and the highest sulfate concentration was in up-gradient monitoring well U-4. The groundwater plume is centered on monitoring well U-1 for TPHg and U-2 for MTBE. A dissolved phase TPHg iso-concentration map is presented on **Figure 5** and a dissolved phase MTBE iso-concentration map is presented on **Figure 6**.

The anaerobic sulfate reduction of hydrocarbons uses ferric (insoluble) iron as a co-metabolite. In this TEAP, as sulfate is utilized and depleted during the degradation of hydrocarbons, you typically see an increase in the concentrations of ferrous (soluble) iron in the source areas. Concentrations of ferrous iron in the plume area ranged from 2,200 micrograms per liter ( $\mu\text{g/L}$ ) (U-2) to 2,400  $\mu\text{g/L}$  (U-1) during the June 2011 groundwater monitoring and sampling event. Ferrous iron outside the plume area was reported at a concentration of 200  $\mu\text{g/L}$  (U-4). This data strongly suggests that sulfate is being consumed in the process of anaerobic hydrocarbon biodegradation and the current low sulfate concentrations may be the limiting factor for continued remediation of the plume. Antea Group proposes that biodegradation may be expedited by replenishing sulfate where depleted at the core of the plume (U-1 and U-2)

### **3.0 PROPOSED BIODEGRADATION ENHANCEMENT**

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Antea Group has been awarded a patent for the application of sulfate for the purposes of accelerating the cleanup of soil and groundwater. With in-situ heterotrophic microbes and iron (ferric iron), the introduction of magnesium sulfate solution ( $\text{MgSO}_4$  – dissolved Epsom salt), into petroleum hydrocarbon-impacted groundwater yields the following reaction:





Data shows that conditions are favorable at the site for sulfate enrichment for the purpose of petroleum hydrocarbon remediation. Antea Group proposes a series of  $MgSO_4$  applications and sampling for sulfate and ferrous iron to monitor the breakdown of petroleum hydrocarbons in groundwater.

Prior to the first proposed magnesium sulfate injection, monitoring wells U-1, U-2, and U-4 will be analyzed for ferrous iron and sulfate in addition to TPHg, BTEX, and fuel oxygenates. These three monitoring wells will be used as the source and up-gradient data collection points. This information will be used to assess the remedial success of the  $MgSO_4$  infiltration events and will be used to make an assessment for future infiltration events. Following the addition of magnesium sulfate, ferrous iron and sulfate will be added to the semi-annual suite for monitoring wells U-1, U-2, and U-4.

For each infiltration event, Antea group will introduce a pre-mixed solution of Epsom salt and tap water into monitoring wells U-1 and U-2 by gravity feed. Monitoring wells U-1 and U-2 are screened between 5 and 20 feet bgs, providing a large vertical surface area for  $MgSO_4$  infiltration into the impacted area. The volume and concentration of the infiltration solution is determined by several factors: site layout conditions, contaminant concentrations, soil types encountered in the vicinity of U-1 and U-2, estimated pore space volume and a target source area 60 feet wide by 120 feet long by 15 feet thick. The goal of these infiltration events is to raise the starting sulfate concentration in groundwater to between 3,000 and 5,000 mg/L. It is estimated that optimal initial application into each monitoring well is approximately 300 pounds of  $MgSO_4$  with the appropriate amount of water required, to be determined during application.

A baseline groundwater sample from monitoring wells U-1 and U-2 will be collected prior to the first infiltration application of  $MgSO_4$ . The samples will be analyzed for pH, TPHg, BTEX, MTBE, sulfate, ferrous iron and ferric iron. Monitoring wells U-1 and U-2 will be sampled once a month for three months after the initial infiltration event. The samples will be analyzed for pH, TPHg, BTEX, MTBE, sulfate and ferrous iron. After three months, groundwater samples will be collected on a semi-annual basis.

Antea Group will perform additional infiltration events when sulfate concentrations in monitoring wells U-1 and U-2 decrease to approximately 1,000 mg/L. These continued applications, anticipated to be successively smaller in concentration, are necessary to maintain elevated concentration of sulfate in order to sustain the accumulated anaerobic heterotrophic biomass. The mass of Epsom salt applied during the next application will be determined based upon the 1,000 mg/L benchmark for this feasibility study. Samples will be collected on the same schedule that followed the previous  $MgSO_4$  application

event. Based on the previous  $MgSO_4$  infiltration event and the sulfate degradation rates observed, an injection every two to three months is planned. Antea Group recommends continuing these infiltration events for two or four quarters to evaluate the remedial strategy and effectiveness of the application procedure.

#### **4.0 REPORTING**

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Antea Group will compile a semi-annual remedial progress report summarizing the remedial progress at the site, including detailed assessment of the  $MgSO_4$  applications, site contaminant reductions, and recommendations for future applications. Required electronic submittals will be uploaded to the State Geotracker database.

## 5.0 REMARKS

The recommendations contained in this report represent Antea USA, Inc.'s professional opinions based upon the currently available information and are arrived at in accordance with currently accepted professional standards. This report is based upon a specific scope of work requested by the client. For any reports cited that were not generated by Delta or Antea Group, the data from those reports is used "as is" and is assumed to be accurate. Antea Group does not guarantee the accuracy of this data for the referenced work performed nor the inferences or conclusions stated in these reports. The contract between Antea USA, Inc. and its client outlines the scope of work, and only those tasks specifically authorized by that contract or outlined in this report were performed. This report is intended only for the use of Antea USA, Inc.'s client and anyone else specifically identified in writing by Antea USA, Inc. as a user of this report. Antea USA, Inc. will not and cannot be liable for unauthorized reliance by any other third party. Other than as contained in this paragraph, Antea USA, Inc. makes no express or implied warranty as to the contents of this report.

Prepared by:



Edward T. Weyrens, G.I.T.  
Staff Geologist

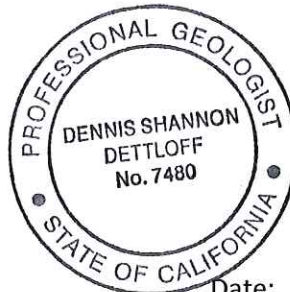
Information, conclusions, and recommendations provided by Antea Group in this document regarding the site have been prepared under the supervision of and reviewed by the licensed professional whose signature appears below.

Licensed Approver:



Dennis S. Dettloff, P.G.  
Project Manager

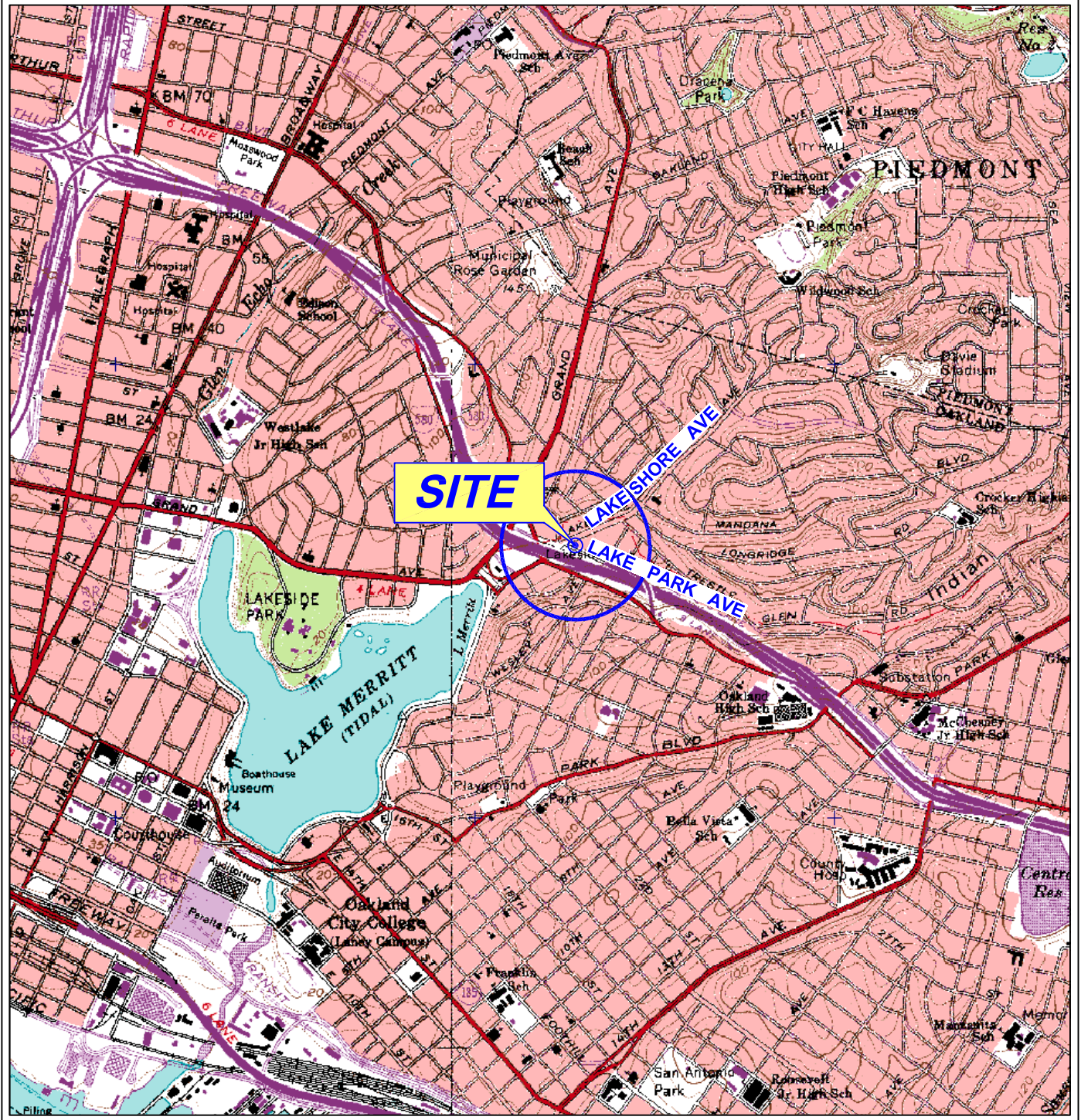
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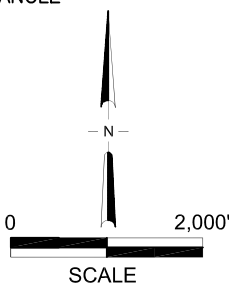
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## ***Figures***

- Figure 1      Site Location Map
- Figure 2      Site Plan
- Figure 3      Historical Groundwater Flow Directions
- Figure 4      Groundwater Elevation Contour Map – June 3, 2011
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- Figure 6      Dissolved Phase MTBE Isoconcentration Map – June 3, 2011



GENERAL NOTES:  
 BASE MAP FROM 3-D TOPO QUADS  
 OAKLAND WEST & OAKLAND EAST, CA. QUADRANGLE  
 7.5 MINUTE TOPOGRAPHIC MAP

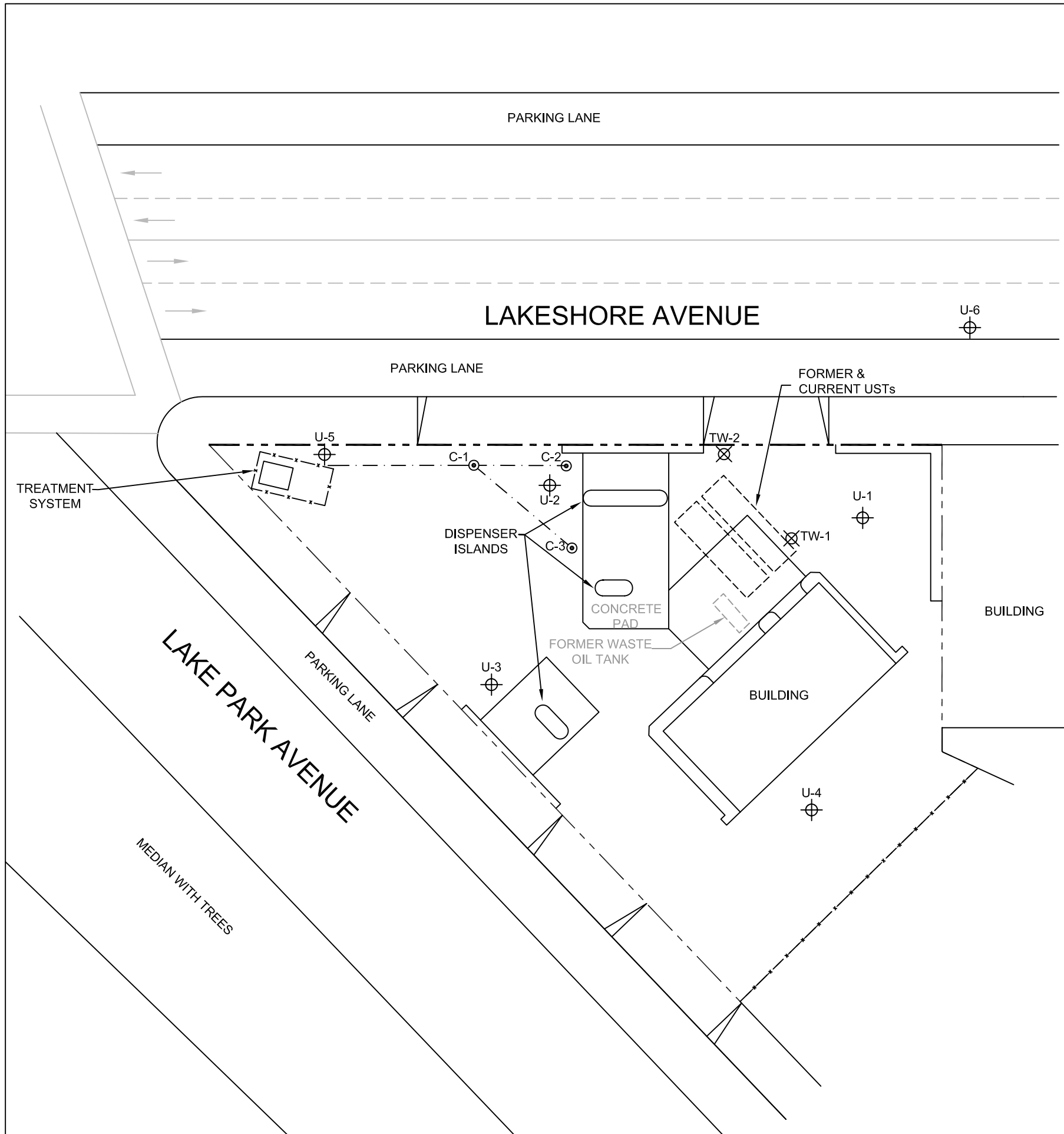


**FIGURE 1  
 SITE LOCATION MAP**




76 SERVICE STATION NO. 5325  
 3220 LAKESHORE AVENUE  
 OAKLAND, CALIFORNIA

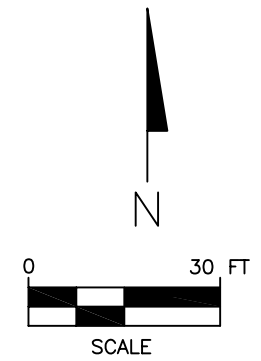
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FILE NO. 5325-SLM	PREPARED BY EW
DATE 28 JAN 11	REV. 2
	REVIEWED BY





**LEGEND**

- U-6  MONITORING WELL
- TW-1  TANK CAVITY WELL
- C-1  SPARGE POINT
- PROPERTY BOUNDARY
- - - TRENCHING
- x-x-x- FENCE



**FIGURE 2**  
**SITE PLAN**

76 SERVICE STATION NO. 5325  
3220 LAKESHORE DRIVE  
OAKLAND, CALIFORNIA


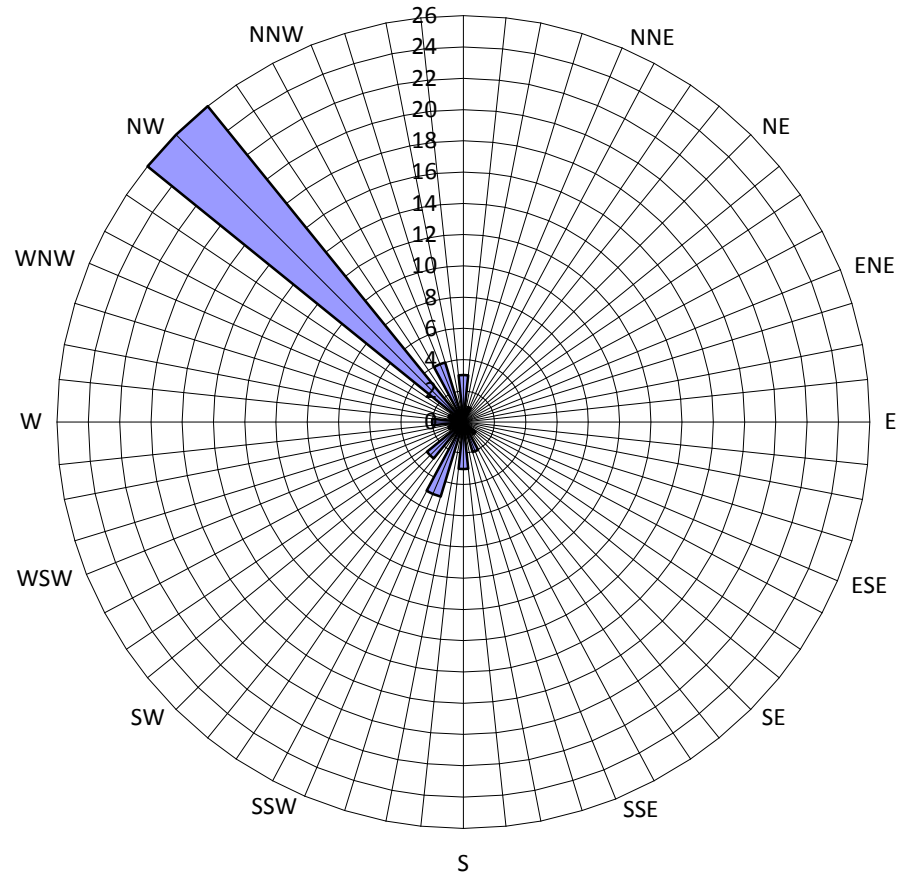
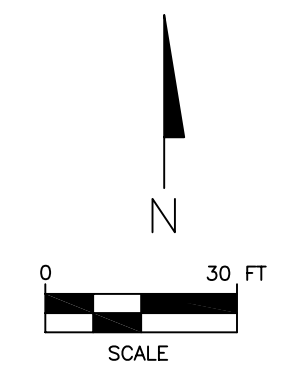
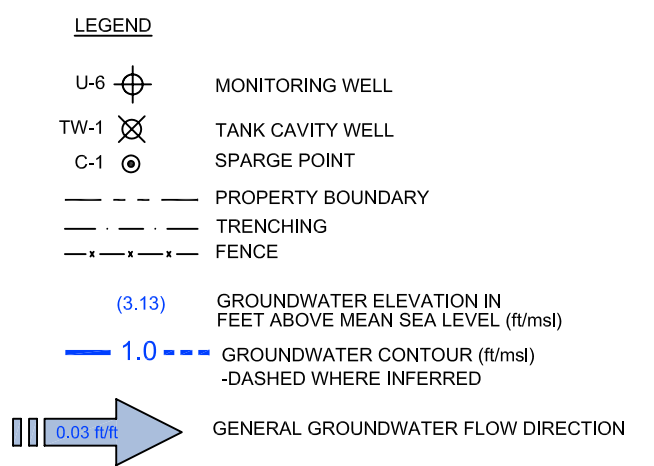
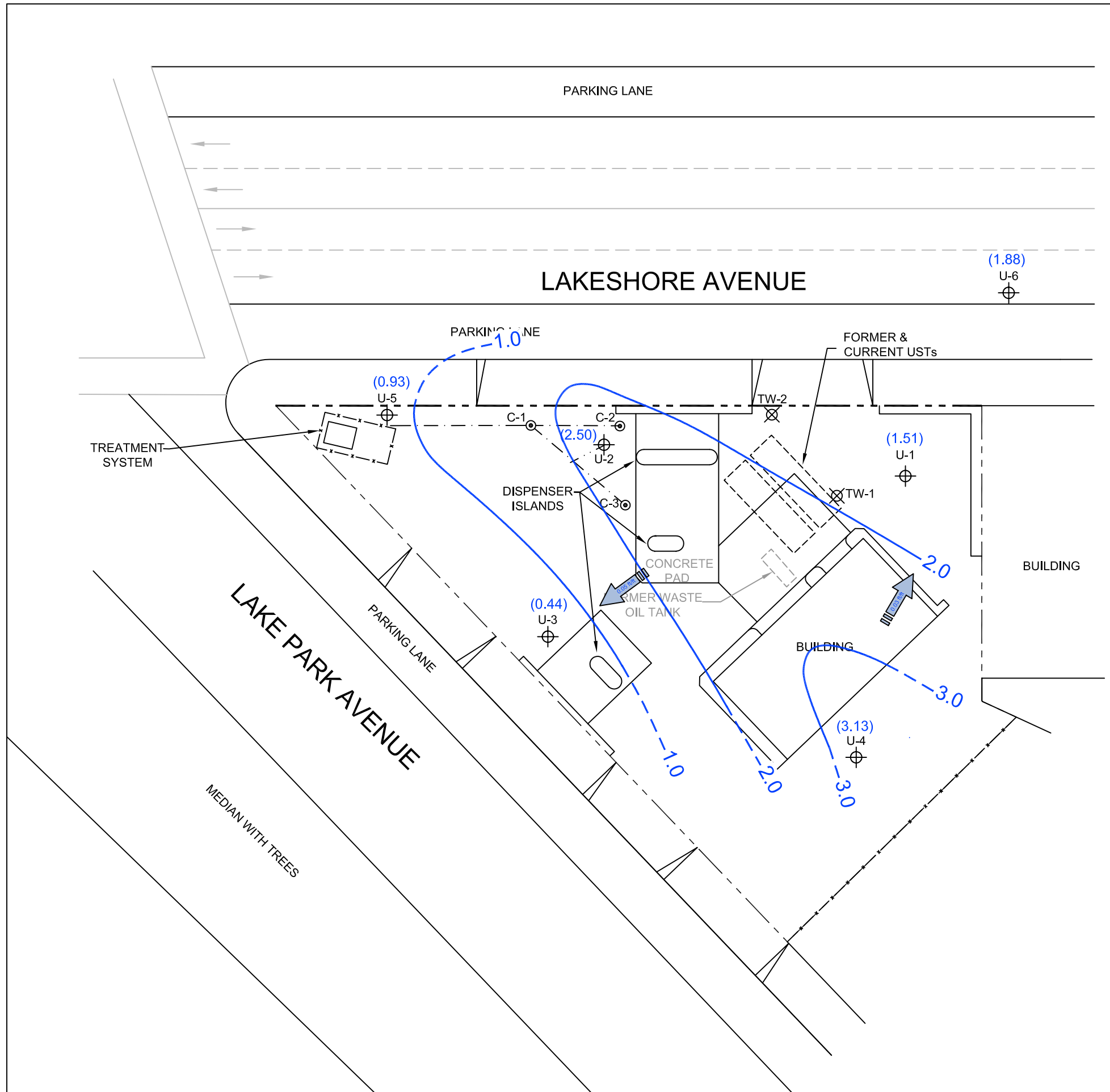
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DATE 01/28/11	REVIEWED BY DD	FILE NAME 76-5325	

Figure 3  
HISTORICAL GROUNDWATER FLOW DIRECTIONS  
76 SERVICE STATION NO. 5325  
3220 LAKESHORE AVENUE  
OAKLAND, CALIFORNIA  
N




Legend  
Groundwater flow directions are based on data from the Third Quarter 1990 to the Second Quarter 2011. 52 data points shown.

Groundwater Flow Direction

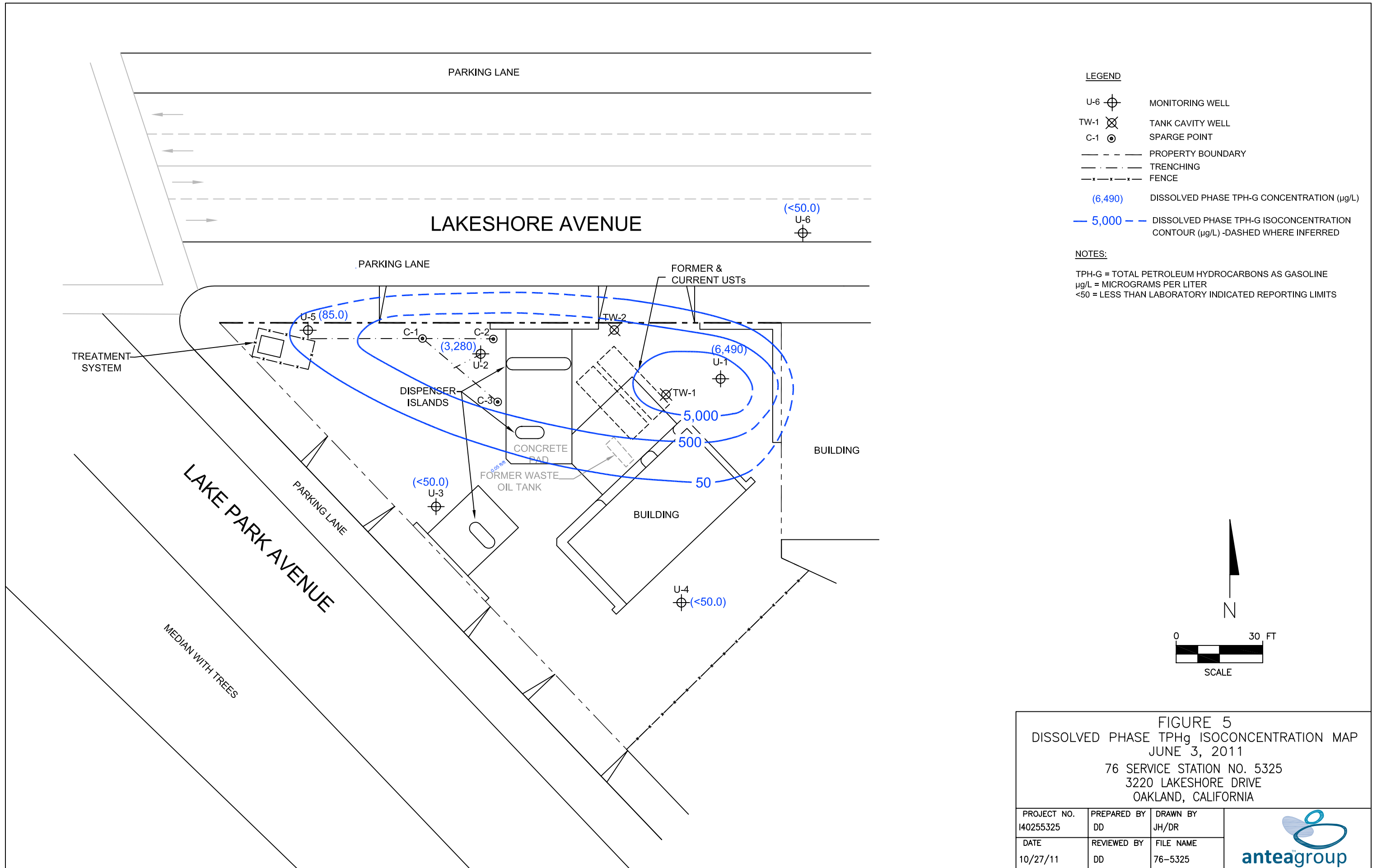


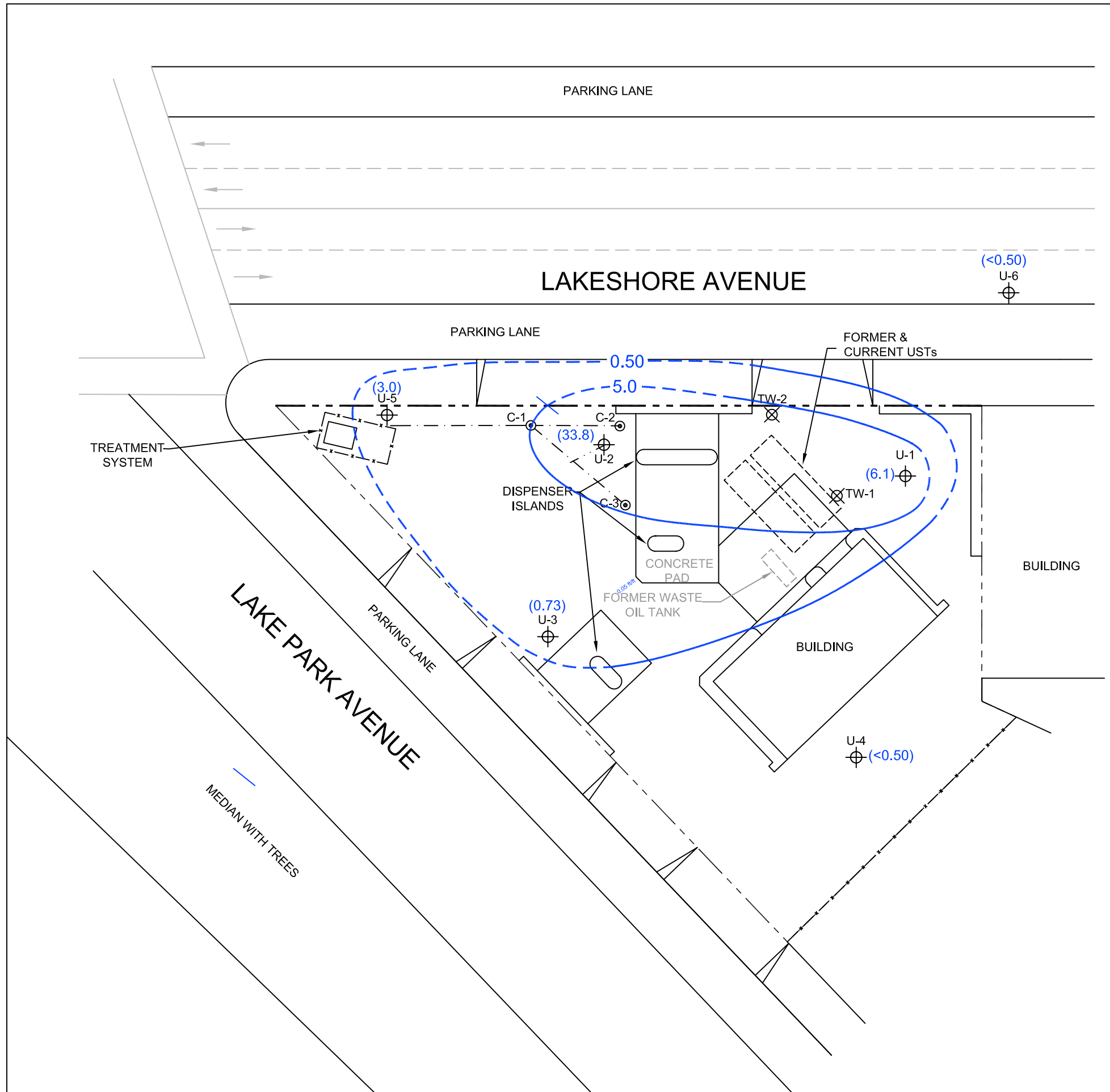
**FIGURE 4**  
**GROUNDWATER ELEVATION CONTOUR MAP**  
 JUNE 3, 2011  
 76 SERVICE STATION NO. 5325  
 3220 LAKESHORE DRIVE  
 OAKLAND, CALIFORNIA

PROJECT NO. I40255325	PREPARED BY DD	DRAWN BY JH/DR
DATE 10/27/11	REVIEWED BY DD	FILE NAME 76-5325



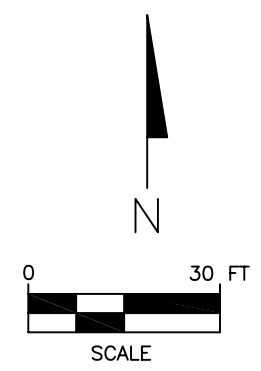






- LEGEND**
- U-6 MONITORING WELL
  - TW-1 TANK CAVITY WELL
  - C-1 SPARGE POINT
  - PROPERTY BOUNDARY
  - - - TRENCHING
  - x-x-x- FENCE
  - (33.8) DISSOLVED PHASE MTBE CONCENTRATION (µg/L)
  - 5.0— DISSOLVED PHASE MTBE ISOCONCENTRATION CONTOUR (µg/L) -DASHED WHERE INFERRED

**NOTES:**  
 MTBE = METHYL TERTIARY BUTYL ETHER  
 µg/L = MICROGRAMS PER LITER  
 <0.50 = LESS THAN LABORATORY INDICATED REPORTING LIMITS



**FIGURE 6**  
 DISSOLVED PHASE MTBE ISOCONCENTRATION MAP  
 JUNE 3, 2011  
 76 SERVICE STATION NO. 5325  
 3220 LAKESHORE DRIVE  
 OAKLAND, CALIFORNIA

PROJECT NO. I40255325	PREPARED BY DD	DRAWN BY JH/DR	
DATE 10/27/11	REVIEWED BY DD	FILE NAME 76-5325	