Groundwater Data Evaluation to Support Vapor Intrusion Assessment Montrose and Del Amo Superfund Sites Torrance, California

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ACRONYMS AND ABBREVIATIONS

bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene, and xylene
COC	Chemical of concern
CSM	Conceptual site model
DDT	Dichloro-diphenyl-trichloroethane
DNAPL	Dense non-aqueous phase liquid
DTSC	California Environmental Protection Agency, Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
ERT	Environmental Response Team
ft/yr	Feet per year
LBF	Lower Bellflower
LNAPL	Light non-aqueous phase liquid
µg/L	Micrograms per liter
MBFB/C	Middle Bellflower B and C Sand
MBFM	Middle Bellflower Mud
MCL	Maximum Contaminant Level
msl	Mean sea level
NAPL	Non-aqueous phase liquid
OU	Operable Unit
PCE	Tetrachloroethylene
ROD	Record of Decision
SAP	Sampling and analysis plan
SVOC	Semivolatile organic compound
TCE	Trichloroethylene
UBF	Upper Bellflower
VI	Vapor Intrusion
VOC	Volatile organic compound
USGS	U.S. Geological Survey
WRD	Water Replenishment District

1.0 INTRODUCTION

Tetra Tech, Inc. (Tetra Tech) has prepared this technical memorandum to present an evaluation of monitoring data in support of vapor intrusion (VI) assessments for the Montrose and Del Amo Superfund Sites. The Montrose and Del Amo Superfund Sites are located in the southwestern portion of Los Angeles County, between the cities of Torrance and Carson, California (Figure 1).

This evaluation was conducted in response to a request from the U.S. Environmental Protection Agency (EPA) to gather current information from multiple published sources on groundwater monitoring and VI assessments conducted to date. The VI pathways have been previously evaluated at some of the operable units (OUs) associated with the Montrose and Del Amo Superfund Sites. The VI exposure pathway needs to be further assessed for OU-3 (termed "Dual Site Groundwater") to addresses groundwater contamination for both the Montrose and Del Amo Superfund Sites.

1.1 Purpose and Objectives

The EPA's Environmental Response Team (ERT) has planned for up to four phases of work for VI investigations at OU-3, including:

(1) Gather current information from multiple groundwater monitoring sources and various assessment and modeling reports.

(2) Perform the VI modeling and evaluate the results to provide an assessment of data gaps, uncertainty, and weaknesses in the ability to quantify the risks from this pathway.

(3) Develop a detailed plan to collect specific information necessary to further evaluate the VI pathway.

(4) Implement the plan and report the results with interpretation.

This technical memorandum relates to the first phase. The overall purpose of groundwater data evaluation is to support further VI assessment for OU-3. The principal objectives are to:

- Summarize current information relevant to VI evaluation based on the latest groundwater monitoring reports, previous VI assessments, and modeling (Figures 11-14); and
- Identify areas with potentially complete VI exposure pathway above the commingled groundwater plumes downgradient from the Montrose and Del Amo Superfund Sites.

The groundwater data evaluation presented in this report is not designed to draw conclusions on whether there are VI risks or a need for soil gas and indoor air sampling in select residential areas. Rather, the information gathered and groundwater data evaluation will support selection of areas that may need further evaluation through a site-specific screening level VI modeling (second phase of work).

1.2 Site Background

Uses and history of contaminant releases differ for the Montrose and Del Amo sites (EPA 1998; Dames and Moore 1998). However, the groundwater impacts from both sites are addressed under OU-3, which also includes groundwater plumes of dissolved volatile organic compounds (VOCs) from the adjacent or upgradient sources.

Table 1 briefly summarizes past and current uses for each site as well as historical releases of contaminants and media affected. Also included is information for adjacent and upgradient sites that contributed contamination to groundwater.

The Montrose Superfund Site is a former plant that manufactured technical grade dichloro-diphenyl-trichloroethane (DDT) from 1947 to 1982. As a result of industrial operations at the site, chemical impacts to soil and groundwater included VOCs, chlorobenzene, and non-volatile DDT (EPA 1998).

The Del Amo Superfund Site is a former plant that manufactured synthetic rubber, styrene, and butadiene from 1943 until 1972. As a result of large-scale industrial operations at the site, petroleum hydrocarbons were released to soil at multiple locations. The primary dissolved VOC in groundwater is benzene (Dames and Moore 1998).

1.3 Document Organization

The subsequent sections are as follows:

- Section 2.0 – briefly overviews the VI pathway and mechanisms and factors that influence soil gas movement, and summarizes vapor intrusion assessments conducted for the Montrose and Del Amo Superfund sites to date.
- Section 3.0 – summarizes groundwater data evaluation used to support upcoming VI modeling and scoping of VI investigations for select residential areas.
- Section 4.0 – discusses vapor intrusion modeling approach.
- Section 5.0 – presents conclusions and recommendations.
- Section 6.0 – provides a list of references.

2.0 VAPOR INTRUSION PATHWAY

Vapor intrusion is the migration of volatile chemicals from the subsurface into overlying buildings (EPA 2002). Volatile chemicals may include VOCs, select semivolatile organic compounds, some inorganic analytes, and sometimes methane. Vapors originating from subsurface contamination might migrate into residences and cause an immediate threat, or a chronic health risk if at lower, less detectable levels (EPA 2005).

This section briefly overviews the vapor intrusion pathway as presented in the guideline document developed by the Interstate Technology & Regulatory Council (ITRC) Vapor Intrusion Team (ITRC 2007), including the processes and factors that influence movement of soil gas. In addition, a brief summary of vapor intrusion evaluations conducted to date is provided.

2.1 Conceptual Model for Vapor Intrusion

Vapor intrusion can be conceptualized as shown on Figure 2 (ITRC 2007). Chemicals volatilize from contaminated soil and/or groundwater beneath a building and diffuse toward regions of lower chemical concentration (for example, the atmosphere, conduits, or basements). Soil gas can flow into a building due to a number of factors, including changes in barometric pressure, wind load, thermal currents, or depressurization from building exhaust fans. The rate of movement of the vapors into the building is a difficult value to quantify and depends on soil type, chemical properties, building design and condition, and the pressure differential. When it enters a structure, soil gas mixes with the existing air through the natural or mechanical ventilation of the building (ITRC 2007).

Vapor sources, vapor migration pathways, and receptors are three main components of the VI conceptual model. Buildings near primary release areas of VOCs may have multiple vapor sources such as free product (both light and dense non-aqueous phase liquids [LNAPL and DNAPL]) or contaminated soil and groundwater. However, dissolved VOCs in shallow groundwater would be the only source of vapors for buildings located at a distance from a primary release.

Figure 2 schematically depicts commercial/industrial buildings and houses. However, of primary concern for the subsequent evaluation discussed in this technical memorandum is the potential for vapors to enter residences over the commingled groundwater plume southeast of the Montrose Site and south of the Del Amo Site. Mechanisms of vapor migration from groundwater contamination through the vadose zone to buildings are discussed briefly below, including the factors to consider in vapor intrusion evaluations.

2.2 Vapor Migration Mechanisms and Factors to Consider

Figure 3 presents a generalized conceptual model of vapor migration from contaminated groundwater to buildings. Both diffusion and advection are mechanisms of transport of subsurface soil gas into the indoor air environment.

Diffusion is the mechanism by which soil gas moves from high concentration to low concentration as a result of a concentration gradient. Advection is the transport mechanism by which soil gas moves because of differences in pressure. These pressure differences can be generated by changes in atmospheric pressure, temperature changes creating natural convection in the soil, or forced pressure changes created by building ventilation systems (ITRC 2007).

Advective transport is likely to be the most significant in the region very close to a basement or a foundation, and soil gas velocities decrease rapidly with increasing distance from the structure. Once soil gases enter the "building zone of influence," they are generally swept into the building through cracks in the foundation by advection caused by the indoor-outdoor building pressure differential. The reach of the "building zone of influence" on soil gas flow is usually less than a few feet, vertically and horizontally (ITRC 2007).

When the potential for the vapor intrusion pathway is assessed, it is important to consider the volatility of the contaminants, their potential for degradation and/or sorption in the vadose zone, and their concentrations. Other factors to be considered include subsurface lithology, soil moisture, depth to groundwater, distance of a building from the contaminant source, the building structure (size and age), the competence of the foundation, and the presence of utilities and preferential pathways.

Existing buildings within 100 feet of subsurface contamination are typically considered at risk for vapor intrusion (EPA 2002). Accordingly, buildings within 100 feet of soil gas or groundwater plumes should be evaluated for vapor intrusion (DTSC 2011). Buildings greater than 100 feet from a plume boundary are typically assumed not to be at risk if preferential pathways, either natural or anthropogenic, do not exist in the subsurface that link the buildings with the contaminant plume (EPA 2002; DTSC 2011).

Petroleum hydrocarbons such as the benzene found at the Montrose and Del Amo Sites are expected to attenuate below levels of concern within shorter distances than 100 feet, mostly because petroleum hydrocarbons tend to degrade readily by microorganisms in the presence of oxygen. In general, a distance of 100 feet for chlorinated solvents and 30 feet for petroleum hydrocarbons applied in both vertical and lateral directions is typically considered a threshold limit within which VI may require further evaluation (CH2MHILL 2012).

A complicating factor in evaluating the potential risks from vapor intrusion is the presence of some of the same chemicals at or above background concentrations (from the ambient [outdoor] air and/or emission sources in the building, for example, household solvents, gasoline, cleaners) that may pose, separately or in combination with vapor intrusion, a significant human health risk (EPA 2002).

With respect to a VI exposure scenario (residential or commercial structures), the screening levels are used to determine if there are potential VI risks. The VI screening levels for protection of human health include indoor air screening levels for long-term exposures, which consider the potential for cancer and noncancer effects. The VI screening levels for human health protection also include subsurface screening levels for comparison to sub-slab soil gas, "near-source" soil gas, and groundwater sampling results (EPA 2012c).

2.3 Summary of Vapor Intrusion Evaluations to Date

A detailed discussion of VI assessments conducted for the Montrose and Del Amo Sites was presented in the technical memorandum prepared by CH2MHILL in October 2012 (CH2MHILL

2012). Areas where potential for VI had been previously assessed included Montrose OU-1, Del Amo OU-1 (soil and nonaqueous phase liquid [NAPL]) and OU-2 (Waste Pits), Montrose OU-7, and portion of OU-3, Dual Site Groundwater, as depicted on Figure 4. Table 2 summarizes previous VI assessments conducted for the Montrose and Del Amo Sites.

Operable units listed in Table 2 address the primary release areas and include several potential VI sources such as contaminated vadose zone soil, LNAPL and/or DNAPL, and contaminated groundwater. VI impacts associated with OU-3 Dual Site Groundwater outside these primary release areas are limited to the dissolved VOC contamination at the water table. The water table unit serves as a barrier to upward vertical migration of VOC vapors from deeper aquifer units (CH2MHILL 2012).

Based on previous VI assessments, the following findings and conclusions were drawn:

(1) Montrose OU-1: On and Near-Property Soils and Montrose OU-3 (DNAPL):

- Most frequently detected VOCs that exceeded risk-based screening levels were: chlorobenzene, chloroform, carbon tetrachloride, tetrachloroethylene (PCE), and trichloroethylene (TCE);

- Preliminary results indicated no impacts to indoor air quality in excess of EPA's acceptable health risk range.

(2) Montrose OU-7 (Jones Chemical Industries):

- Soil gas surveys detected high levels of PCE and other VOCs near the dry well, main yard sump, former PCE storage tank/ neutralization tank areas, and southwestern corner of the site;

- Within commercial buildings, VOC concentrations in indoor air samples exceeded industrial screening criteria.

(3) Del Amo OU-1 (Soil and NAPL):

- Based on soil gas (exterior and subslab) and indoor air data, the target risk levels for PCE and TCE were exceeded in two buildings (URS 2009, 2010);

- The OU-1 Record of Decision (ROD) (EPA 2011) provides mitigation for buildings and areas with potential VI risk, including areas under existing buildings that can be identified in the future.

(4) Del Amo OU-2 (Waste Pits):

- Vapors are not migrating from the Waste Pits area (EPA 2010a);

- Ongoing source remediation and vapor monitoring are designed to detect any potential future vapor migration from the Waste Pits source.

(5) Montrose and Del Amo OU-3 (Dual Site Groundwater):

- VOCs were either below the indoor air reference levels and/or below health comparison levels (Agency for Toxic Substances and Disease Registry [ATSDR] 1995);

- Estimates of indoor air levels for several VOCs in the western neighborhood indicated the groundwater does not pose a health hazard to residents; based on indoor air samples of a few homes in the eastern neighborhood, no health threat exists from the groundwater vapors (California Department of Health Services [CDHS] 2004).

Overall, the prior studies showed that potential VI risks appear to have been sufficiently evaluated at the primary release areas of the Montrose and Del Amo Sites. Further evaluation was recommended to evaluate potential VI impacts associated with the dissolved VOC contamination outside the primary release areas. This tech memo addresses that recommendation.

3.0 GROUNDWATER DATA EVALUATION

This section summarizes information on site geology and hydrogeology, sources of groundwater contamination, and dissolved plumes of VOCs as it pertains to the VI assessment.

3.1 Geology and Hydrogeology

The Montrose and Del Amo Sites are located on the Torrance Plain, a physiographic province within the broad coastal plain of the greater Los Angeles area (EPA 1998; Dames and Moore 1998).

The hydrostratigraphic units beneath the Montrose and Del Amo Sites include the Bellflower Aquitard and the underlying Gage and Lynwood aquifers. The Bellflower Aquitard is subdivided into the Upper Bellflower (UBF), Middle Bellflower B Sand (MBFB), Middle Bellflower Mud (MBFM), Middle Bellflower C Sand (MBFC) and the Lower Bellflower Aquitard (LBF). Figure 5 illustrates the relative positions of the hydrostratigraphic units (URS 2012).

The main geologic units that make up the 55 to 60 feet thick unsaturated zone are shown on cross sections included as Figures 6 to 8. Playa deposits that underlie the surficial soil and fill material (Figures 7 and 8) are mostly fine-grained (clayey silt to clay) and range in thickness from 7 to 27 feet. Palos Verdes Sand unit underlies the Playa deposits and consists of fine-grained sand and silty sand; its thickness ranges from 11 to 28 feet (EPA 1998). The base of the fossiliferous sand of the Palos Verdes Sand marks the contact between the Palos Verdes Sand and the underlying UBF Aquitard. The UBF Aquitard consists of interbedded silty sand, silt, and clay; saturated at approximately 60 feet below ground surface (bgs).

As shown on Figure 5, the water table currently lies within the UBF to the east of Normandie Avenue (see Figure 1), and within the MBFB to the west because of the slight northeasterly dip of the hydrostratigraphic units and the groundwater gradient. Figure 9 shows contours for February 2012 groundwater elevations of the UBF (URS 2012).

Many existing water table wells located to the west of Normandie Avenue are screened across the basal portion of the UBF and extend into the MBFB because of the proximity of the water table to the UBF/MBFB contact (URS 2012). However, the screened intervals of some of the wells that originally straddled the water table became fully submerged as a result of rising groundwater levels.

It has been reported by the Water Replenishment District (WRD) that groundwater levels have been rising in the basin since management of the resource was initiated in the 1960s (WRD 2004). The water level in the region in general has been rising at an annual rate of approximately 1 foot per year (ft/yr) for the last 30 years (Dames & Moore 1998). Groundwater model projections by the U.S. Geological Survey (USGS) indicate that groundwater levels are likely to continue to rise in the future before they stabilize near sea level (USGS 2003). As illustrated on cross sections (Figures 7 and 8), the water level rose approximately 10 feet from 1997 to 2002. The rising trend of the water level is consistent with hydrographs for wells screened in the UBF beneath the sites (see Figure 10).

Based on February 2012 measurements (URS 2012), water table elevations within the dual site ranged from a high of -3.87 feet mean sea level (msl) to a low of -10.04 feet msl (see Figure 9). Interpretive groundwater elevation contours for the water table indicate a southwesterly flow direction. However, the water table surface appears variable, with local areas of mounding in the vicinity of the Waste Pit area and near the southeastern corner of the Del Amo Site. This mounding is likely caused by artificial recharge from anthropogenic sources. The direction of groundwater flow as a whole is similar to that reported for the previous 2006 monitoring event (URS 2012).

Configurations of some of the groundwater plumes indicate southeasterly components of the groundwater flow. For example, the chlorobenzene plume in the water table zone of the UBF (see Section 3.3) emanating from the Montrose Site appears to be expanding in the southeastern direction (see Figure 11).

3.2 Sources of Groundwater Contamination

As summarized in Table 1, sources of VOC contamination in groundwater are associated with the former Montrose and Del Amo facilities, Jones, as well as some upgradient sites including former Boeing facility, APC, PACCAR, International Light Metals, and others.

In its 35 years of operation, the Montrose facility released hazardous substances into the surrounding environment, including surface soil, groundwater, stormwater drainage ditches and sewers, and sanitary sewers. The VOCs such as chlorobenzene entered the ground within the former plant property as a result of leaks from valves or clogged lines and other elements of the DDT manufacturing process (CH2MHILL 2012). Soil and groundwater beneath the former plant property also contains a DNAPL that consists of chlorobenzene and DDT. The approximate DNAPL-contaminated area on the plant property is shown on Figure 4.

Over nearly 30 years of large-scale industrial operations, the Del Amo plant released petroleum hydrocarbons as LNAPL to soil and groundwater at multiple locations. The primary dissolved VOC encountered in groundwater beneath the former plant property is benzene (Dames and Moore 1998).

Chemical manufacturing and storage operations at a 5-acre Jones site adjacent to the Montrose plant property have resulted in releases of chlorinated VOCs. PCE and TCE were identified in soil and groundwater beneath the site. The plume of dissolved TCE, originating at Jones and upgradient sources such as the former Boeing facility, APC, PACCAR and others, is commingled with the groundwater contamination from the Montrose and Del Amo Superfund Sites (EPA 1998; Dames and Moore 1998; CH2MHILL 2012).

The commingled plumes of chlorobenzene, benzene, TCE and other VOCs originating at the Montrose and Del Amo Superfund Sites as well as at the adjacent and upgradient sites are addressed under OU-3 Dual Site Groundwater. As presented in the groundwater ROD (EPA 1999), the selected OU-3 Dual Site Groundwater remedy includes containment of the source areas with DNAPL and LNAPL occurrence and prevention of migration of dissolved contaminants into the Montrose and Del Amo Superfund Sites from other adjacent and upgradient areas.

The following sections provide details on the main dissolved plumes of VOCs in the UBF Aquitard (also referred to as the water table zone).

3.3 Chlorobenzene Plume

The chlorobenzene plume emanating from the DNAPL source at the former Montrose plant property is present in multiple aquifer units. It extends approximately 900 feet from the southeastern corner of the property (see Figure 11) in the water table zone of the UBF, with its 400-foot-long leading edge portion under the residential area. In deeper units, it extends for more than 1.5 miles southeast of the property. This plume is commingled with the benzene and TCE plumes (see Section 3.6). The benzene plume originates at the Del Amo Site, while TCE plume is associated with source areas at Jones and other upgradient properties (see Section 3.5).

Based on both historical and recent data, most of the chlorobenzene concentrations above in situ groundwater standards of 70 micrograms per liter (µg/L) (CH2MHILL 2012) in the water table zone of the UBF occur beneath the Montrose plant property. Elevated chlorobenzene concentrations of up to 160 µg/L occur west of the Montrose plant property in a commercial and industrial business area and are reportedly attributed to transport via a 10-inch-diameter sewer line, which Montrose used for wastewater discharge prior to 1953.

Most recently the chlorobenzene concentrations increased in well SWL0049 from 2,900 µg/L in February 2012 (AECOM 2012c) to 5,000 µg/L (AECOM 2013), which are above the historical range of 8 to 1,900 µg/L. The well is located in the residential area (Figure 11) southeast of the Montrose plant property (at West 204th Street near Normandie Avenue) and is screened in the sandy interval of the UBF (see well construction details and the boring log in Attachment 1).

3.4 Benzene Plume

Multiple source areas at the Del Amo Site and surrounding vicinity produced commingled benzene plumes. However, majority of these plumes remain within the containment area (see Figure 12) defined in the groundwater ROD (EPA 1999).

Figure 12 shows benzene distribution for the water table zone of UBF based on 2012 monitoring data (URS 2012). The highest concentrations of benzene of up to 610,000 µg/L occur near the source areas at the Del Amo Site. Historically high concentrations of benzene (greater than 1,000 µg/L) were also detected near the southwestern corner of Jones (abandoned well XMW-7) and near a source located south of the Waste Pits (abandoned well XP-01).

The 2012 benzene concentrations significantly decreased relative to previous monitoring events for several wells in the vicinity of the waste pits at the southern end of the plant site. For example, benzene concentrations in well PZL0020 decreased from a maximum of 510,000 µg/L in 2004 to 190,000 µg/L in 2012. Likewise, benzene concentrations in well SWL0044 decreased from a maximum of 56,000 µg/L in 2006 to 0.82 µg/L in 2012. The above reductions in benzene concentrations likely resulted from the active soil vapor extraction system at the Waste Pit area that has been operating since 2006, in conjunction with natural attenuation (URS 2012). Based on historical and most recent data, the majority of the wells exhibited decreasing trends in the benzene concentrations (URS 2012).

3.5 TCE Plume

Figure 13 shows the most recent TCE distribution based on 2012 monitoring results (URS 2012). Based on historical data, maximum TCE concentrations (up to 46,000 µg/L) were detected west of the Del Amo Site, in the vicinity of PACCAR property wells XMW-04T and XMW-05T. Additional local concentration maxima occur to the west of the Del Amo Site at well IRZMW001A (16,000 µg/L) and near the southwestern corner of the plant site at XMW-13 (810 µg/L) (URS 2012).

Elevated TCE concentrations were also encountered in groundwater beneath the Del Amo Site, where the TCE plume is commingled with the benzene plume, and in the area south of Jones, where TCE concentrations range from 530 µg/L (near the southern boundary of the Jones property) to 270 µg/L at a distance of about 1,100 feet south of Jones. Low concentrations of TCE (around 10 µg/L) were also detected south of the southeastern corner of the Del Amo Site, where a landfill was formerly located. Substantial portions of the TCE plume west and southwest of the plant site are outside of the containment zone. (CH2MHILL 2012).

Based on historical and most recent data, the majority of the wells exhibited decreasing TCE concentration trends (URS 2012). However, TCE concentrations in well SWL0049 increased from non-detected in March 1996 to 91 µg/L in February 2012. The well is located in the residential area (Figure 13) southeast of the Montrose plant property and is screened in the sandy interval of the UBF.

3.6 Commingled Plumes Underneath Residences

Figure 14 presents the extents of commingled plumes of chlorobenzene, benzene, and TCE in the water table zone of the UBF. As discussed in Section 3.2, the plumes originate from multiple sources at the Montrose and Del Amo Superfund Sites as well as at the adjacent and upgradient sites.

The extensive data presented above provides information for conservative VI screening to identify areas where further site-specific evaluations may be warranted. The screening process that includes comparison of the dissolved VOC concentrations to the EPA's groundwater-to-indoor-air screening levels is intended to evaluate a potential VI risk. The VI screening levels are based on a number of conservative assumptions. In addition, predicting indoor area concentrations using groundwater data is subject to many uncertainties. Therefore, the exceedance of a groundwater-to-indoor-air screening level does not necessarily translate into an unacceptable vapor exposure or risk.

There are several areas recommended for further evaluation, including occupied residential and commercial buildings that overlie the commingled plumes of VOCs: (1) the residential area southeast of the Montrose Site (with elevated concentrations of chlorobenzene and TCE); (2) commercial/industrial area with elevated TCE concentrations south of the Montrose and Jones sites; and (3) residences south of the Waste Pits (with historic detections of TCE; see Figures 12 and 13). These areas are shown on Figure 14.

Area 1: The residential area southeast of the Montrose Site is an area that would require site-specific screening evaluation of potential VI risks for the following reasons:

(1) Based on most recent data, concentrations of chlorobenzene and TCE in the water table zone of the UBF (well SWL0049) are increasing and currently exceed the EPA's groundwater-to-indoor-air screening levels of 410 µg/L for chlorobenzene and 1.1 µg/L for TCE;
(2) The water table continues to rise, which would result in shrinking of the vadose zone; thus, the VI potential may increase. (Theoretically, the water table can go up approximately 5 to 10 feet in the next decade or so; thus, the vadose zone thickness at the location of well SWL0049 would decrease from the current depth of approximately 42 feet bgs to less than 40 feet bgs.)
(3) Per the boring log for well SWL0049 (Dames and Moore 1998) included in Attachment 1, the vadoze zone is composed predominantly of fine sand, which would tend to favor migration of vapors upward.

On behalf of Montrose Chemical Corporation of California (Montrose), AECOM (2013) conducted a vapor intrusion evaluation for chlorobenzene impacts to groundwater at monitoring well SWL0049. AECOM used the results of Johnson & Ettinger vapor intrusion model (GW-ADV, Version 3.1, dated February 2004) that were obtained by Exponent (2013) to evaluate the potential for vapor intrusion from groundwater to indoor air in the vicinity of this monitoring well.

Based on model results, the concentrations of chlorobenzene detected in groundwater at monitoring well SWL0049 were not found to pose an increased or unacceptable non-carcinogenic vapor intrusion health risk to residents. However, the evaluation did not consider other VOCs such as TCE in the commingled plume at location of well SWL0049, nor did it account for the likelihood of an increase in chlorobenzene concentrations and a decrease in the vadoze zone thickness in future.

The groundwater-to-indoor-air screening values are from the VISL (EPA, 2013c) based on a conservative attenuation factor of 0.001. The use of the EPA GW-ADV spreadsheet will refine the attenuation factor, supporting more realistic decisions for public protection.

<u>Area 2: Commercial/Industrial Area with elevated TCE concentrations south of the Montrose and Jones sites</u> would require site-specific screening evaluation of potential VI risks because:

(1) TCE concentrations historically detected in wells XMW-06 and XMW-16 (see Figure 13) exceeded the EPA's groundwater-to-indoor-air screening level of 1.1 µg/L;

(2) At locations of these wells the vadoze zone thickness is expected to be between 48 and 58 feet and may decrease in future as a result of the water table rise;

(3) The cross sections for the Montrose Site (see Figures 7 and 8) indicate that upper 25 feet of the vadose zone soil in the area south of the Montrose and Jones sites is composed of clayey silt and silt, while the remaining 30 or so feet of soil consists mostly of fine-grained sand.

Note that TCE concentrations in groundwater beneath this area range from 270 to 530 µg/L (wells XMW-16 and XMW-06 shown on Figure 13) and are similar to those detected near the western border of the Del Amo Site (for example, in wells SWL0002 and SWL0004 (Figure 13). Wells SWL0002 and SWL0004 are close to the leading edge of the large TCE plume that appears to originate west of the Del Amo property boundary. As discussed in Section 2.3 and detailed in Table 2 for the Del Amo OU-1 (Soil and NAPL), TCE concentrations in soil gas (exterior and subslab) and indoor air exceeded the target risk levels in two buildings (URS 2009, 2010). The parcels which include these two buildings are shown with yellow boxes on Figure 15. Both parcels overlie the eastern "nose" of the TCE plume shown on Figure 13.

Area 3: Residences south of the Waste Pits overlie a southern portion of the 400-foot-long commingled TCE and benzene plume. Historically, LNAPL was measured in well XP-01 (see Figure 12). Concentrations of TCE measured in wells SWL008 and SWL0051 (see Figure 13) ranged from 5.3 to 9.1 µg/L, which exceed the EPA's groundwater-to-indoor-air screening level for TCE of 1.1 µg/L.

Soil gas and indoor air sampling conducted in 1995 in residential areas south of the Waste Pits (ASTDR 1995), estimates of indoor air levels for several VOCs in the western neighborhood, and indoor air samples of a few homes in the eastern neighborhood (CDHS 2004) did not indicate health threats from the VI exposure pathway. However, community representatives have expressed concern. Therefore, additional site-specific screening evaluation of current conditions will focus on TCE and take into account potentially decreasing thickness of the vadose zone and its lithological makeup.

It is recommended that more rigorous tools for site-specific screening, such as VI modeling, using the most current data, be used to further evaluate the three areas identified above.

4.0 VAPOR INTRUSION ASSESSMENT APPROACH

This section briefly discusses an approach for conducting additional site-specific screening evaluation of potential VI risks from groundwater in select areas. In general, the VI assessment will follow multiple lines of evidence approach (with modeling used as one line of evidence) and will include the following steps:

- Compile historic and most recent data for preliminary screening evaluation
- Perform more rigorous evaluation of recommended areas using historic and current site specific information (e.g., VI modeling).
- Assess data gaps, uncertainties and limitations in evaluating VI pathway for recommended areas.
- Develop a detailed plan to collect specific information necessary to further evaluate the VI pathway.

Selecting appropriate model and input data are important for implementation of the VI assessment approach as discussed in the following sections.

4.1 Selected Vapor Intrusion Model

The Johnson and Ettinger (J&E) model (1991) was selected for the site-specific screening evaluation of potential VI risks for the residential areas identified in Section 3.6. EPA has identified the J&E model as a commonly used model for evaluating indoor air exposure (EPA 2004). It is a screening-level model that incorporates both convective and diffusive mechanisms for estimating the transport of contaminant vapors emanating from either subsurface soils or groundwater into indoor spaces located above the source of contamination (EPA 2002). EPA programmed the J&E model into Microsoft EXCEL™ and added a health risk component that calculates the risk from inhaling a specific chemical at the concentration estimated in indoor air (EPA 2004).

The J&E model provides an estimated attenuation coefficient or factor (denoted with symbol α) that relates the vapor concentration in the indoor space to the vapor concentration at the source of contamination (EPA 2002). The vapor attenuation factor is an inverse measurement of the overall dilution that occurs as vapors migrate from a subsurface source into a building. Lower attenuation factor values indicate lower vapor intrusion impacts and greater dilution; higher values indicate greater vapor intrusion impacts and less dilution (EPA 2012a, b).

The J&E model uses the conservation of mass principle and a number of simplifying assumptions. It cannot evaluate preferential migration pathways or address highly variable and heterogeneous subsurface conditions.

4.2 Model Input Data

Inputs to the J&E model include chemical properties of the contaminant, properties of saturated and unsaturated soils, and structural properties of the building. Current EPA chemical-specific properties and toxicity values (EPA 2012a, c) for the COPCs will be used in the model.

Data on site-specific physical and geotechnical parameters (for example, soil type, depth to groundwater, average groundwater temperature, porosity, and permeablility) have been compiled from the RI (EPA 1998, Dames and Moore 1998), geotechnical (EarthTech AECOM 2008), and groundwater monitoring reports (AECOM 2012c, URS 2012). If not available for some of the areas, conservative default parameters will be used.

Table 3 summarizes model input parameters for site-specific screening evaluations (DTSC 2011) for soils properties and structural properties of the building. The basis for each individual parameter is provided in the last column of the table.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on conservative screening evaluations using current information gathered from multiple sources on groundwater monitoring and VI assessments at Montrose and Del Amo Superfund Sites, several areas with occupied buildings (residential or commercial) were selected for further evaluation. These areas overlie commingled plumes of VOCs in groundwater (Figure 14) and include the following:

(1) The residential area southeast of the Montrose Site (with elevated concentrations of chlorobenzene and TCE);

(2) Commercial/Industrial area with elevated TCE concentrations south of the Montrose and Jones sites; and

(3) Residential area south of the Waste Pits (with historic TCE detections and expressed community interest).

It is recommended that more rigorous tools for site-specific screening, such as VI modeling, using the most current data, be used to further evaluate the three areas identified above.

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TABLES

Table 1. Site Uses and Media Affected

Site Name (Area)	Years of Operation	Past Uses	Current Uses	Historical Releases	Media Affected
Del Amo Superfund Site (280 acres)	1943-1972	Large-Scale Industrial Operations (Styrene Plant/Butadiene Plant/Synthetic Rubber Plant	Industrial Park (Developed since 1972)	LNAPL (Benzene)	Soil and Groundwater
Montrose Superfund Site (13 acres)	1947-1982	Pesticide DDT Plant	None (Demolished 1983)	DNAPL (Chlorobenzene, DDT)	Surface soil, groundwater, stormwater drainage ditches and sewers, sanitary sewers
Jones Chemicals Industries (5 acres)	1940s -1968	Sulfuric Acid Manufacturing Plant (1940s-1952) Water Treatment Chemicals Manufacturing, Storage (1963-1968)	Manufacturing/ Repackaging (sodium hypochlorite, sodium bisulfate, other chemicals)	PCE, TCE	Soil and Groundwater
Other Sites - Former Boeing Facility, APC, PACCAR	--	Industrial Operations	--	TCE	Soil and Groundwater

Notes:

DDT	Dichloro-diphenyl-trichloroethane	PCE	Tetrachlorothylene
DNAPL	Dense Non-Aqueous Phase Liquid	TCE	Trichloroethylene
LNAPL	Light Non-Aqueous Phase Liquid	--	Not available

Table 2. Summary of Previous Vapor Intrusion Assessments

Operable Unit	Primary Release Areas	Vapor Sources	Vapor Migration	Vapor Receptors	Vapor Intrusion Assessments
Montrose OU-1: *On and Near-Property Soils* and Montrose OU-3: *DNAPL*	Central Process Area (CPA)	• Contaminated vadose zone soil, • DNAPL, and • Dissolved VOCs in groundwater: primarily chlorobenzene (small percentage of other VOCs)	Soil vapor concentrations exceeding industrial screening levels detected in the shallow subsurface along the northern property boundary	Three occupied commercial warehouse buildings (GLJ Holdings Property) north of the property line; no occupied structures on the plant property.	- 2003 onsite soil vapor survey (Earth Tech 2004); - 2010 shallow soil vapor survey along the northern property boundary and around commercial warehouse buildings offsite to the north (AECOM 2012a); - December 2010, building evaluations, followed up in 2011 with air sampling at the three warehouse buildings (AECOM 2012b).
Montrose OU-7: *Jones Chemical Industries*	The dry well main yard sump, former PCE storage tank/ neutralization tank areas, former drum storage areas, and other processes	• Contaminated vadose zone soil, • Dissolved VOCs in groundwater: primarily PCE, TCE and 10 other VOCs above screening criteria.	Benzene, carbon tetrachloride, chloroform and PCE in indoor air samples exceeded screening criteria within buildings on the Jones property	Several existing occupied buildings (main offices, warehouse, manufacturing, repackaging facilities and other)	- 1994-1994 soil gas sampling (EPA 1998); - 2011 and 2012 soil gas and indoor air sampling (Arcadis 2012a, b)
Del Amo OU-1: *Soil and NAPL*	Former plant site outside the Waste Pits Area (former styrene and butadiene plants)	• Contaminated shallow and deep vadose zone soil, • LNAPL, and • dissolved VOCs in groundwater: primarily benzene (also toluene, ethyl-benzene, styrene, PCE, and TCE)	VI/indoor air exposure pathway: target risk levels exceeded in two buildings (URS 2010)	Approximately 68 commercial buildings, most of which occupied (used for logistics, manufacturing, and office purposes)	- Shallow soil and soil vapor samples collected during RI activities between 1992 and 2003 (URS 2007) - An indoor air study conducted 1993 – 1995 (URS 2001) - Subslab samples collected at five occupied parcels in 2009 and confirmed the need for remedy to address potential VI at two buildings (URS 2009)
Del Amo OU-2: *Waste Pits*	Waste Pits and likely a petroleum pipeline directly south	• Contaminated vadose zone soil, • LNAPL, and • dissolved VOCs in groundwater: benzene and other petroleum related VOCs	VI pathway associated with Waste Pits for nearby structures in residential area to the south.	No occupied structures at the Waste Pits area and/or within 30 feet of the benzene contamination at the Waste Pits	- 1995 indoor air sampling (ASTDR 1995); - soil vapor sampling south of the Del Amo Waste Pits (CDHS 2004); - soil vapor monitoring began in 2003; - SVE/IBT system operates since 2006.

Operable Unit	Primary Release Areas	Vapor Sources	Vapor Migration	Vapor Receptors	Vapor Intrusion Assessments
Montrose and Del Amo OU-3: *Dual Site Groundwater*	Areas of former plants and industrial operations at Montrose and Del Amo Sites and several nearby source areas	• Dissolved plumes outside the source areas: primarily benzene, chlorobenzene, and TCE (other VOCs: ethylbenzene, naphthalene, PCE, and DCE)	VI pathway associated with OU-3 groundwater outside source areas likely insignificant, except for a few areas with elevated concentrations of TCE and chlorobenzene beneath the residential land use areas.	Occupied structures of various types in residential, commercial, and industrial areas. Residential areas include single-family detached houses and multiplex apartment buildings	- 1995 indoor air sampling in 25 houses south of the Del Amo Waste Pits (ASTDR 1995); - 2004 evaluation of indoor air effects for two regions of the neighborhood south of the Del Amo site (CDHS 2004): (1) high chlorobenzene and benzene concentrations in groundwater beneath the western neighborhood and (2) elevated benzene concentrations and other VOCs, including vinyl chloride and naphthalene (eastern neighborhood)

Notes:
DDT Dichloro-diphenyl-trichloroethane
DCE Dichloroethylene
DNAPL Dense Non-Aqueous Phase Liquid
LNAPL Light Non-Aqueous Phase Liquid
PCE Tetrachlorothylene
TCE Trichloroethylene
VOC Volatile Organic Compound
- Not available

TABLE 3 - Input Parameters for Site-Specific Screening Evaluation

Primary Input Parameters		Site-Specific Evaluation	Basis for Site-Specific Parameter
C_s	Subsurface concentrations[1]	Statistical approximation[1]	Use ProUCL (EPA 2010b)
θ_t	Soil total porosity[2]	Site-specific	Use ASTM D854
θ_w	Soil volumetric water content[2]	Site-specific	Use ASTM D2216
θ_a	Soil volumetric air content[2]	Site-specific	Calculate from θw
ρ_s	Soil bulk density	Site-specific	Use ASTM 2937
θ_{tcap}	Capillary zone total porosity	Site-specific	Use ASTM D854
θ_{wcap}	Capillary zone volumetric water content	Site-specific	Calculate from EPA 2003
θ_{acap}	Capillary zone volumetric air content	Site-specific	Calculate from θ_{wcap}
L_{cap}	Thickness of the capillary fringe	Site-specific	Calculate from Fetter (2001)
k	Soil permeability[3]	Site-specific	In-situ measurement
f_{oc}	Soil fraction organic carbon	Site-specific	Use Walkley-Black method
°T	Soil and groundwater temperature	Site-specific	Field measurement
ΔP	Indoor – outdoor pressure differential	40 g/cm-s2	EPA 2002
η	Crack-to-total area ratio	0.005	Johnson 2002
E_b	Indoor air exchange rate – residential	0.5 / hour	EPA 1997 (California data)
E_b	Indoor air exchange rate - commercial	1.0 / hour	CEC 2001
L_{crack}	Foundation slab thickness	Site-specific	-
L_b,W_b,H_b	Building dimensions[4]	Site-specific	-
L_f	Foundation depth below grade – building with no basement	15 cm	EPA 2002
	Foundation depth below grade – building with basement	200 cm	EPA 2002
L_t	Distance from foundation to source	Site-specific	-
L_{wt}	Distance from foundation to groundwater	Site-specific	-
Q_{soil}	Soil gas advection rate[5]	5 L/minute	EPA 2002

CEC = California Energy Commission
cm = centimeters
g/cm-s^2 = grams per centimeter – seconds squared
L = liters

Notes:

1 For existing buildings use maximum concentrations unless a robust statistical data set is available;

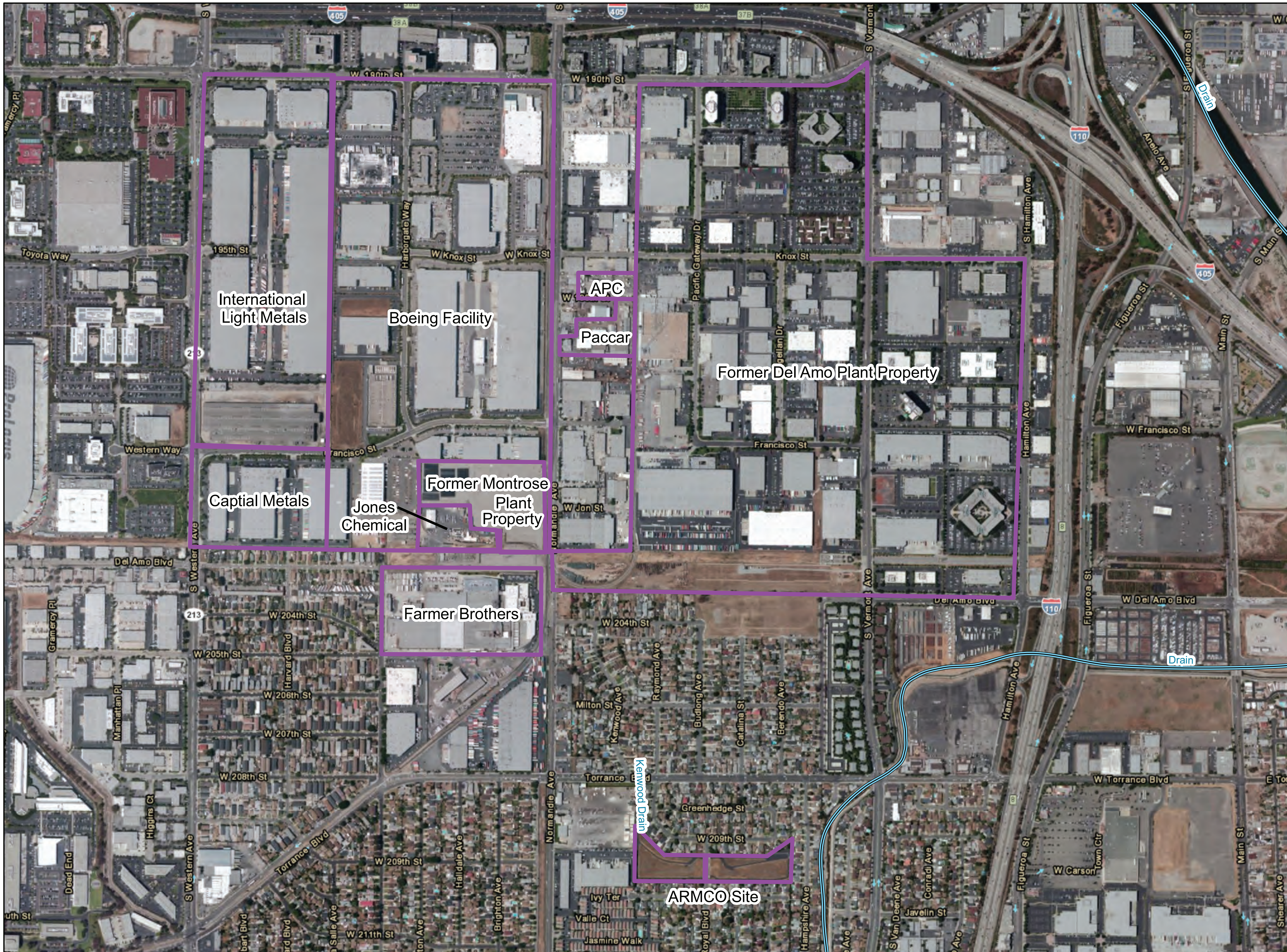
2 In-situ measurement of effective diffusion coefficient is recommended over inferring the input parameter from the soil's water content, air content, and total porosity.

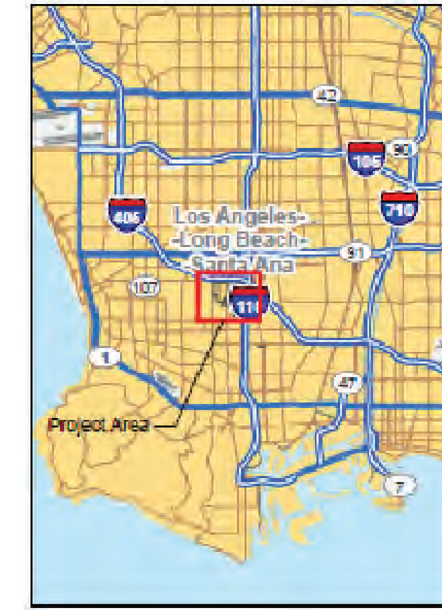
3 Use a soil gas advection rate (Qsoil) of 5 liters per minute with the default building size unless an in-situ measurement of air permeability of the shallow soil is available. Hence, the EPA Vapor Intrusion Model should only calculate a site-specific Qsoil when site-specific permeability measurements are available.

4 The default building size is 10 meters by 10 meters (EPA 2002).

5 For structures larger than the default building size, the default value for Qsoil of 5 liters per minute should be proportionally increased in a linear fashion as a function of the spatial footprint of the building. For example, a building of 1,000 square meters will have, for modeling purposes, a soil gas advection rate of 50 liters per minute.

FIGURES





Legend

Drain

Project Areas

N

0 500 1,000 2,000

Feet

Montrose and Del Amo Superfund Sites

Torrance, California

Figure 1
Site Location Map

TETRA TECH

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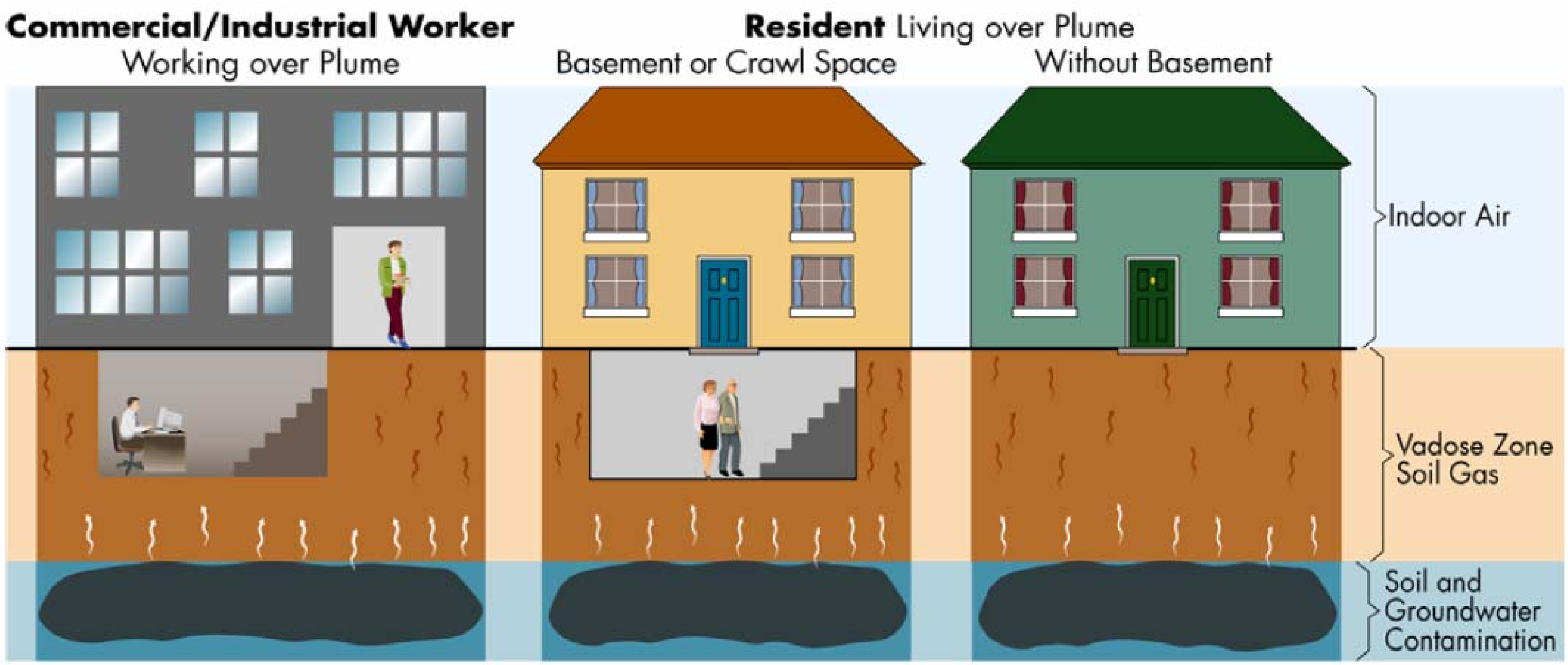
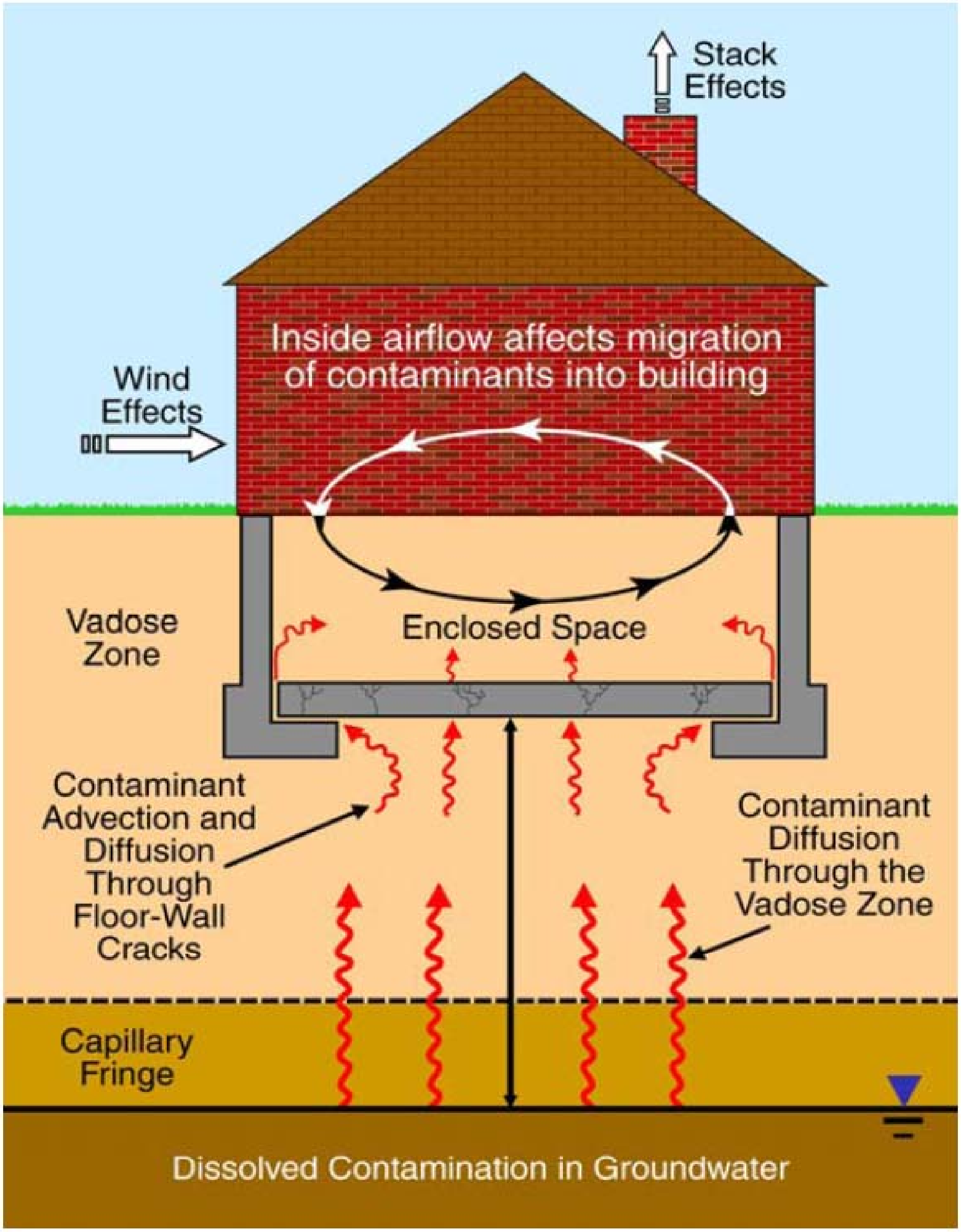
User: ali.rodrian

Date: 9/12/2013



Source: Interstate Technology & Regulatory Council (ITRC). 2007. Vapor Intrusion Pathway: A Practical Guideline. VI-1. Washington, D.C.: ITRC, Vapor Intrusion Team. www.itrcweb.org.

Montrose and Del Amo Superfund Sites Torrance, California
Figure 2 **Typical Conceptual Model of Vapor Intrusion**
TETRA TECH

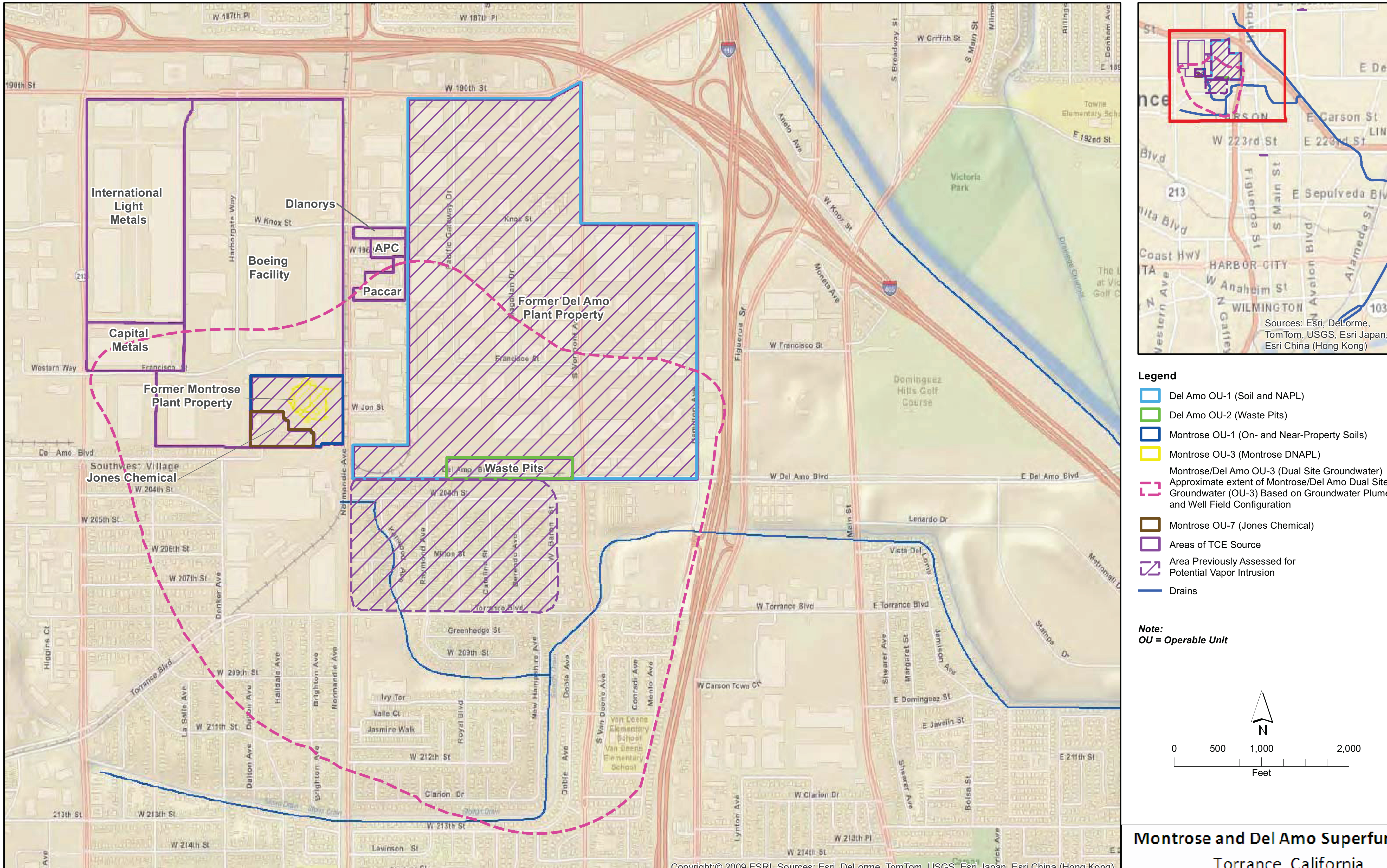


Source: Interstate Technology & Regulatory Council (ITRC). 2007. Vapor Intrusion Pathway: A Practical Guideline. VI-1. Washington, D.C.: ITRC, Vapor Intrusion Team. www.itrcweb.org.

Montrose and Del Amo Superfund Sites
Torrance, California

Figure 3
Conceptual Site Model: Vapor Intrusion from Groundwater Contamination

TETRA TECH



Montrose and Del Amo Superfund Sites

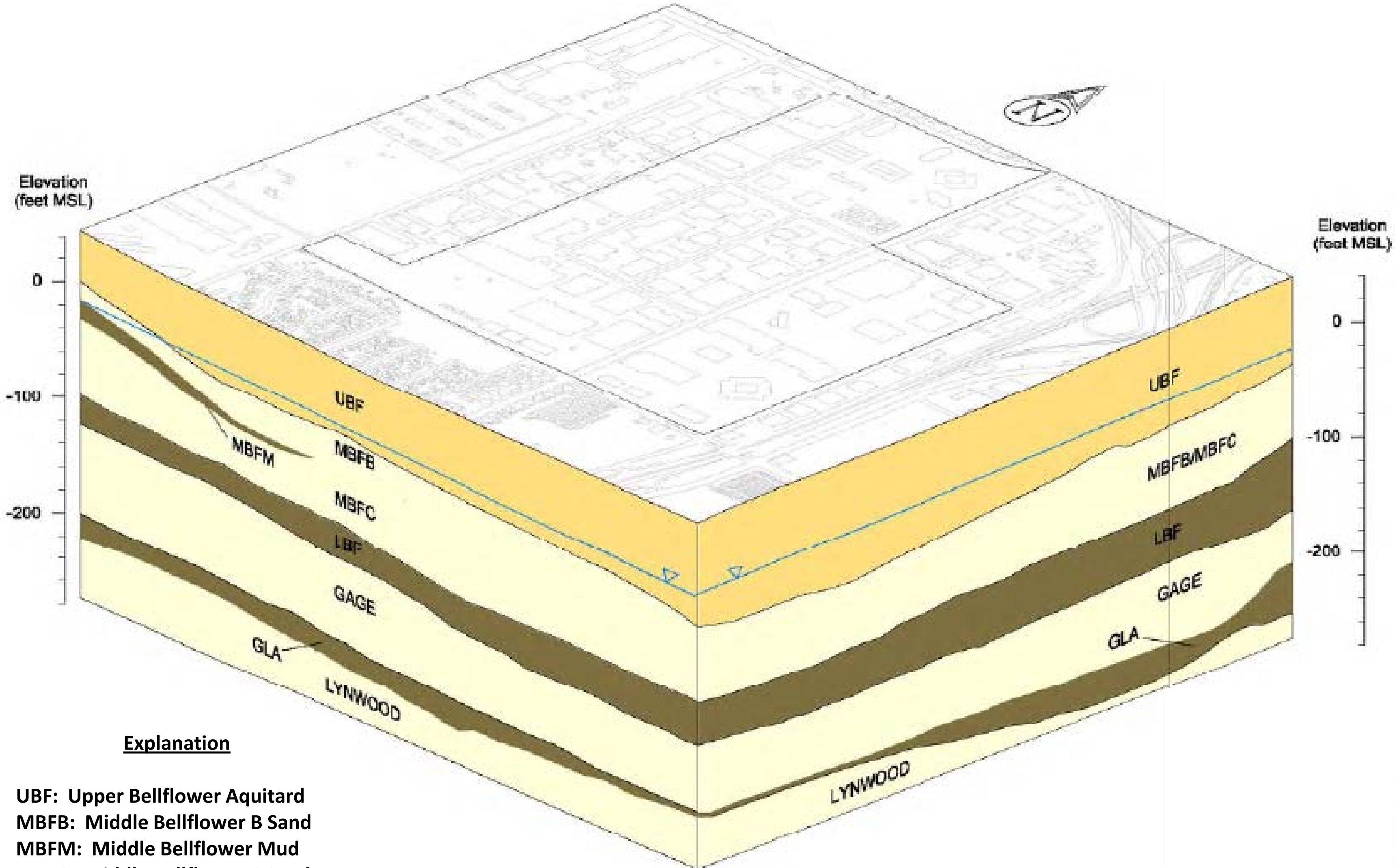
Torrance, California

Figure 4

Areas of Previous Vapor Intrusion Assessments

TETRA TECH

Source: CH2MHILL 2012. Current Status of Vapor Intrusion Assessment, Montrose and Del Amo Superfund Sites, Torrance, California. Original figure prepared by CH2MHILL.



Explanation

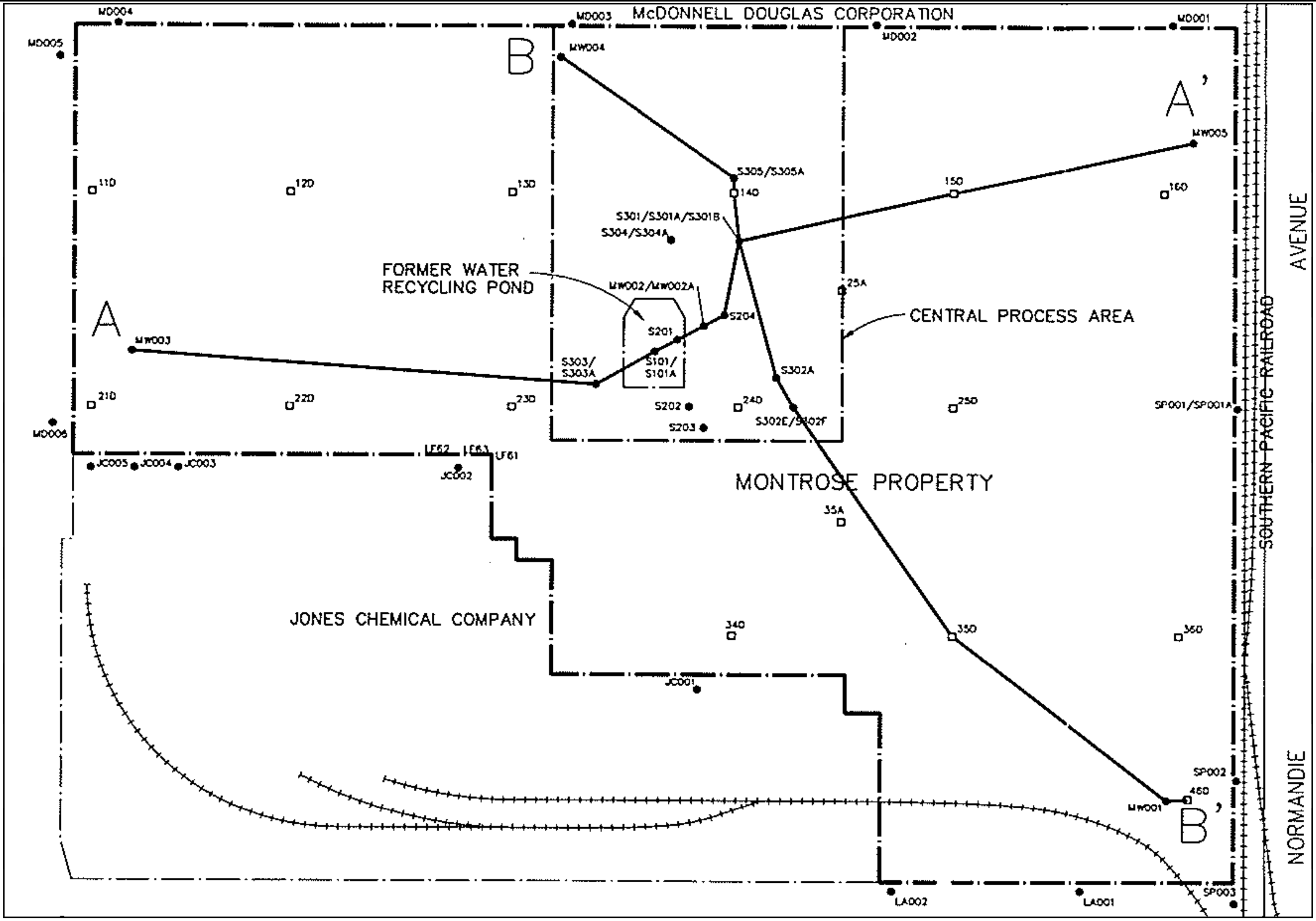
UBF: Upper Bellflower Aquitard
MBFB: Middle Bellflower B Sand
MBFM: Middle Bellflower Mud
MBFC: Middle Bellflower C Sand
LBF: Lower Bellflower Aquitard
Gage: Gage Aquifer
GLA: Gage-Lynwood Aquitard
Lynwood: Lynwood Aquifer

Source: URS 2012. Groundwater Monitoring Report, Dual Site Operable Unit. Original figure prepared by URS Corporation.

Montrose and Del Amo Superfund Sites
Torrance, California

Figure 5
Hydrostratigraphic Block Diagram

TETRA TECH

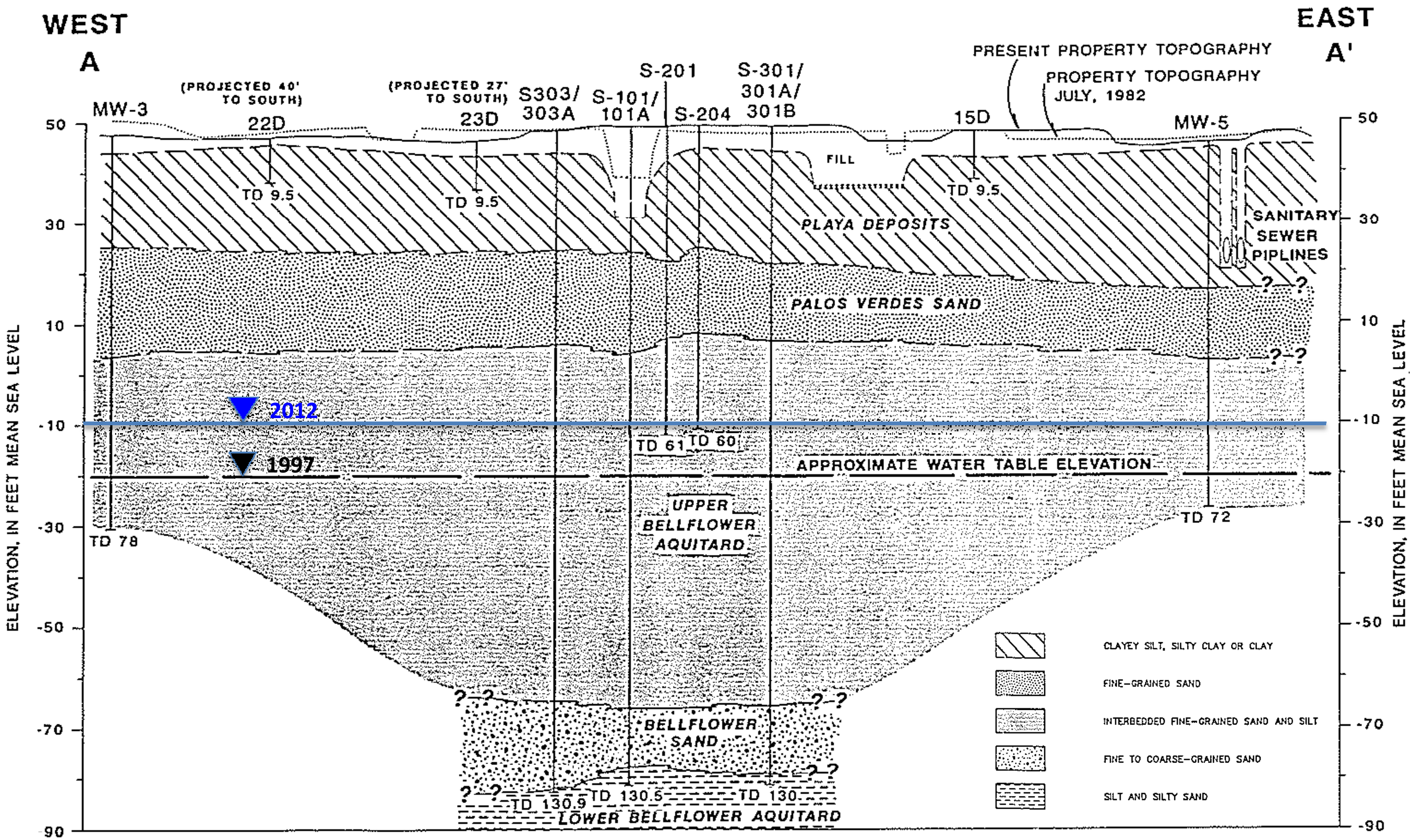


Montrose and Del Amo Superfund Sites
Torrance, California

Figure 6
Location of Cross Section Lines
Montrose Superfund Site

TETRA TECH

Source: Hargis & Associates 1998. Final Remedial Investigation Report for the Montrose Superfund Site, Los Angeles, California.

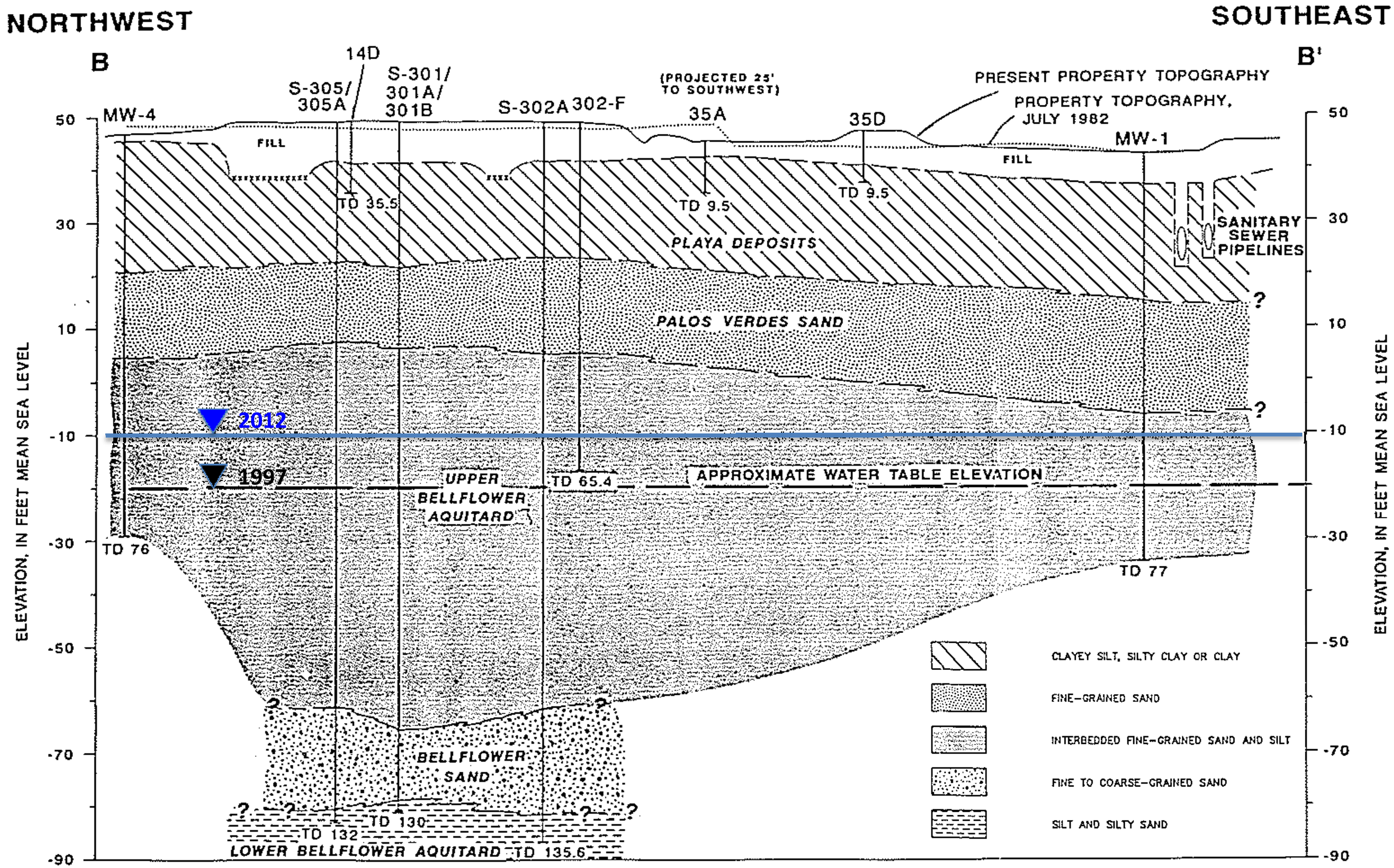


Montrose and Del Amo Superfund Sites
Torrance, California

Figure 7
Cross Section A - A'
Montrose Superfund Site

TETRA TECH

Source: Hargis & Associates 1998. Final Remedial Investigation Report for the Montrose Superfund Site, Los Angeles, California.

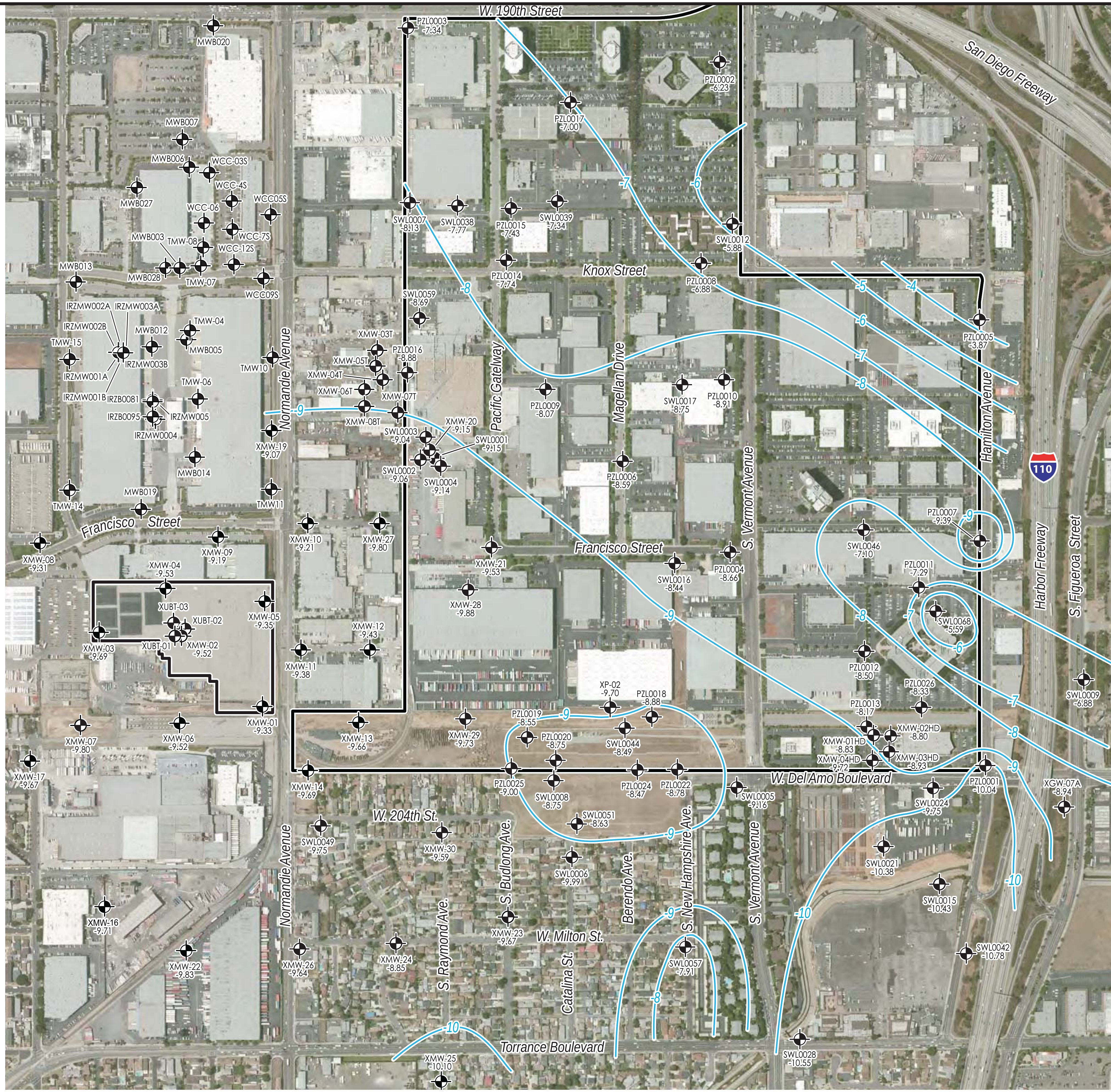


Source: Hargis & Associates 1998. Final Remedial Investigation Report for the Montrose Superfund Site, Los Angeles, California.

Montrose and Del Amo Superfund Sites
Torrance, California

Figure 8
Cross Section B - B'
Montrose Superfund Site

TETRA TECH



N

0 600 1200

Scale in Feet

Legend

Monitoring location with groundwater elevation (feet MSL)

SWL0017
-8.75

Source: URS 2012. Groundwater Monitoring Report, Dual Site Operable Unit. Original figure prepared by URS Corporation.

Montrose and Del Amo Superfund Sites

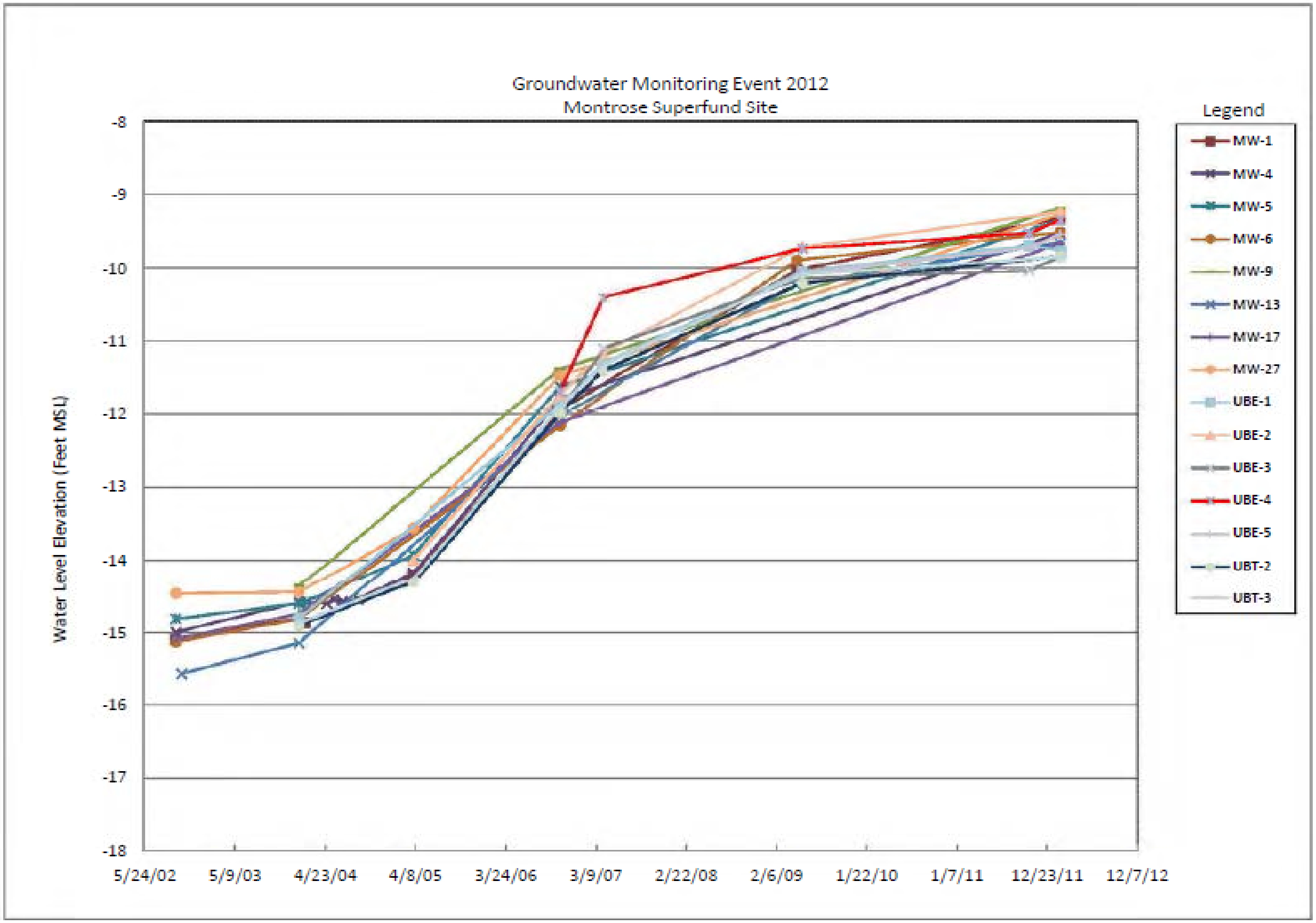
Torrance, California

Figure 9

2012 Groundwater Elevation Map

Upper Bellflower Aquitard

TETRA TECH

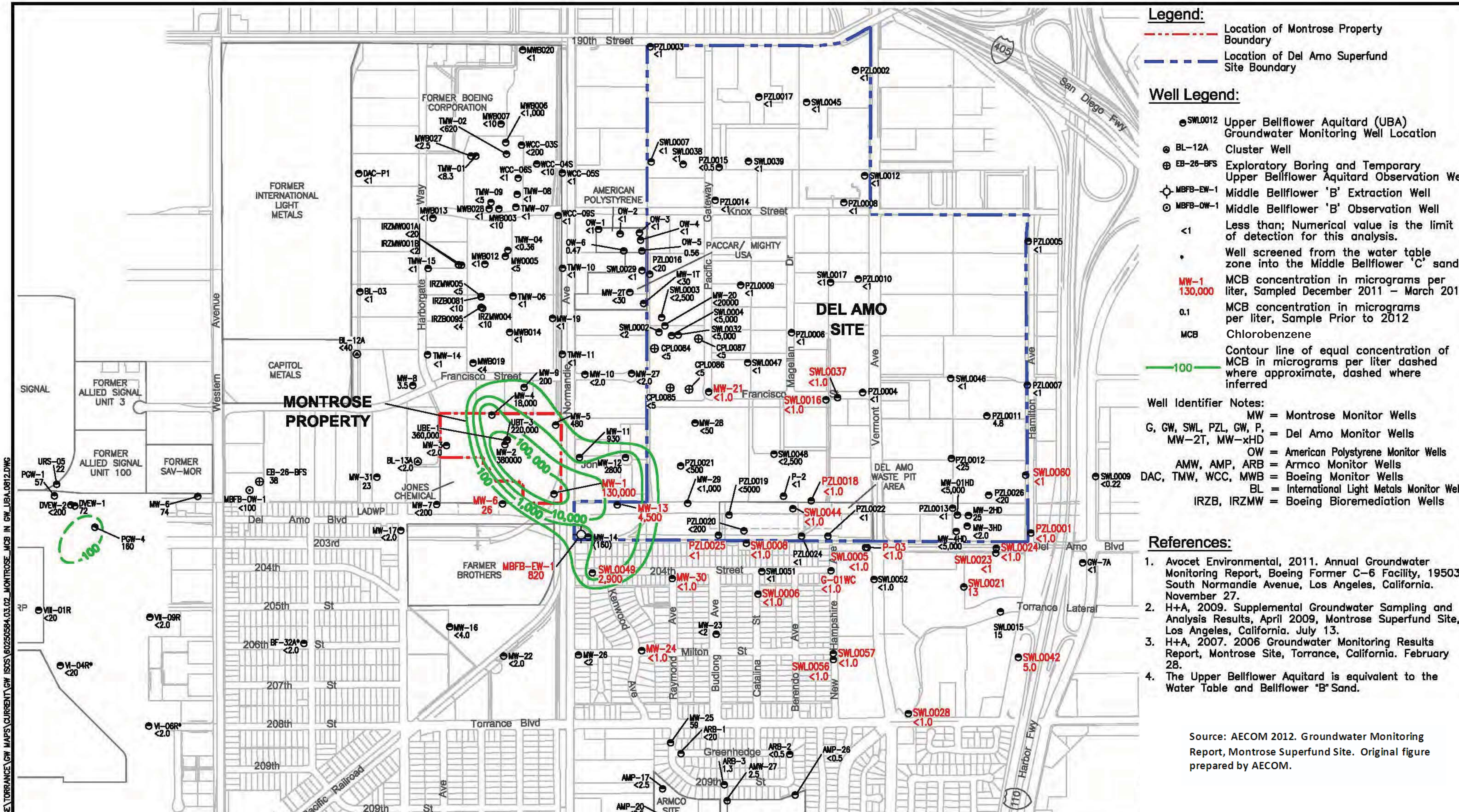


Source: AECOM 2012. Groundwater Monitoring Report, Montrose Superfund Site.

Montrose and Del Amo Superfund Sites
Torrance, California

Figure 10
Upper Bellflower Aquitard
Water Level Hydrographs

TETRA TECH



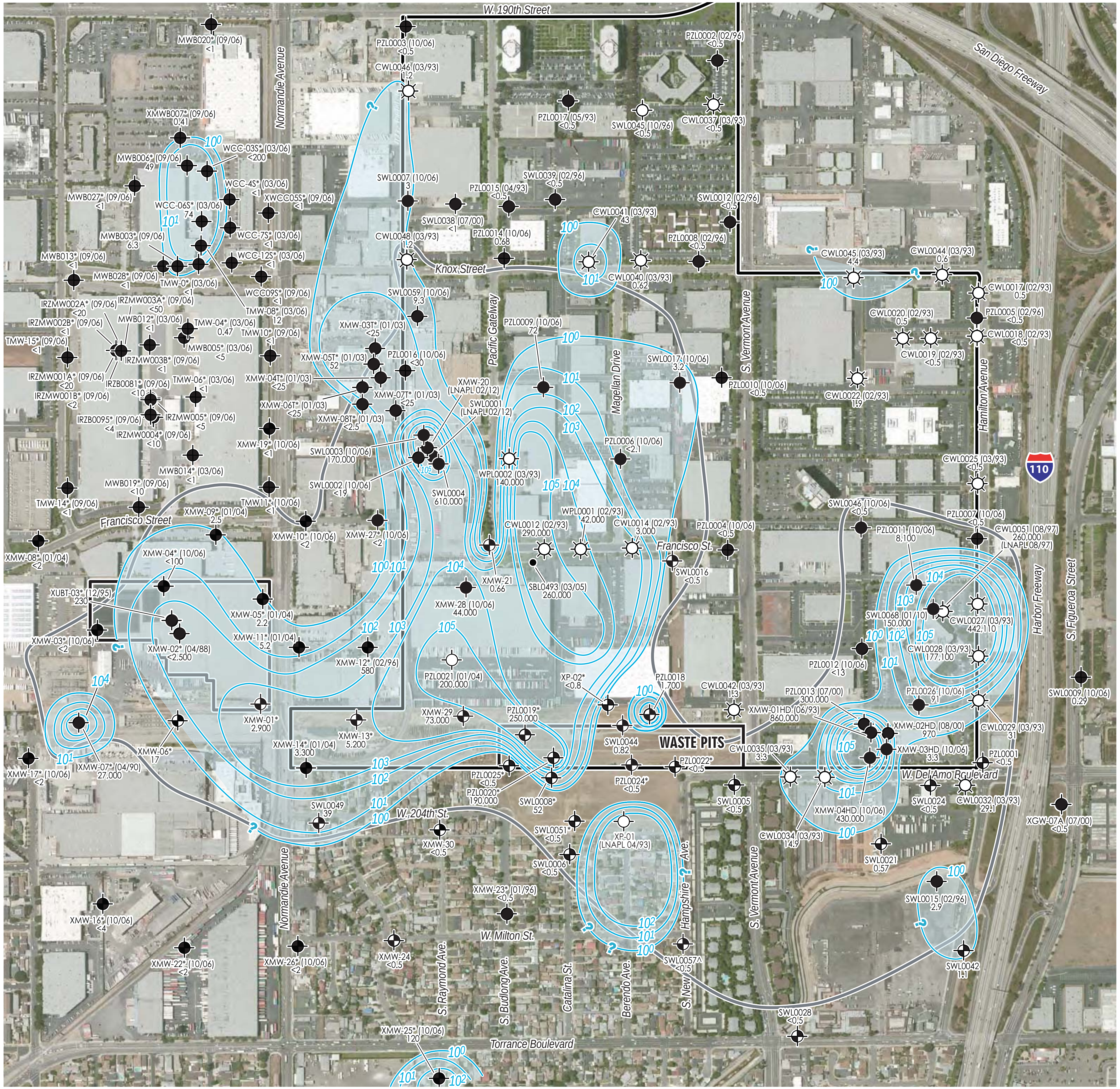
Montrose and Del Amo Superfund Sites

Torrance, California

Figure 11

2012 Dissolved Chlorobenzene Concentrations Upper Bellflower Aquitard

TETRA TECH



N

0 600 1200

Scale in Feet

Legend

SWL0016 <0.5	Monitoring well location with 2012 benzene concentration (µg/l)
PZL0005 (02/96) <0.5	Monitoring well not sampled in 2012 with most recent historical benzene concentration (µg/l) and date
SBL0493 (03/05) 260,000	Hydropunch sampling location with benzene concentration (µg/l) and date
CWL0025 (03/93) <0.5	Temporary well point with historical benzene concentration (µg/l) and date
SWL0045 (10/96) <0.5	Abandoned/destroyed monitoring well with historical benzene concentration (µg/l) and date
(LNAPL 02/12)	Light non-aqueous phase liquid present and date of observation
	Containment zone, as presented in the groundwater ROD (EPA, 1999)
100	Benzene Concentration Isopleth (µg/l)
*	Data collected by other investigators
^	Concentration isopleths in the vicinity of this well are influenced by historical detections

Source: URS 2012. Groundwater Monitoring Report, Dual Site Operable Unit. Original figure prepared by URS Corporation.

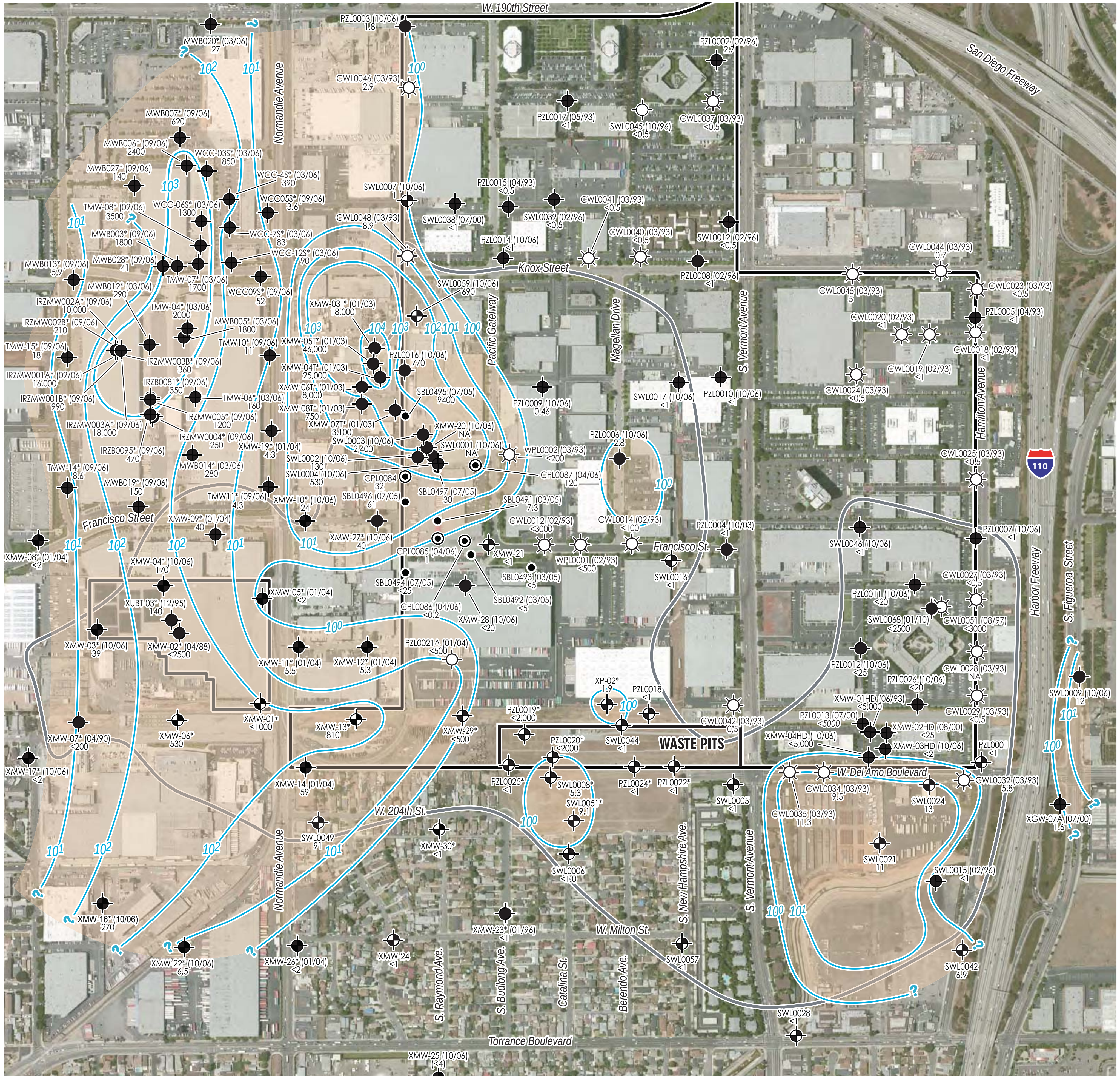
Montrose and Del Amo Superfund Sites

Torrance, California

Figure 12

2012 Dissolved Benzene Concentrations Upper Bellflower Aquitard

TETRA TECH



N

0 600 1200

Scale in Feet

Legend

- Monitoring well location with 2012 TCE concentration (µg/l) (SWL0017 <1)
- Monitoring well not sampled for VOCs in 2012 with most recent historical TCE concentration (µg/l) and date (SWL0015 (02/06) <1)
- Abandoned/destroyed monitoring well with most recent historical TCE concentration (µg/l) and date (PZL0021 (01/04) <500)
- Temporary well point with historical TCE concentration (µg/l) and date (CWL0025 (03/93) <0.5)
- Temporary well location with TCE concentration (µg/l) and date (CPL0085 (04/06) 1)
- Hydropunch sampling location with TCE concentration (µg/l) and date (SBL0496 (07/05) 61)
- Containment zone, as presented in the groundwater ROD (EPA, 1999)
- TCE concentration isopleth (µg/l) (10^1)
- ^ Concentration isopleths in the vicinity of this well are influenced by historical detections
- * Data collected by other investigators

Source: URS 2012. Groundwater Monitoring Report, Dual Site Operable Unit. Original figure prepared by URS Corporation.

Montrose and Del Amo Superfund Sites

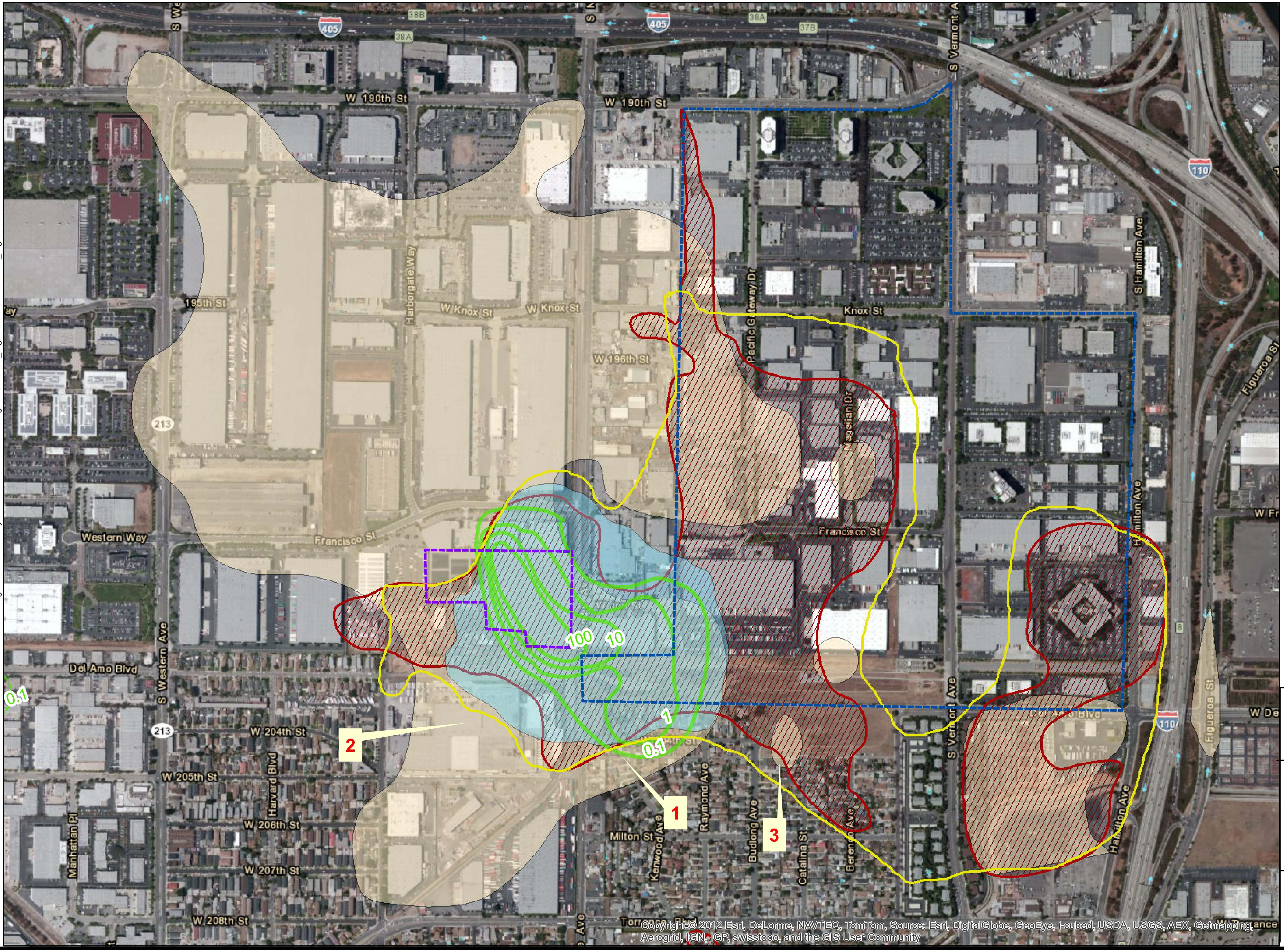
Torrance, California

Figure 13

2012 Dissolved Trichoroethylene Concentrations

Upper Bellflower Aquitard

TETRA TECH



Legend

- Montrose Property
- Del Amo Site
- Containment Zone, as presented in the groundwater ROD (EPA, 1999)
- Contour line of equal concentration of MCB in mg/L dashed where approximate, dashed where inferred
- Schematic Chlorobenzene Plume >0.07 mg/L
- Schematic Benzene Plume > 0.001 mg/L
- Schematic TCE Plume > 0.001 mg/L
- 3 Approximate area recommended for further evaluation

Notes:
0.001 mg/L (milligram per liter) = 1 µg/L (microgram per liter)
TCE= Trichloroethylene

Sources: AECOM 2012; CH2MHILL 2007, 2012; URS 2012.

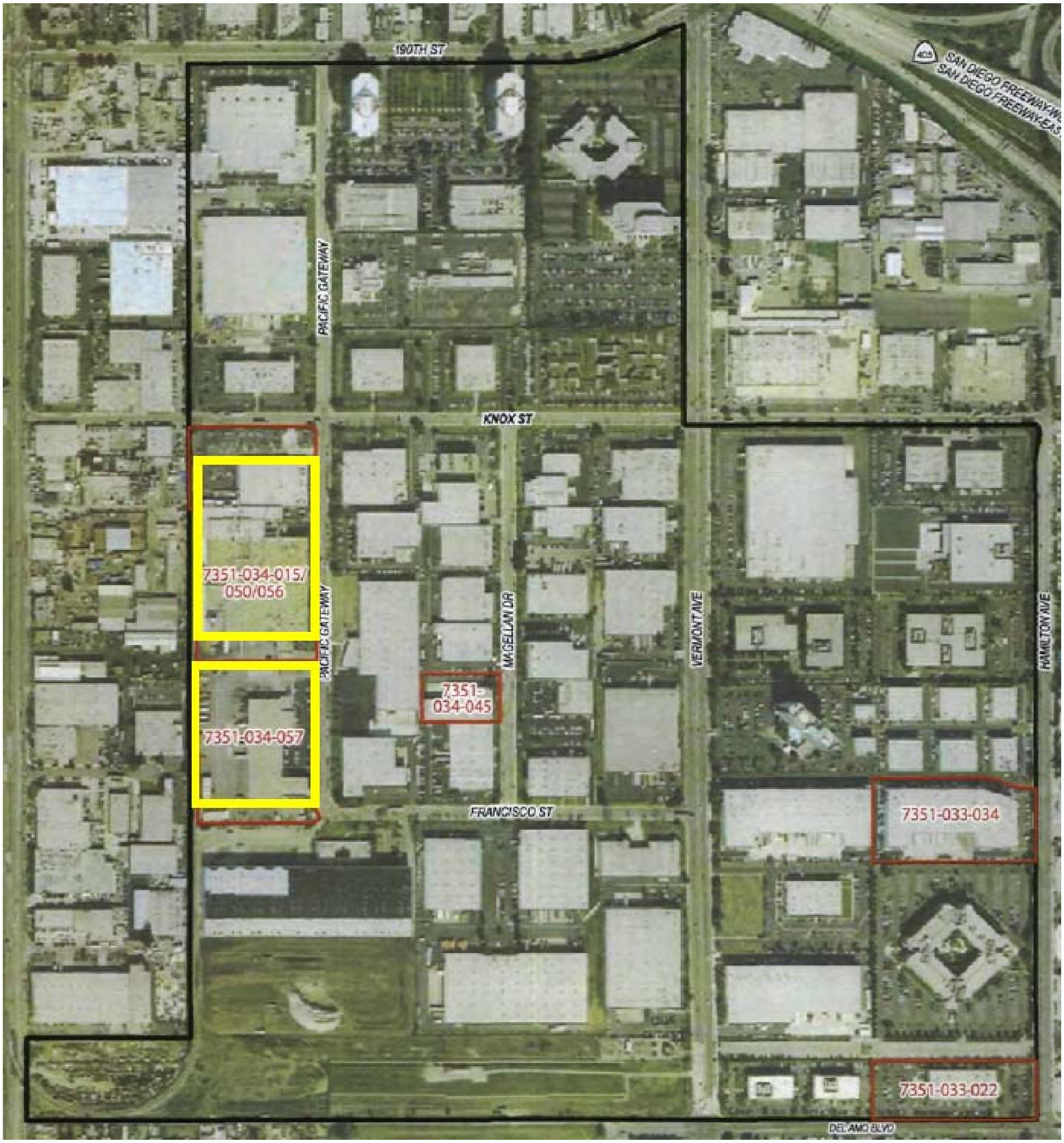
0 375 750 1,500
Feet

Montrose and Del Amo Superfund Sites
Torrance, California

Figure 14
2012 Chlorobenzene, Benzene, and TCE Plumes in Groundwater Upper Bellflower Aquitard (Water Table Zone)

TETRA TECH

Path: C:\Documents and Settings\Karen.Black\My Documents\ArcGIS\Packages\Montrose_Figure14v10\Montrose_Figure14.mxd
User: Karen.Black
Date: 9/24/2013



Source: URS 2009. Subslab Soil Vapor Sampling Results, Del Amo Superfund Site, Los Angeles, California

Montrose and Del Amo Superfund Sites
Torrance, California

Figure 15
2009 Subslab Soil Vapor Sampling
Del Amo Superfund Site

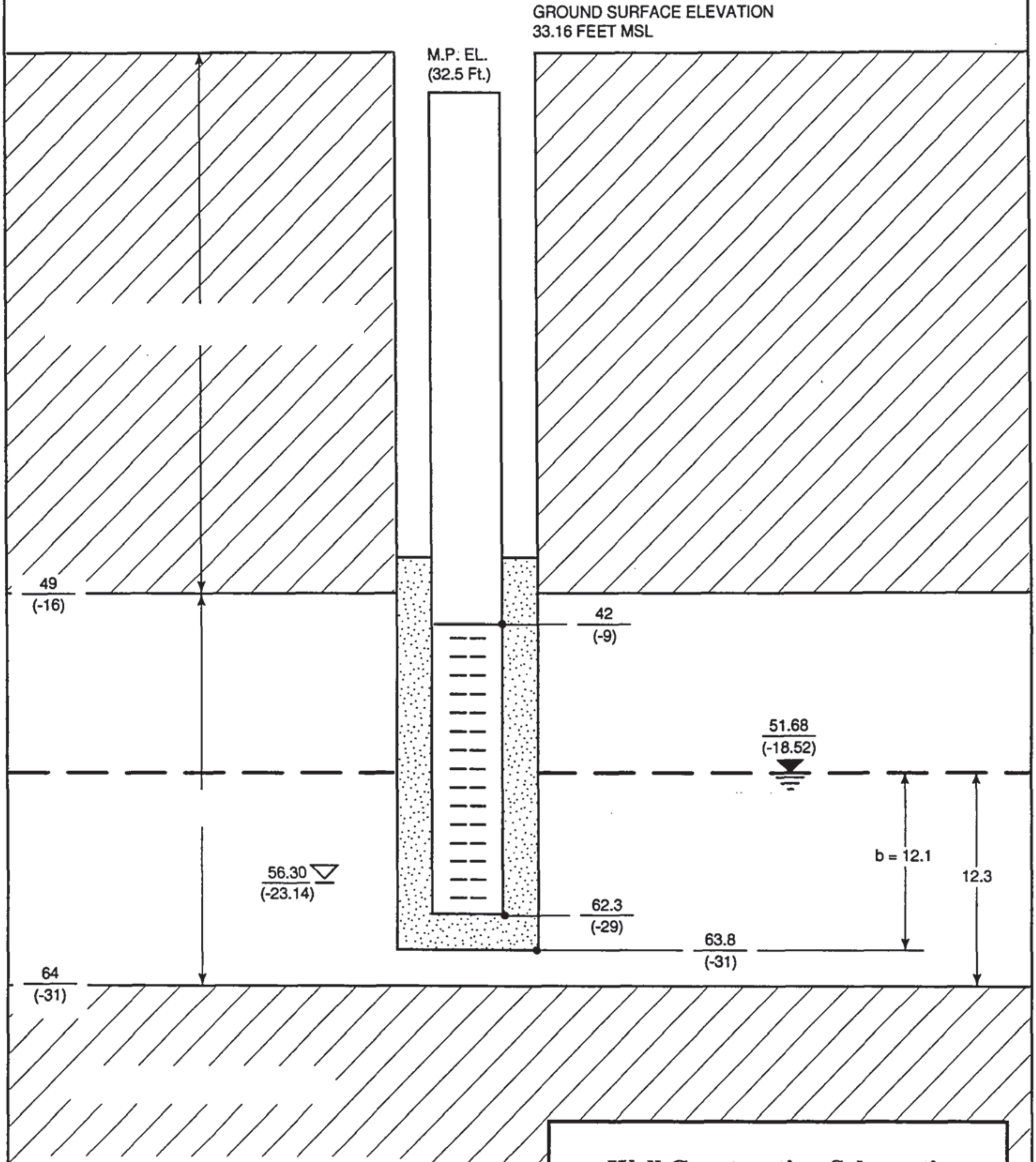
TETRA TECH

ATTACHMENT 1

WELL CONSTRUCTION DETAILS AND BORING LOG OF WELL SWL0049

896/099/B

WELL SWL0049



Explanation:

51.68 / (-18.52)	Depth Below Ground Surface in Feet / Elevation in Feet MSL (Mean Sea Level)
▼	Static Water Level Immediately Prior to Start of Aquifer Test
▽	Final Pumping Water Level
b = 12.1	Aquifer Thickness (feet) used for Calculation of Hydraulic Conductivity

Well Construction Schematic for Well SWL0049

Groundwater Remedial Investigation Report
Del Amo Study Area

DAMES & MOORE

Location: 204th St. Near Normandie	Site Id: SBL0104
Land Surface Elevation: 32.48' Mean Sea Level	Northing: 56197 Easting: 197538
Date(s) Drilled: 09/05/95 - 09/06/95	Drilling Contractor: All Terrain
Drilling/Sampling Method: Mud Rotary/94mm continuous core sampler	Site-Wide Cross Section Reference: None
Remarks: 0-6', hand augered 6-132', continuously cored Colocated with Water Table MBFB well SWL0049	Logged By: Mat Kelliher Checked By: Gib Fates RG# 6321 Total Depth of Borehole: 132.0'

Elevation (ft)	Depth (ft)	Recovery	PID (ppm)	Graphic Log	Material Description
					DARK OLIVE GRAY 5Y 3/2 SILTY GRAVEL (Fill) with little SAND and trace CLAY, loose, dry, disturbed, 50, 15, 30, 5.
30					
					5'-5.25', grades to VERY DARK GRAYISH BROWN 2.5Y 3/2 SILTY Very Fine SAND (SM), with trace fine GRAVEL, dense, dry, disturbed, 10, 60, 30, 0.
			4.3		Contains 1mm weathered BLACK specks, 5% of matrix, GRAVEL decreases, 0, 70, 30, 0.
			1.4		
	10		0		10'-10.1', root structures.
			4.3		
20					SAND increases to 0, 80, 20, 0.
			4.3		
					16.3'-17.3', oxidized burrows.
					17.5', sharp contact: OLIVE BROWN 2.5Y 4/4 Fine SAND (SP) with trace SILT, dense, moist, massive, 0, 95, 5, 0.
			4.3		
					18.75', 1" lens of BROWN 10YR 4/3 SILT (ML) with trace CLAY, stiff, moist, massive, 0, 0, 90, 10.
					18.9', horizontal laminations and stratifications.
	20				19.5'-19.75', Fine to Medium SAND.
					21.1' becomes Medium SAND, color change to LIGHT OLIVE BROWN 2.5Y 5/3, cross-stratified.
10					22.4'-22.8', Fine SAND,
					22.8'-23.35', Medium SAND.
					23.35'-24.9', Fine SAND.
			4.3		
					24.9', sharp contact: OLIVE BROWN 2.5Y 4/3 SILTY SAND (SM) with trace CLAY, dense, moist, oxidized burrows,

DAMES & MOORE

Location: 204th St. Near Normandie	Site Id: **SBL0104**
Land Surface Elevation: 32.48' Mean Sea Level	Northing: 56197 Easting: 197538
Date(s) Drilled: 09/05/95 - 09/06/95	Drilling Contractor: All Terrain
Drilling/Sampling Method: Mud Rotary/94mm continuous core sampler	Site-Wide Cross Section Reference: None
Remarks: 0-6', hand augered 6-132', continuously cored Colocated with Water Table MBFB well SWL0049	Logged By: Mat Kelliher Checked By: Gib Fates RG# 6321 Total Depth of Borehole: 132.0'

Elevation (ft)	Depth (ft)	Recovery	PID (ppm)	Graphic Log	Material Description
					0, 50, 45, 5. 25.5'–25.75', Very Fine SAND lens with micaceous minerals, 30% of matrix.
					27.5', sharp contact: PALE OLIVE 5Y 6/3 Very Fine SAND (SP) with trace SILT, medium dense, moist, oxidized burrows, 0, 95, 5, 0.
					29.3'–29.8', deeply oxidized.
	30		4.3		
					31.2'–34.2', oxidized burrows.
0					
					33.3'–33.7', indistinct horizontal laminations.
			4.3		34.6' color change to LIGHT OLIVE BROWN 2.5Y 5/6.
					36.5'–36.75', Fine to Medium SAND, mafic minerals 40% of matrix. 36.8'–36.95', partially cemented. 36.95', sharp contact: OLIVE BROWN 2.5Y 4/4 SILT (ML) with some Very Fine SAND, stiff, moist, massive, 0, 20, 80, 0. 37.35', sharp contact: LIGHT OLIVE BROWN 2.5Y 5/4 Very Fine SAND (SM) with little SILT, medium dense, moist, horizontal laminations, 0, 85, 15, 0. 37.6', 1" SILT lens. 38.5', sharp contact: LIGHT OLIVE GRAY 5Y 6/2 SILT (ML) with little Very Fine SAND, medium stiff, moist, oxidized burrows, 0, 15, 85, 0. 39.4', sharp contact: OLIVE 5Y 5/3 Very Fine SILTY SAND (SM), medium dense, moist, massive, 0, 70, 30, 0.
	40		2.8		41.1', 1" Very Fine SAND lens, 41.2', 1" SILT lens.
–10					41.8', sharp contact: OLIVE 5Y 4/4 Fine SAND (SP) with trace SILT, dense, moist, massive, micaceous minerals 20% of matrix, 0, 95, 5, 0.
					43.4', grades to: OLIVE 5Y 4/4 Very Fine SILTY SAND (SM), dense, moist, massive.
			1.4		
					45.1', sharp contact: OLIVE 5Y 4/3 Very Fine SAND (SP) with trace SILT, medium dense, moist, mafic minerals 70% of matrix, local 1" SILT lenses, 0, 95, 5, 0. 46.1', sharp contact: OLIVE 5Y 4/3 SILTY Very Fine SAND (SM), dense, moist, oxidized burrows, lenses of Very Fine SAND, mafic minerals 75% of matrix, 0, 70, 30, 0.
					49.2', sharp contact: OLIVE 5Y 4/3 Fine SAND (SP), medium dense, moist, indistinct horizontal laminations, mafic minerals 65% of matrix, 0, 100, 0, 0.

DAMES & MOORE

Location: 204th St. Near Normandie	Site Id: SBL0104
Land Surface Elevation: 32.48' Mean Sea Level	Northing: 56197 Easting: 197538
Date(s) Drilled: 09/05/95 - 09/06/95	Drilling Contractor: All Terrain
Drilling/Sampling Method: Mud Rotary/94mm continuous core sampler	Site-Wide Cross Section Reference: None
Remarks: 0-6', hand augered 6-132', continuously cored Colocated with Water Table MBFB well SWL0049	Logged By: Mat Kelliher Checked By: Gib Fates RG# 6321 Total Depth of Borehole: 132.0'

Elevation (ft)	Depth (ft)	Recovery	PID (ppm)	Graphic Log	Material Description
			2.8		50.1'-50.6, cross-laminations. 50.9', 1" SILT lens. 51', Fine to Medium SAND 51.3'-52.6', horizontal and cross-laminations.
-20					52', 1/2" SILT lens. 52.65'-52.85', SANDY SILT lens.
			2.8		54'-56.4', horizontal laminations, local cross-laminations
					57.6'-58', Fine to Medium SAND.
			2.8		58'-63', Medium SAND, wet, 58.1'-58.4', Very Fine SILTY SAND lens. 58.7'-59', Very Fine SILTY SAND lens with 1/2" seams of SILT. 59'-59.4', indistinct horizontal laminations.
	60				
-30					
			5.7		Inferred contact: LIGHT OLIVE BROWN 2.5Y 5/3 SILTY Very Fine to Fine SAND (SM), dense, moist, oxidized burrows, 0, 55, 45, 0.
					66.1', Very Fine SAND increases, 0, 85, 15, 0. 66.8'-69', interlayered SAND and SILT seams, local deeply oxidized burrows.
	70		14		69'-69.4', grades to LIGHT OLIVE GRAY 5Y 6/2 SILT (ML) with little Very Fine SAND, stiff, moist, local oxidized burrows, 0, 15, 85, 0.
-40					
			28		72.75'-73.15', grades to: OLIVE GRAY 5Y 5/2 Very Fine SAND (SM) with little SILT, dense, moist, local deeply oxidized burrows, 0, 80, 20, 0. 74.5', color change: OLIVE BROWN 2.5Y 4/4.

DAMES & MOORE

Location: 204th St. Near Normandie	Site Id: **SBL0104**
Land Surface Elevation: 32.48' Mean Sea Level	Northing: 56197 Easting: 197538
Date(s) Drilled: 09/05/95 - 09/06/95	Drilling Contractor: All Terrain
Drilling/Sampling Method: Mud Rotary/94mm continuous core sampler	Site-Wide Cross Section Reference: None
Remarks: 0-6', hand augered 6-132', continuously cored Colocated with Water Table MBFB well SWL0049	Logged By: Mat Kelliher Checked By: Gib Fates RG# 6321 Total Depth of Borehole: 132.0'

Elevation (ft)	Depth (ft)	Recovery	PID (ppm)	Graphic Log	Material Description
					75.35', sharp contact: LIGHT OLIVE BROWN 2.5Y 5/6 Fine to Medium SAND (SP) with trace SILT, medium dense, wet, massive, mafic minerals 10% of matrix, very fine-grained.
			7.2		78.7', indistinct horizontal laminations.
	80				
-50					
					84.5', sharp contact: LIGHT OLIVE BROWN 2.5Y 5/6 Very Fine to Fine SAND (SM) with some SILT, medium dense, moist, massive, local oxidized burrows, 0, 75, 25, 0. 86', color change: LIGHT OLIVE GRAY 5Y 6/2.
					87.1'-87.3' grades to OLIVE GRAY 5Y 5/2 SILT (ML) with little Very Fine to Fine SAND, stiff, moist, local oxidized burrows, 0, 15, 85, 0. 87.7'-87.8', color grades to DARK GRAY 2.5Y N4/0.
					88.2', sharp contact: DARK GRAY 2.5Y N4/0, Very Fine SILTY SAND (SM), dense, moist, massive, 0, 70, 30, 0. 89', color change: DARK GREENISH GRAY 5GY 4/1, local oxidized burrows.
	90		15		
-60					92.4' local oxidized burrows. 92.8', color change: OLIVE BROWN 2.5Y 4/4.
			86		93.7'-94' grades to LIGHT OLIVE BROWN 2,5Y 5/4 Very Fine SAND (SP) with trace SILT, medium dense, moist, local horizontal lenses of OLIVE GRAY 5Y 5/2, Very Fine SAND, 0, 95, 5, 0. 95.9'-96.6', 1/4" shell fragments, 10% of matrix.
					96.6'-96.7' partially cemented Fine GRAVEL-size concretions.
					97.25'-98.3', Fine GRAVEL-sized shell fragments 40% of matrix.
			21		98.35', Medium SAND, trace Coarse SAND-size concretions.
					99.5'-99.6', partially cemented.

DAMES & MOORE

Location: 204th St. Near Normandie	Site Id: **SBL0104**
Land Surface Elevation: 32.48' Mean Sea Level	Northing: 56197 Easting: 197538
Date(s) Drilled: 09/05/95 - 09/06/95	Drilling Contractor: All Terrain
Drilling/Sampling Method: Mud Rotary/94mm continuous core sampler	Site-Wide Cross Section Reference: None
Remarks: 0-6', hand augered 6-132', continuously cored Colocated with Water Table MBFB well SWL0049	Logged By: Mat Kelliher Checked By: Gib Fates RG# 6321 Total Depth of Borehole: 132.0'

Elevation (ft)	Depth (ft)	Recovery	PID (ppm)	Graphic Log	Material Description
			7.2		100.7'-101', partially cemented.
					101.2'-102.7', Fine GRAVEL-size shell fragments and concretions 30% of matrix.
-70					
					102.7', sharp contact: OLIVE 5Y 5/3 SILTY Very Fine to Fine SAND (SM), medium dense, moist, massive, trace shell fragments, local oxidized burrows, 0, 70, 30, 0.
			230		
					105.3'-107.4', local oxidized burrows, SILT decreases, Very Fine to Fine SAND with little SILT, 0, 85, 15, 0.
	110		308		109.5'-113.8', local oxidized burrows.
					111.1'-113.4' SILT increases, SILTY Very Fine SAND, 0, 65, 35, 0, local oxidized burrows.
-80					
			195		113.8'-114.8' grades to DARK YELLOWISH BROWN 10YR 4/6 Very Fine to Fine SAND (SP) with trace SILT , dense, moist, massive, 0, 95, 5, 0. 114'-114.6', local oxidized burrows.
					117.6'-117.9',grades to OLIVE 5Y 4/4 Very Fine SANDY SILT (ML), medium stiff, moist, massive, local 1/4" seams of Very Fine SAND, 0, 30, 70, 0.
					118.85', sharp contact: OLIVE GRAY 5Y 4/2 SILTY Very Fine to Fine SAND (SM), medium dense, moist, local oxidized voids and burrows, 0, 70, 30, 0.
	120		1.4		119.5', sharp contact: OLIVE 5Y 5/3 Fine SAND (SP), medium dense, moist, horizontal and cross-laminations, mafic minerals 30% of matrix, 0, 100, 0, 0. 120.5'-121.2', Medium SAND. 121.7'-122.2', Fine to Medium SAND. 122.2, local oxidized burrows.
-90					122.4'-122.6', SILTY SAND lens.
			96		124.45', sharp contact: OLIVE GRAY 5Y 5/2 SILT (ML) with little Very Fine SAND, stiff, moist, massive, 0, 10, 90, 0.

DAMES & MOORE

Location: 204th St. Near Normandie	Site Id: **SBL0104**
Land Surface Elevation: 32.48' Mean Sea Level	Northing: 56197 Easting: 197538
Date(s) Drilled: 09/05/95 - 09/06/95	Drilling Contractor: All Terrain
Drilling/Sampling Method: Mud Rotary/94mm continuous core sampler	Site-Wide Cross Section Reference: None
Remarks: 0-6', hand augered 6-132', continuously cored Colocated with Water Table MBFB well SWL0049	Logged By: Mat Kelliher Checked By: Gib Fates RG# 6321 Total Depth of Borehole: 132.0'

Elevation (ft)	Depth (ft)	Recovery	PID (ppm)	Graphic Log	Material Description
					125.3', color change: DARK GRAY 2.5Y N4/0.
					126.1', 1" SILTY SAND lens.
					127.7'-128.2', shell fragments 15% of matrix.
					128.25'-128.7' grades to DARK GREENISH GRAY 5G 4/1 Very Fine to Fine SAND (SP), medium dense, moist, massive, 0, 100, 0 ,0. 128.9'-129.2', Medium SAND.
	130		1.4		129.8'-130.1', grades to DARK GREENISH GRAY 5G 4/1 SILT (ML) with little Very Fine to Fine SAND, stiff, moist, massive, 0, 85, 15, 0. 130.9', SANDY SILT, 0, 30, 70, 0. Inferred contact: DARK GREENISH GRAY 5G 4/1 Fine SAND (SP), dense, moist, massive, 0, 100, 0, 0. Boring completed to 132' below ground surface on 9/6/95.
-100					Backfilled from total depth to ground surface with volclay grout.
	140				
-110					

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