6.0 CONTAMINANT FATE AND MOBILITY

Presented in this section is a discussion of the mobility and attenuation of groundwater contaminants in their dissolved and non-aqueous phases. Mobility and attenuation mechanisms have been thoroughly investigated and evaluated at the Del Amo site using the extensive time-series database of groundwater analytical data, as well as historical, soil and soil vapor data compiled over the past 10 years. The conclusion of this investigation is that mobility and attenuation mechanisms are balanced, and the distribution of the dissolved phase benzene plumes in each HSU has stabilized. Current research indicates that dissolved contaminant plumes (particularly plumes of dissolved aromatic hydrocarbon contaminants) can reach a quasi-steady state condition where the plume does not continue to expand, and may retreat over time (Rifai et al., 1995). Stability of aromatic hydrocarbon plumes at other sites has been attributed to the balance between four major processes: (1) release of dissolved contaminants from a source; (2) transport of dissolved phase contaminants; (3) abiotic and biologically mediated transformations of contaminants and, (4) volatilization of contaminants (API Publication 1628, 1996; Rifai et al., 1995; McAllister and Chiang, 1994).

Groundwater contamination in at least some locations has been present beneath the study area since near the beginning of facility operation[1]. Site-specific evidence indicates that dissolved contaminant transport and attenuation processes have become balanced over the past forty years. The balance between these processes results in the current distribution of contaminants. Following published methods and protocols for evaluating dissolved phase plume behavior, site-specific data are presented below to develop the lines of evidence that have brought us to the conclusion that the benzene plume is stable in each HSU. Furthermore, the preponderance of the evidence indicates that intrinsic biodegradation is the dominant attenuative mechanism contributing to plume stability. The reader should be aware that there may be alternative interpretations of any single line of evidence presented below. To the extent that there is uncertainty associated with a line of evidence, the uncertainty is discussed, and examples of alternative interpretations are provided for consideration. Many alternative interpretations of the data were considered during data analysis. Many of these interpretations were explored during the regional groundwater modeling effort performed as part of the Montrose and Del Amo Joint Groundwater Feasibility Study (sensitivity analyses, historical plume matching,

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[1] Sources of groundwater contamination at Del Amo are probably attributal to operations through the active life of the facility. Some of the earliest contamination may be attributed to the small pits in the western portion of the Waste Pit Area (located along the southern boundary of the former plant) received liquid waste from the mid-1940s until they were covered in 1951.

calibration, etc.). The conclusions presented in the Section are consistent with the findings of the regional groundwater modeling effort and are the most compelling interpretation of the data set when considered as a whole.

The following sections are structured to guide the reader through the exhaustive database used to evaluate contaminant fate and mobility. We begin with a brief description of the processes involved in the transport and attenuation of contaminants, including solubility, advection, dispersion, retardation and degradation. To prevent confusion with nomenclature, the terms "attenuative mechanisms" and "attenuative processes" are adopted to describe the family of processes which inhibit migration of contaminants. The term "attenuation" is preserved to describe the specific processes of intrinsic biological degradation of dissolved contaminants. The following section, 6.2, then relates these processes to the site as they apply to benzene, using site-specific data. The ensuing discussion draws upon published protocol for evaluating the occurrence of biodegradation, and provides the basis for the conclusion that biodegradation plays a significant role in inhibiting and ultimately balancing dissolved phase contaminant transport.

Presented in Section 6.3 are the time-series groundwater data, and a discussion of plume morphology. Again, following published protocol, the time-series data are interpreted to evaluate contaminant plume migration in each HSU. These data provide the basis for the conclusion that the contaminant plumes in each HSU have stabilized, indicating a balance between transport and attenuative mechanisms.

Section 6.4 includes a discussion of the fate and mobility of LNAPLs, and makes extensive use of the previously published work in the MW-20 LNAPL source area. Finally, the discussion of conclusions presented in Section 6.5 synthesizes the multiple lines of evidence, as presented in the preceding sections, to support the most compelling conclusion that the benzene plume is stable.

The general description of fate and mobility concepts presented below is followed by site-specific discussion of these processes as they apply specifically to benzene.

6.1 OVERVIEW OF MOBILITY AND ATTENUATION MECHANISMS

Mobility of groundwater contaminants is a function of solubility, advective and dispersive flow, diffusion, retardation, and degradation (biotic and abiotic). Solubility limits the amount of

contaminant mass which can enter the groundwater system, while flow and diffusion contribute to contaminant movement, and retardation and degradation limit contaminant movement. Of these processes, volatilization is not considered to be a significant attenuation factor in the lower HSUs and where the unsaturated zone comprises fine grained, low transmissivity soils (Rifai et al., 1995; McAllister and Chiang, 1994, Chiang et al., 1989). Therefore, volatilization is not discussed below.

6.1.1 Solubility

Solubility of a contaminant in groundwater is a function of the physio-chemical characteristics of the source material and the groundwater. Each compound has a maximum aqueous solubility that can be experimentally determined through laboratory partitioning experiments using a pure phase of the compound. The solubility of a VOC is influenced by the presence of other chemicals, particularly other organic compounds. In general, when multiple compounds are present in a source material, the solubility of each compound is reduced from its maximum solubility as a function of its mole fraction in the source material (Roult's or Henry's Law). For example, pure benzene has a solubility of 1,780 μg/L; however, the solubility of benzene in a plume from a gasoline source is approximately 3 to 20 μg/L based on the mole fraction of benzene in the gasoline.

6.1.2 Advective Transport

Dissolved contaminant transport is controlled principally by advective flow and dispersion[2]. Advective transport is the portion of contaminant migration attributable directly to the flow of groundwater, and is equal to the average groundwater flow velocity. Average flow velocities for identified hydrostratigraphic units at the Del Amo site are presented and discussed in Section 6.2.2.

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[2] Contaminants also migrate by diffusion. However, the diffusive transport mechanism has negligible contribution relative to advective and dispersive transport under flow conditions observed at the site, and therefore is not discussed.

6.1.3 Dispersion

Dispersion describes the mixing of contaminated and uncontaminated water in porous media due to particle flow tortuosity. That is, contaminant particles will move through an aquifer at unequal rates and along paths that are deflected away from the bulk advective flow direction as they navigate through pores and around soil particles of various sizes. As contaminant particles are deflected from the principal groundwater flow direction, they will tend to move longitudinally with groundwater flow (ahead of, and behind the bulk flow field) and transversely (horizontally and vertically perpendicular to groundwater flow). The result of this dispersion is that contaminant plumes spread out three-dimensionally and concentrations within the plume become diluted.

Gelhar et al., (1992) report that dispersivity (the measure of dispersion) is highly dependent on the scale or distance over which flow is being examined. The range of longitudinal dispersivities reported by Gelhar et al. (1992), from 10^{-2} to 10^{4} meters (0.03 to 32,800 feet), is based on scales ranging from 10^{-1} to 10^{5} meters (1/3 to 300,000 feet). However, reliable data are only available for scales up to 250 meters (820 feet). This study indicates that an appropriate longitudinal dispersivity value should be approximately one-tenth (0.1) of the scale of interest. For example, when evaluating particle transport on the scale of 100 feet, approximately 10 feet of that transport distance can be attributable to longitudinal dispersion. The same data set indicates that horizontal transverse dispersivity ranges from about one-third to one-tenth of longitudinal dispersivity, and vertical transverse dispersivity is approximately two orders of magnitude less than longitudinal dispersivity (Gelhar et al., 1992).

6.1.4 Retardation

Retardation is a process which describes the tendency for dissolved organic contaminant molecules to be removed from solution and become adsorbed to solid soil particles within the aquifer. For most soils, adsorption is dominated by sorption to the organic carbon fraction of the soil matrix. Where the fraction of organic carbon in the aquifer is less than 0.1 percent by weight, sorption to mineral surfaces may be the dominant process. However, for the purpose of the following discussion, retardation is discussed as a function of organic carbon only. Consequently, retardation estimates appearing below should be considered as conservative, lower bound estimates.

Retardation of a dissolved contaminant is a function of that compound's affinity for organic carbon and the amount of organic carbon in the aquifer. In saturated flow conditions, the reduction in the transport velocity of dissolved organic molecules due to retardation can be related to groundwater flow velocity by the following relationship:

$$v_c = v_x / [1+(P_b/\theta)(K_d)]$$

where:

v_c = average solute velocity (units)
v_x = average linear groundwater velocity (units)
P_b = dry soil bulk density (units)
K_d = soil-water partitioning coefficient [K_d=(K_{oc})(%organic carbon in soil/100)]
θ = effective porosity

As shown by this equation, the contaminant transport velocity is dependent on K_d, which is assumed to be a function of the percentage or fraction of organic carbon in the aquifer sediments (f_{oc}) and the soil-water partitioning coefficient (K_{oc}). For the reason discussed above, this correlation may underestimate K_d for soils with less than 0.1 percent organic carbon.

The retardation of groundwater contaminants can be estimated using site-specific f_{oc} data and published K_{oc} values for the major compounds of interest. K_{oc} values are summarized in the following table. Although not listed, p-CBSA has the lowest K_{oc} and thus, is the least retarded of the contaminants. Due to its low retardation it may be used as a conservative tracer for contaminant migration. Compounds characterized as conservative are those that are not significantly retarded, do not decay significantly, and migrate at rates close to the groundwater flow velocity.

Compound	K_{oc}*	Relative Mobility
Benzene	83**	Higher
Trichloroethene	152	
1,1-Dichloroethene	217	
Toluene	242	
Tetrachloroethane	303	
Chlorobenzene	318	
o-Xylene	363	
Styrene	380	
p-Xylene	552	
m-Xylene	588	
Ethylbenzene	622	Lower

* Fetter, 1988

** Hargis + Assoc., 1992; Karickhoff, et al., 1979

6.1.5 Contaminant Degradation

Naturally occurring biotic (aerobic, hypoxic or anaerobic biodegradation) and abiotic (precipitation, mechanical alteration, ion exchange, oxidation and reduction) processes degrade dissolved contaminants during transport through an aquifer. For dissolved BTEX in the study area, biodegradation is likely the dominant destructive process and the focus of this section.

Field and analytical data can be obtained to assess the occurrence and mechanisms of biodegradation processes. A document prepared by the Air Force Center For Environmental Excellence (AFCEE) Technical Protocol For Implementing The Intrinsic Remediation With Long-Term Monitoring Option For Natural Attenuation of Dissolved-Phase Fuel Contamination in Ground Water, (Wiedemeier et al., 1994) and the technical publication by McAllister and Chiang (1994) are two examples of a growing body of literature which describe data requirements for evaluating the occurrence and processes of intrinsic biodegradation. The AFCEE guidance document identifies three lines of evidence which can be used to identify the occurrence of insitu biodegradation: (1) contaminant mass reduction at the field scale; (2)

laboratory microcosm studies; and, (3) geochemical evidence. These lines of evidence are discussed below.

6.2 DISSOLVED PHASE CONTAMINANT MOBILITY AT DEL AMO

6.2.1 Solubility

Within the Del Amo plant site, there are several known and suspected sources of benzene. As discussed in earlier sections, the MW-20 LNAPL is 95 percent benzene, which is consistent with the observed dissolved benzene concentrations near the maximum solubility for pure benzene. In contrast, the dissolved benzene concentration in groundwater which is in contact with the P-1 LNAPL[3] is approximately 3 μg/L, which is a direct reflection of the reduced benzene mole fraction in the hydrocarbon source material. Based on dissolved concentrations, benzene source concentrations range from 3 μg/L in the P-1 area to near the maximum solubility of approximately 1,800 μg/L in the MW-20 area and the Hamilton-Dutch area[4].

6.2.2 Advective Transport

Average flow velocities for the various aquifers have been calculated in Section 4.1 and are summarized below.

Hydrostratigraphic Unit	Average Flow Velocities
UBF	18.3 feet/year
MBFB	36.5 feet/year
MBFC	317 feet/year
Gage	61 feet/year

[3] The P-1 LNAPL is a petroleum LNAPL suspected to have originated from pipelines located along the southern site boundary.

[4] The P-1 LNAPL is a petroleum LNAPL suspected to have originated from pipelines located along the southern site boundary.

Contaminants were released from the Waste Pit Area source prior to 1961, when water levels were at historically low levels. Thus, it is probable that contaminants would have impacted the groundwater table when the water table was present within the deeper merged MBFB and MBFC. This hypothesis is corroborated by the deep occurrence of LNAPL in the MW-20 area (submerged below the present water table down to the middle Bellflower mud).

In the 45 year period between the time the Waste Pits were covered in 1951 until the most recent sampling event reported herein, contaminants have been present in, and transported by groundwater. In the absence of attenuative mechanisms, advective transport of contaminants in the MBFB and MBFC would be approximately 1,640 feet, and 14,260 feet, respectively.

To estimate the potential advective transport in the UBF, the history of the rising water table and transport of contaminants in the MBFB must be considered. At the time the water table rose from the MBFB into the UBF approximately 24 years ago (beneath the Waste Pit Area), advective transport had been occurring in the MBFB for approximately 21 years. Therefore, as the water table encountered the UBF, the distribution of contaminants in the MBFB would have been imprinted in the UBF. In the absence of retardation or attenuation, this would have resulted in a UBF plume extending approximately 770 feet from the Waste Pit Area source. In the 24 year period leading up to current conditions, advective transport in the UBF would have accounted for an additional 440 feet of downgradient transport, for a total plume length of 1,210 feet from the Waste Pit Area.

6.2.3 Dispersion

Starting with the reported empirical observations by Gelhar et al., site-specific values were refined through the application of numerical modeling. Accordingly, the scale of interest is a function of the grid cell size used in the numerical model, 200 feet by 200 feet. Through sensitivity analyses and historical plume matching, the reported site-specific dispersivity values were developed.

Using this correlation and a three-dimensional transport modeling (MT3D96) with site-specific data, the following values have been developed for longitudinal, lateral, and vertical dispersivity: 1 foot, 0.5 feet, and 0.01 feet, respectively.

6.2.4 Retardation

The very low f_{oc} values in the study area result in retardation factors approaching unity, indicating very little sorption of dissolved contaminants. Values for benzene used in the regional groundwater model are shown in the table below.

BENZENE RETARDATION FACTORS AND TRANSPORT VELOCITIES								
HSU	f_{oc}*	K_{oc} (mL/g)	K_d (mL/g)	ρ (kg/L)	θ	R	v_x (ft/yr)	v_c (ft/yr)
UBF	2.00E-05	83	1.7E-3	1.7	0.3	1.01	18.3	18.1
MBFB	1.50E-04	83	12.5E-3	1.7	0.3	1.07	36.5	34.4
MBFC	5.10E-04	83	42.3E-3	1.7	0.3	1.24	317	259
Gage	1.01E-03	83	83.8E-3	1.7	0.3	1.48	61	43

*Source: Hargis + Assoc., 1996a.

Thus, benzene transport is expected to be retarded only to a very small degree due to adsorption to the scant organic fraction in the saturated sediments.

6.2.5 Contaminant Degradation

The AFCEE guidance document identifies three lines of evidence which can be used to identify the occurrence of insitu biodegradation: (1) contaminant mass reduction at the field scale; (2) laboratory microcosm studies; and, (3) geochemical evidence. These lines of evidence are discussed below. In addition to these lines of evidence, sensitivity analyses were conducted with the regional groundwater model, to assess the half-life term used for benzene. The results are discussed below.

6.2.5.1 Contaminant Mass Reduction

Benzene mass reduction may be supported by the presence and distribution of phenol, an intermediate byproduct in the benzene degradation process (Rifai et al, 1995). As described in Section 5.2.1.3, phenol occurs only within areas of high benzene concentrations in the water table and was not used or known to have been produced in historic facility processes.

Studies by Grbic-Galic and Vogel (1987), using radiolabeled carbon to trace the degradation pathway of benzene under methanogenic conditions, show phenol to be the initial intermediate daughter product of benzee degradation by ring oxidation. Comparison of Figures 5.2-2, 5.2-10 and 6.2-9 reveals that phenol and elevated benzene in the water table zone typically coincide with areas of elevated methane. Additional indication of mass reuction is discussed in light of other data in Section 6.5.

6.2.5.2 Microcosm Study

The Air Force guidance document (Wiedemeier et al., 1994) describes the use of microcosm studies, or controlled laboratory testing using site-specific aquifer material, to confirm that indigenous biota are capable of degrading contaminants of concern. Such testing was conducted for groundwater samples collected from numerous wells within each of the HSUs within the Study Area. Samples were evaluated for the presence of BTEX degrading aerobic microorganisms by the analytical method described by Salanitro (1992).

Results indicate the presence of BTEX degrading micro-organisms in each aquifer, with the highest concentrations associated with high dissolved benzene concentrations in the water table zone, and lower concentration distribution associated with the low benzene concentrations in the Gage (Appendix G1). BTEX degrading microorganisms are present in each HSU, as shown in Figures 6.2-1 through 6.2-4. Concentrations of degrading microorganisms are reported in units per liter on the figures, in accordance with the methods of Salanitro. As indicated on the figures, elevated degrader concentrations (greater than 10^5 units per liter) are generally associated with benzene concentrations greater than 1,000 μg/L.

6.2.5.3 Geochemical Evidence of Biodegradation

Geochemical evidence of BTEX biodegradation is best illustrated by comparing the distribution of dissolved BTEX with geochemical indicators involved in the BTEX degradation processes (described below). Figures 6.2-6 through 6.2-24 illustrate site-specific examples of the distribution in each HSU of reactants or products involved in the geochemical processes discussed below.

Petroleum hydrocarbon biodegradation occurs under aerobic, hypoxic and anaerobic conditions (Rifai et al., 1995; Wiedemeier et al., 1995). Biologically mediated transformation of BTEX compounds relies on the presence of a terminal electron acceptor (TEA) to complete the process. Oxygen is the electron acceptor in the aerobic respiration process. Under hypoxic

and anaerobic conditions, TEAs include nitrate (NO^{3-}), sulfate (SO_4^{2-}), ferric iron (Fe^{3+}), and CO_2 (methanogenesis). These processes occur according to the following reactions.

Aerobic Respiration: $C_6H_6 + 7.5O_2 \rightarrow 6CO_2 + 3H_2O$

Denitrification: $C_6H_6 + 6H^+ + 6NO^{3-} \rightarrow 6CO_2 + 3N_2 + 6H_2O$

Iron Reducing: $C_6H_6 + 30Fe^{3+} + 12H_2O \rightarrow 6CO_2 + 30H^+ + 30Fe^{2+}$

Sulfate Reducing: $C_6H_6 + 3.75SO_4^{2-} + 7.5H^+ \rightarrow 6CO_2 + 3.75H_2S + 3H_2O$

Methanogenesis: $C_6H_6 + CO_2 + 26H^+ \rightarrow 7CH_4 + 2H_2O$

Aerobic degradation of BTEX occurs at a higher rate than hypoxic or anaerobic degradation when available oxygen concentrations are greater than 1 μg/L (Rifai et al., 1995; McAllister and Chiang, 1994). In confined and unconfined aquifers most aerobic degradation occurs at the periphery of the contaminant plume where the greatest supply of oxygen is present. The available dissolved oxygen is readily consumed at the plume margins, resulting in hypoxic to anaerobic conditions in the interior of the contaminant plume. It is suspected that aerobic degradation also occurs within the interior of the contaminant plume as oxygen dissolves into the system from the vadose zone. Where oxygen is not abundant, anaerobic processes may be responsible for the majority of contaminant mass reduction, albeit at a slower rate.

As the equations above indicate, biodegradation by aerobic respiration, denitrification, iron reduction, and sulfate reduction results in BTEX and TEA concentrations that are inversely related. Therefore, if these degradation mechanisms are active, concentration of dissolved oxygen, NO^{3-}, SO_4^{2-}, and Fe^{3+} should be low within the high concentration core of the dissolved BTEX plume. Conversely, in the methanogenic process, CO_2 is the TEA and methane is produced as a metabolic byproduct of BTEX transformation. This results in increased methane concentrations within the BTEX plume (Rifai et al., 1995; Wiedemeier et al., 1994, 1995; and McAllister and Chiang, 1994).

To facilitate analysis of these distribution patterns in the study area, groundwater chemistry data collected from October 1995 are shown in Figures 6.2-5 through 6.2-24. Distribution patterns in the water table zone (Figures 6.2-5 through 6.2-9) indicate BTEX biodegradation occurs by aerobic respiration, denitrification and methanogenesis mechanisms. Sulfate data shown in Figure 6.2-8 suggests that sulfate reduction is not a significant process in the water

table zone. The amount of benzene degradation due to iron reduction cannot be established since speciation of ferric and ferrous iron has not been performed in the study area.

Anaerobic conditions dominate the MBFB in the study area (Figure 6.2-11). Dissolved oxygen concentrations within the MBFB BTEX plume cannot be compared to upgradient concentrations due to the presence of offsite, upgradient, and contaminant plumes (Trico, McDonnell Douglas, etc.). Likewise, the nitrate and sulfate concentration distributions are equivocal. Methane distribution, however, strongly suggests the occurrence of methanogenesis in the MBFB.

Time-series chemical data clearly demonstrate plume stability in the MBFC and Gage, indicating that transport and attenuation mechanisms are balanced. Although sufficient data are not available (Figures 6.2-15 through 6.2-24) to discern which specific degradation process is dominant, the presence of BTEX degrading organisms, methane, and the stability of benzene plumes in the highest permeability MBFC and Gage support the conclusion that biodegradation (likely methanogenesis) is an active process in the lower HSUs.

6.2.5.4 Biodegradation Rates

Estimating the rate of contaminant decay is difficult. While many laboratory studies have been conducted to evaluate the half-life of many common groundwater contaminants, the range of half-life values published in the literature is quite large. Additionally, determination of actual half-lives for compounds in the natural environment is difficult due to the many site-specific mechanisms and factors that are responsible for attenuating organic contaminants in the subsurface.

As part of groundwater modeling tasks performed as part of the Montrose and Del Amo Joint Groundwater Feasibility Study, an analytical solution was used in a focused transport calibration (FTC) to evaluate a site-specific range for benzene half-life. The FTC was conducted in the Waste Pit and Hamilton-Dutch areas where other transport factors have been characterized, such as average bulk hydraulic conductivity, gradient, porosity, organic carbon content, source size, source strength, and source history. The FTC exercise was intended to develop an average range of values of benzene half-life for the study area sediments. Results of the FTC indicate benzene half-lives ranging from 75 days to 600 days, which is very reasonable in light of literature values reported for benzene half-life. Reported degradation rates for benzene vary. Rifai et al. (1995) compiled a table of field-derived benzene degradation rates ranging from nondetectable (very long half-life) to approximately 70 days,

with the average rate of about 350 days. Also, Olsen and Davis (1990) report a half-life of 110 days. FTC results indicate that the more aggressive (lower) half-life occurs in the MBFB, followed by the MBFC, and the less aggressive (higher) half-life occurs in the water table zone. While the FTC cannot be used to definitively assign the benzene half-life, it does provide confidence in the range of half-lives and support for the relative aggressiveness of biodegradation within each of the units examined.

Results of this FTC were incorporated into the regional groundwater numerical model, and then evaluated during quasi-transport calibration. Modifications to half-life were made where simulated benzene plume distribution differed significantly from the measured concentrations. Benzene degradation half-lives were increased in two general areas of the model domain. These areas are (1) where multiple benzene sources are located in close proximity, thus elevating dissolved benzene concentrations and decreasing available terminal electron acceptors required for the biodegradation of benzene; and (2) within the distribution of chlorobenzene where low benzene concentrations are distributed over a large area. In the latter area, a benzene degradation half-life of 9,000 days was found during the quasi-transport calibration to provide a simulated benzene distribution within the higher concentration chlorobenzene plume which most closely approximated observed concentrations.

In the calibrated model benzene degradation half-lives outside the distribution of chlorobenzene and p-CBSA range from 100 days to 600 days. In the UBF aquitard, a t1/2 of 600 days was used for the area encompassing the ethylbenzene production units. Elsewhere in the UBF aquitard and in the Gage Aquifer, the half-life was set to be 300 days. In the MBFB, MBFM and MBFC, the half-life (t1/2) was specified to be 300 days in the MBFC sand in the MW-20 area; and 100 days elsewhere (outside the distribution of chlorobenzene and p-CBSA).

6.3 DISSOLVED PHASE PLUME BEHAVIOR AT DEL AMO

This section discusses the distribution of the dissolved phase plume over time, and the behavior of the plume with respect to transport and attenuative mechanisms. Contaminant plume morphology is a function of source location, source strength, and solute transport properties (including advective and dispersive flow, retardation, and attenuation). The relative strength of transport and attenuative processes govern the movement of a dissolved phase plume with respect to the source location. A dissolved phase plume will expand downgradient away from the source area until the transport processes become balanced by retardation and attenuation. As long as these forces remain balanced, the plume will remain stable. When conditions

change so that attenuative processes are greater than transport processes (e.g. when the source material is sufficiently diminished), the leading edge of the plume will recede, moving backward toward the source area.

6.3.1 Time-Series Benzene Concentrations

Changes in dissolved contaminant distribution over time are best understood by reviewing concentration time-series data for groundwater monitoring wells. Intuitive evaluation of concentration stability can be gained from inspecting Plates 5-1 through 5-4. These plates include graphs of BTEX concentrations through time for each well in each hydrostratigraphic unit. For quantitative assessment, the time-series concentration data are included in the comprehensive table presented in Appendix G1. For the purposes of this RI, benzene is used to characterize temporal trends in contaminant concentrations at individual wells, and for the overall groundwater contamination plume. Benzene is judged to be the contaminant of greatest concern based on its toxicity, concentration, mobility, and distribution relative to other contaminants associated with the Del Amo plant site.

Time-series benzene concentrations for individual wells on Plates 5-1 through 5-4 and in Appendix G1 are described by one of six conditions: (1) relatively stable concentration through time; (2) trend of increasing concentration through time; (3) trend of decreasing concentration through time; (4) concentrations variable with no discernable trend; (5) stability unable to be evaluated due to insufficient number of data points and/or elevated detection limits; and (6) concentrations typically not detected and well locations outside of the benzene plume.

Monitoring locations with relatively stable benzene concentrations (category 1) were subjectively identified based on time-series concentration graphs with characteristically horizontal lines connecting data points (e.g. XMW-04HD, near southeast corner of plant site). Monitoring locations where benzene concentrations remained at or just above the detection limit (<5 μg/L to approximately 5 μg/L) were also considered to be relatively stable (e.g. PZL0018, north of the Waste Pit Area). Additionally, benzene concentrations were deemed stable when several or more data points were consistent, yet one data point was anomalous (e.g. PZL0026, southeast corner of plant site; and SWL006, south of plant site).

Monitoring locations with trends of increasing or decreasing concentration through time (categories 2 and 3) were identified using statistical methods, as described in Section 5.2. Each graph showing a statistically significant trend is presented in Appendix G2. There are

relatively few occurrences of statistically significant increases or decreases in contaminant concentrations. The reasons for these occurrences are unknown.

Benzene concentrations were subjectively judged to be variable (category 4) when there was substantial variation in concentrations over time, with no statistically significant trend (e.g. XMW-21, southwestern portion of plant site). The reason for the concentration variability at the locations is unknown.

The stability of the benzene concentration was indeterminable at a few locations (category 5). Reasons for this include insufficient data points (less than three) or non-detectable benzene concentrations with elevated detection limits (e.g. XMW-02T, just west of western plant site boundary). A location with only three data points was judged sufficient to evaluate stability only if the concentrations persisted over a relatively long time span and were tightly constrained (e.g. PZL0009, central portion of plant site).

Monitoring locations that are consistently beyond the margin of the plant site benzene plume (Figure 5.2-2) have a substantial history of non-detectable benzene concentrations (category 6). These locations are not relevant to evaluation of benzene plume stability. Monitoring locations that are at or near the edge of the benzene plume based on their history of low to non-detectable concentrations were considered relevant and included in the stability evaluation.

Table 6.3-1 characterizes each well in the Del Amo monitoring program in terms of the six categories described above. Conclusions regarding plume stability can be drawn from the relative abundance of monitoring locations within categories 1, 2 and 3 (stable concentrations, trends of increasing concentration, and trends of decreasing concentration). Stable or decreasing concentrations are evidence of a stable or receding plume. Trends of increasing benzene concentration are evidence for plume expansion. Conclusions regarding plume stability cannot be drawn from the number of monitoring locations in categories 4, 5, and 6 (variable concentration, insufficient data, and location outside of the benzene plume), but these data are provided for reference and documentation. The following sections summarize findings for each hydrostratigraphic unit with respect to the above lines of evidence.

6.3.1.1 Water Table

Benzene concentrations are stable or decreasing at 26 of the 27 category 1, 2, and 3 water table monitoring locations. A trend of increasing benzene concentrations is identified for one well (XMW-03HD, southeast corner of plant site). The remaining 41 wells have variable

concentrations (12), insufficient data (11) or are outside of the benzene plume (19), and are therefore inconclusive with respect to plume stability.

6.3.1.2 Middle Bellflower B Sand

Benzene concentrations are stable or decreasing at 11 of 12 category 1, 2, and 3 MBFB monitoring locations. The remaining 25 locations have variable concentrations (5), insufficient data (11) or are located outside of the benzene plume (9) and are inconclusive with respect to plume stability.

6.3.1.3 Middle Bellflower C Sand

Benzene concentrations are stable or decreasing at four of the five category 1, 2, and 3 MBFC monitoring locations. A trend of increasing benzene concentration is identified for one well (SWL0040, near Waste Pit Area). The remaining 20 locations have variable concentrations (1), insufficient data (8), or are outside of the benzene plume (11), and are inconclusive with respect to plume stability.

6.3.1.4 Gage Aquifer

Benzene concentrations are stable or decreasing at all 9 category 1, 2, and 3 Gage monitoring locations. Data for the remaining nine locations are variable or the wells are outside of the benzene plume.

6.3.1.5 Summary

Considering all hydrostratigraphic units collectively, 43 of 45 category 1, 2, and 3 monitoring locations in the Del Amo monitoring program were judged to have either relatively stable (38 locations) or decreasing (5 locations) benzene concentrations through time[5]. Only two monitoring locations were identified with trends of increasing benzene concentration through time. This provides compelling evidence that benzene concentrations are not increasing over time, and the plume is stable.

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[5] The total number of monitoring locations for each category does not equal the sum of the total for each hydrostratigraphic unit since some locations are included in both the water table and MBFB units.

6.3.2 Contaminant Plume Migration

Plume geometry and stability characteristics can be evaluated by plotting contaminant concentration as a function of distance downgradient along flow direction from a distinct source (McAllister and Chiang, 1994). The plot of decreasing concentrations with distance from a source can be described by a best-fit curve with a negative slope. The steeper the slope, the more abrupt the decrease of contaminant concentrations with distance. The graphs of concentrations versus distance can be used to evaluate the stability of the plume front when comparing concentration versus distance plots from consecutive sampling events. If the absolute values of the slopes of plotted lines decrease (flatten) over time, it can be inferred that the plume is continuing to migrate (the distance from the source to the non-detect leading edge of the plume increases). An increase in the absolute values of the slopes (steepening) over time indicates a receding plume (the non-detect leading edge of the plume is retreating toward the source). If the slopes of the lines remain constant over time, the plume would be considered stable, indicating an overall balance between transport and attenuation mechanisms.

6.3.2.1 Water Table Zone

In the water table, the multiple source areas and associated coalescing dissolved phase plumes constrain the application of this evaluative method in the Del Amo study area to the downgradient-most source areas in the water table. There are two source areas which can be used for this evaluation. Figure 5.1-1 shows two source areas along the southern boundary of the former rubber plant. The westernmost is associated with the Waste Pit Area, and the easternmost source is referred to as the Hamilton-Dutch source area. Although these source areas are on the downgradient boundary of the former rubber plant, offsite sources of benzene are located downgradient from both. Figure 5.1-1 shows the XP-1 LNAPL down- and cross-gradient of the Waste Pit Area. Downgradient, across Del Amo Boulevard, from the Hamilton-Dutch source area is an inactive landfill and former leaking UST site which contribute low levels of benzene to the water table. A detailed description of the source areas and their history is included in Appendix A of Dames & Moore, 1993d. Although these offsite sources are present, transects can be constructed along groundwater flow lines from the Del Amo source areas to distances where benzene concentrations are non-detectable or very low (less than 5 μg/L).

Additional uncertainty of using a transect extending south from the Waste Pit Area arises from the presence of localized perturbations in the water table surface. Beneath and south of the Waste Pit Area there exists a groundwater mound. This mound results in radial flow away

from the southern Waste Pit Area boundary. However, as long as the wells which define the local groundwater high also have the maximum benzene concentration along the transect of interest, then any transect which extends radially away from the groundwater high is valid for assessing the relative movement or stability of the dissolved phase. As shown in Figures 4.1-4 and 5.2-2, a transect extending south (parallel to the regional flow direction) from the southern Waste Pit Area can be used for this method.

Figure 6.3-1 shows benzene concentrations measured over time along a transect of wells aligned parallel to the predominant flow direction extending from the Waste Pit Area through the leading edge of the solute plume. This transect is not influenced by offsite sources, and includes Monitoring Wells PZL0020, SWL0008, SWL0051, and SWL0006. The highest concentrations along this transect are present in PZL0020 and SWL0008. Because these two wells consistently have the highest water levels, and water levels consistently decrease along the transect, this alignment of wells provides a viable method for characterizing the leading edge of the contaminant plume over time.

Each of the nine lines on Figure 6.3-1 represents a snapshot in time. The period of this chart extends from the Phase I RI sampling event (February through August, 1993) to the February 1996 sampling event. As shown on the figure, dissolved benzene concentrations decrease abruptly from over 100,000 µg/l near the Waste Pit Area to less than 10 µg/l about 400 feet downgradient, and to non-detectable levels less than 600 feet downgradient. This steep benzene concentration gradient is consistent with recent publications which document abrupt decrease in concentrations of dissolved benzene emanating from underground petroleum releases (Rice et al., 1995). As discussed in Section 6.2.2, an unattenuated contaminant plume would be expected to extend approximately 1,210 feet downgradient of the Waste Pit Area.

Within the upper water bearing zone, another example of the steep benzene concentration gradient is present along the southern boundary of the former butadiene plant. A transect parallel to groundwater flow extending south from well XMW-04HD to SWL0021 shows benzene concentrations dropping from 960,000 µg/L to 4.4 µg/L within approximately 500 feet (Figure 6.3-2). The actual attenuation may be even more significant than apparent from the concentration data, since the benzene concentration at well SWL0021 is likely the result of sources unrelated to the Del Amo plant site. The relatively broad areal occurrence of low levels of benzene south of the butadiene plant can be attributed to several potential sources, including known releases from one or more UST from Rollins Leasing, and the inactive Gardena Valley #4 Landfill. The landfill is a Class II facility, and accepted solid and liquid wastes, including paint sludge and petroleum tank bottom sediments. The transect from XMW-

04HD to SWL0021 is entirely along the groundwater flow direction and is not affected by localized water table mounding.

6.3.2.2 Middle Bellflower B Sand

The best transect of wells for evaluating plume migration in the MBFB extends southeasterly from the Waste Pit Area (downgradient along flow line) and includes Wells SWL0041, XP-3 (projected), and SWL0052 (Figure 5.2-14). As seen in the water table, benzene concentrations decrease with distance from the Waste Pit Area source from between 100,000 to 10,000 μg/L to less than 0.5 μg/L over a distance of approximately 550 feet. As discussed in Section 6.5, this is markedly different from an unattenuated plume length of 1,640 feet. This steep concentration gradient is consistent during the period of this investigation as indicated by the relatively consistent slope of the best-fit lines on Figure 6.3-3. The consistency of the slopes of the lines suggests a balance between transport and attenuative mechanisms.

6.3.2.3 Middle Bellflower C Sand

The only transect of wells available downgradient from a Del Amo source area in the MBFC extends southeasterly from the Waste Pit Area (downgradient along flow line) and includes Wells SWL0040, XBF-13, and SWL0053 (Figure 5.2-25). Other areas of the MBFC benzene plume are within the distribution of chlorobenzene. Low (less than 100 μg/l) concentrations of benzene extend relatively long distances along and transverse to flow lines in the area where chlorobenzene concentrations are in excess of 1,000 μg/l. Although the reasons for the observed difference in benzene gradients are not clear, it is believed to be directly associated with the presence of chlorobenzene, since benzene downgradient of the Waste Pit Area in the MBFC, where chlorobenzene is not present, attenuates abruptly (Figure 5.2-25). Moreover, this conclusion is supported by the results of the regional groundwater model. During calibration and sensitivity analyses, a benzene half-life of 9,000 days was required to more closely match the measured distribution of benzene within the distribution of chlorobenzene. A half-life of 300 days was used to match the measured downgradient distribution from the Waste Pit Area.

As shown on Figure 5.2-25, concentrations decrease from 110,000 μg/L to less than 0.5 μg/L over a distance of approximately 550 feet along the transect through the Waste Pit Area. As discussed in Section 6.5, this is markedly different from an unattenuated plume length of 14,260 feet. The time series graph of this concentration gradient (Figure 6.3-4) shows that this trend has been consistent during the period from February 1993 to February, 1996. The

consistency of the slopes of the lines suggests a balance between transport and attenuative mechanisms.

6.3.2.4 Gage Aquifer

Del Amo source areas are not known to exist in the Gage aquifer. Therefore, the assessment method used for overlying units is not applicable, and was not performed using Gage aquifer wells.

6.4 NON-AQUEOUS PHASE HYDROCARBONS

Non-aqueous phase liquids have been detected in several locations within the study area. Two of the more significant NAPLs are a chlorobenzene DNAPL present beneath the central process area of the former Montrose Chemical facility and a benzene LNAPL present in the area of monitoring well MW-20. Characterization of the chlorobenzene DNAPL was not performed as part of this RI, and will not be discussed below. An ongoing intensive investigation is being conducted to evaluate the presence, distribution and mobility of LNAPL in the MW-20 area, much of which has been completed. Discussion of tasks performed to date and related findings are presented in summary documents previously submitted to EPA (Dames & Moore, 1994d, 1995d). Presented below is a summary of findings presented in the referenced documents, as well as more recent findings. A final report on the findings of the MW-20 Pilot Program will be issued following the completion of the pilot program in 1998.

As discussed in Section 5.1.1, the detection of accumulation of LNAPL in Monitoring Well MW-20 has prompted focused investigations in the area to characterize the nature and extent of the LNAPL. Previous reports indicate that as much as eight feet of accumulated LNAPL has been measured in MW-20. Currently, the greatest accumulation of LNAPL in the area is present in monitoring well SWL0001, which recently had approximately three feet of accumulated LNAPL.

Results of the focused investigations indicate that LNAPL is distributed within sediments extending from the water table surface to approximately 30 feet below the water table (about 60-85 feet bgs). The distribution is believed to be the result of low water table levels during the period over which LNAPL could have been released, and the concurrent, and subsequent rise in the water table. When LNAPL encountered groundwater, the water table was at least 30 feet below its current position. As water levels rose at an average rate of 1 foot per year

(Section 4.1.1), LNAPL became trapped in the fine grained media which is characteristic of the estuarine environment which deposited the sediments. Over the past 30 years the LNAPL has been subjected to the prevailing groundwater flow regime, resulting in the distribution and saturation profile observed today.

Detailed inspection and testing (on the scale of millimeters) was performed on over 500 feet of continuous cores collected from approximately a 300 square-foot region of the MW-20 LNAPL area. Sediments were grouped into four lithotypes based on grain size distribution. These groups, ranging from fine/medium sand to silty/clay, are assigned letter designations (in order of decreasing grain size) A, B, C or D. The cores were screened for LNAPL distribution using two methods in a controlled laboratory environment. Cores were visually inspected under full spectrum and high-intensity ultra-violet light (the spectrum of light energy in which benzene is most fluorescent), and each 0.2-foot interval from 40 feet bgs to 90 feet bgs (saturated zone begins at about 60 feet bgs) was subjected to a jar test using a hydrophobic hydrocarbon-specific dye (Sudan Red) to determine the presence of LNAPL. An example of core photography is provided as Figure 6.3-1, which depicts one of the most abundant occurrences of LNAPL.

The validity of screening tests results were then verified by laboratory Dean Stark relative fluid saturation tests. Over 110 plug samples were tested from the various lithotypes by the Dean Stark method. These test results provided the basis for developing a profile of LNAPL distribution and saturation in the MW-20 area. Additional laboratory tests were performed on MW-20 sediments to characterize the intrinsic and fluid specific properties of the MW-20 sediments. These tests included intrinsic permeability, relative fluid permeability, capillary pressure curve, and grain size distribution.

Saturation data corroborate laboratory screening results, and indicate that LNAPL is trapped within each of the classified sediment types at saturation levels near or below residual saturation. Generally LNAPL is present adjacent to permeability boundaries characterized by a contact between sediments of differing grain size distribution. In the predominantly coarse grained material, LNAPL is generally present at the top and bottom of the stratum or lamina, possibly indicating that LNAPL was flushed from within the central portion of the individual strata or lamina where higher groundwater flow velocities are expected. Where present in the fine grained and finely interbedded units, LNAPL tends to be present throughout the unit, indicating that the flushing action of groundwater has not completely removed LNAPL from these units. Maximum detected LNAPL saturations and laboratory derived residual oil saturation values are summarized in the following table by lithotype.

Lithotype	Total Number of Samples	Number of Samples Above Residual Saturation	Maximum LNAPL Saturation	Residual Oil Saturation*
Fine to medium Sand (A)	41	1	20.80%	13%
Silty Sand (B)	46	1	31.89%	22.60%
Sandy Silt (C)	11	0	8.79%	17.30%
Silt/Clay (D)	13	1	26.21%	23.5%**

* Average values developed by Shell Bellaire Technology Center June, 1996 based on three samples for each lithotype.
** The results of a single sample, however this value is within the range of values developed by PTS Laboratories.

6.5 CONCLUSIONS

The following conclusions are supported by careful evaluation of all of the relevant data collected during and prior to the Del Amo Groundwater Remedial Investigation:

- Advective transport is the dominant transport mechanism responsible for the migration of dissolved benzene and other contaminants in groundwater at the Del Amo site;

- Intrinsic biodegradation is the dominant attenuative mechanism responsible for benzene mass reduction in groundwater at the Del Amo site; and

- Benzene plume migration and attenuative mechanisms are in balance at the Del Amo site such that the benzene plume front is essentially stable.

Following is a summary of the evidence supporting these conclusions.

The mechanisms and processes which influence the fate and mobility of contaminants in the subsurface environment have been presented and discussed in the preceding sections. Furthermore, the specific nature and occurrence of these mechanisms and processes in the Del Amo study area has been described by applying and interpreting data collected during site investigations conducted over the past 10 years. Various lines of evidence have been developed to describe which transport and attenuative processes occur at the site, and how these processes interact. Each line of evidence discussed above has a level of uncertainty

associated with it that place limits on extrapolating compelling conclusions. However, as one considers each piece of evidence, an understanding of site conditions emerges, and when all of the data and evidence are considered as a whole, a lucid and convincing picture of contaminant fate is manifest.

The following sections contain a summary of how the various lines of evidence interrelate and support a single, compelling conclusion that dissolved benzene plumes are stable as a result of the balance between advective transport and intrinsic biodegradation.

6.5.1 Dissolved Contaminants

Discussion of the principal contaminant transport processes showed that advection has the greatest affect on dissolved contaminant distribution. Diffusive transport is considered negligible relative to the other transport mechanisms. Indeed, published dispersivity values have been shown to be only about 10 percent of total advective transport distances. Therefore, it is concluded that benzene transport is mainly controlled by advection.

If the distribution of dissolved contaminants was entirely a function of advective transport, we would expect the downgradient distribution of dissolved benzene plume to be a function of groundwater flow rate and time since benzene entered groundwater. As discussed, advective transport of contaminants from the Waste Pit Area would result in a benzene plume extending approximately 1,210 feet, 1,640 feet, and 14,260 feet, downgradient in the UBF, MBFB and MBFC, respectively. These distances are significantly farther than observed transport distances of 600 feet, 550 feet, and 550 feet in the UBF, MBFB and MBFC, respectively. The difference between observed and calculated distances indicates that the advective transport of groundwater contaminants must be diminished by attenuative processes.

Section 6.1 described retardation and contaminant degradation as the principal attenuative mechanisms influencing the distribution of dissolved contaminant concentrations. Because of the low organic content of the aquifer material in the study area, retardation of benzene is very low, ranging from 1.01 to 1.48 (a conservative or unretarded compound such as chloride has a retardation factor of 1). This leaves degradation as the principal factor inhibiting benzene transport.

AFCEE guidance identifies three lines of evidence which can be used to identify the occurrence of intrinsic biodegradation, including: (1) contaminant mass reduction at the field

scale; (2) laboratory microcosm studies; and, (3) geochemical evidence. Although benzene mass reduction cannot be directly measured, the stability of the dissolved phase plume over time in the presence of continuing sources and the distribution of phenol (an intermediate byproduct of benzene degradation) relative to benzene both suggest that benzene mass is being reduced. Microcosm studies, the second line of evidence, have been performed and confirm the presence of indigenous BTEX degrading microorganisms. The relative distribution of geochemical parameters associated with the biodegradation of BTEX provides the third line of evidence of biodegradation. The distribution of dissolved oxygen, nitrate and methane relative to BTEX concentrations in the water table indicates that benzene is being degraded by aerobic and anaerobic processes. Although the data collected from deeper HSUs are insufficient to identify the specific degradation processes that are occurring, time-series chemical data clearly demonstrate plume stability in deeper units, and travel distances from known source locations are substantially shorter than would be expected if biodegradation were not occurring.

With site-specific data, these concepts have been applied to an analytical solution to calculate average benzene half-life. The results of the analysis indicate that the water bearing sediments in the study area degrade dissolved BTEX at a half-life rate ranging from 75 days to 600 days, which is within the range of published values for benzene. This range of values was further corroborated by calibration of the regional groundwater model.

The lines of evidence presented in this section show that advection dominates transport of contaminants, and biodegradation dominates attenuation of contaminants. The rates of these processes are balanced based on the behavior of the dissolved phase plume over time. The time-series data from each HSU show that contaminant concentrations are stable over the three-year monitoring period and the lateral distribution of contaminants has remained stable over this period. In the water table zone, well SWL0006 is located at the leading edge of the plume as indicated by the sporadic detection of benzene concentrations less than 1 μg/L, and just above the detection limit (0.5 μg/L). Since there has been no trend of increasing concentrations in Monitoring Well SWL0006, and recent sampling events have not consistently detected benzene, it is concluded that the leading edge of the plume is not migrating.

Based on all available data, the best description of dissolved phase contaminant fate and mobility is that plume migration has become balanced by attenuative mechanisms, primarily intrinsic biodegradation. As a result, the distribution of contaminants has reached a maximum limit, which should not be exceeded unless fundamental changes occur in the flow regime or the natural chemistry of the groundwater system.

6.5.2 LNAPL

Based on the history of contaminant releases, the regional trend of rising groundwater levels, and the similarity of depositional settings and aquifer matrices across the study area, the character of other sources is expected to be similar to the MW-20 area. Thus, it is reasonable to conclude that those observations and conclusions which are based on the extensive investigations conducted at MW-20 can be applied to other source areas across the study area.

Figure 6.5-1 shows that LNAPL is trapped below the water table (approximately 60 feet bgs) and occurs as singlets, doublets and ganglia. It is also clear from the LNAPL distribution in this photograph that, even in the most permeable units, LNAPL mobility at observed saturations is significantly restricted by subtle permeability contrasts. Comparison of Dean Stark saturation data and laboratory derived residual (irreducible) oil saturation data suggest that although a small fraction of the MW-20 LNAPL may be mobile, much of the LNAPL detected throughout the MW-20 area is at, or below residual saturation, and thus is immobile under the current groundwater flow regime.

Immobile LNAPL, trapped below the water table, represents a continuing source of groundwater contamination at the Del Amo site. Such LNAPL occurrences, at or below residual saturation, present an extremely difficult condition to overcome during remediation. However, it is important to remember that, at the Del Amo site, intrinsic biodegradation continues to function as an effective mechanism reducing benzene contaminant mass in groundwater, and that the resulting dissolved phase benzene plume front is essentially stable.

TABLE 6.3-1
CHARACTERIZATION OF BENZENE CONCENTRATION THROUGH TIME

HSU	Location	Relatively Stable	Trend Increasing	Trend Decreasing	Variable	Unable to Evaluate	Location Outside Benzene Plume
Water Table	PZL0001				X		
	PZL0002						X
	PZL0003						X
	PZL0004						X
	PZL0005						X
	PZL0006					X	
	PZL0007						X
	PZL0008						X
	PZL0009	X					
	PZL0010						X
	PZL0011	X					
	PZL0012				X		
	PZL0013	X					
	PZL0014						X
	PZL0016				X		
	PZL0018	X					
	PZL0019	X					
	PZL0020	X					
	PZL0021				X		
	PZL0022	X					
	PZL0024	X					
	PZL0025	X			X		
	PZL0026	X					
	SWL0002	X					
	SWL0003	X					
	SWL0004	X					
	SWL0005				X		
	SWL0006	X					
	SWL0007						X
	SWL0008			X			
	SWL0009						X
	SWL0012						X
	SWL0015	X					
	SWL0016				X		
	SWL0017	X					
	SWL0021			X			
	SWL0024	X					
	SWL0028						X
	SWL0038						X
	SWL0039						X
	SWL0042	X					
	SWL0044					X	

TABLE 6.3-1

HSU	Location	Relatively Stable	Trend Increasing	Trend Decreasing	Variable	Unable to Evaluate	Location Outside Benzene Plume
Water Table	SWL0045						X
	SWL0046					X	
	SWL0049					X	
	SWL0051					X	
	SWL0057					X	
	XGW-07A						X
	XMW-01	X					
	XMW-01T					X	
	XMW-02T					X	
	XMW-03					X	
	XMW-03HD			X			
	XMW-04HD	X					
	XMW-10	X					2
	XMW-11					X	
	XMW-12	X					
	XMW-13	X					
	XMW-14				X		
	XMW-21				X		
	XMW-23						X
	XMW-24						X
	XMW-26						X
	XMW-27					X	
	XMW-28		X				
	XMW-29				X		
	XMW-30	X					
	XP-02				X		

TABLE 6.3-1

HSU	Location	Relatively Stable	Trend Increasing	Trend Decreasing	Variable	Unable to Evaluate	Location Outside Benzene Plume
	(PZL0021)				X		
	(SWL0002)	X					
	(SWL0003)	X					
	(SWL0004)	X					
	SWL0010						X
	SWL0011						X
	SWL0019						X
	SWL0023						X
	SWL0029	X					
	SWL0037						X
	SWL0041	X					
	SWL0047					X	
	SWL0048					X	
	(SWL0049)					X	
	SWL0050					X	
	SWL0052						X
	SWL0056					X	
	XG-01WC					X	
MBFB	XG-02WC						X
	XGW-07C						X
	(XMW-01)	X					
	(XMW-01T)					X	
	(XMW-02T)					X	
	(XMW-03)					X	
	(XMW-10)	X					
	(XMW-11)					X	
	(XMW-12)	X					
	(XMW-13)	X					
	(XMW-14)				X		
	(XMW-21)				X		
	(XMW-26)						X
	(XMW-27)					X	
	(XMW-28)		X				
	(XMW-29)				X		
	(XMW-30)	X					
	(XP-02)				X		
	XP-03	X					

TABLE 6.3-1

HSU	Location	Relatively Stable	Trend Increasing	Trend Decreasing	Variable	Unable to Evaluate	Location Outside Benzene Plume
MBFC	SWl0013						X
	SWL0014						X
	SWl0018						X
	SWL0027						X
	SWL0030						X
	SWL0033			X			
	SWL0035						X
	SWL0040		X				
	SWL0043						X
	SWL0053						X
	SWL0054					X	
	SWL0055					X	
	SWL0058					X	
	XBF-04					X	
	XBF-05						X
	XBF-06	X					
	XBF-07				X		
	XBF-10						X
	XBF-13	X					
	XBF-14	X					
	XBF-15					X	
	XBF-19					X	
	XBF-21					X	
	XBF-23						X
	XBF-24					X	
Gage	SWL0020						X
	SWL0022						X
	SWL0025						X
	SWL0026						X
	SWL0031						X
	SWL0034	X					
	SWL0036	X					
	XDA-1B						X
	XG-04	X					
	XG-05	X					
	XG-06	X					
	XG-08						X
	XG-09			X			
	XG-11						X
	XG-12	X					
	XG-13	X					
	XG-14						X
	XG-17	X					

Locations in parentheses are included in both water table and MBFB hydrostratigraphic units

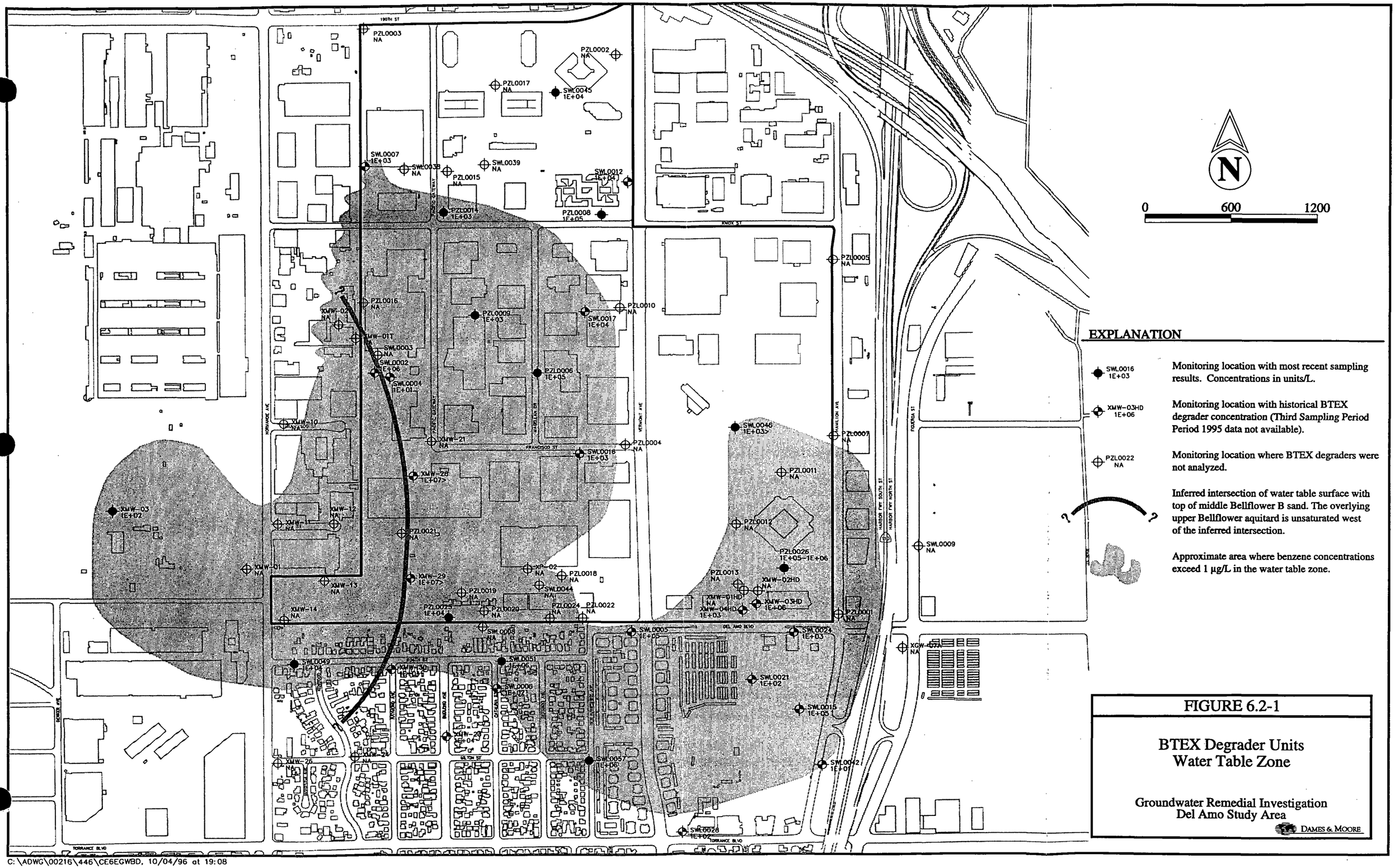

FIGURE 6.2-1

BTEX Degrader Units
Water Table Zone

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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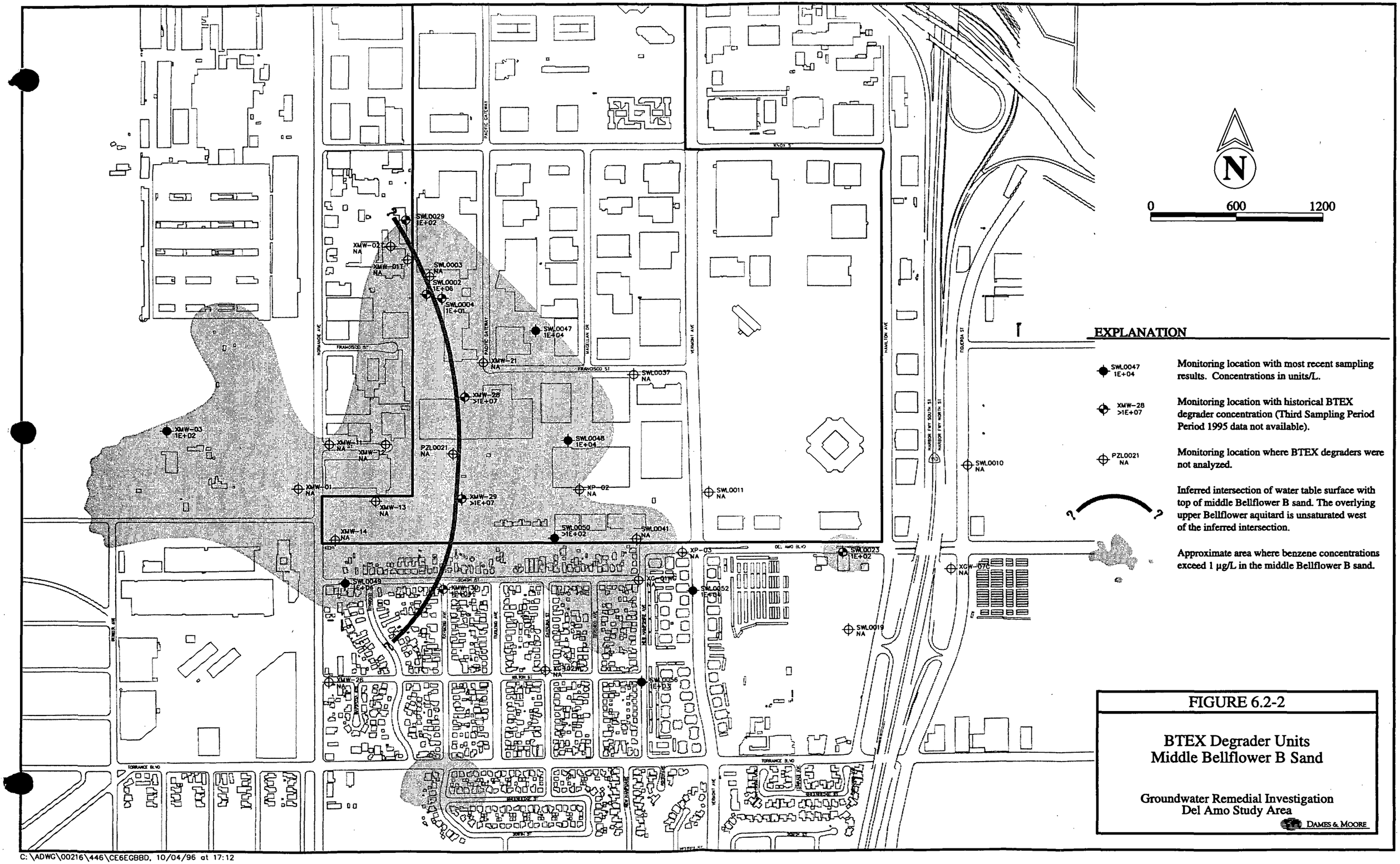

FIGURE 6.2-2

BTEX Degrader Units
Middle Bellflower B Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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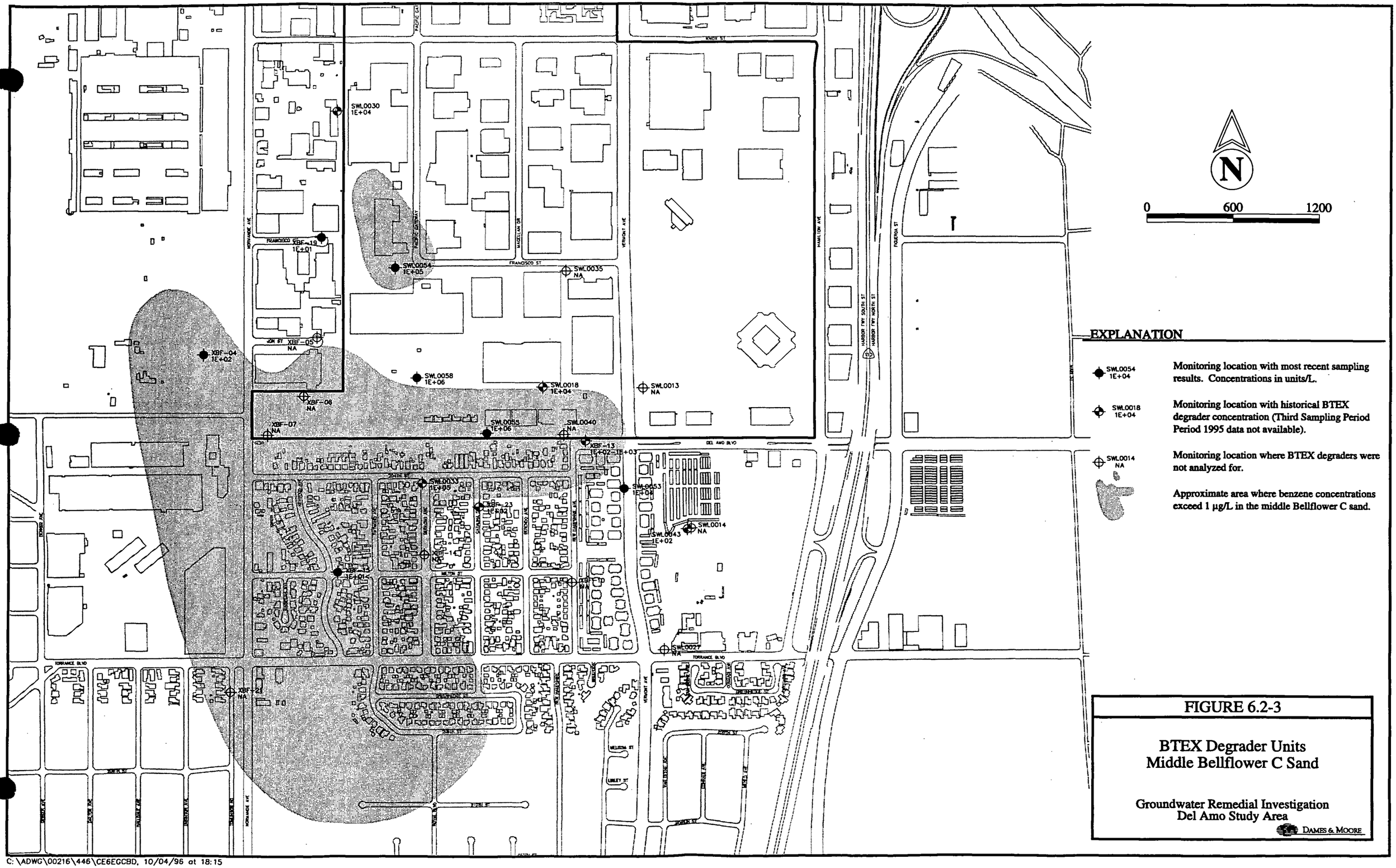

FIGURE 6.2-3

BTEX Degrader Units
Middle Bellflower C Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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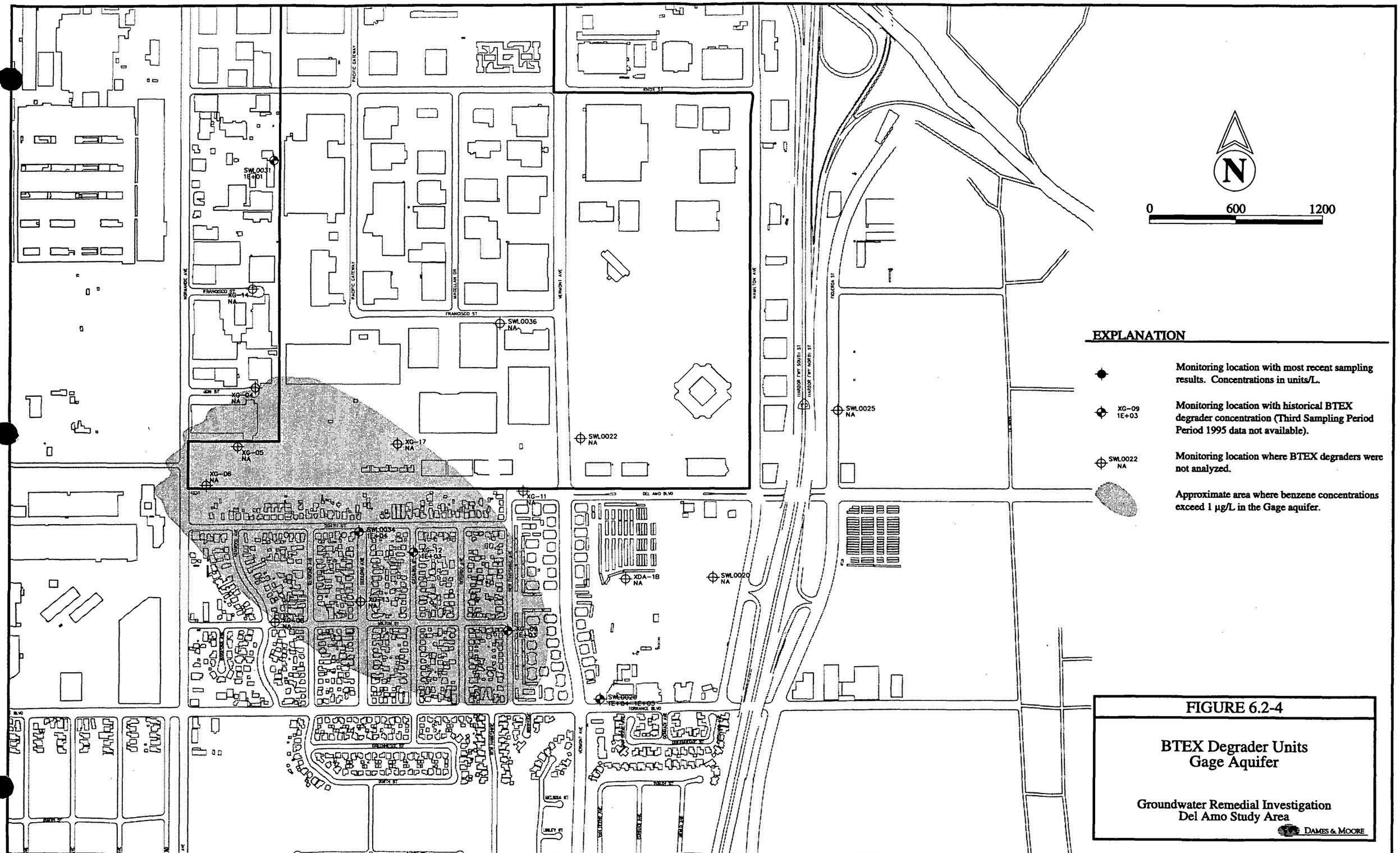

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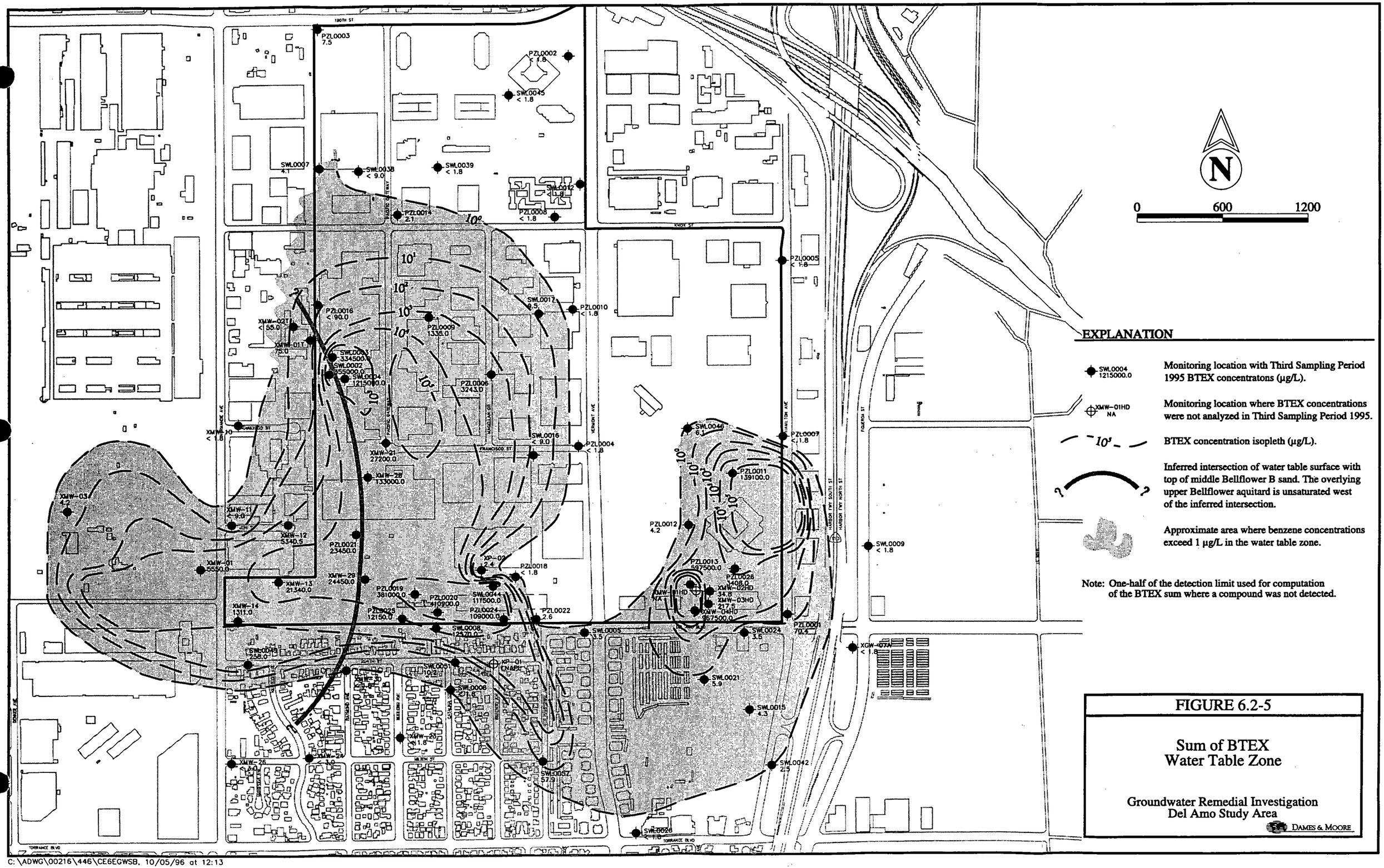

FIGURE 6.2-5

Sum of BTEX
Water Table Zone

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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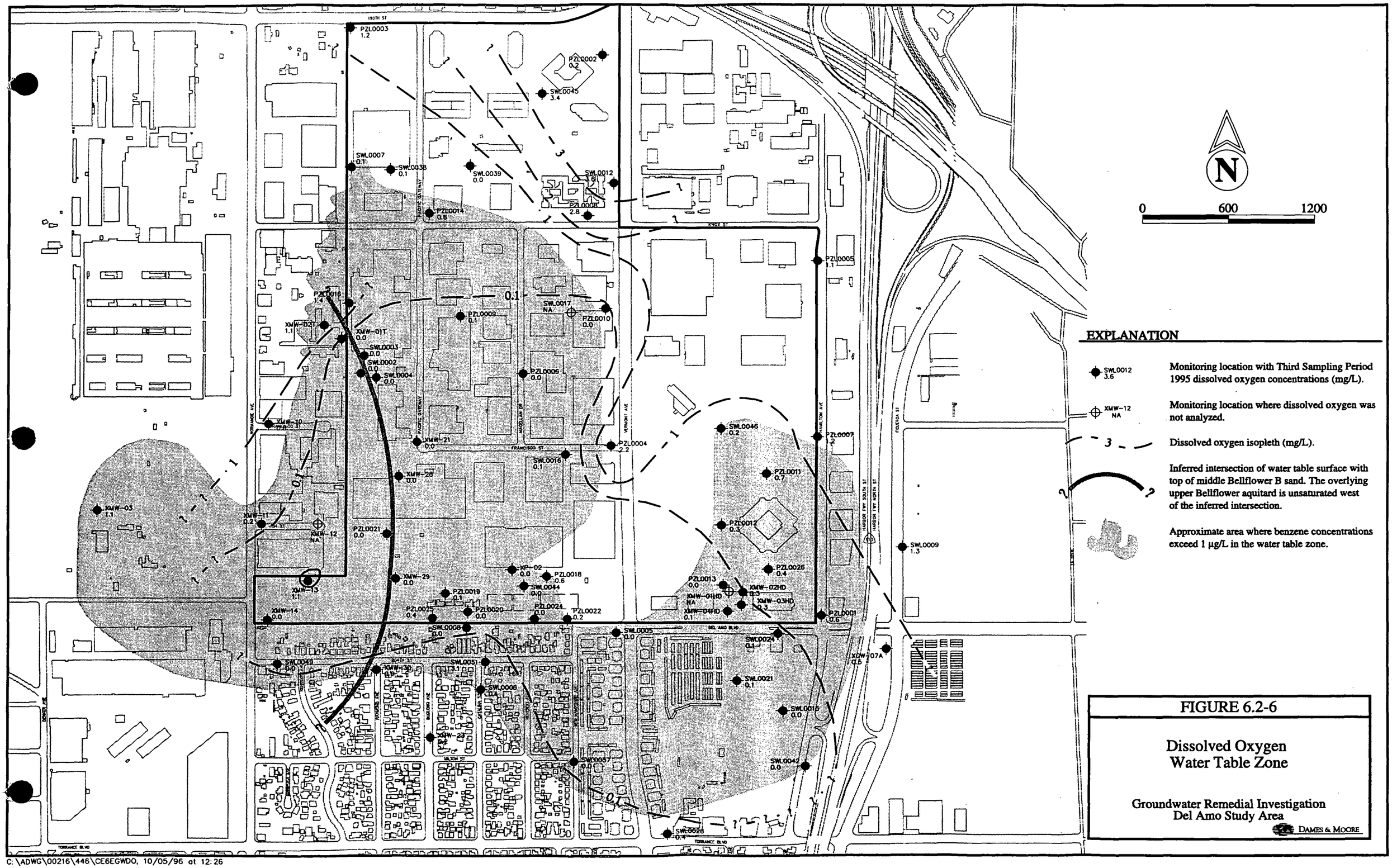

FIGURE 6.2-6

Dissolved Oxygen
Water Table Zone

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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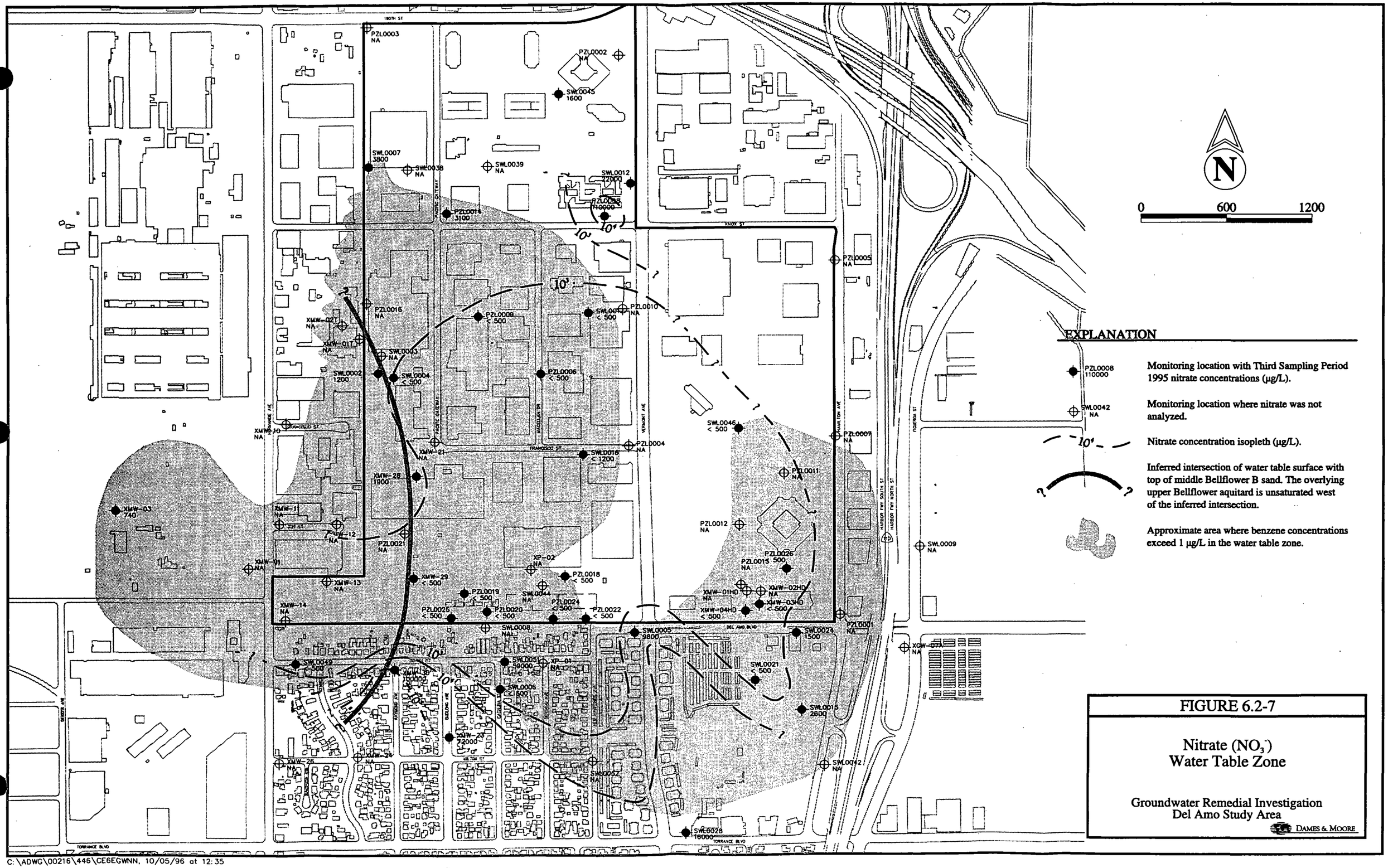

FIGURE 6.2-7

Nitrate (NO_3^-)
Water Table Zone

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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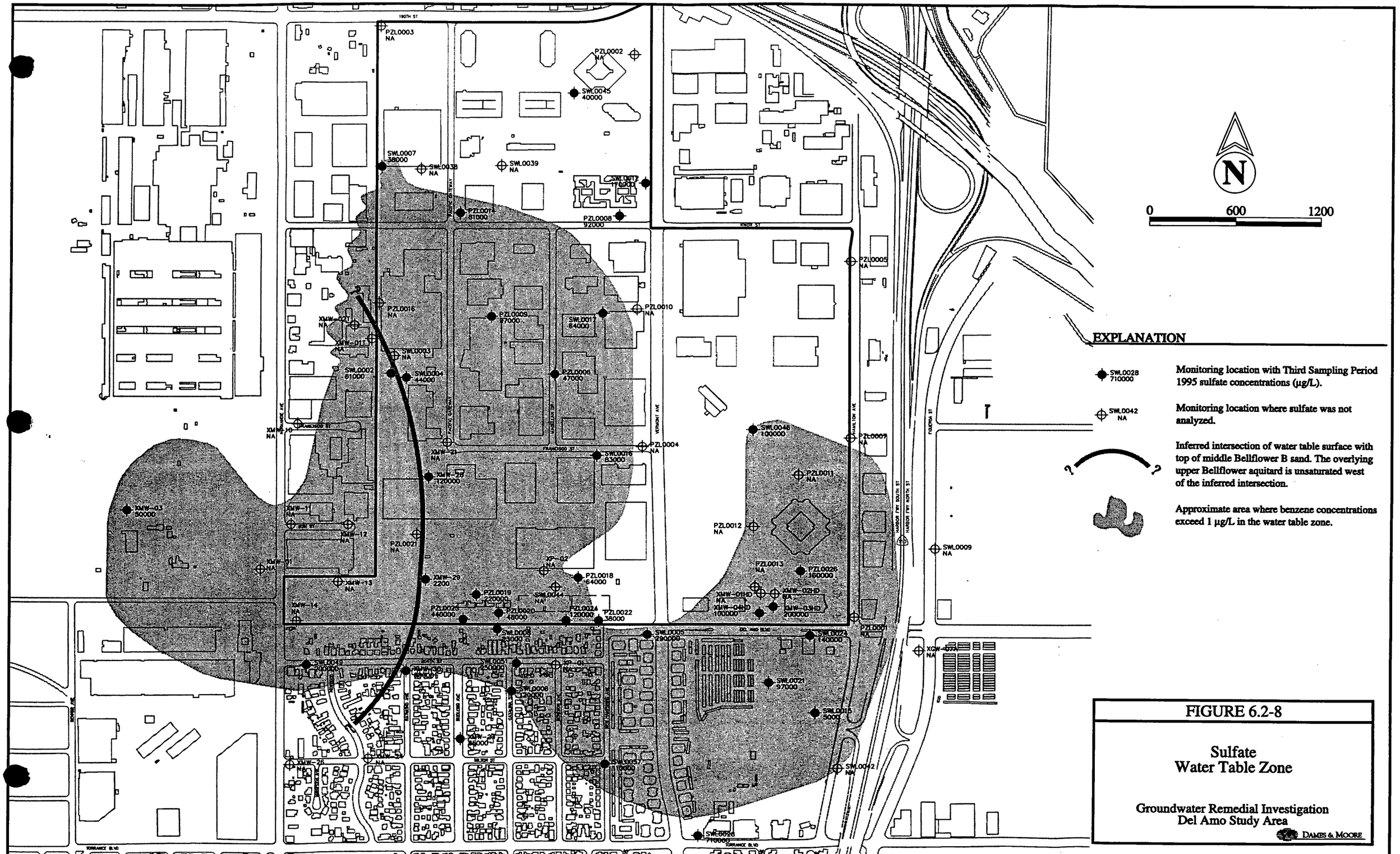

FIGURE 6.2-8

Sulfate
Water Table Zone

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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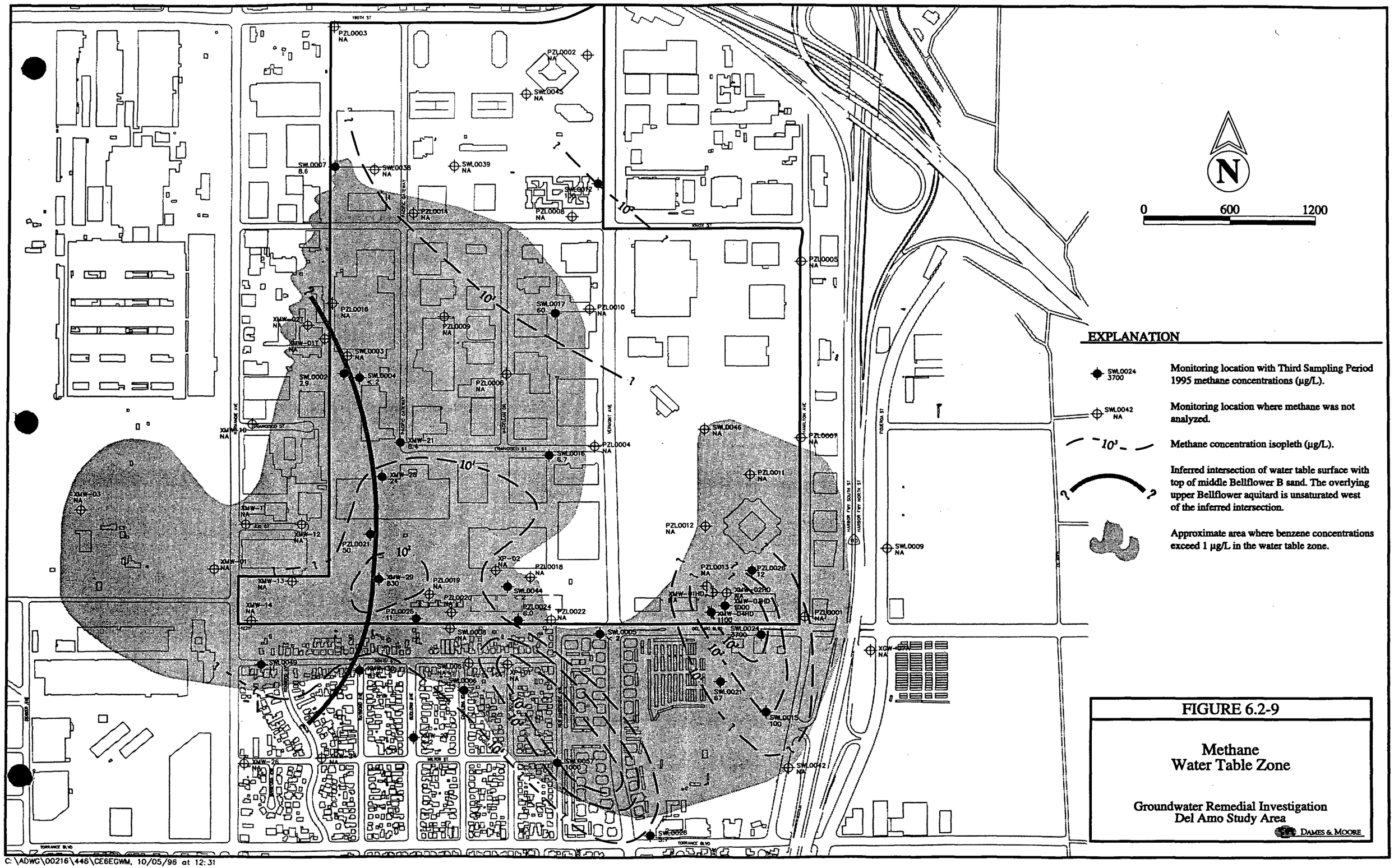

FIGURE 6.2-9

Methane
Water Table Zone

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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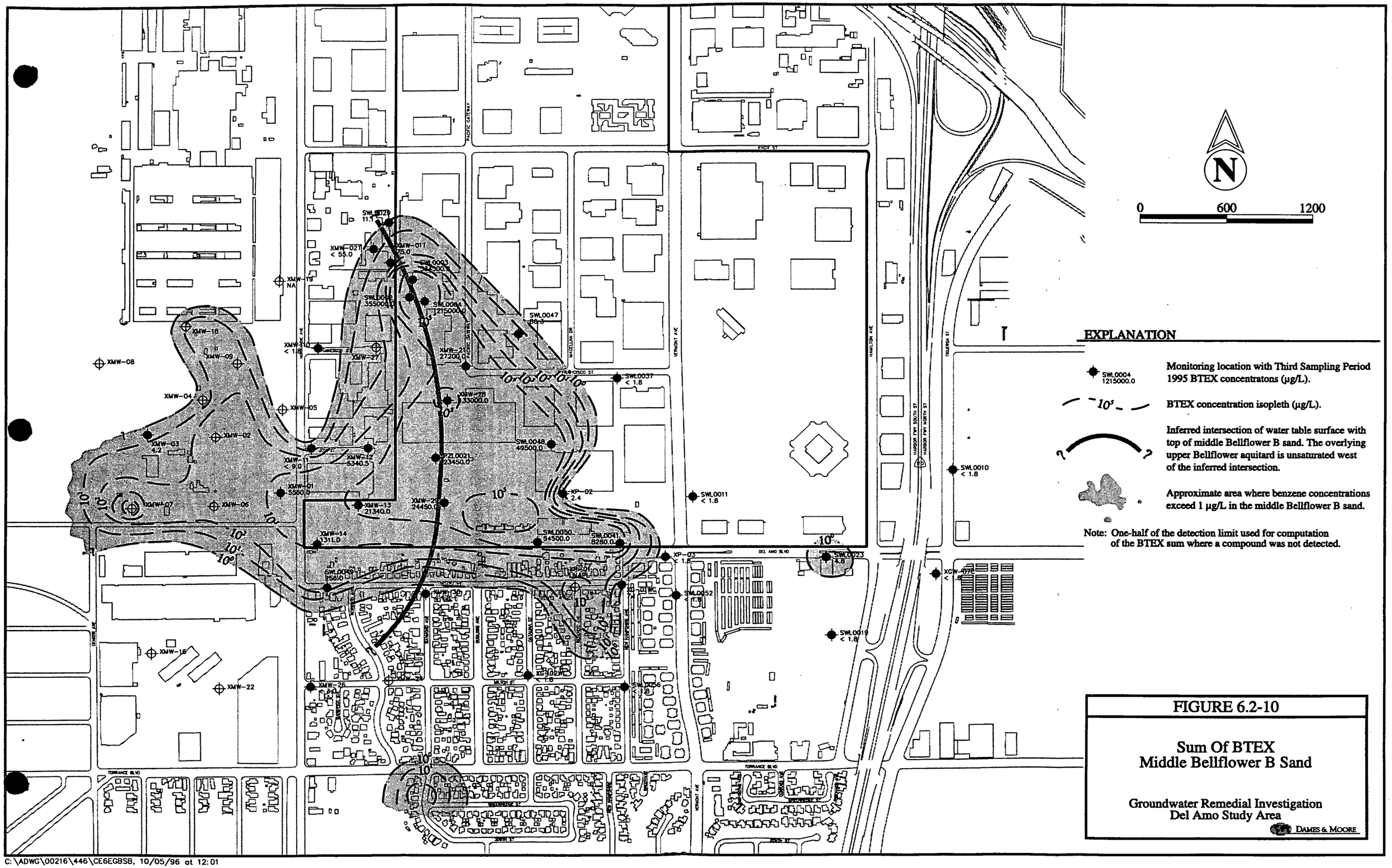

FIGURE 6.2-10

Sum Of BTEX
Middle Bellflower B Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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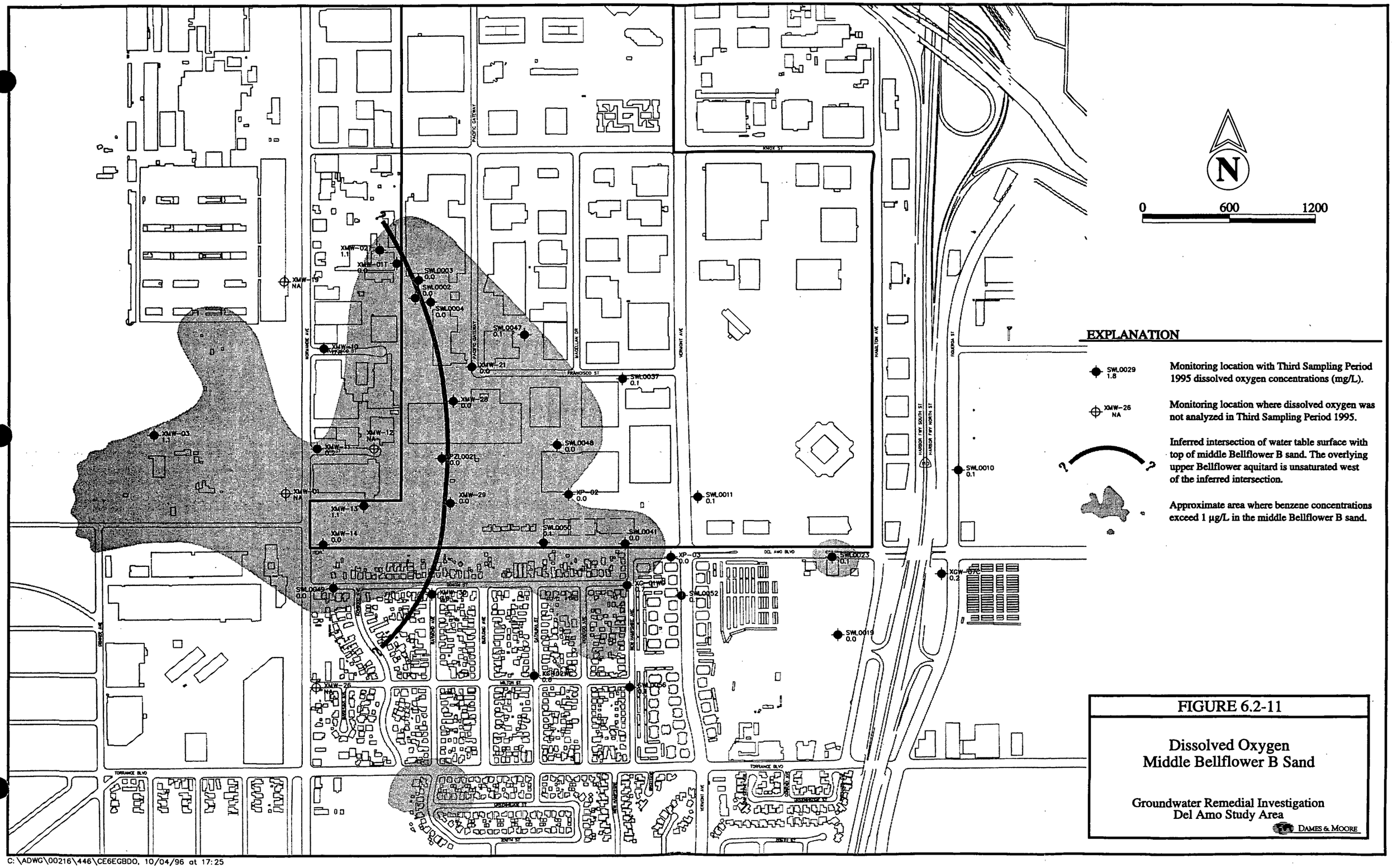

FIGURE 6.2-11

Dissolved Oxygen
Middle Bellflower B Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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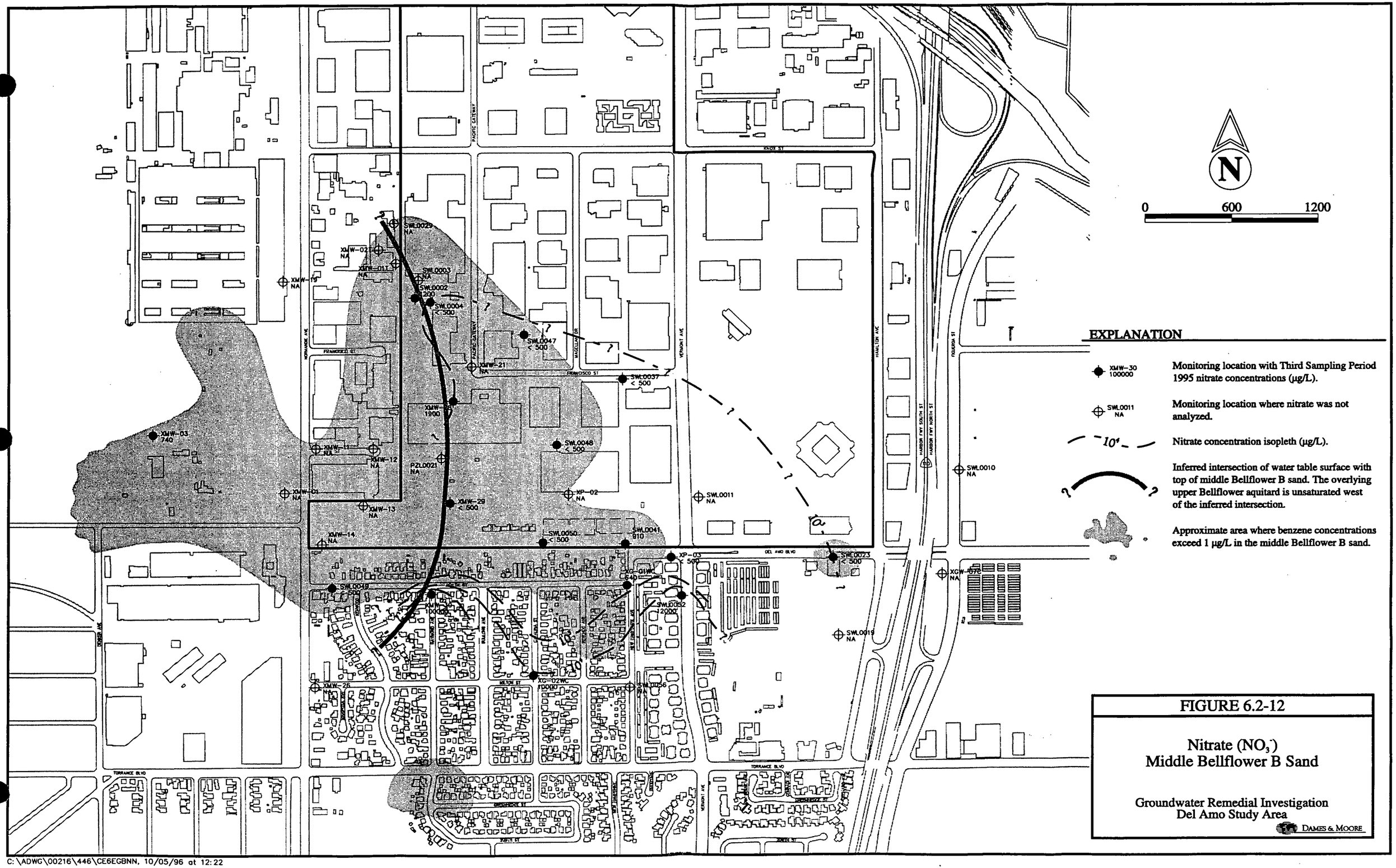

FIGURE 6.2-12

Nitrate (NO_3^-)
Middle Bellflower B Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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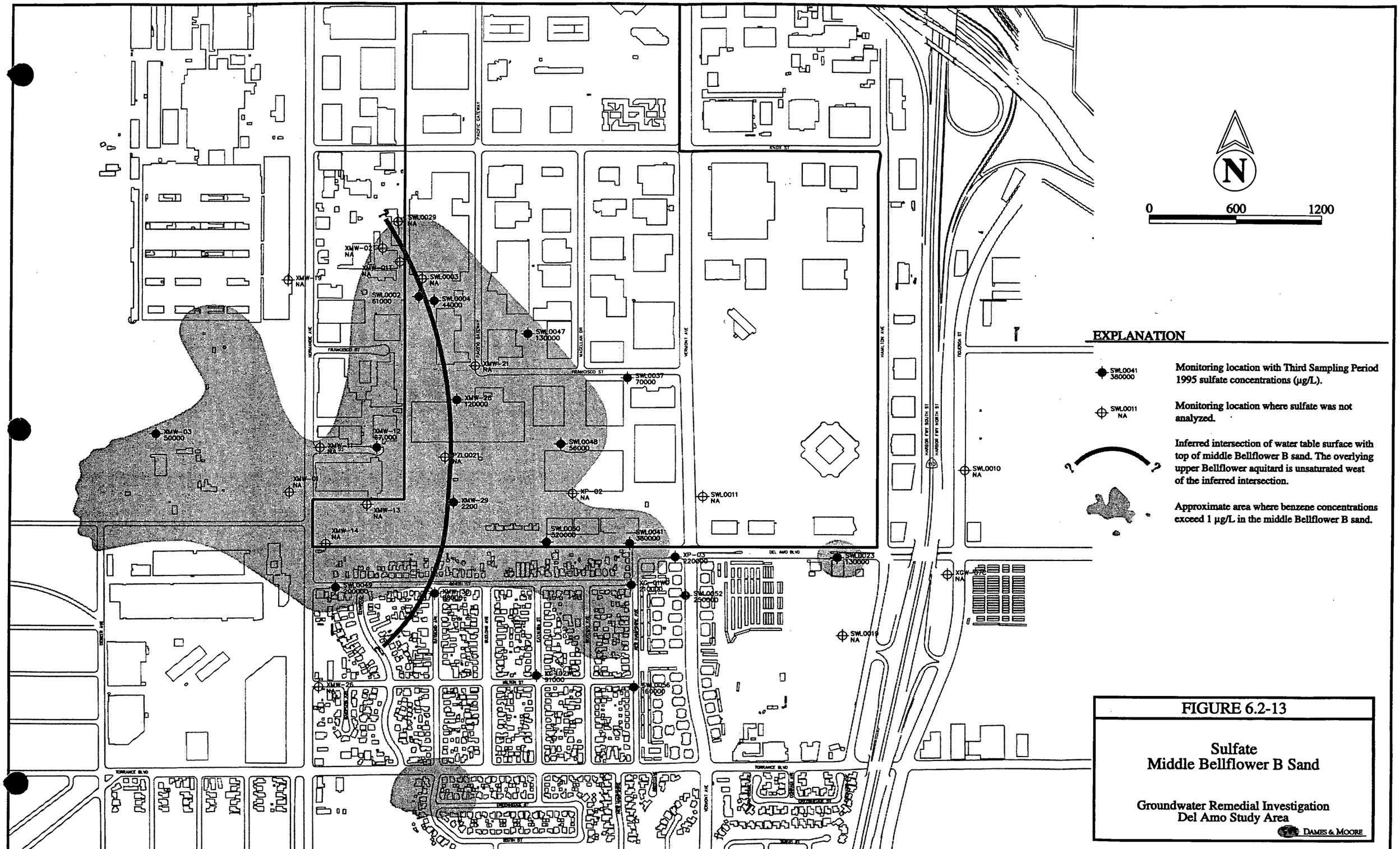

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FIGURE 6.2-13

Sulfate
Middle Bellflower B Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

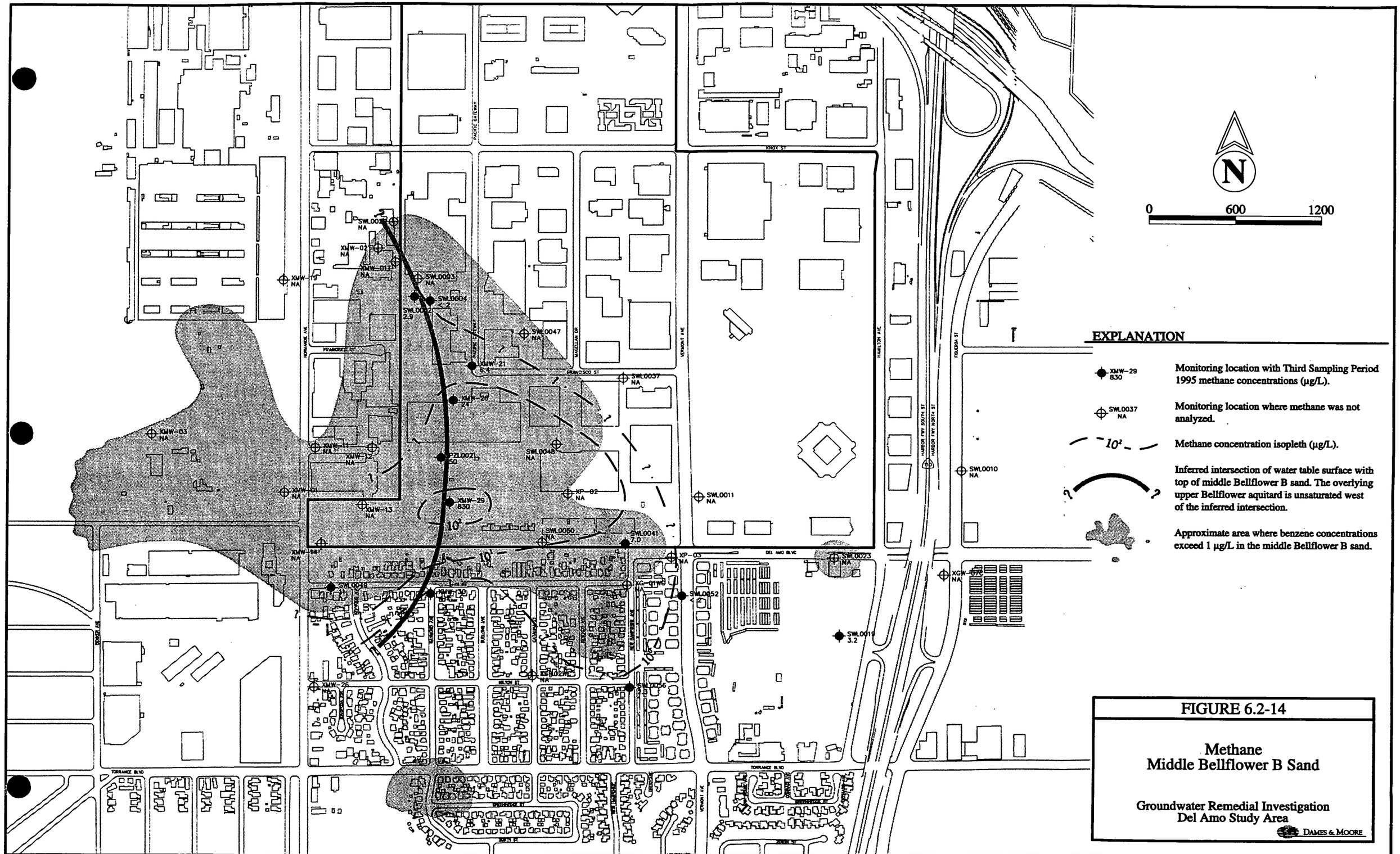

FIGURE 6.2-14

Methane
Middle Bellflower B Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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FIGURE 6.2-15

Sum of BTEX
Middle Bellflower C Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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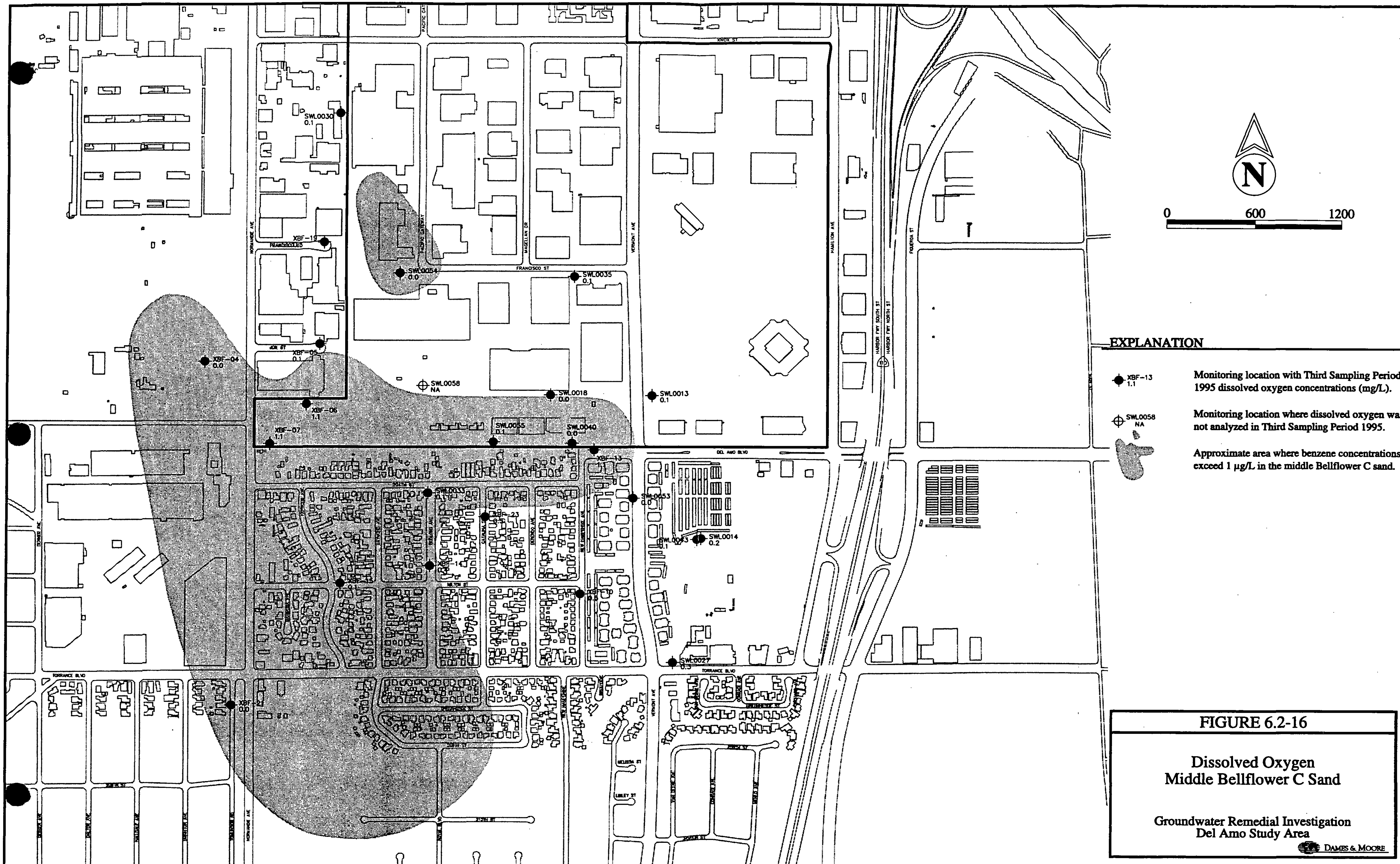

FIGURE 6.2-16

Dissolved Oxygen
Middle Bellflower C Sand

Groundwater Remedial Investigation
Del Amo Study Area

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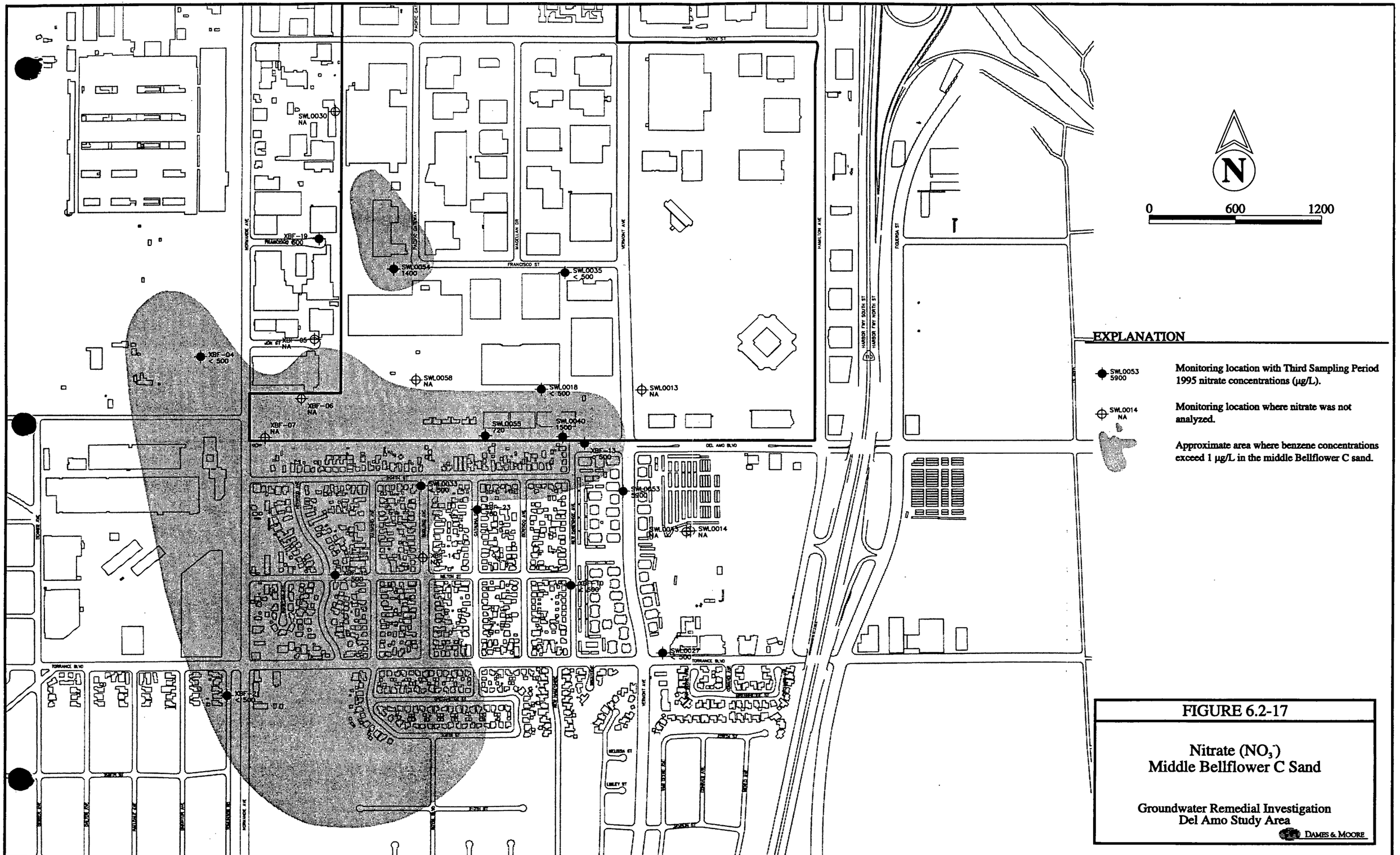

FIGURE 6.2-17

Nitrate (NO_3^-)
Middle Bellflower C Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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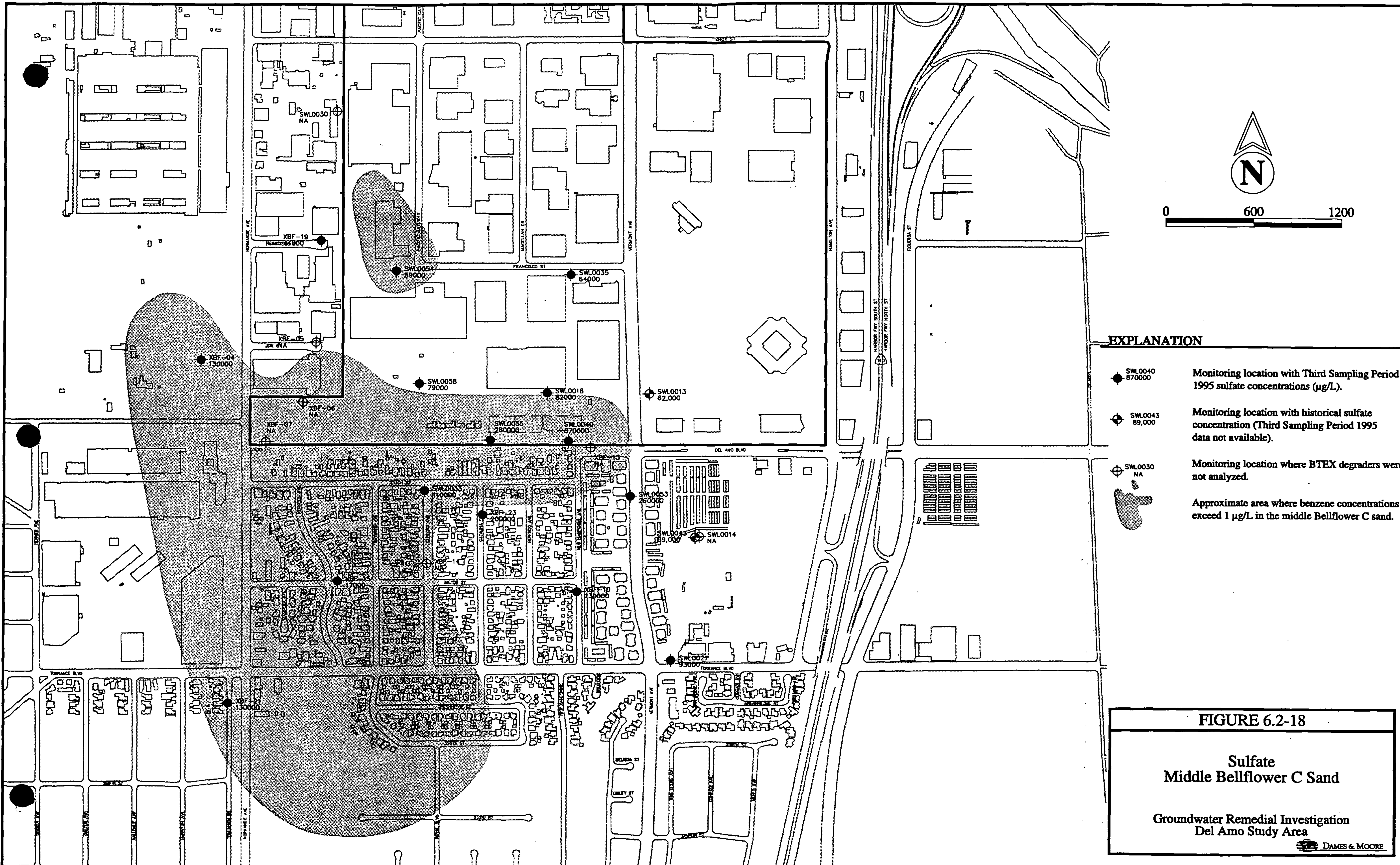

FIGURE 6.2-18

Sulfate
Middle Bellflower C Sand

Groundwater Remedial Investigation
Del Amo Study Area

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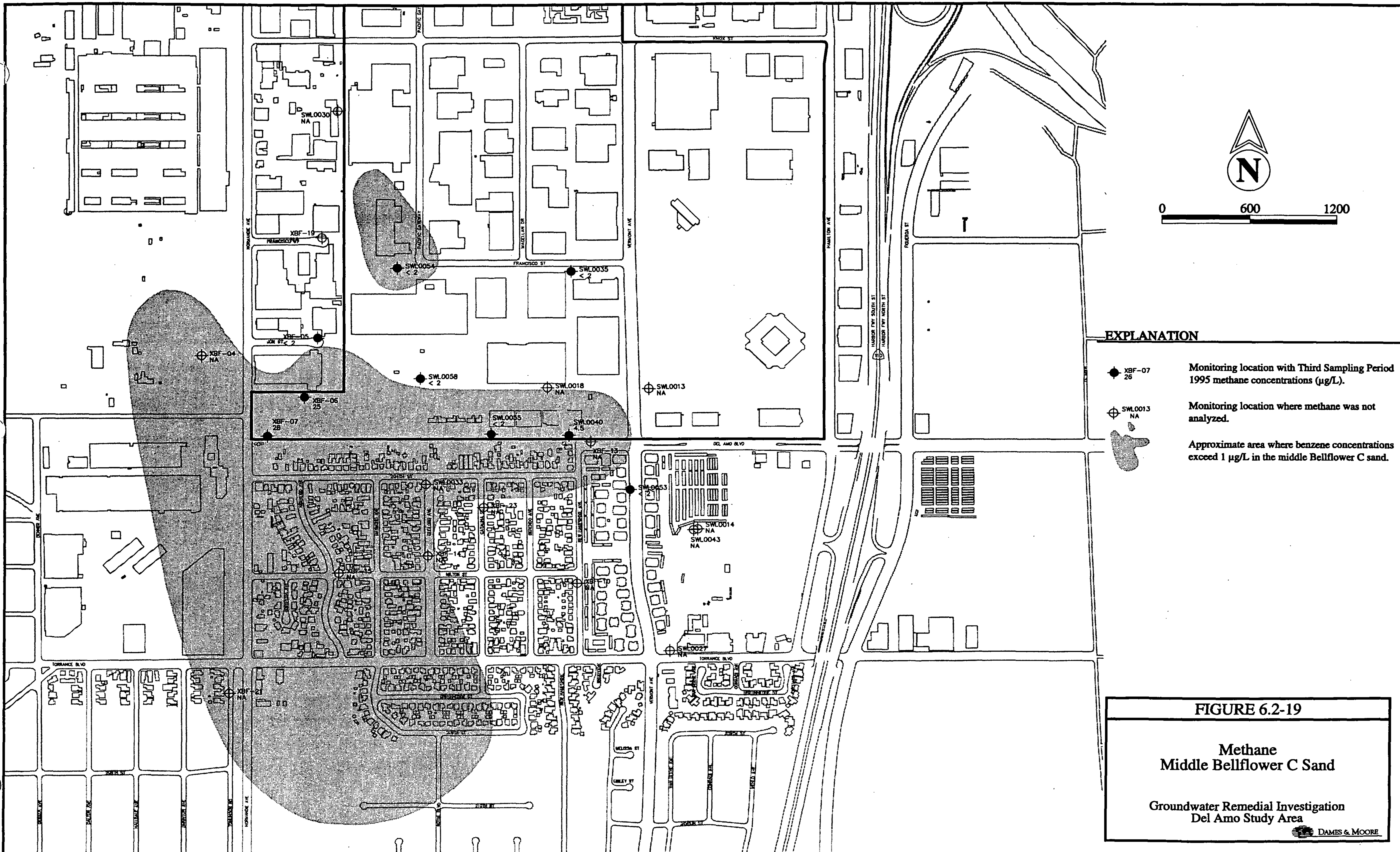

FIGURE 6.2-19

Methane
Middle Bellflower C Sand

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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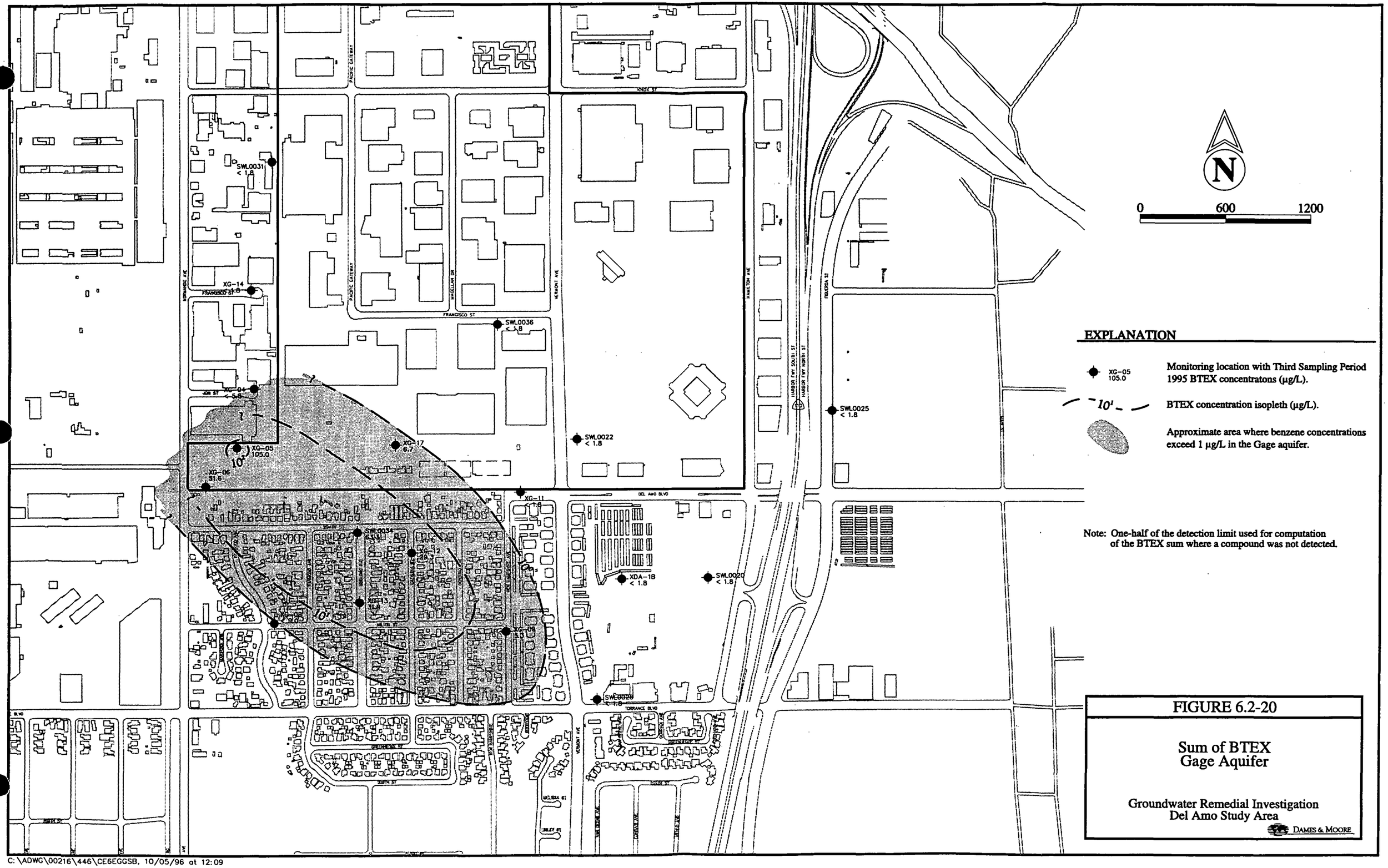

FIGURE 6.2-20

Sum of BTEX
Gage Aquifer

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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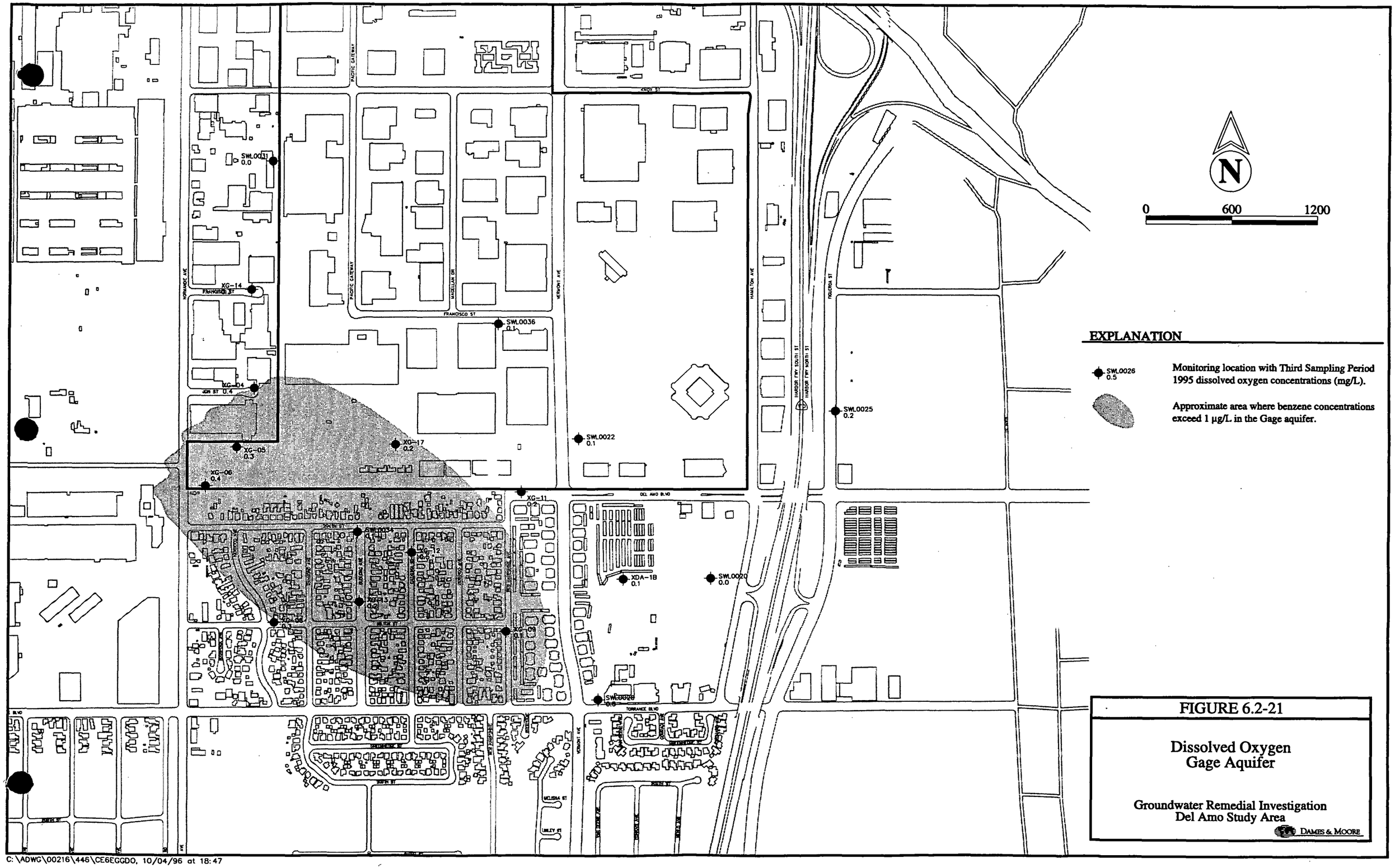

FIGURE 6.2-21

Dissolved Oxygen
Gage Aquifer

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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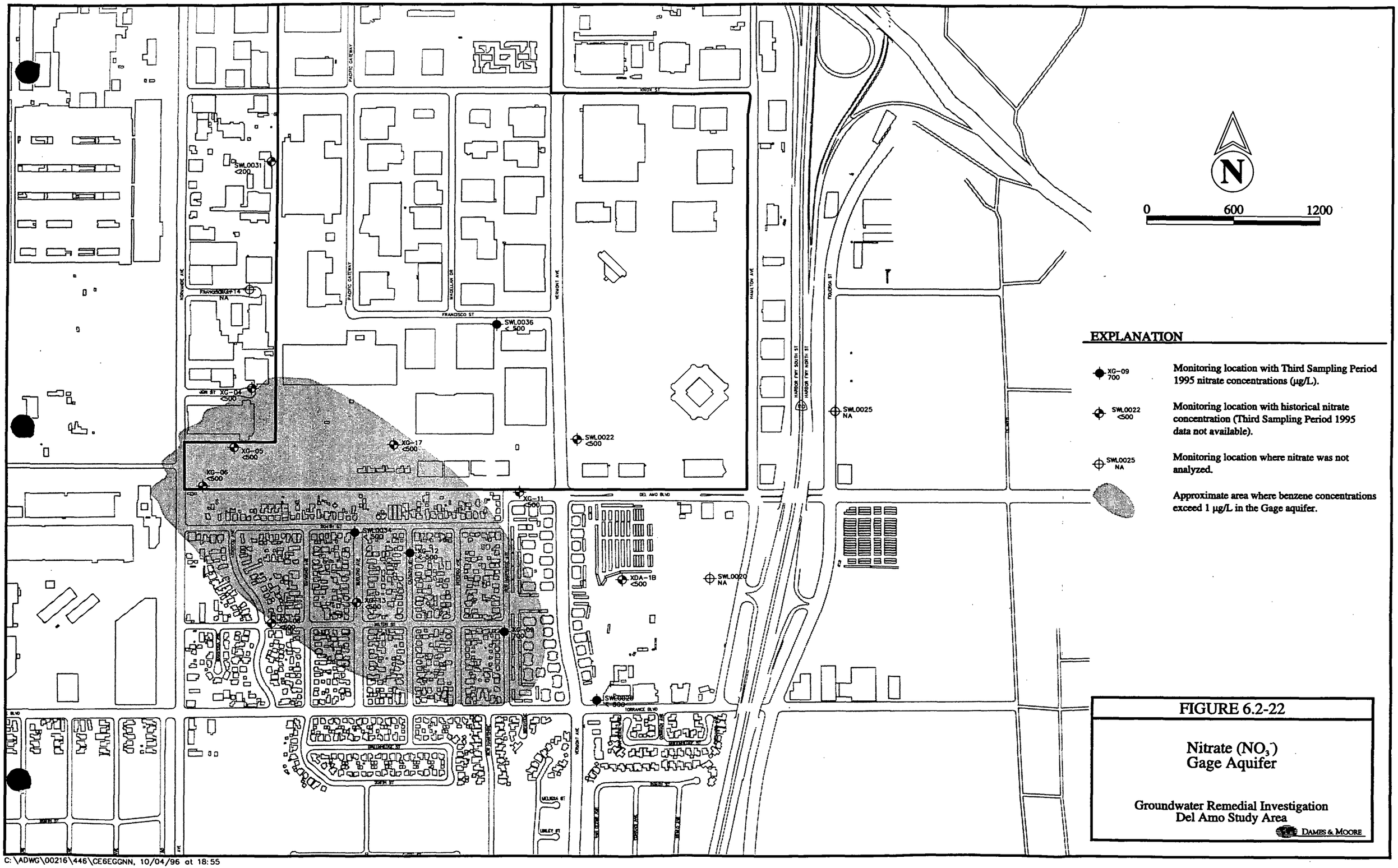

FIGURE 6.2-22

Nitrate (NO_3^-)
Gage Aquifer

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

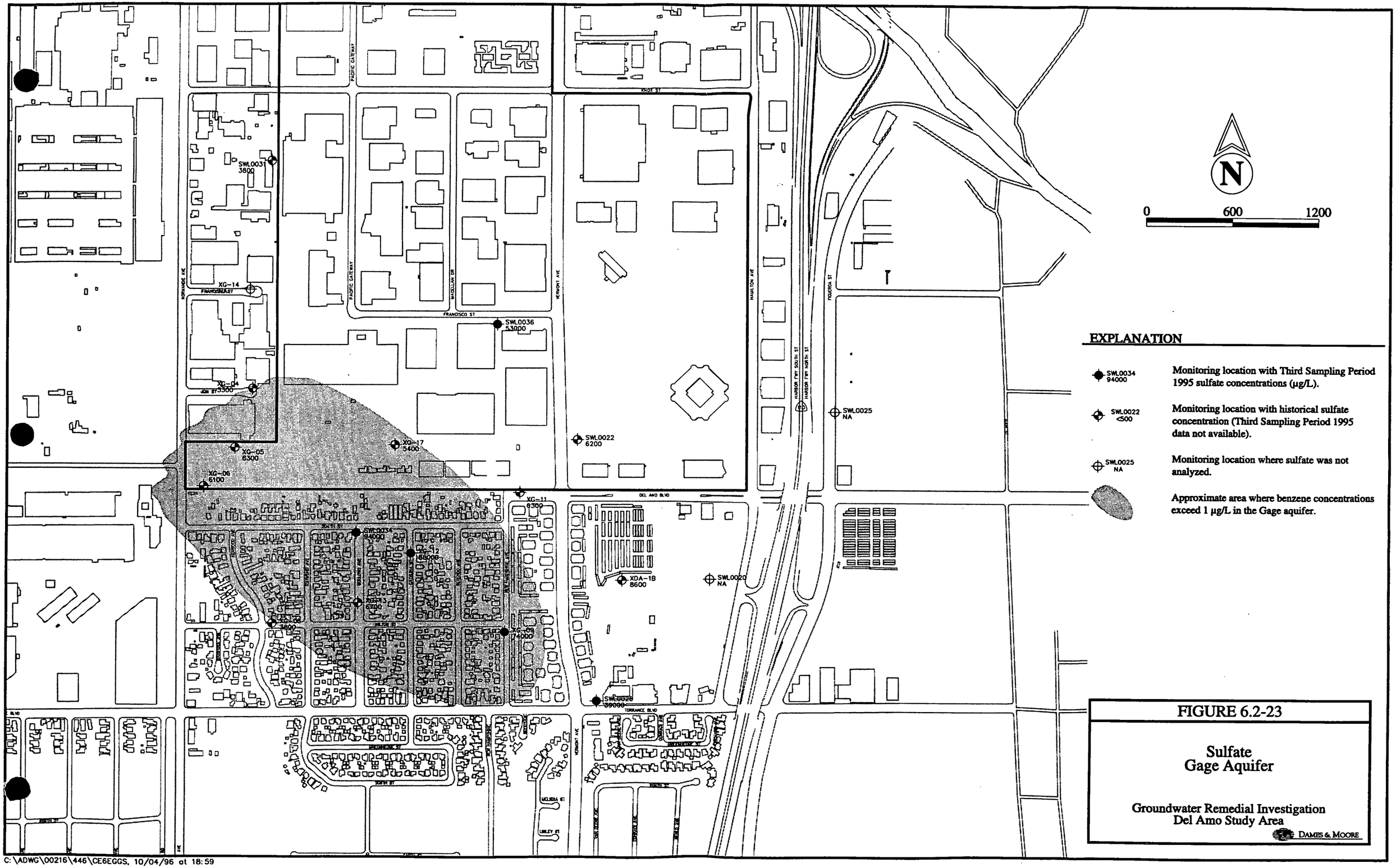

FIGURE 6.2-23

Sulfate
Gage Aquifer

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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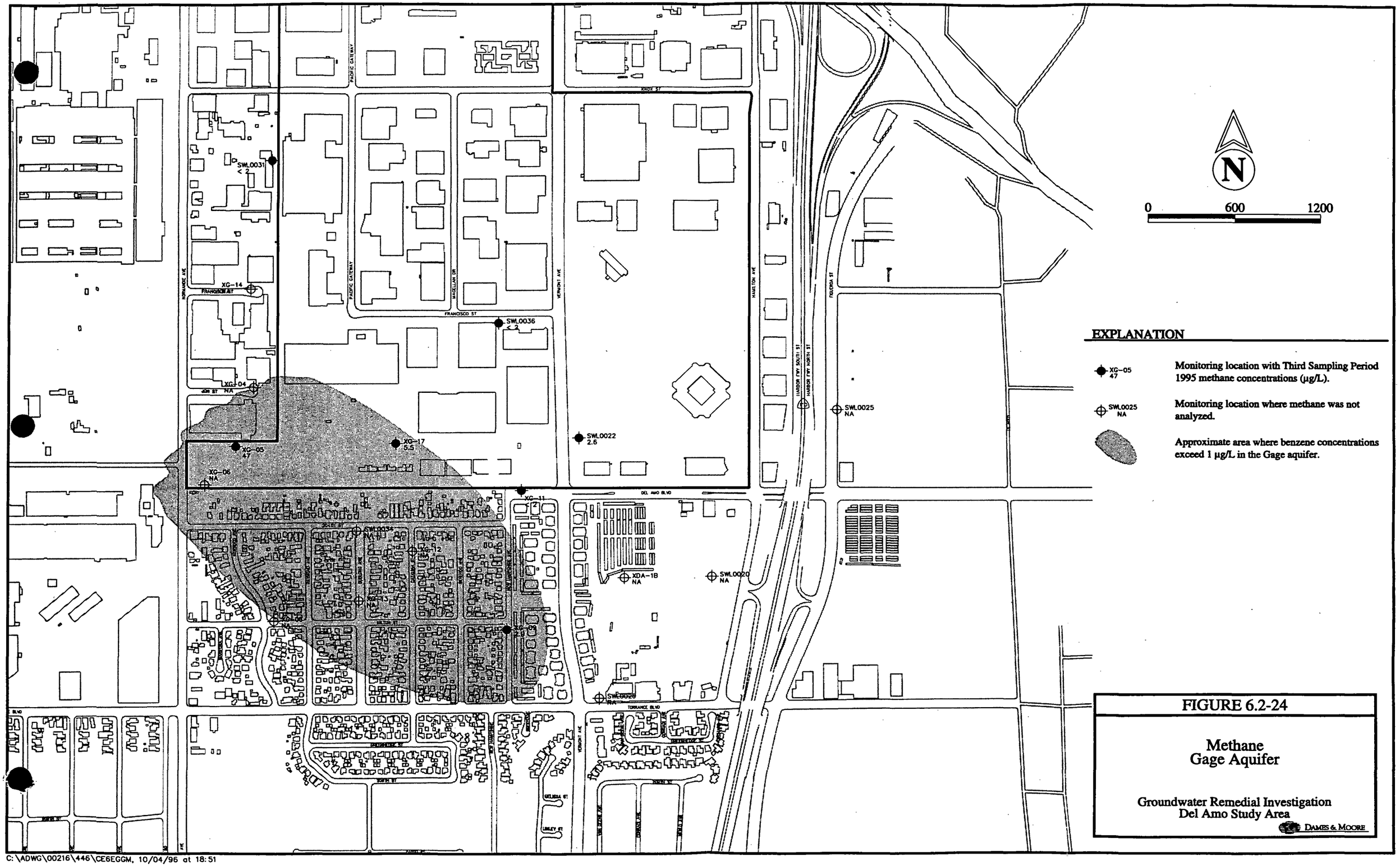

FIGURE 6.2-24

Methane
Gage Aquifer

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

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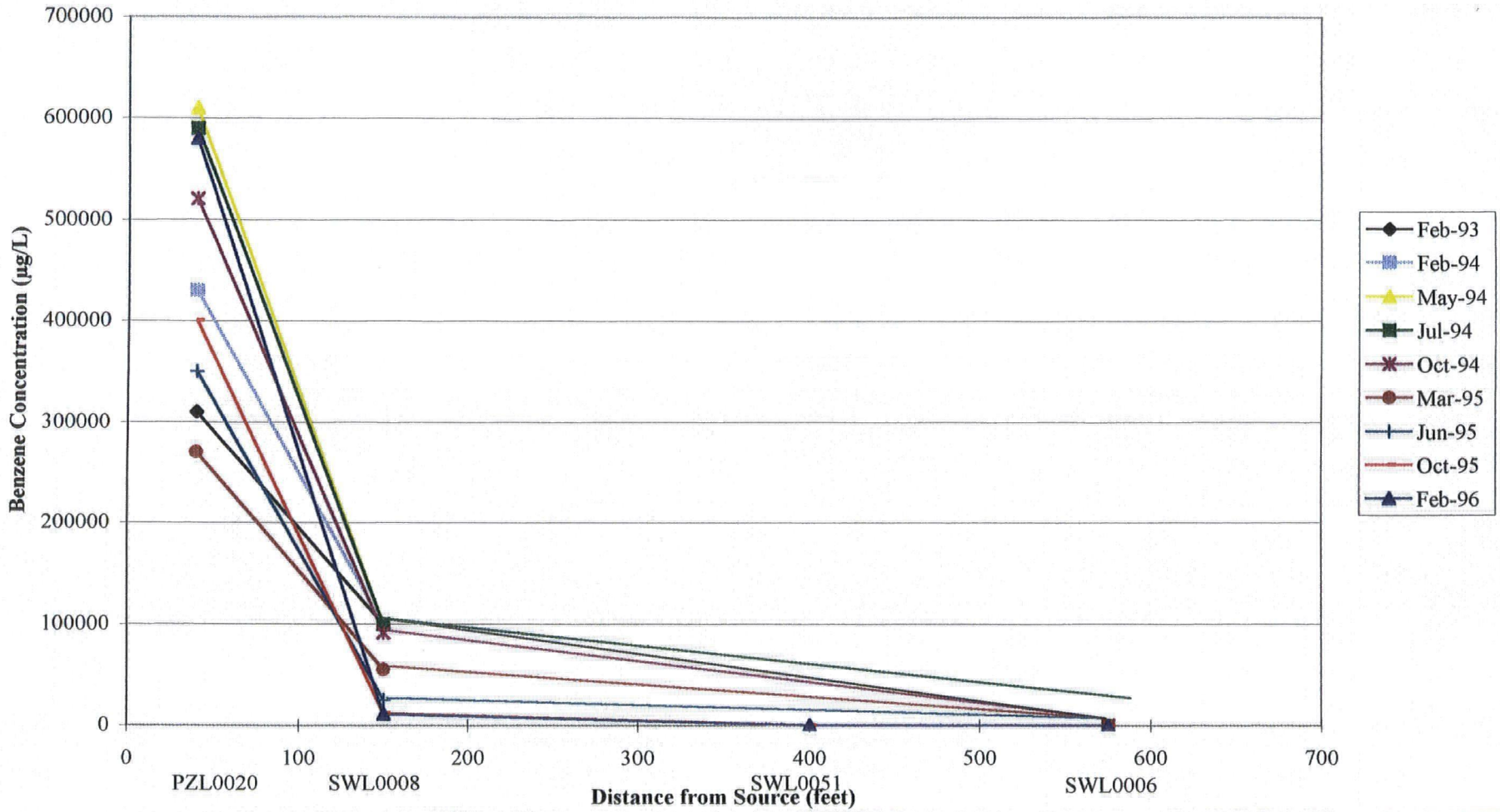

FIGURE 6.3-1b

Benzene Concentrations As a Function of Distance From Source

Groundwater Remedial Investigation Report
Del Amo Study Area

DAMES & MOORE

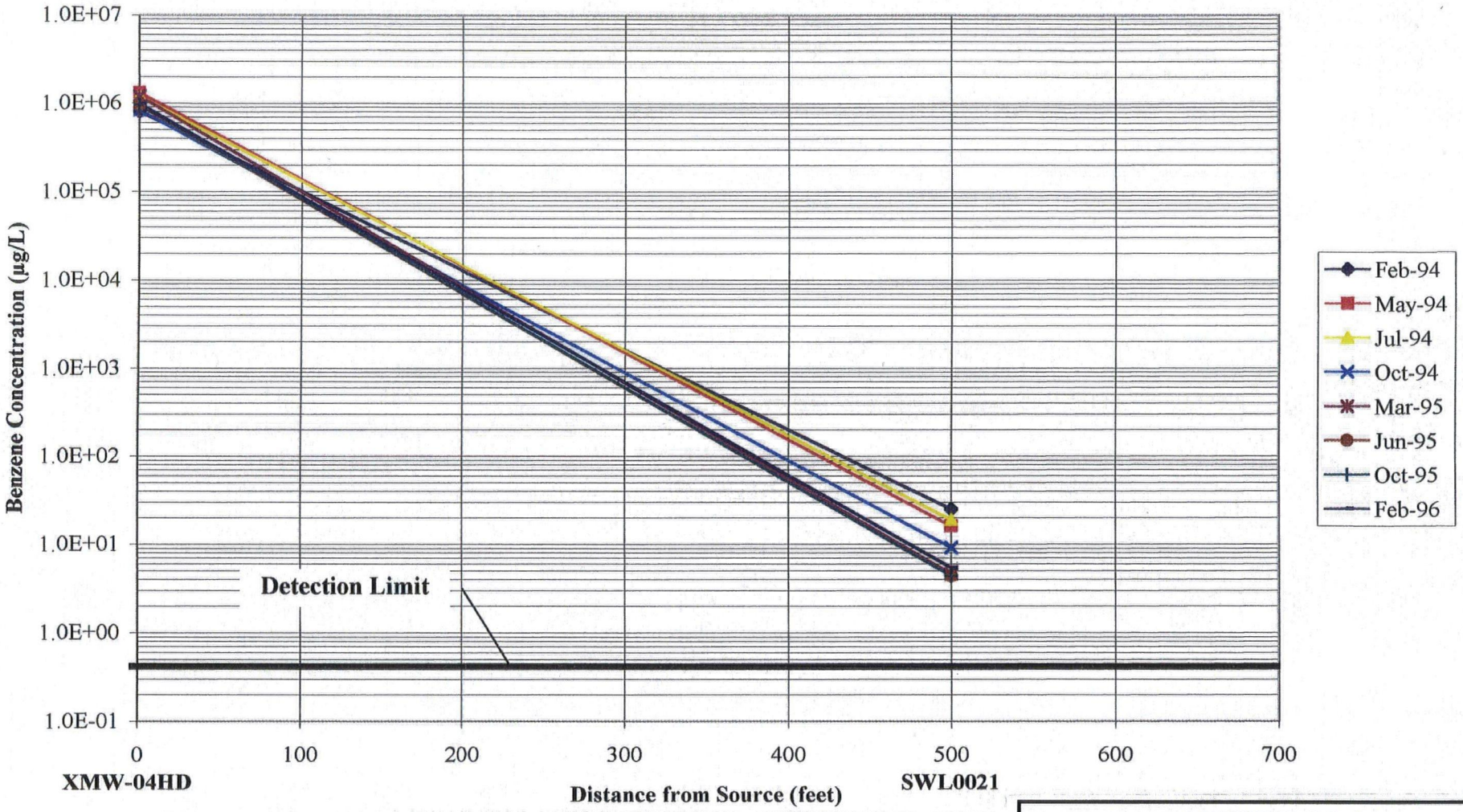

FIGURE 6.3-2a

Benzene Concentrations As a Function of Distance From Source

Groundwater Remedial Investigation Report
Del Amo Study Area

DAMES & MOORE

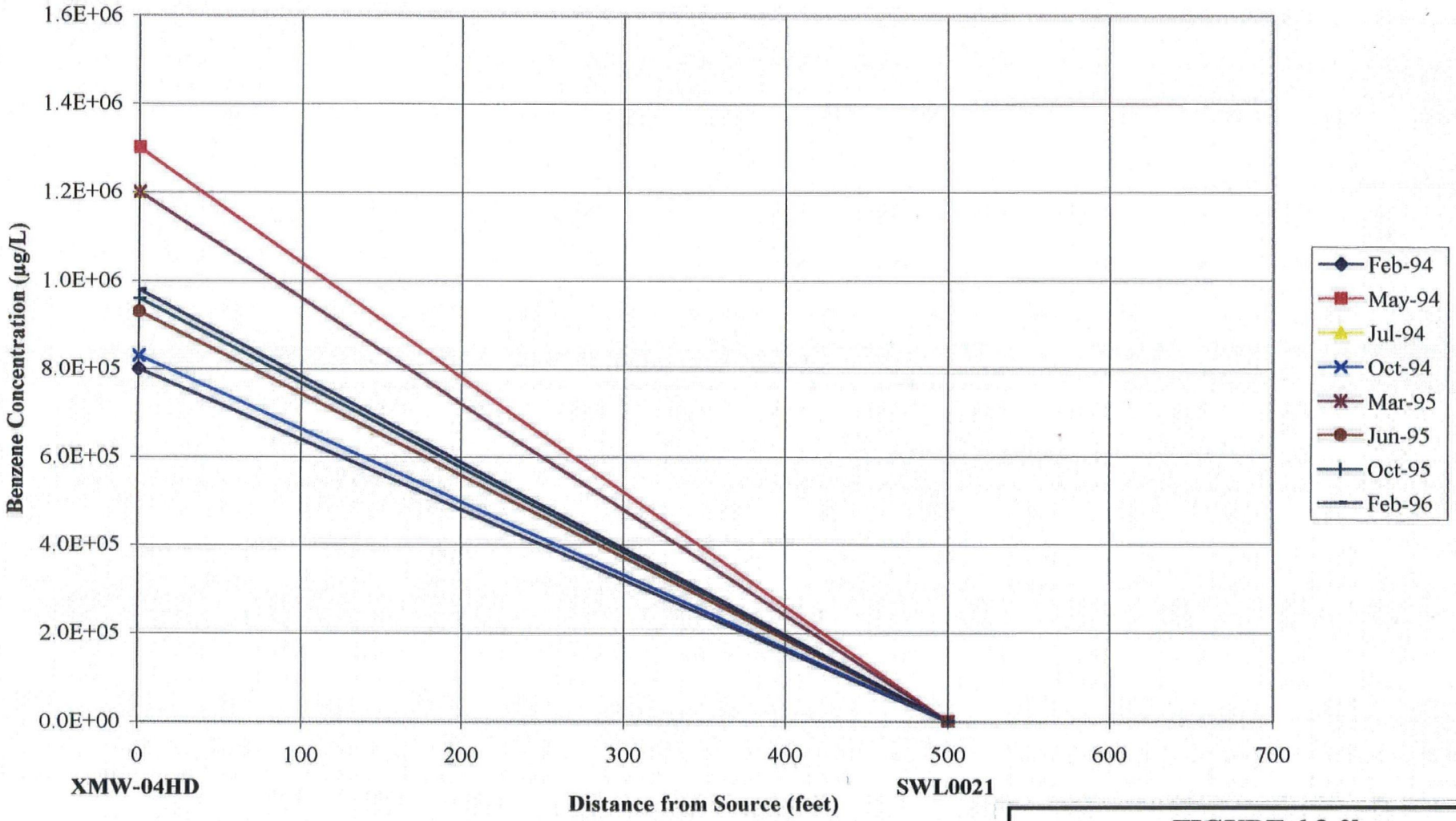

FIGURE 6.3-2b

Benzene Concentrations As a Function of Distance From Source

Groundwater Remedial Investigation Report
Del Amo Study Area

DAMES & MOORE

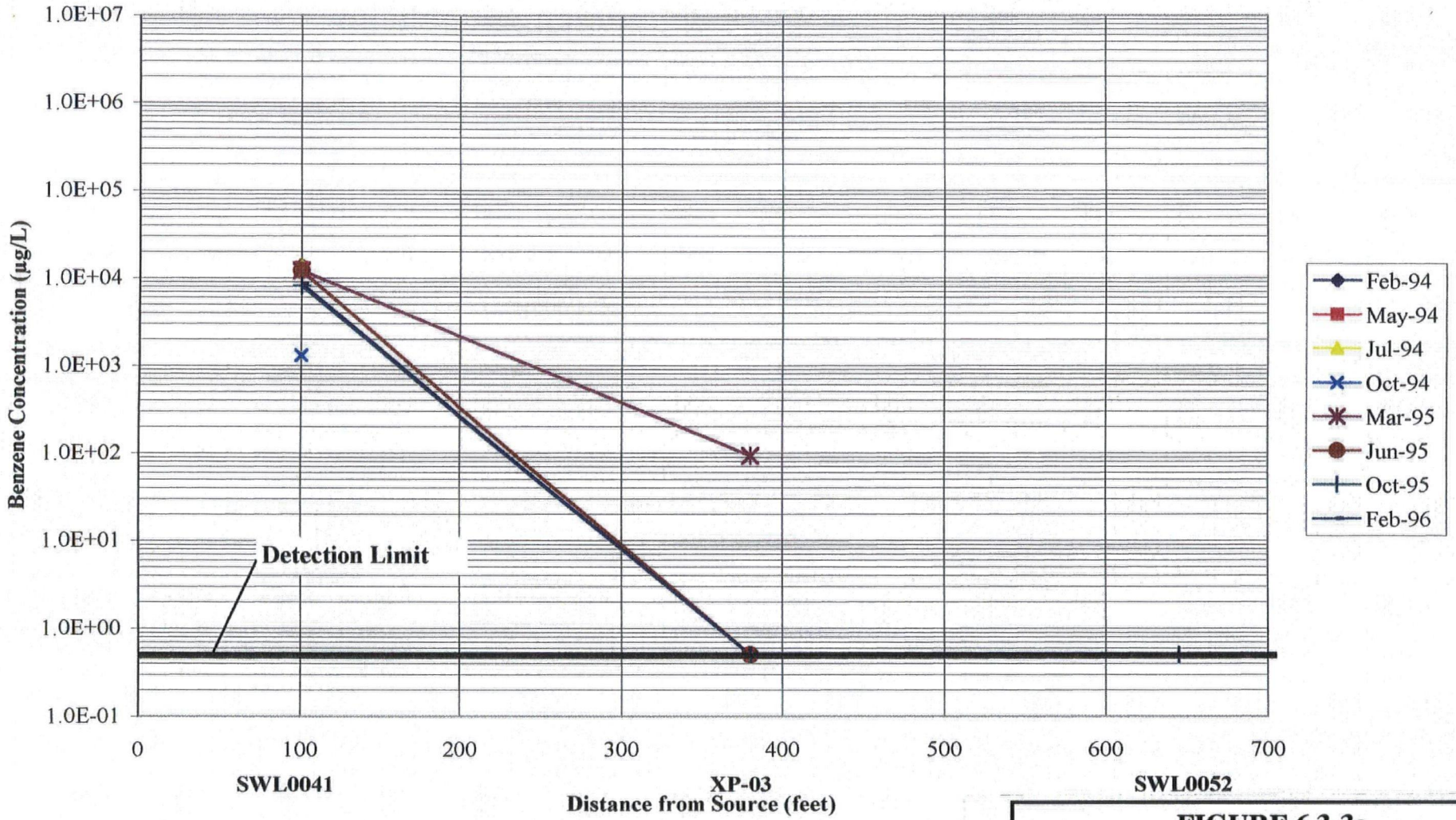

FIGURE 6.3-3a

Benzene Concentrations As a Function of Distance From Source

Groundwater Remedial Investigation Report
Del Amo Study Area

DAMES & MOORE

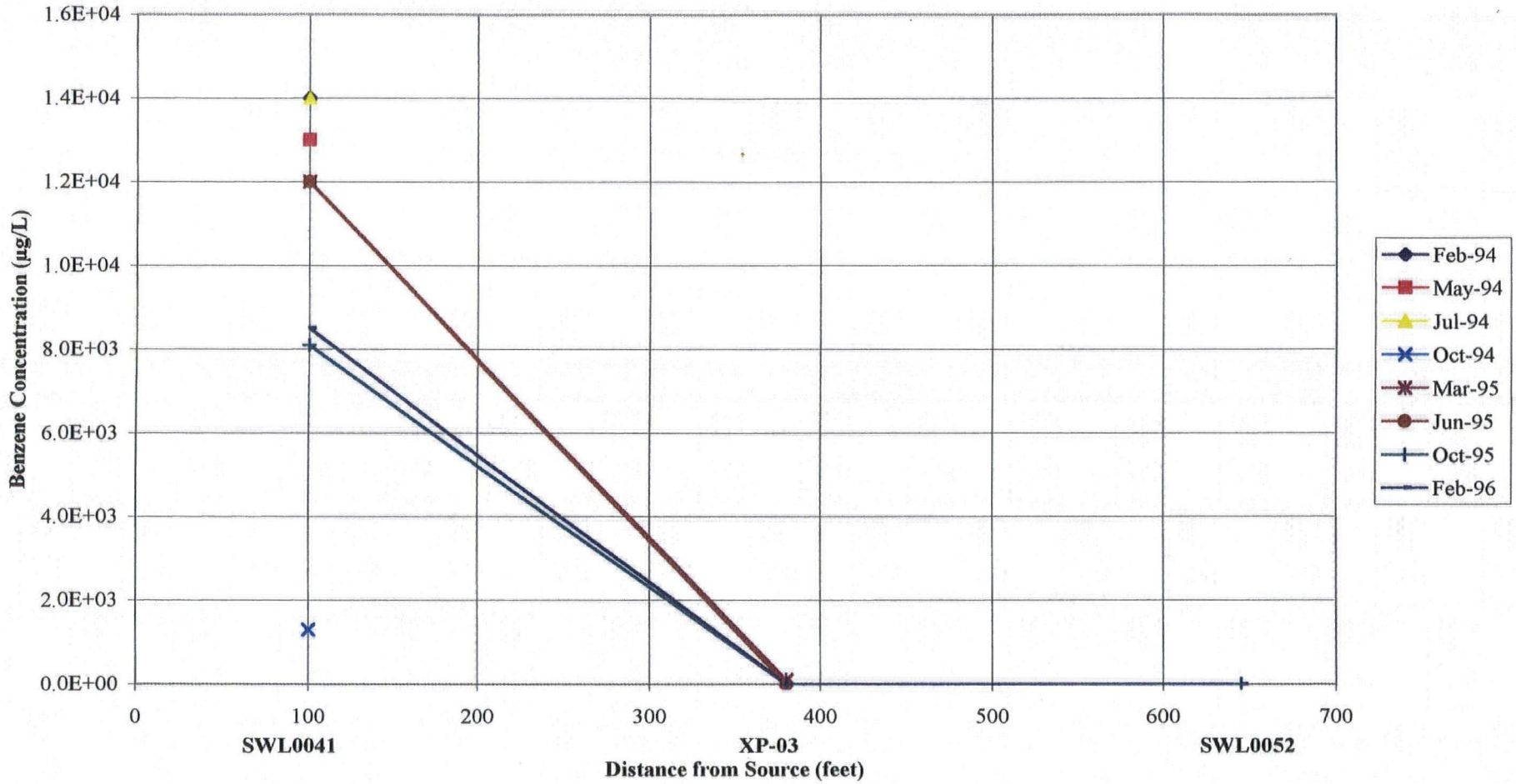

FIGURE 6.3-3b

Benzene Concentrations As a Function of Distance From Source

Groundwater Remedial Investigation Report
Del Amo Study Area

DAMES & MOORE

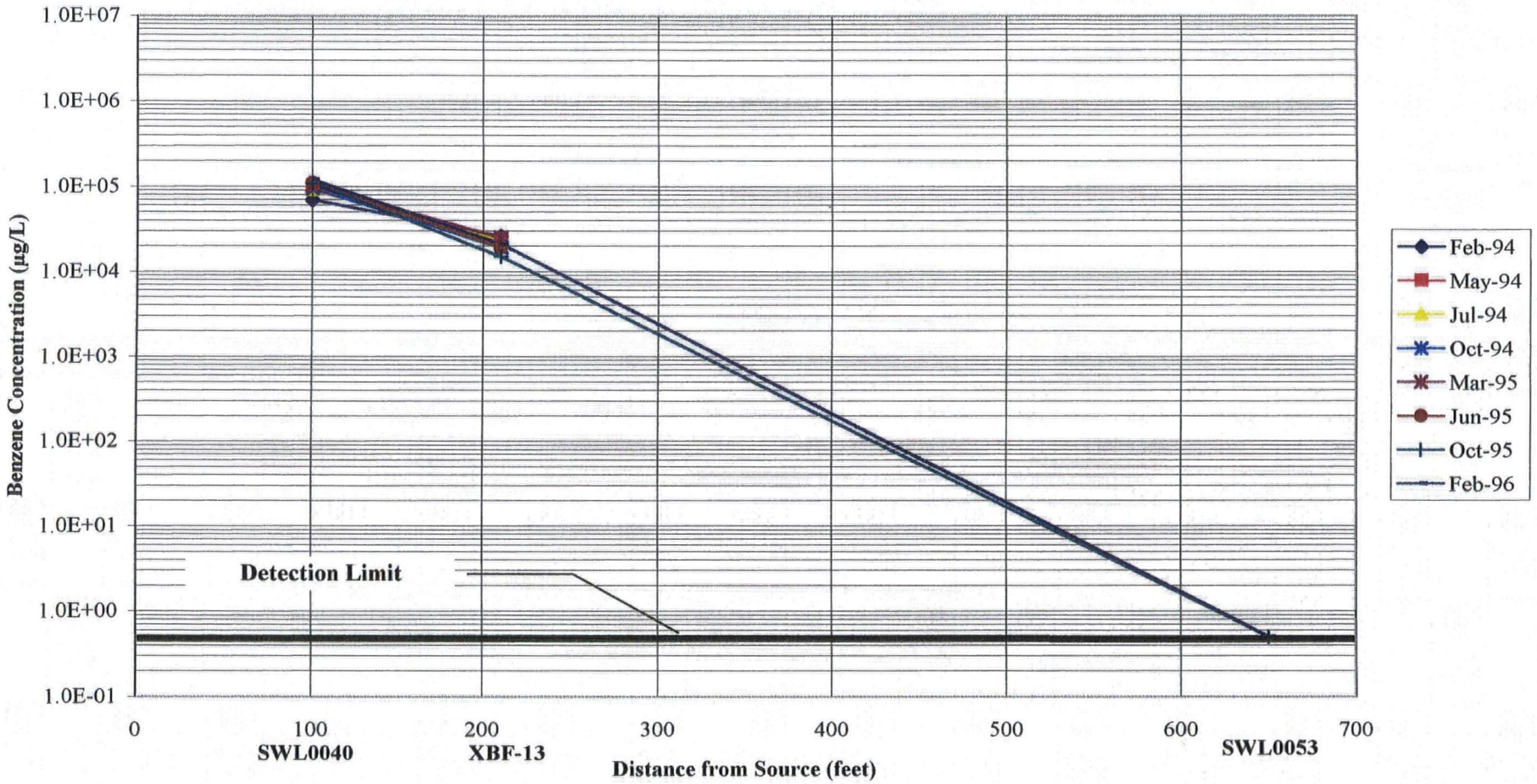

FIGURE 6.3-4a

Benzene Concentrations As a Function of Distance From Source

Groundwater Remedial Investigation Report
Del Amo Study Area

DAMES & MOORE

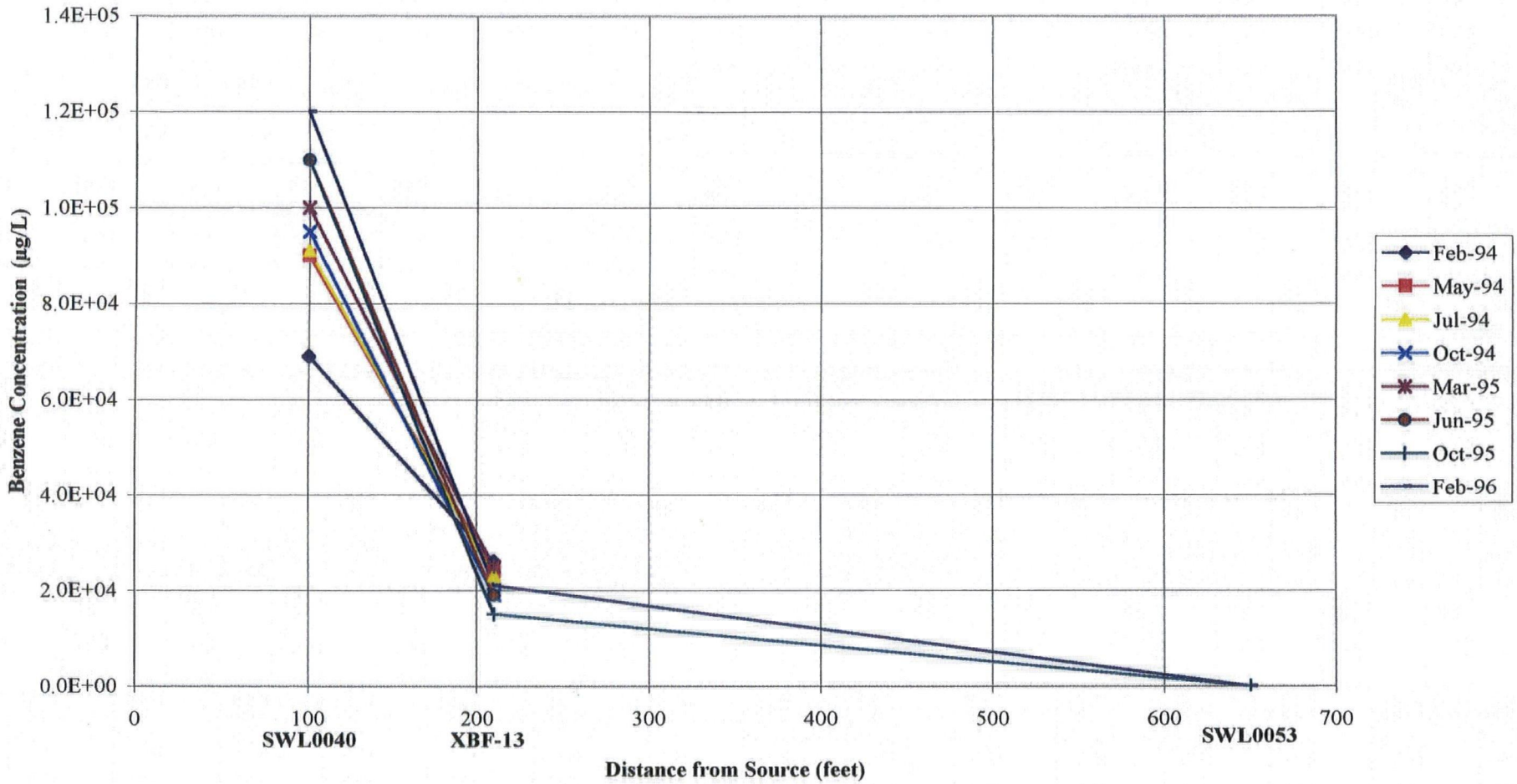

FIGURE 6.3-4b

Benzene Concentrations As a Function of Distance From Source

Groundwater Remedial Investigation Report
Del Amo Study Area

DAMES & MOORE

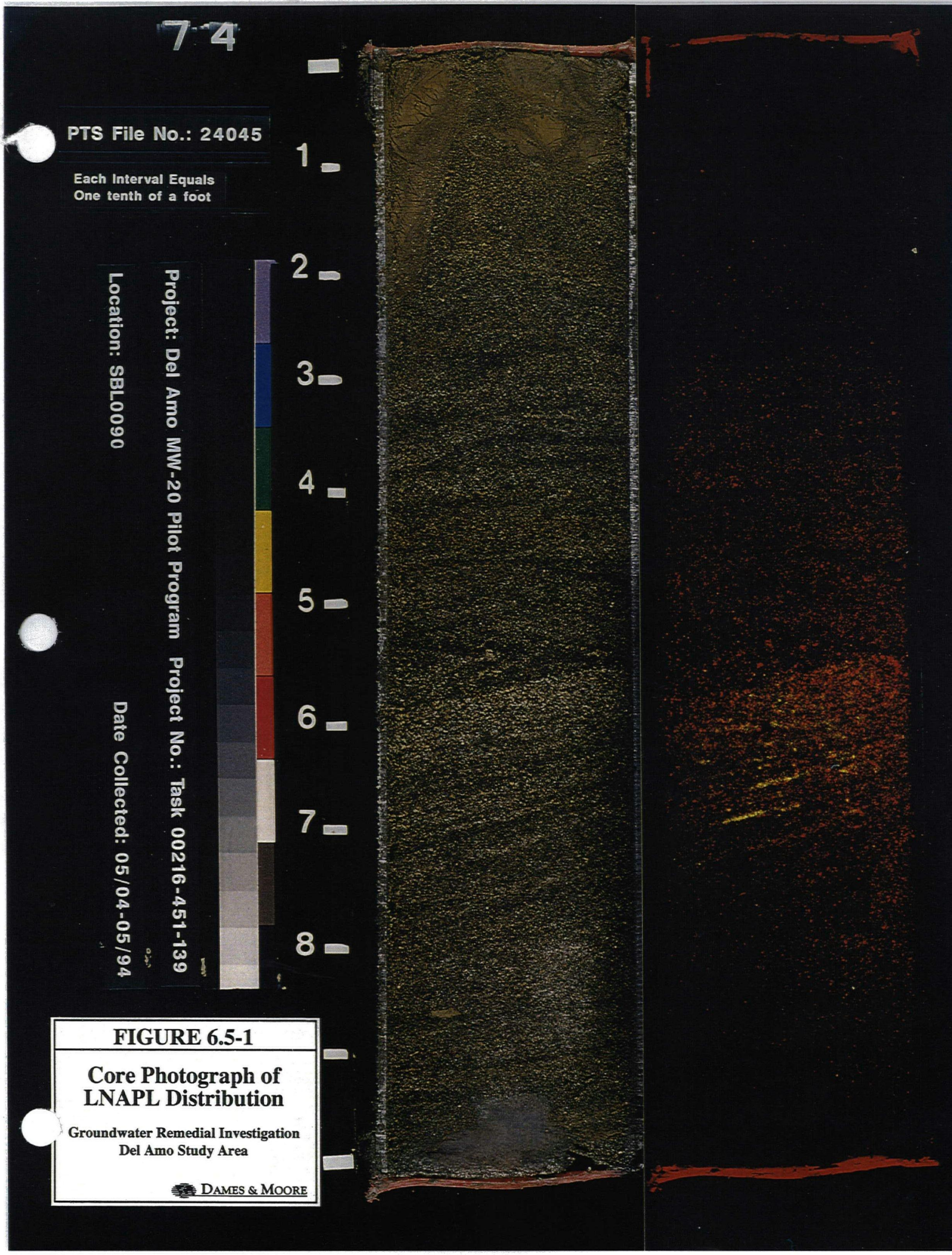

FIGURE 6.5-1

Core Photograph of LNAPL Distribution

Groundwater Remedial Investigation
Del Amo Study Area

DAMES & MOORE

7.0 GROUNDWATER DEVELOPMENT AND USE

This section describes groundwater resources development and use within the study area and surrounding vicinity, and discusses current administrative and institutional controls on the development of local groundwater resources. This information is presented to assist in evaluating remedial measures for groundwater and may also assist in evaluating the significance of potential health risks posed by groundwater contamination in the study area.

7.1 GROUNDWATER RESOURCES AND USE IN THE WEST COAST BASIN

As described in Section 3.0, water-bearing sediments of the West Coast basin include the upper Pleistocene Lakewood formation and lower Pleistocene San Pedro formation. Sediments of the deeper San Pedro formation, including the Lynwood aquifer and the Silverado aquifer, constitute the principal groundwater resources for the West Coast basin. Investigations conducted during the current study have focused primarily upon evaluating groundwater conditions within the shallower water-bearing sediments of the upper Pleistocene Lakewood formation, including the Bellflower aquitard and the underlying Gage aquifer. While limited production rates and poor water quality (high total dissolved solids and inorganic constiutuents) characterize some units within the Lakewood Formation, the CRWQCB has designated all water-bearing units in the basin as municipal and domestic water supply resources.

CDWR documents indicate that 80 to 90 percent of all groundwater produced from the West Coast basin (potable or otherwise) is extracted from the Silverado aquifer, which lies at depths in excess of 500 feet beneath the study area. The remainder of groundwater is produced primarily from the overlying Lynwood aquifer. Groundwater extractions from the basin total approximately 55,000 acre-feet per year, or only 15 percent of total water usage in the West Coast basin, with the remaining 85 percent being imported from outside the Los Angeles area (CDWR, 1995, 1996).

7.2 WATER SUPPLY WELLS

An inventory of recorded water supply wells located within a two-mile radius of the Montrose-Del Amo study area was compiled from previous documents related to the Montrose and Del Amo sites (Hargis + Associates, 1990b, 1992 and Dames & Moore, 1993d, respectively). The

information presented in these source documents specific to public water supply wells was augmented and updated using data presented in recent West Coast basin Watermaster Service reports (CDWR, 1995, 1996), and telephone inquiries to the appropriate water purveyors or municipalities owning/operating public water supply wells within the two-mile radius. Information regarding wells with recorded uses other than public water supply was not updated or reconfirmed for this report.

A total of 80 wells have been identified within the two-mile radius search area, in excess of 80% of which are situated in up gradient or cross gradient locations relative to the Montrose and Del Amo sites. The nature and status of the identified wells are summarized below:

WELL USE	TOTAL WELLS	WELL STATUS[1]		
		ACTIVE[2]	INACTIVE	UNKNOWN
Municipal Water Supply	6	6	0	0
Domestic Water Supply	8	2	4	2
Irrigation Water Supply (including livestock)	10	3	6	1
Irrigation/Domestic Water Supply	8	3	4	1
Industrial Water Supply	12	2	8	2
Remediation Wells[3]	10	6	3	1
Observation Wells	12	0	6	6
Unknown Use[4]	14	0	14	0
TOTALS	80	22	45	13

NOTES

1 Well status as designated in CDWR 1996, or as summarized in Hargis+Associates (1992)

2 "Active" designation does not necessarily indicate recent or current groundwater production

3 Remediation wells limited to those associated with ongoing cleanup at Mobil Oil Co. Torrance refinery

4 Wells of "unknown use" were identified from CDWR 1996, Plate 3, Location of Wells; no further information for these wells was presented in document

The locations of these wells are illustrated in Figure 7.2-1, and a summary of available details regarding well identity, ownership, construction and activity status is presented in Table 7.2-1.

Approximately 43% of all wells designated with an "active" status have no recorded groundwater production for the period 1995-1996 (CDWR, 1995, 1996). This is the case with all "active" domestic, irrigation and domestic/irrigation wells of record within the two-mile radius. Furthermore, the nearest up-gradient well with an "unknown" activity status is located approximately 0.7 miles from the Del Amo plant site. Several other cross-gradient wells of unknown activity status are located one mile or more from the plant site.

Municipal groundwater production accounts for only about 31% of the total combined groundwater extractions recorded during 1995 through 1996 reporting periods for all wells lying within the two-mile radius, with industrial supply (62%) and remediation/cleanup extractions (7%) accounting for the remainder.

7.2.1 Municipal Water Supply Wells

Groundwater production within the West Coast basin is reported annually in the basin Watermaster report, issued at the end of each September and covering the period July 1 through June 30 for each year. In excess of 96% of groundwater produced for municipal supply purposes within two miles of the study area is extracted from wells screened in either the Lynwood aquifer or the underlying Silverado aquifer. Only limited groundwater is produced for public consumption from two municipal supply wells completed within portions of the Gage, Lynwood and Silverado aquifers (CDWR, 1995, 1996). These wells are operated by the city of Torrance and situated in a cross gradient location relative to the plant site.

Available information indicates six municipal supply wells within a two-mile radius of the Del Amo plant site (Figure 7.2-1). Of these six wells, four have recorded groundwater production during one or both of the two latest reporting periods between July 1, 1994 through June 30, 1996 (CDWR, 1995, 1996). Four of these six municipal supply wells, including three of the four with reported production, are situated in up gradient or cross gradient positions relative to the Del Amo plant site. The one producing municipal supply well situated in a down gradient position is completed exclusively within the Silverado aquifer and located approximately 1.4 miles southeast of the former plant site (well 836A, Table 7.2-1 and Figure 7.2-1).

The City of Torrance owns a cluster of three wells located approximately two miles southwest of the plant site in a cross gradient direction (Figure 7.2-1). While none of these wells were active during the 1994-1995 reporting period, two of the three were active during the 1995-

1996 reporting period, producing a combined total of approximately 166 acre-feet of groundwater for municipal consumption (Table 7.2-1). While cross sections presented in a CDWR document indicate the GLA to be absent in the Torrance area, there appears to be little stratigraphic control for this conclusion (CDWR, 1961, cross section E-E´). Hydrogeologic data developed during groundwater investigations at the nearby Mobil oil refinery indicate the GLA to be locally present at thicknesses of up to 100 feet beneath portions of the refinery (Harding-Lawson Associates, 1986). Construction details for the two producing City of Torrance wells indicate they are screened within what is depicted on CDWR cross sections as the merged Gage-Lynwood aquifer and the underlying Silverado aquifer.

A new municipal water supply well has recently been installed for the city of Torrance within the 2-mile radius area (Torrance #7 in Figure 7.2-1). This new well is located approximately 1.7 miles cross gradient from the plant site toward the southwest and is completed at a total depth of approximately 870 feet bgs (Torrance City Water Department, personal communication, 1996). This well is equipped with a 200-foot concrete surface sanitary seal, and is screened at depths in excess of 400 feet bgs, corresponding to portions of the Silverado aquifer (Kennedy-Jenks, personal communication, 1996). This new well has not yet been brought on line, but it is anticipated to be activated sometime during May 1997 (Torrance City Water Department, personal communication, 1997).

The Southern California Water Company operates a single municipal supply well located approximately one mile northwest of the plant site in an up gradient direction (Figure 7.2-1). Information from Watermaster reports indicate this well to have been used during each of the past two years, with reported production of approximately 626 acre-feet for the 1994-1995 reporting period and approximately 389 acre-feet for the 1995-1996 reporting period. Construction details indicate this well is screened exclusively within the Silverado aquifer at depths in excess of 500 feet below ground surface (Table 7.2-1). The Southern California Water Company currently has no plans to install additional municipal water supply wells within the 2-mile radius area (Southern California Water Company, personal communication, 1996).

The Dominguez Water Corporation operates a single municipal supply well located approximately 1.6 miles southeast of the plant site in a down gradient position (Figure 7.2-1). Recent production information for this well indicates approximately 1200 acre-feet of groundwater was extracted from this well during the 1994-1995 reporting period and approximately 1855 acre-feet during the 1995-1996 reporting period. Construction details indicate this well is also screened exclusively within the Silverado aquifer at depths in excess of 500 feet below ground surface (Table 7.2-1). The Dominguez Water Corporation currently

has no plans to install additional municipal water supply wells within the 2-mile radius area (Dominguez Water Corporation, personal communication, 1996b).

Total groundwater extractions from all municipal wells located within the two-mile radius range between approximately 1,826 and 2,410 acre-feet annually for the 1994 through 1996 reporting periods. For comparison purposes, annual groundwater extractions within the entire West Coast basin have averaged approximately 55,000 acre-feet since 1979-1980 (CDWR, 1996). With the exception of comparatively minor production for municipal purposes from the two wells completed partially in the merged Gage-Lynwood aquifer, totaling only approximately six percent of the total municipal production from within this 2-mile radius, the great majority of groundwater produced for municipal supply within 2 miles of the plant site is extracted from the Silverado aquifer. There is no record of groundwater extraction for municipal purposes from the Bellflower aquitard nor from the Gage aquifer in areas where it is separated from the underlying Lynwood aquifer by the intervening Gage-Lynwood aquitard. Note that older wells tend to be constructed to lower standards, possibly without sealing materials placed in the annular space between aquifers and at the surface. Where these wells exist, the potentially open annular space may allow hydraulic continuity between shallow and deeper aquifers.

7.3 EXISTING BENEFICIAL USES OF GROUNDWATER RESOURCES

Beneficial uses of groundwater within the West Coast basin are designated in the Water Quality Control Plan (basin plan) for the Los Angeles region of the CRWQCB (CRWQCB, 1994). As described in the basin plan, beneficial uses form the cornerstone of water quality protection and, together with water quality objectives, provide the basis for setting water quality standards. The basin plan identifies a total of five possible *existing*[1] and/or *potential*[1] beneficial uses for groundwater, including municipal and domestic water supply (MUN), industrial service supply (IND), industrial process supply (PROC), agricultural supply (AGR), and aquaculture (AQUA). *Existing* beneficial uses identified specifically for groundwater of the West Coast basin include MUN, IND, PROC and AGR, as defined in the table below. The

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Existing beneficial uses are defined as those that have been attained for a waterbody on, or after, November 28, 1975. Beneficial uses can be designated as *potential* for several reasons, including: (1) implementation of the State Board's policy entitled "Sources of Drinking Water Policy" (State Board Resolution No. 88-63); (2) plans to put the water to such future use; (3) potential to put the water to such future use; (4) designation of a use by the Regional Board as a regional water quality goal; or, (5) public desire to put the water to such future use (CRWQCB, 1994).

basin plan does not identify any *potential* beneficial uses for groundwater in the West Coast basin.

EXISTING BENEFICIAL USE	DEFINITION
Municipal and Domestic Water Supply (MUN)	Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.
Industrial Service Supply (IND)	Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well re-pressurization.
Industrial Process Supply (PROC)	Uses of water for industrial activities that depend primarily upon water quality.
Agricultural Supply (AGR)	Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

7.4 LEGAL AND ADMINISTRATIVE CONTROLS ON GROUNDWATER DEVELOPMENT AND USE

7.4.1 Adjudication of the West Coast Basin

Groundwater production throughout the West Coast basin has been carefully managed since 1961 when the basin was adjudicated. Basin adjudication was undertaken in response to substantial declines in groundwater levels and resultant seawater intrusion following decades of excessive and uncontrolled pumping throughout the basin. Early efforts at groundwater resource management within the West Coast basin began with the formation of the West Basin Water Association in 1946, which developed a plan to: (1) provide a supplemental supply for major users; (2) limit groundwater extractions; and, (3) create an exchange pool to provide pumping rights for users not having access to supplemental water (CDWR, 1995).

In 1947 the West Basin Municipal Water District was created to administrate water deliveries from the Colorado River to provide supplemental water to the basin. Following further definition of groundwater conditions in the West Basin by CDWR between approximately 1946 and 1952, and the worsening of groundwater supply problems in the ensuing years, the Superior Court, Los Angeles county, approved an interim agreement in 1955 that limited groundwater extractions and prescribed groundwater rights to the individual parties involved until a final judgement could be approved. CDWR was appointed as Watermaster to administer this interim agreement. Following a period of additional data analysis, the Court, in 1961, signed the West Coast basin Judgement and appointed CDWR as the Watermaster. This judgement has been amended several times since 1961, most recently to address non-consumptive uses associated with groundwater cleanup operations at oil refineries within the basin. The Judgement allocated prescriptive groundwater rights to each involved party, limiting the amount of groundwater each party could legally pump during each reporting period.

The CDWR serves as Watermaster for the basin under the current adjudicated management system, and is responsible for tracking the use of allocated rights and overall groundwater extraction within the basin. Groundwater producers report extractions to the Watermaster on a monthly basis, and this amount is then deducted from the user's annual groundwater allocation account. This allows a detailed accounting of groundwater balance within the basin. The judgement allows parties to exchange adjudicated groundwater rights, obtain additional rights or make changes to their account. Groundwater rights must be secured before any individual well can be pumped; these rights can be purchased or leased from parties who hold the adjudicated rights. Once the rights are secured and a water meter installed, the user must then report groundwater usage to the Watermaster on a monthly basis.

The Watermaster summarizes groundwater extractions and account balances in an annual report, covering the fiscal year July 1 through June 30. Total groundwater extractions during the reporting period are tabulated by month for each user and well.

7.4.2 State and Local Water Purveyor Well Construction Standards

While not a guarantee that existing and/or future groundwater production wells will not be impacted by contamination, current California well construction standards and local water purveyor construction practices reduce the likelihood that this will occur. California well construction standards have been in place since December 1981 (Bulletin 74-81, December 1981, amended by Bulletin 74-90, June 1991). Wells installed before December 1981 may not

have surface seals. For wells without adequate seals, shallow contamination can be drawn down through annular materials to deeper units. Current CDWR regulations require that water supply wells be situated in areas removed from known contamination and specify installation in locations upgradient of known contaminant sources, wherever possible (CDWR, 1991). In areas where adverse environmental conditions exist, the state guidance recommends extending the length (depth) of the annular seal for water supply wells beyond the minimum required depth of 50 feet, and extend downward to the first "impervious stratum" below this minimum depth. Furthermore, state standards specify that wells penetrating zones containing poor quality water or pollutants be completed using methods to "seal off" or "isolate" these intervals to reduce the potential for degradation of water quality in other units. All municipal water purveyors in the area, including Dominguez Water Corporation, Southern California Water Company and the city of Torrance, construct their water supply wells with sanitary seals that meet, and typically exceed, minimum state standards. Sanitary seals for all their wells are designed and constructed considering well-site specific conditions, such as the nearby presence of sewer lines, flood control channels, landfills, etc. In such situations, sanitary seals typically extend to depths considerably deeper than 50 feet, and in some cases may extend as deep as 200 feet.

Dominguez Water Corporation is the major local water purveyor in the study area and operates the only active municipal water supply well positioned in a down gradient location relative to the plant site. All municipal supply wells operated by Dominguez Water Corporation are constructed with a concrete annular seal extending to a minimum depth of 200 feet, effectively isolating all water-bearing zones down to, and including the majority of, the Gage aquifer. Furthermore, the Dominguez Water Corporation also has adopted a policy which precludes completion or operation of production wells within any water-bearing zone other than the Silverado aquifer (Dominguez Water Corporation, personal communication, 1996a).

7.5 GROUNDWATER MANAGEMENT PLANNING

Municipal water districts within the west and central basins have co-authored an urban water management plan that addresses important issues regarding total water supply and demand within these basins through the year 2020 (Central Basin Municipal Water District and West Basin Municipal Water District, 1995). Future groundwater management programs under consideration for these basins include the following goals:

- Expand conjunctive operation of these groundwater basins with surface water supplies to provide more underground storage for both local and imported surplus surface water during wet years;

- Continue recovery and desalination of brackish groundwater from portions of the West Coast basin;

- Increase use of recycled water for injection into the coastal seawater intrusion barriers;

- Increase use of recycled water by major industrial consumers; and,

- Use recycled water for artificial recharge of groundwater basins.

The successful implementation of these and other programs presented in the urban water management plan will provide expand groundwater supplies in the future through a combination of more flexible conjunctive use policies, increased use of recycled water for industrial and replenishment purposes, and continued mitigation and corrective actions within areas of seawater intrusion and brackish groundwater. This long-term water supply planning has been undertaken on a regional rather than local scale, and may not necessarily directly influence the current practices of water purveyors operating within 2-miles of the Del Amo plant site.

TABLE 7.2-1

WELLS WITHIN A 2-MILE RADIUS OF PLANT SITE
GROUNDWATER REMEDIAL INVESTIGATION REPORT
DEL AMO STUDY AREA

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
3S/13W-29E3	821P		H.W. Abernathy	1.7 miles NNE Up gradient		72			DO	Unknown	
3S/13W-30J1				1.7 miles NNE Up gradient					Unknown	Inactive	
3S/13W-30J5	822B		C.F. Johnson	1.6 miles NNE Up gradient	1937	156	18	135-142	IR DO	Inactive	Gage\Gardena[5]
3S/13W-30K1	812D		Olaf and Anna Nelson	1.2 miles N Up gradient	1932	200	12		DO	Inactive	
3S/13W-30N2[+]									Unknown	Inactive	
3S/13W-30Q1	822F		Emily Cost	1.3 miles NNE Up gradient	1933	80	7		IR DO	Unknown	
3S/13W-30Q7	812Z		Morningside Service Garage	1.1 miles NNE Up gradient	1949	152	8		IR	Inactive	

TABLE 7.2-1

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
3S/13W-31B7	822FF		Clark and Grace Day	1.1 miles NNE Up gradient	1948	384	10	365-370	IR DO	Active No recorded production 1995-1996	Silverado[4]
3S/13W-31C2	812M		Glenn Voss and Nellie Olson	0.9 mile NNE Up gradient	1920	650	12		IR DO	Inactive	
3S/13W-31K1	813Y		Ben F. Karran	0.7 mile NE Up gradient	1948	35	8		DO	Unknown	
3S/13W-31K2	813Z		Pet Haven Pet Cemetary and Crematory	0.7 mile NE Up gradient	1959				IR	Active No recorded production 1995-1996	
3S/13W-31M1	813N		Maxwell Zeigler	0.3 mile N Up gradient	1949	664	10	550-574 638-644	IR DO	Active No recorded production 1995-1996	Silverado[4]
3S/13W-32C1	833D		John Larronde, et al.	1.5 miles NE Up gradient		275	8		DO	Inactive	

TABLE 7.2-1

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
3S/13W-32E2	823F		Clyde L. Sheets	1.1 miles NE Up gradient	1953	597	10-8		IR DO	Active No recorded production 1995-1996	
3S/13W-32F2	833A		L.A. Co. Highway Dept.	1.5 miles NE Up gradient	1918	750	12	628-635 643-733	IR	Inactive Abandoned	Silverado[5]
3S/14W-25F3				1.5 miles WNW Up gradient					Unknown	Inactive	
3S/14W-25K6	802T	Norm 1	Mayflower Nursery	1.2 miles NNW Up gradient	1947	120	6	112-120	IR	Active No recorded production 1995-1996	Gage/Gardena[5]
3S/14W-25L1	792E		M.G. Marcellus	1.4 miles NNW Up gradient	1936		8		IR	Unknown	
3S/14W-25N2	792K		A.D. Seaback	1.3 miles NNW Up gradient	1936	205	6		IR DO	Inactive	
3S/14W-25N4				1.2 miles NW Up gradient					Unknown	Inactive	

TABLE 7.2-1

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
3S/14W-25P4	792W	Dalton #1	Southern California Water Co.	1.1 mile W Up gradient	1948	751	16	623-648 662-698 699-734	MS	**Active** 626 AF 1995 395 AF 1996	Silverado[4]
3S/14W-26J1	792		Mrs. E.V. Kuape	1.4 miles NW Up gradient	1927	321	8		DO	Active No recorded production 1995-1996	
3S/14W-35B3	782B		Warren J. Ogle	1.4 miles NW Up gradient	1923	400	8		IR DO	Inactive	
3S/14W-35M7	773N		Allied Signal (ShinodaBros. Inc) (Garrett Corp.)	1.4 miles WNW Up gradient	1964	324	12	292-321	IR	Active No recorded production 1995-1996	Lynwood[5]
3S/14W-35Q2+									Unknown	Inactive	
3S/14W-35R1			Southern California Edison	0.7 mile W Cross gradient	1919	550	12	470-485	Unknown	Inactive Abandoned	Lynwood-Silverado[5]
3S/14W-36K1			L.H. Floge	0.2 mile N Cross/up gradient		322			IR	Inactive	

TABLE 7.2-1

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
3S/14W-36N1	793J		John Zurlite	0.5 mile W Cross gradient		80	4		Unknown	Inactive	
3S/14W-36N2	794D		John Zurlite	0.5 mile W Cross gradient		62	6		OBS	Inactive Abandoned	
3S/14W-36P1	804			0.3 mile W Cross gradient					Unknown	Inactive	
3S/14W-36P2	803N			0.3 mile W Cross gradient					Unknown	Inactive	
3S/14W-36P3	793A			0.2 mile W Cross gradient					Unknown	Inactive	
3S/14W-36P4				0.2 mile W Cross gradient					Unknown	Inactive	
3S/14W-36Q1	803Q		F.C. Irvine Ranch	0.1 mile W Cross gradient	1949	572	10		OBS	Inactive	
3S/14W-36Q2	804A		Joe B. Ramos	0.2 mile W Cross gradient		352	6		IR	Inactive	
3S/14W-36Q3	804B		M.E. Woods	0.1 mile W Cross gradient		702	12		Unknown	Inactive	

TABLE 7.2-1

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
3S/14W-36R1			F.J. Easter	0.2 mile N Up gradient		254	10		DO	Inactive	
3S/14W-36R2			Bennett	0.2 mile N Up gradient		70			DO	Inactive	
4S/13W-5L1	834		Del Amo Estate Co.	1.0 mile E Cross gradient	1948	720	16	555-562 570-636 640-644 672-676	IR	Inactive	Silverado[4]
4S/13W-6Q1	814A		LACFCD	0.2 mile E Cross gradient	1937	70			OBS	Inactive	
4S/13W-7H1	825		Clyde Sheets	0.6 mile ESE Downgradient	1948	698	16	555-562 570-636 640-644 672-676	IR	Inactive	Silverado[4]
4S/13W-7L1	816		Sunset Oil Co.	0.2 mile SE Down/cross gradient	1946	580	12	528-580	Unknown	Inactive Destroyed 1972	Silverado[5]
4S/13W-17D1	836A	19A	Dominguez Water Corp.	1.4 miles SE Down gradient	1991	1701	12	504-511 525-560 585-610 635-660	MS	Active 1200 AF 1995 1855 AF 1996	Silverado[4]

TABLE 7.2-1

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
4S/13W-18P1	818A		C.G. Fiesel	1.8 miles S Down gradient	1900+-	250	8		DO	Active No recorded production 1995-1996	
4S/13W-19B1	818B		General Petroleum Co.	1.9 miles SSE Down gradient	1922	251	12		IS	Inactive	
4S/14W-1F1	794A	#1	McDonnell Douglas (Alcoa)	0.3 mile W Cross gradient	1942	600	14	473-514	IS	Inactive	Silverado[4]
4S/14W-1F2	794B	#2			1942	600	14	477-506 525-530 535-540	IS	Inactive	Silverado[4]
4S/14W-1F3	794C	#3			1942	600	14	427-433 478-516 538-550	IS	Inactive	Silverado[4]
4S/14W-1P1	795		Stauffer Chemical (Jones Chemical Co.)	0.3 mile SW Cross gradient	1943	727	16	486-560 603-560 673-714	IS	Destroyed 1995	Silverado[4]
4S/14W-2F1		EW-5	Mobil Oil Co.	1.2 miles WNW Cross gradient		160		65-145 150-155	REM	Active 91 AF 1995 50 AF 1996	Gardena[6]

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
4S/14W-2L1		EW-2		1.2 miles W Cross gradient		170		80-155 160-165	REM	**Active** 126 AF 1995 96 AF 1996	Gardena[6]
4S/14W-2L2		EW-3		1.1 miles W Cross gradient		160		74-145 150-155	REM	**Active** 113 AF 1995 59 AF 1996	Gardena[6]
4S/14W-2L3		EW-4		1.1 miles W Cross gradient		155		65-140 145-150	REM	**Active** 96 AF 1995 84 AF 1996	Gardena[6]
4S/14W-2M1		RW-1		1.4 miles W Cross gradient					REM	Inactive	
4S/14W-2M2		RW-2		1.4 miles W Cross gradient					REM	Inactive	
4S/14W-2M3		RW-3		1.3 miles W Cross gradient					REM	Inactive	
4S/14W-2M4		EW-1		1.4 miles W Cross gradient		177		82-162 167-172	REM	**Active** 66 AF 1995 92 AF 1996	Gardena[6]
		EW-6		0.9 mile WSW Cross gradient		159		74-144 149-154	REM	**Active** 54 AF 1995 45 AF 1996	Gardena[6]

TABLE 7.2-1

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
		EW-7		1.0 mile SW Cross gradient		165		75-145 150-160	REM	Unknown	Gardena[6]
4S/14W-3L8		T0009		1.4 miles WNW Cross gradient					IS	**Active** 1740 AF 1995 1673 AF 1996	
		T0010		1.2 miles W Cross/up gradient					IS	**Active** 2826 AF 1995 2316 AF 1996	
4S/14W-10J1	776	#2	City of Torrance	1.8 miles WSW Cross gradient	1935	623	16-12	170-320 360-520	MS	Active No reported production 1995-1996	Gage/Gardena-Silverado[5]
4S/14W-10K2	766A	#4		2.0 miles WSW Cross gradient	1965	812	16	180-812	MS	**Active** 0 AF 1995 140 AF 1996	Gage/Gardena-Silverado[5]
4S/14W-10K3	766B	#5		1.9 miles WSW Cross gradient	1966	816	16	210-786	MS	**Active** 0 AF 1995 26 AF 1996	Gage/Gardena-Silverado[5]

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
		#7		1.7 miles SW Down/cross gradient	1996	870		400+	MS	Considered Active (to be activated 5/97) 0 AF 1996	Silverado
4S/14W-11F1	785B	#3	Columbia Steel Corp.	1.0 mile WSW Cross gradient	1935	600	16	198-200 260-280 305-390	IS	Unknown	Merged Lynwood/Silverado[5]
4S/14W-11F2	785C	#4		1.2 mile WSW Cross gradient	1939	460	24-16	140-450	IS	Unknown	Gage-merged Lynwood/Silverado[5]
4S/14W-11G1	785A	#2	U.S. Steel (Columbia Steel Corp.)	1.1 miles WSW Cross gradient	1942	653	14		IS	Inactive Abandoned	
4S/14W-11G2	785	#1		1.0 mile WSW Cross gradient	1927	613	14	293-304	IS	Inactive	Merged Lynwood/Silverado[5]
4S/14W-11G4	785D	#5		1.2 miles WSW Cross gradient	1935		16	198-218 260-280 305-390	IS	Inactive	Lynwood-Silverado[4]
	792Z			1.1 miles NW Cross/up gradient					OBS	Unknown	
4S/14W-11L1+									Unknown	Inactive	

Well Identification			Owner Name (Former Owner Name)	Approx. Dist. from Site and Position Relative to GW Flow[1]	Year Drilled	Depth (Feet)	Well Diam. (Inches)	Screened Interval (Ft. Depth)	Use	Status[2]	Completion Zone Hydrostratigraphic Unit[3]
CDWR and USGS	LACDPW	Owner									
	802Z			1 mile NNW Cross/up gradient					OBS	Unknown	
4S/14W-12K1+	805		Frank S. Austin			200	7		OBS	Inactive	
4S/14W-12Q1	806		Mrs. J.M. Carson	0.9 mile S Down gradient	1902	377	7		OBS	Inactive	
4S/14W-12Q2	806C		LACFCD	0.7 mile S Down gradient	1956	165	8		OBS	Inactive	
	835E		LACFCD	1.3 miles ESE Downgradient	1954	179	2	117-179	OBS	Unknown	Gage[5]
	846E			1.7 miles ESE Downgradient					OBS	Unknown	
	846G			1.8 miles ESE Downgradient					OBS	Unknown	
	846K			1.7 miles ESE Downgradient					OBS	Unknown	

NOTES:

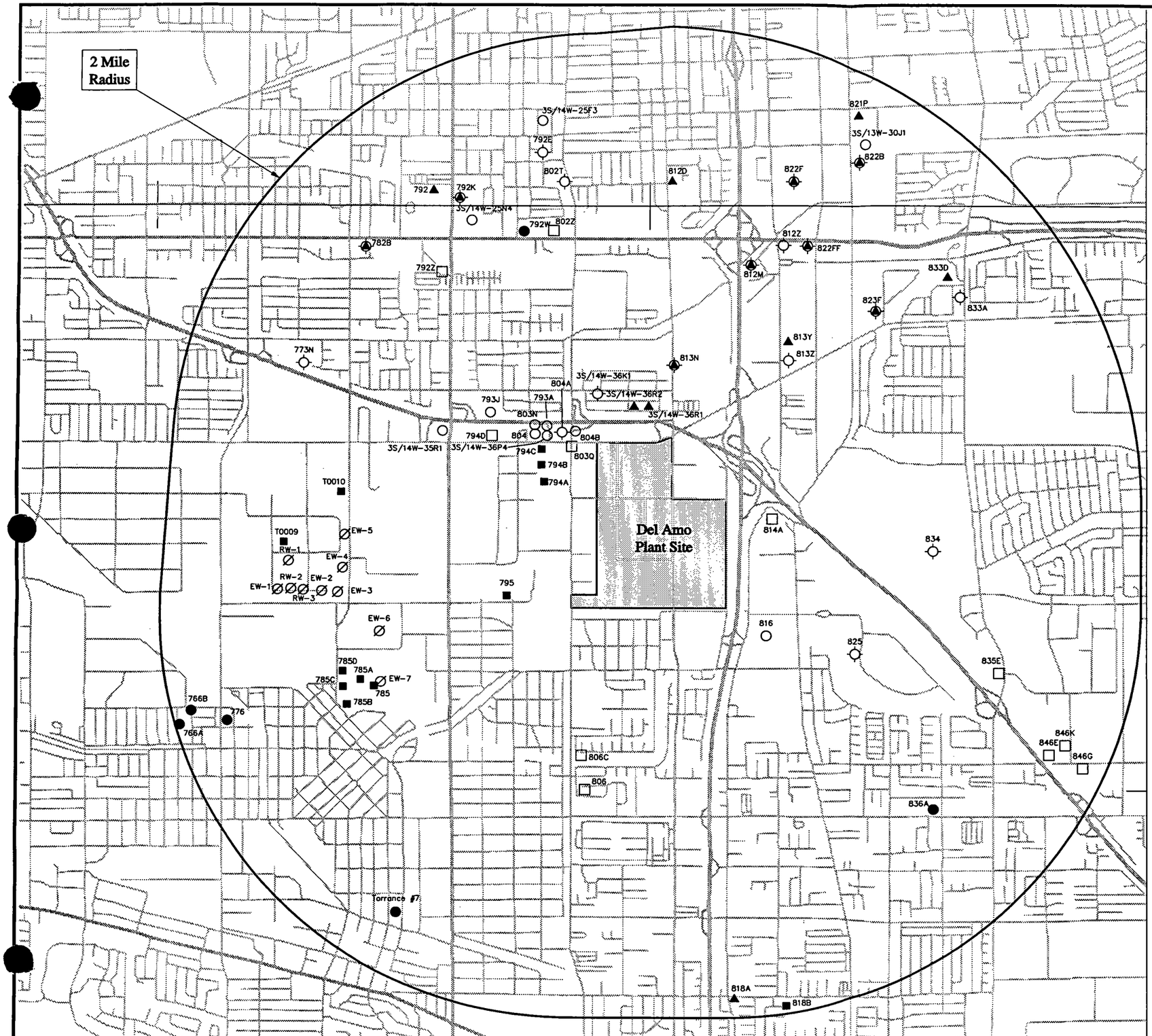
1 Approximate distance from nearest point of Del Amo plant site boundary; Position relative to principal groundwater flow direction in the water table zone

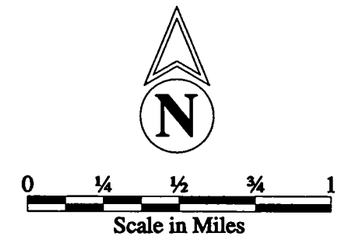
2 Status determined from Watermaster documents Plate 3 - Locations of Wells (CDWR, 1995, 1996) or from Hargis + Associates Draft Remedial Investigation Report, Table 1.3 (1992)

3 Completion zone hydrostratigraphic unit listed only for those wells with information available regarding screened interval(s)

4 Completion zone hydrostratigraphic unit as presented by Hargis + Associates 1992, Table 1.3

5	Completion zone hydrostratigraphic unit as derived from comparison of reported screened interval with stratigraphy depicted on cross sections presented in CDWR, 1961
6	Completion zone hydrostratigraphic unit as listed in Harding-Lawson 1996. The Gardena Aquifer, located north and west of the plant site, is reported to be contemporaneous and in hydraulic continuity with the Gage Aquifer (CDWR, 1961).
+	Well not illustrated on Figure 7.2-1, precise location uncertain
AF	Acre-Feet
D&M	Dames & Moore, (1993d)
DO	Domestic Supply Well
H+A	Hargis + Associates (1992)
IR	Irrigation/livestock Supply Well
IS	Industrial Supply Well
LACFCD	Los Angeles County Flood Control District
MS	Municipal Supply Well
OBS	Observation Well
REM	Remediation Well (limited to facilities associated with ongoing groundwater cleanup at Mobil Oil Co. Torrance refinery)
Unknown	No information available in Watermaster documents





EXPLANATION

- Municipal supply well
- Domestic supply well
- Irrigation supply well
- Domestic/Irrigation supply well
- Industrial supply well
- Remediation/cleanup well
- Observation well
- Well of unknown use

FIGURE 7.2-1

Water Supply Wells Within 2-Mile Radius of Plant Site

Groundwater Remedial Investigation Report
Del Amo Study Area

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8.0 SUMMARY OF FINDINGS AND CONCLUSIONS

Salient findings and conclusions regarding study area conditions derived from the remedial investigation are summarized below. The reader is referred to the referenced sections of this report for more detailed discussions and supporting material for each finding and conclusion.

Section 3.2 Study Area Hydrostratigraphy

- Sediments underlying the study area include estuarine tidal flat and channel deposits of the upper Pleistocene Lakewood formation and the underlying San Pedro Formation of lower Pleistocene age. Hydrostratigraphic units defined within the Lakewood formation include the Bellflower aquitard, the Gage Aquifer, and the Gage/Lynwood aquitard. The Bellflower aquitard has been further subdivided within the study area to include the upper Bellflower aquitard, the middle Bellflower B sand, the middle Bellflower mud, the middle Bellflower C sand, and the lower Bellflower aquitard. Hydrostratigraphic units within the San Pedro Formation include the Lynwood aquifer, an unnamed aquitard, and the Silverado aquifer.

Section 4.1 Groundwater Levels and Flow Conditions

- Groundwater elevations have risen at an average rate of approximately one foot per year in the water table, MBFB, MBFC, and Gage aquifer, and approximately two feet per year in the Lynwood aquifer over the duration of the groundwater monitoring program, a period of approximately two years. Historical water level data and other indirect evidence indicate that the trend of rising groundwater elevations originated approximately 30 years ago, and may be associated with adjudication of the West Coast basin in 1961.

- The groundwater table intersects and crosses stratigraphic boundaries, residing within the upper Bellflower aquitard east of a demarcation line near the western boundary of the Del Amo plant site, and within the underlying middle Bellflower B Sand to the west of the demarcation line.

- Groundwater elevations typically decrease in successively deeper hydrostratigraphic units, and the vertical gradient is therefore generally downward. Groundwater elevations for the water table, MBFB, MBFC, and Gage aquifer are within several feet of each other. Changes in groundwater elevations through time are also similar for the these four units. These conditions are distinct from the Lynwood aquifer, where groundwater elevations are approximately 11 feet lower than the Gage aquifer, and changes in groundwater elevations through time are independent of the overlying water bearing units.

- Groundwater flow is generally vertical in finer grained units, and generally horizontal in coarser grained units. Furthermore, because of typically large differences between vertical hydraulic conductivities in the fine grained aquitards and horizontal hydraulic conductivities in the coarser grained aquifers, the velocity of the horizontal flow in the coarser units typically greatly exceeds the velocity of the vertical flow in the finer grained units.

- The water table, MBFB, and MBFC are likely hydraulically interconnected at the plant site. The presence of the LBF aquitard significantly decreases the hydraulic interconnection of the Gage aquifer with the overlying units at the plant site. However, the Gage aquifer is reported to be merged with the overlying MBFC approximately ½-mile west of the plant site, which may account for the similarity of water level fluctuations in the Gage aquifer and overlying units. The Lynwood aquifer is relatively isolated from the overlying units at the plant site.

Section 4.2 Aquifer Properties

- Aquifer testing demonstrates a wide range of transmissivity and hydraulic conductivity for the sediments of the upper Bellflower aquitard, consistent with the highly heterogeneous character of these sediments. Aquifer testing in relatively homogeneous and coarse-grained units display much less variability, and are typically an order-of-magnitude greater than the highest values obtained for the relatively fine-grained units. Vertical hydraulic conductivity of aquitard materials is up to an order-of-magnitude less than the horizontal hydraulic conductivity for these same materials.

Section 4.3 General Groundwater Chemistry

- General mineral and physical properties are similar for groundwater from the water table, MBFB, MBFC and Gage aquifer. Groundwater from each tends to be non-dominated to calcium dominated with respect to cations, and bicarbonate dominated to chloride dominated with respect to anions. Total dissolved solids content is very similar for the water table and MBFB, ranging from several hundred to a few thousand mg/l. TDS concentrations decrease in the MBFC and Gage aquifer, where concentrations are typically less than or equal to 1,000 mg/l.

- TDS and surfactant concentrations are elevated at MBFB and MBFC monitoring locations near the eastern end of the Waste Pit Area (SWL0041 and SWL0040), and may be related to elevated VOC concentrations at the same locations, although the nature of this relationship is uncertain.

Section 5.1 Distribution of NAPL

- Benzene LNAPL is present in the vicinity of monitoring well XMW-20 at the plant site. This LNAPL is present across an approximately 17,500-square foot area and is restricted to an approximately 30-foot thick smear zone below the groundwater table. The majority of the LNAPL is trapped in soil pores as isolated ganglia at residual (immobile) saturation.

- LNAPL is also present at three locations outside of the plant site, in the vicinity of monitoring wells XMW-07 and XP-01, and soil boring SBL0102. The LNAPLs at these three areas are composed of petroleum hydrocarbons, and are not believed to be associated with the plant site.

- LNAPL is suspected, but has not been directly observed, at five additional plant site areas. If present, the LNAPL at four of these areas is likely composed primarily of benzene and/or ethylbenzene. The remaining suspected LNAPL would likely be composed chiefly of benzene and toluene.

- A DNAPL composed primarily of chlorobenzene is present at the Montrose Plant Property, west of the southwest corner of the Del Amo plant site. An additional DNAPL area is suspected, but not confirmed, near the central portion of the western Del Amo plant site, where elevated PCE and TCE concentrations have been detected in groundwater.

Section 5.2 Distribution of Dissolved Contaminants

- Time-series analytical results for water table monitoring points demonstrate that benzene concentrations are relatively stable. No significant expansion or retreat of the benzene plumes has been detected over the monitoring period.

- Chlorobenzene is distinct from benzene in that its maximum distribution occurs in the MBFC rather than the overlying water table zone or MBFB.

- The ethylbenzene distribution is very similar to the benzene distribution.

- PCE and TCE concentrations within the study area are also quite high relative to MCLs and other detected compounds. The distributions of these compounds are distinct from benzene and chlorobenzene.

- p-CBSA is distributed over a broader area than other dissolved contaminants in the MBFC and Gage aquifer. The high mobility of p-CBSA makes the distribution of this compound a useful indicator of the migration of other dissolved contaminants from a common source area.

- SVOCs have been detected almost exclusively in the water table and MBFB, primarily within the southern plant site area and the area west of the southwest corner of the plant site. This area is within the area of high VOC concentrations.

- Metals concentrations in excess of MCLs have been sporadically detected for several compounds, primarily arsenic and aluminum, within the water table, MBFB, and MBFC. The aluminum exceedances are attributed to suspended sediment in the samples, as MCL exceedances were not detected for filtered samples from the same monitoring locations. A cluster of arsenic concentrations in excess of the MCL exists near the southwest corner of the plant site. The origin of this cluster is uncertain.

- Detection of pesticides at the Del Amo plant site is limited to the extreme southwest corner of the area, and is part of a larger dissolved contaminant plume that underlies and extends downgradient of the Montrose Plant Property. Detected pesticides are limited to isomers of DDT and benzene hexachloride (BHC).

Section 5.3 Groundwater Contamination Source Areas

- Numerous regional groundwater contamination source areas have been identified outside the Del Amo plant site based on analytical data and historical facility information available from regulatory agency files. Elevated concentrations of dissolved VOCs are associated with each of the regional source areas identified.

- Twelve groundwater contamination source areas associated with the Del Amo plant site have been identified. Past releases of VOCs from plant site facilities at each of these areas are inferred to have impacted groundwater. Elevated benzene concentrations are associated with 10 of the 12 source areas.

- VOCs, specifically chlorobenzene and benzene, are considered to be the primary dissolved contaminants within the study area based on their relatively broad distribution, high concentrations relative to MCLs, and known toxicity.

- Benzene contamination originates primarily from multiple source areas within the Del Amo plant site. The individual benzene plumes from these sources have largely coalesced within the water table zone, resulting in the observed distribution of an eastern and western plume area. Most non-benzene plumes associated with the plant site lie entirely within the coalesced benzene plume area.

- Ethylbenzene source areas largely overlap with benzene sources and similarly originate primarily from the Del Amo plant site.

- Chlorobenzene is interpreted to originate primarily from the Montrose Plant Property, to the west of the Del Amo plant site.

- TCE and PCE likely originate primarily from sources west of the southwest corner of the plant site, and also further north, along the western plant site boundary. Groundwater data and historical information indicate sources unrelated to the plant site for both areas, although an additional PCE/TCE contribution from former plant site facilities may have occurred for the more northerly of the two primary source areas.

- The distribution of dissolved SVOCs suggest that they are likely associated with both plant site operations and with LNAPL releases from petroleum pipelines unrelated with the plant site.

- Dissolved metals detected at concentrations in excess of MCLs are unlikely to be associated with the plant site. This judgment is based on the poor correlation between metal MCL exceedances and the areas of historical chemical use and storage at the plant site, and the lack of any known use of concentrated metal solutions.

- The observed distribution of pesticides are is limited to isomers of DDT and BHC in the southwest corner of the plant site. This distribution is inferred to be part of a larger pesticide plume that underlies and extends downgradient of the Montrose Plant Property.

Section 6.1 Plume Migration

- Time-series plots of benzene concentrations versus distance from a single source area indicate dissolved benzene plumes are stable in all HSUs, neither migrating farther downgradient away from sources, nor receding upgradient toward sources.

- Dissolved benzene concentrations attenuate abruptly from a single source where dissolved chlorobenzene is not present. In the water table zone, MBFB and MBFC, dissolved benzene concentrations attenuate from 100,000 μg/L to non-detectable concentrations (less than 0.5 μg/L) in less than 600 feet in a downgradient direction.

- Benzene concentrations of less than 100 μg/L are broadly distributed over 1,500 feet along flow direction in the MBFC and Gage aquifer where dissolved chlorobenzene is also present, indicating that different transport and attenuation mechanisms are in effect than in areas where chlorobenzene is not present.

Section 6.2 Dissolved Phase Contaminant Mobility Characteristics

- Site-specific data indicate that the dissolved benzene distribution is primarily a function of advective-dominated transport and biodegradation-dominated attenuation.

- BTEX degrading microorganisms are present in each of the tested hydrostratigraphic units beneath the study area.

- Based on published guidance criteria, there is strong evidence that both aerobic and anaerobic (denitrification and methanogenesis) biodegradation of BTEX occurs in the study area.

- Site specific data indicates a benzene half-life ranging from 75 to 600 days for the area outside of the distribution of chlorinated compounds.

Section 6.3 Non-Aqueous Phase Hydrocarbons

- The results of detailed field and laboratory studies conducted in the MW-20 area demonstrate that LNAPL is trapped below the water table as isolated singlets, doublets, and ganglia.

- Testing of soil samples from the MW-20 LNAPL area for relative fluid saturations, intrinsic flow properties, and relative permeability indicates that the majority of samples exhibit LNAPL saturations below laboratory derived residual levels. It is therefore inferred that most of the LNAPL is immobile under the current flow regime.

Section 7.1 Groundwater Resources and Use in the West Coast Basin

- Sediments of the lower Pleistocene San Pedro formation, including the Lynwood aquifer and the Silverado aquifer, constitute the principal groundwater resources for the West Coast groundwater basin.

- Between 80 percent and 90 percent of all groundwater produced in the West Coast basin is extracted from the Silverado aquifer, with the remainder being produced primarily from the overlying Lynwood aquifer. Groundwater extractions from the basin total approximately 55,000 acre-feet per year, or only 15 percent of total water usage in the

West Coast basin, with the remaining 85 percent being imported from outside the Los Angeles area.

- While poor water quality and limited production rates naturally limit use of groundwater from some of the Bellflower aquitard units, all groundwater within the recognized units at the Del Amo site is designated as a municipal water supply resource.

Section 7.2 Municipal Water Supply Wells

- Records indicate six municipal groundwater supply wells exist within a two-mile radius of the plant site, only four of which have recorded production during the past two annual reporting periods. In excess of 96 percent of groundwater produced for municipal supply purposes from within 2 miles of the plant site was extracted from wells screened in either the Lynwood aquifer or the underlying Silverado aquifer. Only limited groundwater was produced from two municipal supply wells completed within portions of the Gage, Lynwood and Silverado aquifers.

Section 7.3 Existing Beneficial Uses of Groundwater Resources

- Beneficial uses of groundwater within the West Coast basin have been designated in the Water Quality Control Plan for the Los Angeles region by the California Regional Water Quality Control Board.

Section 7.4 Legal and Administrative Controls on Groundwater Development and Use

- Withdrawals of groundwater from the West Coast basin for any beneficial use are currently monitored and strictly controlled by the California Department of Water Resources, as the Superior Court-appointed Watermaster for the West Coast basin. Groundwater rights must be held and reported to the Watermaster before any party can divert groundwater for beneficial use from the basin.

- While not providing a guarantee that existing and/or future groundwater production wells will not be impacted by contamination, California well construction standards and local water purveyor construction practices reduce the likelihood that this will occur.

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