4.0 INVESTIGATION AREA CHARACTERISTICS

This section summarizes the regional and Muscoy Plume OU geologic and hydrogeologic characteristics. Because no drilling activities were performed as part of this RI/FS, the discussion on geologic conditions is based on the data collected during the Newmark OU RI/FS, a geologic cross-section developed from a review of driller logs for the municipal supply wells in the Muscoy Plume OU, and published information (Dutcher and Garrett 1963). Hydrogeologic characteristics are also based on one round of water level measurements conducted during April through May 1993.

4.1 GEOLOGY

4.1.1 Regional Geology

The model area lies between two major northwest-trending faults (San Andreas and San Jacinto) forming the San Bernardino Valley. The San Bernardino Valley is filled with water-bearing alluvial deposits derived from the San Gabriel Mountains to the northwest and the San Bernardino Mountains to the northeast. Bedrock underlying the alluvium is composed of pre-Tertiary igneous and metamorphic rocks. The San Gabriel Mountains, San Bernardino Mountains, and the various hills that are scattered throughout the study area are also composed of bedrock. The alluvium consists of boulders, gravel, sand, silt, and clay of late Tertiary and Quaternary age (Dutcher and Garrett 1963).

A number of en echelon (offset parallel) faults are present in the region between the two major faults. The Loma Linda fault is located approximately one mile northeast of the San Jacinto fault and extends across the model area along a northwest/southeast trend. Fault K is located approximately one and one-half miles south of the San Andreas Fault and trends northwest/southeast. Fault K has been mapped as extending from the vicinity of the Newmark Wellfield directly north of Shandin Hills to the northwest, north of Wiggins Hill and out of the study area.

The confluent alluvial fans that fill the San Bernardino Valley formed at the base of mountains where erosion provided a supply of sediment. Sediments formed as channel or sheet deposits, depending upon the confining features present in the alluvial valley and the slope of the topography. Thin layers of coarse sediments, such as gravel and sand, deposited at the base of mountains where the greater topographical relief resulted in increased flow velocities. Toward the valley center, where the topography was flatter and flow velocities were slower, finer and thicker the sediment layers were deposited.

Alluvial thicknesses in the San Bernardino Valley vary considerably, with maximum alluvial thickness occurring adjacent to the northeast side of the San Jacinto fault south of the city of San Bernardino (Fife et al. 1976; Hardt and Hutchinson 1980). The alluvial thicknesses increase from 400 feet at the Newmark Wellfield, near the base of the San Bernardino Mountains, to at least 2,100 feet at the Loma Linda/San Jacinto fault zone near the center of the San Bernardino Valley (Youngs et al. 1981). Alluvial thicknesses are based on interpretation of drillers' logs. The northern portion of the study area, just south of the San Bernardino Mountains, consists predominantly of sand, gravel, and boulders with little or no clay. The drillers' log for the Waterman Avenue well (parallel to the southern edge of Shandin Hills) documents the northern most occurrence of a substantial amount of clay. Clay lenses increase in number and thickness toward the central and southern portion of the valley.

4.1.2 Muscoy Plume Investigation Area OU Geology

The geology in the vicinity of the Muscoy Plume OU consists of a complex interfingering of alluvial sediments eroded from the San Bernardino and San Gabriel Mountains. These types of deposits are typically highly heterogeneous and include mixtures of widely varying particle sizes from boulders to fine-grained sands, silts, and clays. A discussion of the lithologic conditions encountered in the vicinity of the Muscoy Plume OU is presented in the following paragraphs.

Figure 4-1 shows the location of and Figure 4-2 depicts geologic Cross-Section A-A'. The cross-section trends from northwest to southeast along the approximate centerline of the Muscoy Plume OU and is a generalized representation of subsurface lithology.

Figure 4-2 shows that the northern portion of the Muscoy Plume OU is dominated by sands, gravels, and boulders as evidenced by the driller's log for well MUNI-108. Further south there appears to be an increase in both the number and thickness of clay and silt lenses (wells MUNI-105 and MUNI-104). The lenses are interpreted as interfingered and appear to be underlain by sands and gravels at depth (wells MUNI-101, MUNI-25, and Meeks and Daley).

The available drillers' logs for the wells in this area of the valley indicate that the sediments to the north tend to be poorly sorted while the sediments to the south tend to be moderately sorted. Logs from wells located north of Shandin Hills cite cobbles and boulders of various sizes, while logs to the south of Shandin Hills cite more uniform sand grain sizes and few cobbles or boulders. This degree of sorting is consistent with sediment models for alluvial fan deposits and with the conceptual model developed for the Newmark OU.

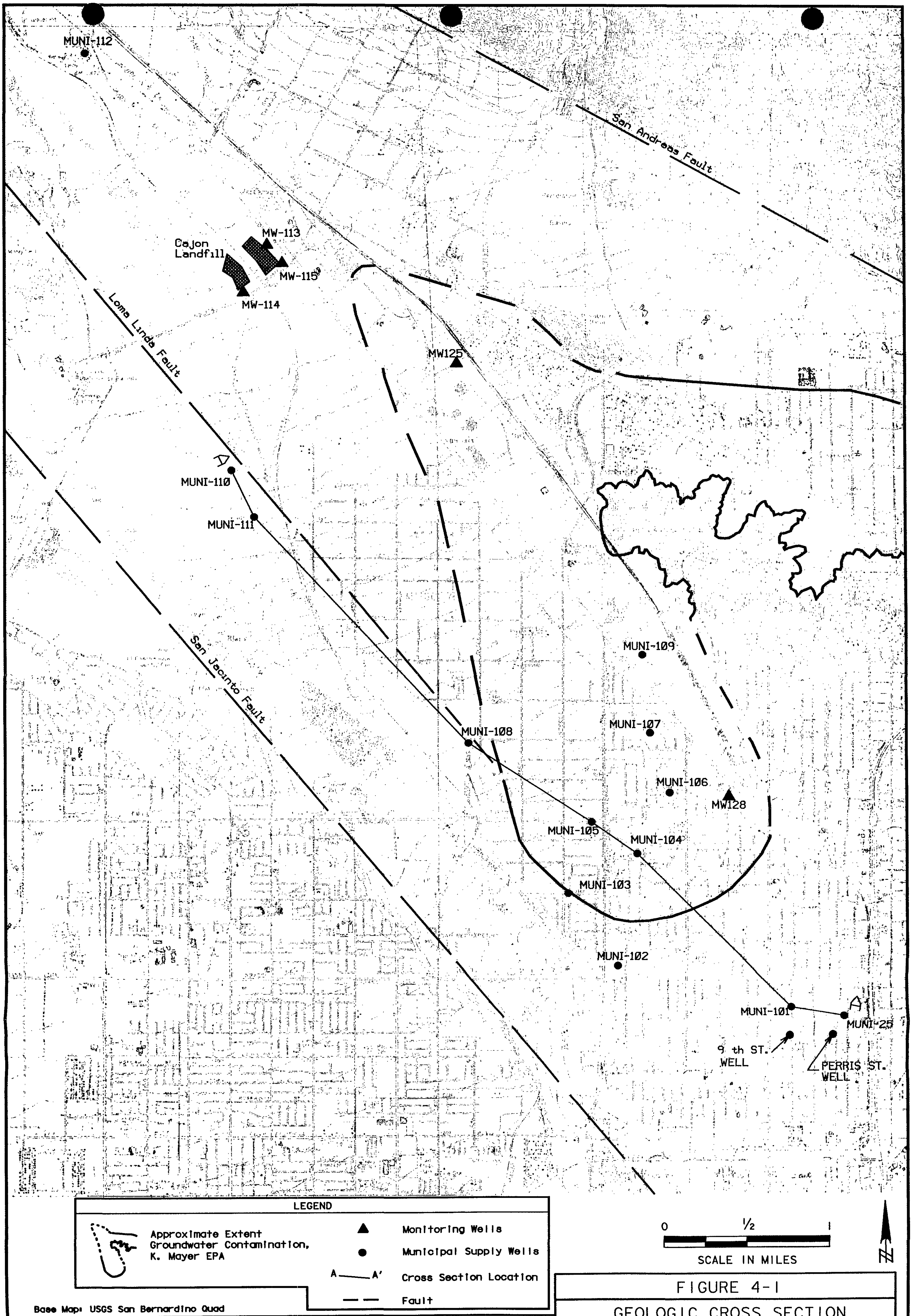
One monitoring well (MW128) was installed as part of the Source OU RI/FS during production of this report. See Appendix 8 for preliminary results.

4.2 HYDROGEOLOGY

4.2.1 Regional Hydrogeology

Within the model area, ground- and surface-water issues are confined to the area occupied by the Bunker Hill groundwater basin, as described by Dutcher and Garrett (1963). This basin is bounded by the San Bernardino Mountains to the northeast, the Crafton Hills and the Badlands on the south, and by the San Jacinto fault on the southwest.

In general, the alluvium closer to the mountains is coarser but more poorly sorted than the alluvium farther from the mountain front. The better sorted zones of sand and gravel are more permeable and, where saturated, yield water freely to wells (Hardt and Hutchinson 1980).



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NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE

FIGURE 4-1
GEOLOGIC CROSS SECTION LOCATION MAP

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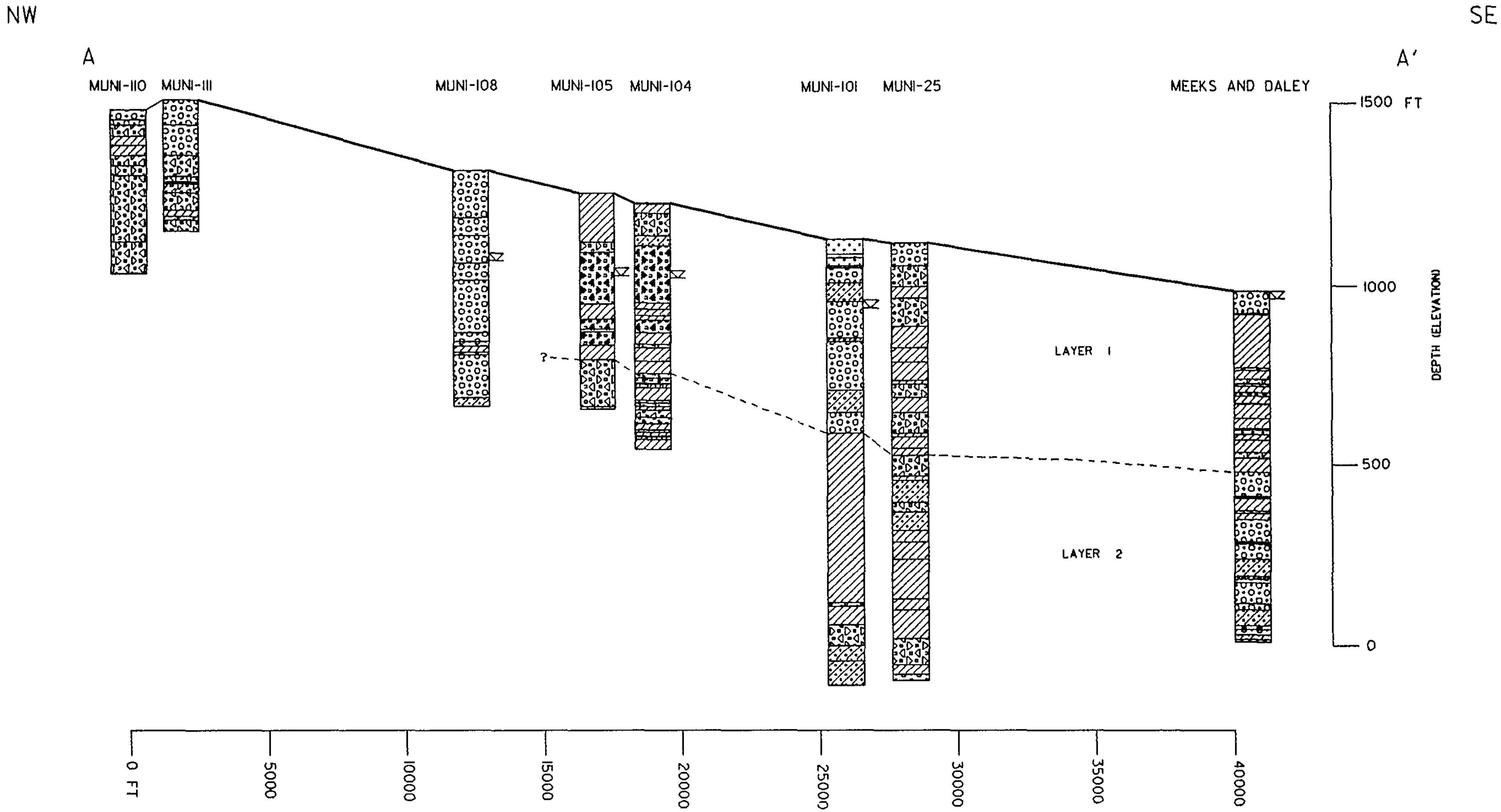
NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE



NOTES :

1 THIS SECTION REPRESENTS GENERALIZED STRATIGRAPHY BASED ON EXISTING DRILLERS LOGS. <u>LITHOLOGIES WERE INTERPRETED AND GROUPED INTO THE UNIFIED SOIL CLASSIFICATION SYSTEM FOR COMPARISON PURPOSES ONLY.</u> CONTACTS ARE NOT EXACT AND MAY BE GRADUATIONAL.

2 LAYER 1 & LAYER 2 CORISPOND TO HYDROGEOLOGIC LAYERS IN THE *PROJECT FLOW MODEL.*

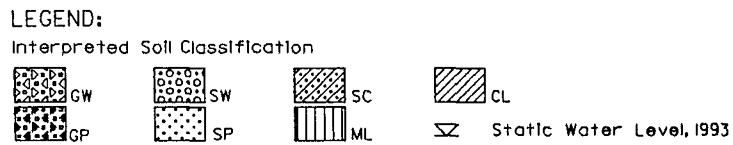


FIGURE 4-2

GEOLOGIC SECTION A-A'

The principal aquifer in the Bunker Hill basin is the older alluvium which is overlain by younger alluvium. Because hydrogeologic properties of younger and older alluvium differ from place to place, the alluvium within the study area has been divided into two aquifer systems separated by a zone consisting predominantly of discontinuous clay lenses. Interpretation of the 130 municipal and monitoring well logs collected from local and state water agencies indicated that the portion of the study area north of the Shandin Hills appears to contain few and discontinuous thin clay lenses; therefore, the aquifer in this area is considered to be an unconfined aquifer (or water-table aquifer) (Dutcher and Garret, 1963). South of the Shandin Hills the alluvium is interfingered with many clay and silt lenses. In this area, the aquifer is divided into two units: an unconfined upper aquifer and a lower aquifer, confined by the relatively low permeability upper aquifer. The identification of two aquifers to the south of the Shandin Hills was based mainly upon historic water levels, well perforations placement, and the interpretation of several driller logs. Hardt and Hutchinson (1980) also support this concept of one unconfined aquifer to the north of Shandin Hills and two aquifers to the south of the Shandin Hills, with the lower aquifer being confined. Dutcher and Garret (1963) further suggest that the lower aquifer is divided into three zones.

Groundwater movement in the study area follows the surface drainage pattern in the Bunker Hill basin. The basin groundwater generally moves southward, with groundwater in Lytle Creek moving in a southeast direction. Once groundwater passes the Shandin Hills, the flows converge and continue south towards the Santa Ana River (Hardt and Freckelton 1987). Groundwater exits the basin beneath the Santa Ana River channel where it crosses the San Jacinto fault.

Inflow into the basin is principally runoff from the San Bernardino Mountains with the bulk of the water from the Santa Ana River and Mill Creek. Water also enters the basin from the San Gabriel Mountains by way of Lytle Creek and Cajon Creek (Youngs, et al. 1981). The importation of northern California water through the California aqueduct and subsequent inflow through the aforementioned percolation basins (see Subsection 2.1), provide additional groundwater recharge.

In the 20-year period 1963 through 1982, recharge to the groundwater basin increased substantially. A sequence of wet years produced greater-than-average natural streamflow and greater percolation through the streambeds. In addition, water agencies upgradient in the basin, acting independently, have recharged diverted natural streamflow and imported water from the California Aqueduct (Danskin and Freckleton 1989). From 1986 to present, the amount of recharge has decreased due to drought conditions. The San Bernardino Valley Municipal Water District (SBVMWD) was organized in 1954 to provide supplemental water for the San Bernardino area. In 1973, the SBVMWD contracted with the California Department of Water Resources [DWR] for a maximum entitlement of 48,000 acre-ft of imported water, increasing annually to 102,900 acre-ft by 1990 (Hardt and Hutchinson 1980).

Groundwater presence is also evident through the appearance of artesian-type wells. Where the potentiometric head (the groundwater level potential) is above the confining beds in this area, and the San Jacinto fault ("Bunker Hill Dike") restricts lateral groundwater flow, groundwater is forced through and around the clay beds into the overlying strata and onto the land surface. Consequently, significant components of vertical flow are created in the groundwater flow regimen. Prior to 1945, potentiometric heads up to 75 feet above the land surface existed in the Warm Creek area adjacent to the north side of the San Jacinto fault (Hardt and Hutchinson 1980). After 1945, potentiometric heads dropped below the land surface, probably as a result from groundwater pumping.

Surface water within the study area significantly affects groundwater recharge. Three main tributary streams -- the Santa Ana River, Mill Creek, and Lytle Creek -- contribute more than 60% of the recharge to the groundwater system. Streamflow originates in mountain areas contiguous to the groundwater basin. For the most part, streamflow that enters the valley is intermittent, averaging 123,000 acre-ft/yr. During storm periods, streamflow emerges from mountain canyons along the valley perimeter and moves down the alluvial fans, where a large part of the flow infiltrates through the permeable surface deposits. Some of the infiltrating water is evaporated and some is transpired by riparian vegetation. However, streamflow records indicate that over long periods of time about 90% of the streamflow that enters the valley recharges the groundwater basin (Danskin and Freckleton 1989).

4.2.2 Muscoy Plume OU Investigation Area Hydrogeology

This subsection discusses the general groundwater flow patterns in the Muscoy Plume OU. Water level data from wells in the Newmark OU are also presented to further support the discussion. The highly variable and discontinuous nature of the subsurface sediments makes it difficult to accurately portray site hydrogeologic conditions. Groundwater surface (or potentiometric surface) maps that are produced for these hydrogeologic environments are critically dependent on depth to water and well design information. All of the water level data available for the Muscoy Plume OU are derived from large capacity, municipal supply wells. Municipal supply wells are designed to yield high volumes of water and, typically, the well screens are located at various elevations and in numerous hydrostratigraphic units to maximize yields. Most of the hydrostratigraphic units are interpreted to be indirectly hydraulically connected. The screened interval(s) of the municipal supply wells located in the Muscoy Plume OU appear to be either completed in the upper portion of the aquifer or across both the shallow and deeper portions of the aquifer(s) (see Table 3-1).

In the Newmark RI/FS (and the project flow model) the hydrogeologic conceptual model was developed based on the division of the alluvium into three depositional sequences. The northern sequence consisted of predominately coarse-grained sediments and formed a single unconfined aquifer. The middle or transition sequence consisted mostly of coarse-grained sediments with minor discontinuous fine-grained lenses and also formed a single unconfined aquifer. The southern depositional sequence, which occurred near the downgradient edge of the plume, consisted of silt, sand, and gravel with many clay lenses. In this sequence the alluvium was divided into two major aquifers: the upper aquifer remained an unconfined aquifer, but the lower aquifer was confined by the overlying zone of interfingered clay lenses. The identification of the two aquifers at the Newmark plume leading edge was based on the recorded water levels, the placement of well perforations during installation of wells in the area, and interpretation of the alluvium described in the drillers' logs for the wells in this area.

In general, it is expected that the above described conceptual model is valid for the Muscoy Plume OU. As previously discussed, an increase in clay lenses to the south was observed in the drillers' logs of municipal supply wells completed in the Muscoy Plume OU. The presence of finer grained material could provide sufficient confinement for development of unconfined and confined aquifer conditions. However, the drillers' logs of the municipal supply wells in the Muscoy Plume OU lacked sufficient detail to correlate lithologic units and limit the assessment of aquifer conditions in this area.

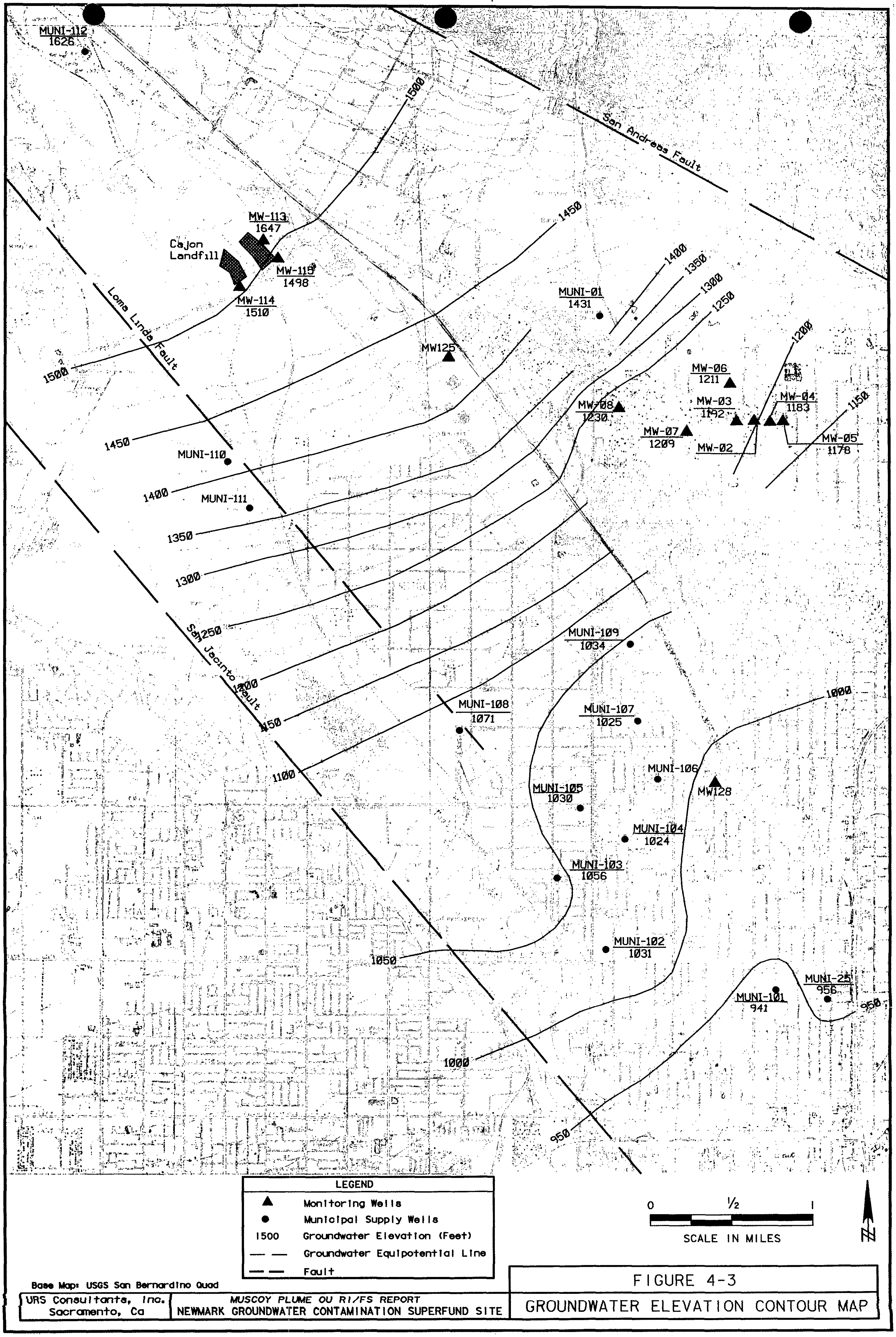
The project flow model used to during the Muscoy Plume OU RI/FS was adapted from the same model that was developed during the Newmark OU RI/FS. Consequently, the upper unconfined aquifer in the Muscoy Plume OU corresponds to layer 1 in the project flow model. The lower confined aquifer in the

Muscoy Plume OU corresponds to layer 2 in the model. The previously described zone of interfingered clay lenses was not modeled as a separate layer. Instead, its combined thickness was embedded in the vertical leakance values for the overlying unconfined aquifer (layer 1). Further explanation and definition of the project flow model is presented in Subsection 6.4 of this report.

Water level measurements from the municipal supply wells are accurate and precise. However, based on the variable screen intervals of the municipal supply wells and the complex hydrogeologic system, errors in groundwater level interpretation may be introduced when a contour map of the water level measurements is constructed. Such maps can be used as general indicators of water surface patterns. They can also be used to interpret groundwater flow directions. These maps, given the complex hydrogeologic system, are useful to help understand overall trends but are not very reliable for making small scale or localized interpretations of groundwater flow patterns. In addition, due to the municipal supply well design, assessment of vertical gradients within the aquifer(s) could not be conducted.

Figure 4-3 shows the contours of groundwater elevations collected from thirty of the thirty-eight municipal water supply and monitoring wells located in the Muscoy Plume, Newmark, and Source OUs during April through May 1993. The water level measurements are included in Appendix 1. The general southeasterly groundwater flow reflects the local surface topography. The Shandin Hills create a groundwater division and force groundwater to flow around the hills to the east and south. Localized disruption of the groundwater surface in the southern portion of the Muscoy Plume OU and in the vicinity of the Newmark Wellfield probably resulted from localized municipal supply well pumping.

Transmissivities from pump tests (URS 1991) conducted in municipal supply wells MUNI-102 and MUNI-25, and other wells slightly south of the Muscoy plume ranged from 72,000 to 845,000 gallons per day per foot (gpd/ft). The average transmissivity equaled 280,000 gpd/ft.



Base Map: USGS San Bernardino Quad

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MUSCOY PLUME OU RI/FS REPORT
NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE

FIGURE 4-3
GROUNDWATER ELEVATION CONTOUR MAP

5.0 NATURE AND EXTENT OF CONTAMINATION

The purpose of the sampling the ten municipal supply wells in the Muscoy Plume OU was to verify previous results from wells suspected to be contaminated and to define the concentrations and extent of the Muscoy plume. The data set from the interim sampling effort provides the basis for this RI/FS. Further investigation/sampling may be performed during the RD/RA phase, if necessary. The results of the interim sampling which was conducted during April through May 1993 are discussed below. The data presentation focuses on results from wells which are within the Muscoy Plume OU only.

As discussed in Section 4.0, the municipal supply well screen intervals are quite variable within the aquifer. As shown in Table 3-1, wells MUNI-103, -105, -106, -107, and -109 screen intervals are generally completed in the upper portion of the aquifer at a minimum total depth of 308 feet bgs (MUNI-105) and maximum total depth of 431 feet bgs (MUNI-109). Wells MUNI-25, -101, -102, -104, and -108 screen intervals are generally completed across the shallow and deeper portions of the aquifer at a minimum total depth of 628 feet bgs (Muni-108) and a maximum total depth of 1160 feet bgs (MUNI-25). Based on the variable screened intervals, an assessment of the vertical extent of contamination could not be evaluated. Additionally, errors in interpretation of the areal extent of the plume may also occur. For example, dilution effects from wells screened across the majority of the aquifer may mask the detections of chemicals that occur in wells completed in only one portion (upper or lower) of the aquifer (e.g., MUNI-106).

The Laboratory Analytical Results which list the constituents analyzed in groundwater by the EPA Region IX laboratory are presented in Appendix 4. The methodologies used for analysis, the constituents analyzed, and Quality Assurance (QA) procedures used for sampling are outlined in Section 3.0.

5.1 VOLATILE ORGANIC COMPOUNDS

Table 5-1 presents detection results of VOCs analyses. Five additional compounds are also listed in Table 5-1 which were detected or tentatively detected at concentrations below the standard detection limit of 0.5 $\mu g/\ell$. EPA used special analytical techniques to attempt to detect contaminants at very low levels for risk assessment estimates. Compounds that were only tentatively detected could not be used for risk assessment calculations, and compounds that were not detected above 0.5 $\mu g/\ell$ are not considered for other analyses such as ARAR determinations.

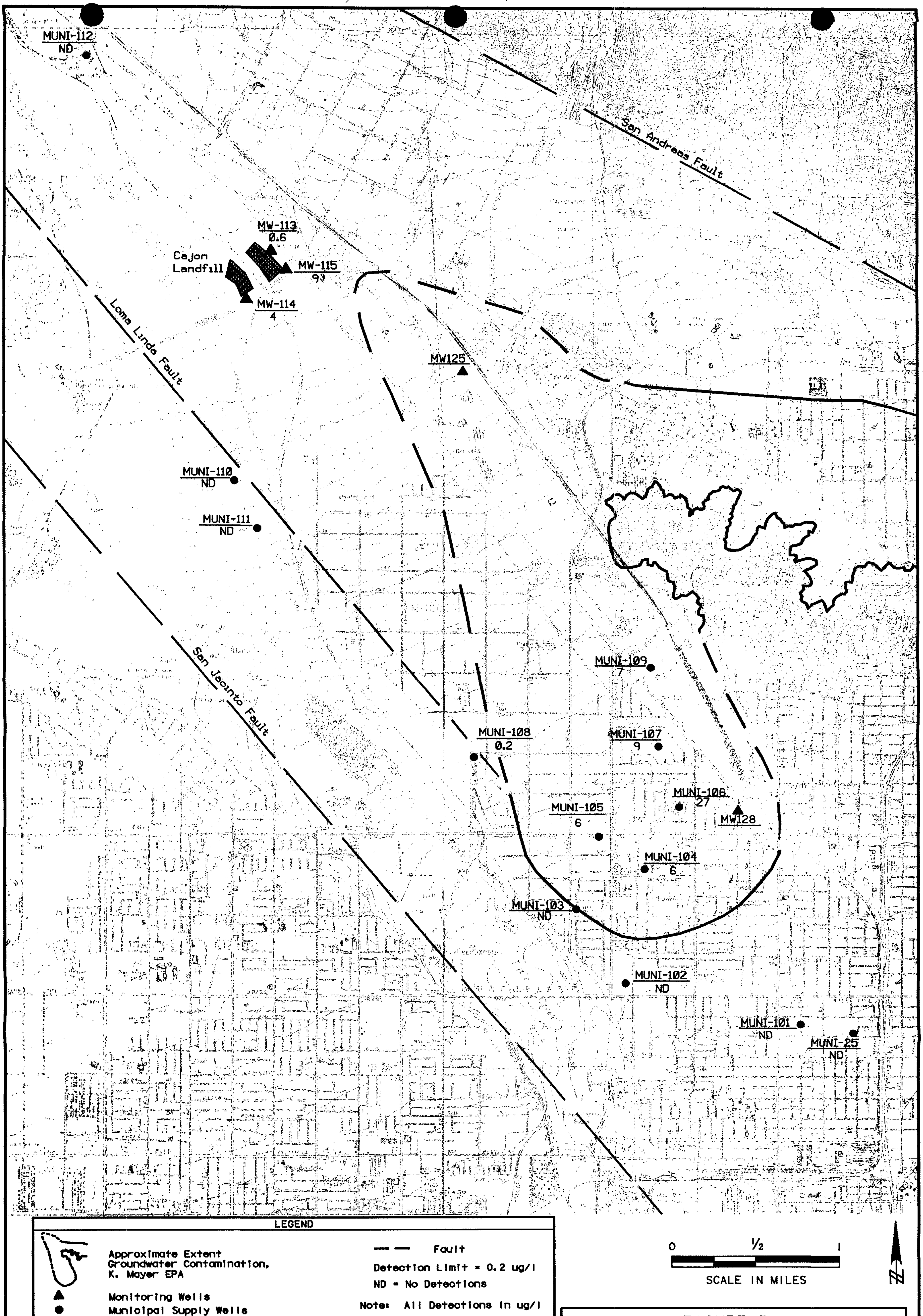
As shown in Table 5-1, 1,1-Dichloroethane (DCA), DCE, TCE, PCE, and total freon (freon 11 and freon 12) were the most frequently detected compounds. Contaminant concentrations ranged from not detected in wells MUNI-101, -102, and -25, to 32 $\mu g/\ell$ total freon in well MUNI-106. Figures 5-1, 5-2 and 5-3 shows the analytical results for PCE, TCE and total freon, respectively. Figure 5-1 includes EPA's estimated areal extent of groundwater contamination. The distribution of PCE was used to construct the plume map because (as discussed below) it appears the areal extent of PCE is larger than the other VOCs detected. Figures showing the results for the other contaminants were not constructed since these contaminants, when detected, were at the same locations where TCE, PCE and freon were present. Additionally, with the exception of 0.6 $\mu g/\ell$ DCE at Muni-104, these constituents were always detected at lower concentrations than TCE, PCE, and freon.

Table 5-1
Municipal Water/Well Volatile Organic Sample Results (detections only)
Muscoy Plume OU Investigation Area

Sample Number	Summary Detection Concentrations (µg/ℓ)											
	1, 1-Dichloroethane (0 2)	cis-1, 2-Dichloroethene (0 2)	Chloroform (0 2)	1, 2-Dichloropropane (0 2)	Trichloroethene (0 2)	Tetrachloroethene (0 2)	Toluene (0 2)	Carbon Tetrachloride (0 2)	Dichlorodifluoromethane (Freon 12) (0 2)	Trichlorofluoromethane (Freon 11) (0 2)	Vinyl Chloride(0 2)	trans-1,2-Dichloroethene(0 2)
MUNI-101-01 †												
MUNI-102-01 †												
MUNI-103-01								0 1 J				
MUNI-104-01		0 6			0 4	6			8	0 8		
MUNI-105-01	0 3	2			0 8	6			10	1		
MUNI-106-01	0 8	6	0 2 J	0 3	6	27			28	4	0 1 J	0 4
MUNI-107-01	0 4	2			3	9			2	0 8		0 2 J
MUNI-108-01						0 2 J			0 3			0 1 J
MUNI-109-01	0 2	0 9			1	7		0 2 J	0 6	0 3		
MUNI-25-01 †												
Federal/State of CA Primary MCLs	NE/5	70/6	100/100	5/5	5/5	5/5	1000/NE	5/0 5	NE/NE	NE/150	2/0 5	100/10

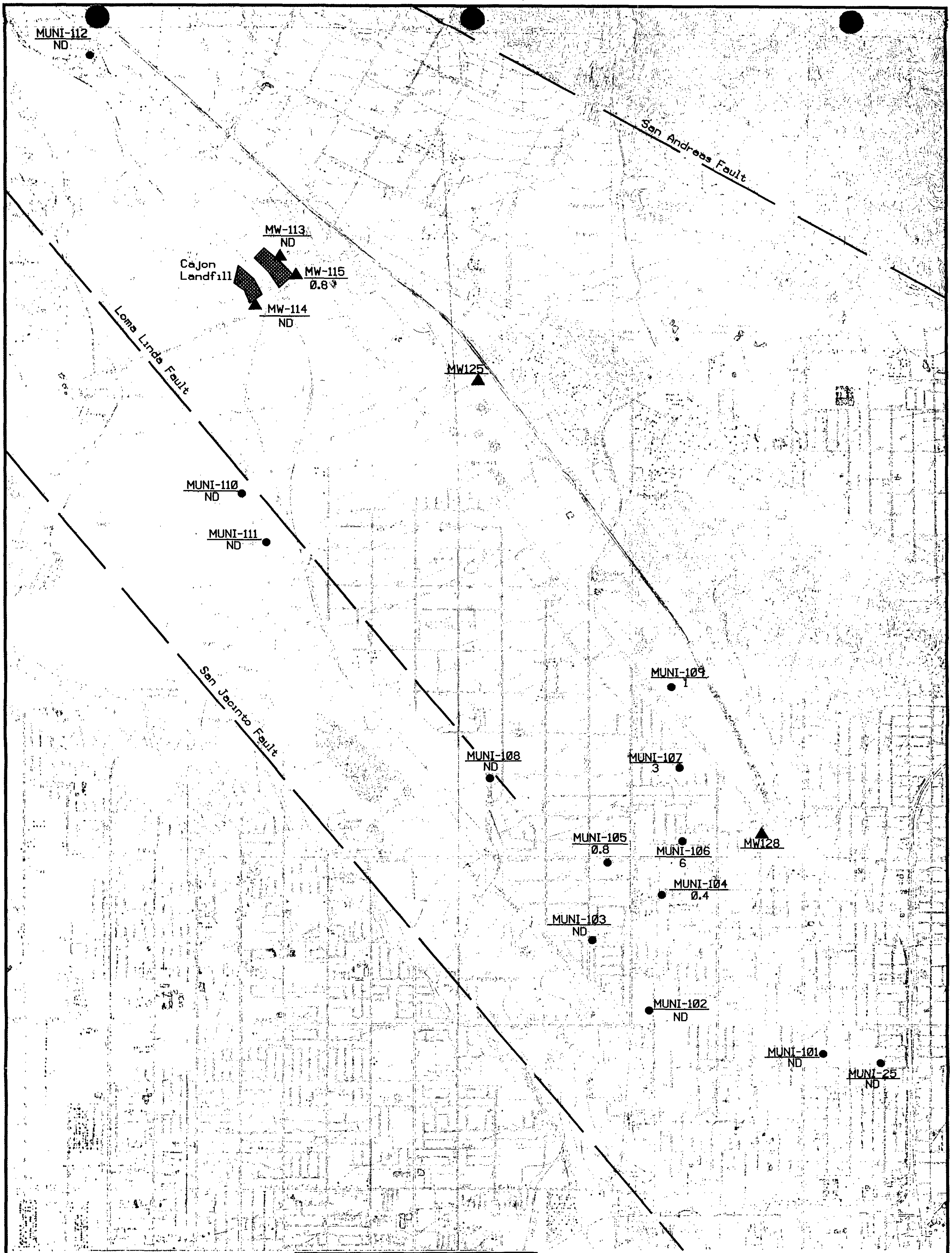
Muscoy OU 001 (Table 5 1) 11/94

Notes
- Sample specific quantification limits are shown in parentheses at the end of the constituent name
- Values followed by the qualifier **J** are estimated quantities and are useful for qualitative purposes only
- "NE" – No MCL yet established
- † - Samples collected were non-detect for volatile organic compounds
- A blank constituent result field indicates that the constituent was not detected
- The table includes all VOC constituents detected
- "+" – MCL effective as of 1/94



Base Map: USGS San Bernardino Quad

URS Consultants, Inc. Sacramento, Ca	MUSCOY PLUME OU RI/FS REPORT NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE	FIGURE 5-1 PCE CONCENTRATIONS



LEGEND

- ▲ Monitoring Wells
- ● Municipal Supply Wells
- — — Fault

Detection Limit = 0.2 ug/l

ND = No Detections

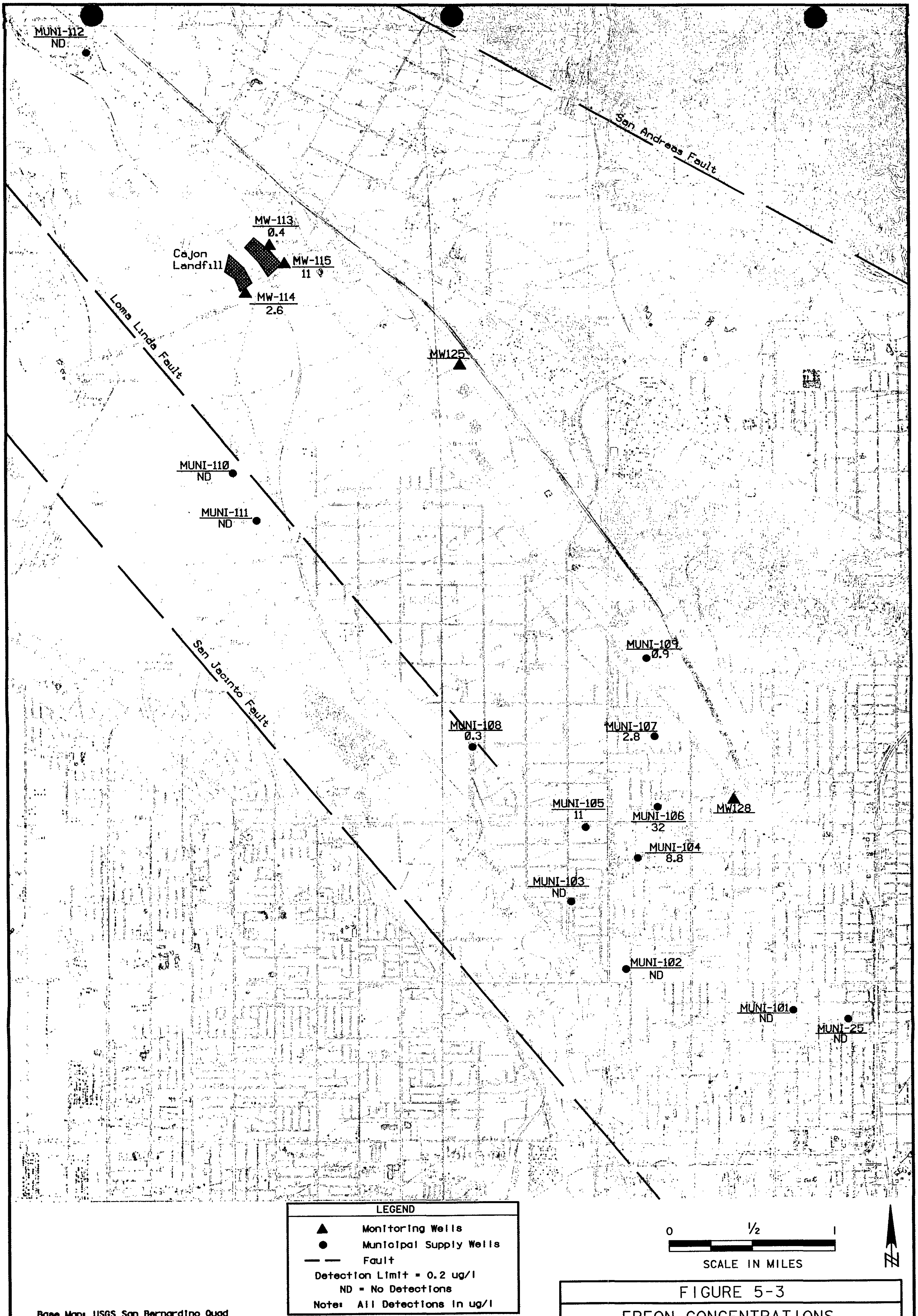
Note: All Detections in ug/l

0 ½ 1

SCALE IN MILES

Base Map: USGS San Bernardino Quad

URS Consultants, Inc. Sacramento, Ca	MUSCOY PLUME OU RI/FS REPORT NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE	FIGURE 5-2 TCE CONCENTRATIONS



Base Map: USGS San Bernardino Quad

URS Consultants, Inc. Sacramento, Ca	MUSCOY PLUME OU RI/FS REPORT NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE	FIGURE 5-3 FREON CONCENTRATIONS (TOTAL OF FREON 11 AND FREON 12)

Figure 5-1 presents PCE concentrations for wells in the Muscoy Plume OU. PCE concentrations ranged from not detected in downgradient wells MUNI-101, -102, and -25 and cross-gradient well MUNI-103 to 27 $\mu g/\ell$ in well MUNI-106. Concentrations of PCE above the MCL (5 $\mu g/\ell$) were detected in five wells. The absence of detectable PCE in wells Muni-101, -102 and -25 appear to define the downgradient extent of the plume. The absence of detectable concentrations in well Muni-103 and the presence of PCE at the analytical detection limit in well Muni-108 generally define the western boundary of the plume. The eastern plume boundary south of Shandin Hills is currently poorly defined.

Figure 5-2 presents the TCE concentrations in groundwater samples collected from the Muscoy plume area. TCE concentrations ranged from not detected in wells Muni-101, -102, -107, -108 and -25 to the maximum concentration at well MUNI-106 (6 $\mu g/\ell$), which is the only well with TCE concentrations above the MCL (5 $\mu g/\ell$). Although concentrations of TCE were lower than PCE, the general distribution of TCE in the Muscoy plume is similar to PCE. The only exception is the absence of detectable TCE in well Muni-108. At this location PCE was present at the detection limit of 0.2 $\mu g/\ell$.

Figure 5-3 shows total freon concentrations (sum of freon 11 and freon 12 compounds) in the Muscoy plume. The distribution of total freon in the Muscoy plume were generally similar to TCE and PCE. The maximum detected total freon concentration was 32 $\mu g/\ell$ at well MUNI-106, which also showed the highest PCE and TCE concentrations. Total freon concentrations were well below the state of California MCL of 150 $\mu g/\ell$ (for freon 11).

As shown in Table 5-1, the only other VOC close to exceeding MCLs is cis-1,2-DCE, which was detected in well MUNI-106 at the MCL concentration of 6 $\mu g/\ell$. As previously discussed, this well also contained the highest levels of TCE, PCE, and total freon.

5.2 SEMIVOLATILE ORGANIC COMPOUNDS

All water samples from the municipal supply wells were also analyzed for semi-volatile organic compounds. These compounds were not detected in any of the samples analyzed.

5.3 METALS

The metal concentrations from the municipal supply wells are presented in Appendix 4, Laboratory Analytical Results. The results from these samples were compared to State of California MCLs. In all wells with exception of one sample taken from well MUNI-109, sample results were below the compound-specific MCLs. Aluminum was reported at 1350 $\mu g/\ell$ in well MUNI-109.

5.4 OTHER CONSTITUENTS

Groundwater samples collected from the municipal supply wells were also analyzed for pesticides, PCBs, and Total Petroleum Hydrocarbons (gasoline and diesel standards). These compounds were not detected in any of the samples analyzed.

The results of samples analyzed for general water chemistry are also presented in Appendix 4.

No differences in metal concentration or inorganic water quality parameters were noted between wells contaminated with VOCs and nearby wells without VOC contaminants (Appendix 4). Other than VOC contamination, groundwater at the leading edge of the Muscoy plume is generally comparable in water quality to the surrounding aquifer (for example, in areas which would be considered for reinjection).

Given the anticipated groundwater flow velocities for the Muscoy Plume OU investigation area, it is expected that aerobic conditions predominate within the aquifer. Only localized areas of anaerobic conditions might occur.