

FINAL
REMEDIAL INVESTIGATION REPORT
FOR
OPERABLE UNITS 1 AND 3:
ON-SITE AND OFF-SITE GROUNDWATER

AT THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JET PROPULSION LABORATORY
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LIST OF ACRONYMS AND CHEMICAL SYMBOLS

1,1-DCA	1,1-Dichloroethane
1,2-DCA	1,2-Dichloroethane
1,1-DCE	1,1-Dichloroethene
ADD	Average Daily Dose
Ag	Silver
Al	Aluminum
As	Arsenic
ASTM	American Society for Testing Materials
Ba	Barium
C	Carbon
CA DHS	California Department of Health Services
Ca ⁺²	Calcium
CaCO ₃	Calcium carbonate
CalTech	California Institute of Technology
CCl ₄	Carbon Tetrachloride
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cl	Chloride
ClO ₄ ⁻	Perchlorate
CLP	Contract Laboratory Program
COPC	Constituent of Potential Concern
CO ₃ ⁻²	Carbonate
CSF	Cancer Slope Factor
Cr	Chromium
Cr(III)	Trivalent Chromium
Cr(VI)	Hexavalent Chromium
Cu	Copper
CN	Cyanide
DHS	California Department of Health Services
DQO	Data Quality Objective
DTSC	California State Department of Toxic Substances Control
EPA	United States Environmental Protection Agency
ESI	Expanded Site Inspection
F	Fluoride
Fe	Iron
FS	Feasibility Study
FSAP	Field Sampling and Analysis Plan
ft	Feet

LIST OF ACRONYMS AND CHEMICAL SYMBOLS

(Continued)

ft/day	Feet per day
gal/min	Gallons per minute
GALCIT	Gugenheim Aeronautical Laboratory, California Institute of Technology
gpd/ft ²	Gallons per day per square foot
gpm	Gallons per minute
HASP	Health and Safety Plan
HCO ₃ ⁻	Bicarbonate
Hg	Mercury
HI	Hazard Index
HQ	Hazard Quotient
IAL	Interim Action Level
JPL	Jet Propulsion Laboratory
K ⁺	Potassium
l	Liter
LADD	Lifetime Average Daily Dose
LAWC	Lincoln Avenue Water Company
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MECLs	Maximum Expected Contaminant Levels
MEK	Methyl Ethyl Ketone
mg/L	Milligrams per liter
mg/kg	Milligrams per kilogram
Mg	Magnesium
ml/min	Milliliters per minute
Mn	Manganese
MP	Multi-Port
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MW	Monitoring Well
Na	Sodium
NA	Not Analyzed or Not Applicable
NASA	National Aeronautics and Space Administration
ND	Not Detected or Not Developed
NDMA	N-nitrosodimethylamine
ng/L	Nanograms per liter
NO ₃ ⁻	Nitrate
NR	Not Regulated
NTU	Nephelometric Turbidity Unit
OU-1	Operable Unit - 1 (On-site Groundwater Investigation)

LIST OF ACRONYMS AND CHEMICAL SYMBOLS

(Continued)

OU-2	Operable Unit - 2 (On-site Contaminant Source Investigation)
OU-3	Operable Unit - 3 (Off-site Groundwater Investigation)
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PO ₄	Phosphate
PCB	Polychlorinated Biphenyl
PCE	Perchloroethene (Tetrachloroethene)
PRG	Preliminary Remediation Goal
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Program Plan
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RPD	Relative Percent Difference
RRF	Relative Response Factors
RSD	Relative Standard Deviations
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
Se	Selenium
SO ₄ ⁻²	Sulfate
SVOC	Semi-Volatile Organic Compound
TBT	Tributyltin
TCA	1,1,1-Trichloroethane
TCE	Trichloroethene
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
µg/L	Micrograms per liter
µmhos	Micromhos
USGS	United States Geological Survey
VOC	Volatile Organic Compound
Zn	Zinc
°C	Degrees Celsius
%D	Percent Difference
%R	Percent Recovery

EXECUTIVE SUMMARY

This report presents the results of the groundwater Remedial Investigation (RI) work completed as part of a Remedial Investigation/Feasibility Study (RI/FS) for the National Aeronautics and Space Administration (NASA)-Jet Propulsion Laboratory (JPL) located in Pasadena, California. In October 1992, JPL was placed on the National Priorities List pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the nature and extent of contamination in the groundwater at the JPL site was characterized.

JPL encompasses approximately 176 acres, of which approximately 156 acres are Federally owned. The remaining land is leased for parking from the City of Pasadena (Pasadena) and the Flintridge Riding Club. JPL is located along the southern edge of the San Gabriel Mountains and at the northern edge of the metropolitan Los Angeles area. The Arroyo Seco, an intermittent stream, lies immediately to the east of JPL. A series of surface impoundments, used for groundwater recharge, lies along the eastern margin of the Arroyo Seco stream channel.

In 1936, a California Institute of Technology (CalTech) professor and a group of students began testing liquid propellant rockets in the Arroyo Seco. Several years later, in 1940, the Army Air Corps provided funding for the first permanent structures in the area. In July 1940, CalTech and the United States, on behalf of the U.S. Army Air Corps, entered into a contract under which CalTech agreed to study jet propulsion for airplanes. This contract was the first of a series of contracts between CalTech and the United States that span the last 59 years for research and development work at JPL by CalTech for various Government agencies. By 1944, the facility officially became known as the Jet Propulsion Laboratory. Starting in 1945, the United States began purchasing the parcels of land comprising JPL. By the 1950's, with the exception of a small area leased from Pasadena, the United States owned JPL. In 1958, NASA took over control of JPL. Today, CalTech performs research and development tasks at JPL under a prime contract with NASA. Many of the tasks conducted at JPL required the use of various chemicals and materials, including a variety of solvents, solid and liquid rocket propellants, and cooling-tower chemicals. During the 1940s and 1950s, many buildings at JPL maintained a cesspool to dispose of liquid and solid sanitary wastes collected from drains and sinks. These cesspools were designed to allow liquid wastes to seep into the surrounding soil. The present-day term for these subsurface disposal areas is "seepage pits." Some of the seepage pits may have received volatile organic compounds (VOCs) and other waste materials that are currently found in the groundwater. In the 1950's and 1960's, a sanitary sewer system was installed and the use of the cesspools for waste disposal was discontinued.

In 1980, analyses of groundwater from Pasadena water-supply wells located in the Arroyo Seco near JPL, revealed the presence of VOCs. Around the same time, VOCs were also detected in two Lincoln Avenue Water Company (Lincoln) supply wells. Initially, the VOC concentrations

were below state and Federal drinking water standards. Over time, however, VOC levels rose above drinking water standards. As a result, the Pasadena and Lincoln wells near JPL were forced to stop pumping between 1985 and 1989 by the California Department of Health Services (CADHS). In 1990, NASA funded the installation of a water treatment plant in the Arroyo Seco so that the Pasadena wells could resume supplying water. By 1992, the Lincoln Avenue Water Company had funded and installed a water treatment plant and had restarted production at one of its wells.

The groundwater beneath and downgradient of the JPL site was originally divided into two operable units, Operable Unit 1 (OU-1) for groundwater beneath JPL and extending to the east across the Arroyo Seco, and Operable Unit 3 (OU-3) for groundwater off-site to the south of JPL and east of the Arroyo Seco. Operable Unit 2 pertains to the on-site soil contaminant source investigation. Originally, it was anticipated that the RI for OU-1 would be completed before the RI for OU-3. However, as the RI for OU-1 progressed, additional work was required, delaying its completion to coincide with the completion of the OU-3 RI. For this reason the data collected from both the OU-1 and OU-3 RIs have been combined into this report.

The primary objectives of the OU-1/OU-3 RI are as follows:

- To characterize the nature and extent of contaminants in the groundwater beneath and downgradient of the JPL facility.
- To assess the fate and transport of contaminants in the groundwater beneath and downgradient of the JPL facility.
- To provide information for the groundwater Feasibility Study (FS) in order to evaluate technologies for remediation of groundwater.
- To provide, in the form of a baseline assessment, an evaluation of the potential human health and environmental risks from contaminants in the groundwater.

Following an Expanded Site Investigation at JPL where VOCs were detected in on-site groundwater above drinking water standards, the site was ranked using the Federal Hazard Ranking System and, in October 1992, the site was placed on the CERCLA National Priorities List.

Prior to the OU-1/OU-3 RI, several other groundwater-related studies were conducted at the JPL site, including general geologic, hydrogeologic, and seismic hazard assessments. A summary of the previous investigations relevant to the RI is provided in the introduction (Section 1.0) to this report.

In order to characterize the groundwater beneath and downgradient of the JPL facility, a total of twenty-three groundwater monitoring wells have been routinely sampled within the study area. Eighteen (18) of these wells were installed for OU-1 and another five (5) were installed for OU-3. Of the total twenty-three, ten (10) wells are shallow standpipe wells that have a single screened interval at the groundwater table. The other thirteen (13) wells are deep, multi-port

wells that contain five (5) screened intervals each positioned at various depths of the aquifer. All five (5) of the wells located off site (OU-3) are deep multi-port (MP) wells.

Over the course of the OU-1/OU-3 RI, groundwater samples were collected from the JPL monitoring wells a total of ten (10) times between 1994 and 1998. Samples collected during the RI were analyzed for VOCs, semi-volatile organic compounds (SVOCs), Title 26 metals, strontium, hexavalent chromium, aluminum, cyanide, total petroleum hydrocarbons (TPH) (MW-4 only), gross alpha/gross beta (MW-13 only), perchlorate, tributyltin (select wells), and general minerals (major anions and cations). A California Department of Health Services certified laboratory, Montgomery Watson Laboratories located in Pasadena, California, performed the groundwater analyses.

In addition to groundwater sampling, water levels within all of the JPL monitoring wells were routinely measured throughout the OU-1/OU-3 RI. Water levels in the shallow standpipe wells were measured automatically, at least once a day, by dedicated battery-powered data loggers coupled to pressure transducers. Data obtained by these data-logging systems were transferred once a month onto a laptop computer for further storage and processing. Water levels in the deep multi-port wells were measured at each screened interval on a monthly basis, using a specialized pressure transducer probe.

The aquifer beneath JPL is generally considered unconfined, although in those monitoring wells located near the Pasadena municipal production wells differences in vertical hydraulic head measurements were observed between individual screen depths when the production wells were pumping. This implies that completely unconfined conditions do not exist. The presence of thin, silt-rich intervals in the aquifer appear to inhibit vertical flow. Based on water level and soil-type data, the aquifer has been divided into four (4) "aquifer layers". The upper three aquifer layers are present beneath JPL, and the fourth layer is represented by the bottom screen in the easternmost off-site JPL multi-port monitoring well (MW-20).

Over the course of the OU-1/OU-3 RI, groundwater samples from all JPL screened intervals were analyzed for major anions and cations to determine the natural chemistry of the waters beneath the study area to further evaluate groundwater flow patterns. The results of these analyses indicate the presence of three (3) basic water-types, based on the predominance of a particular anion and cation. In general, Type 1 waters, the most common water type in the study area, contain calcium as the predominant cation and bicarbonate (HCO_3) as the dominant anion. This water type primarily originates as rainwater runoff from the San Gabriel Mountains and enters the study area mainly through the Arroyo Seco. Type 2 waters are sodium bicarbonate dominated groundwaters and are typically found at greater depths, between approximately 300 and 900 feet below ground surface, within the study area. Type 3 groundwater is also a predominantly calcium-bicarbonate water type, though it contains higher concentrations of chloride and sulfate and total dissolved solids (TDS) than Type 1. Type 3 groundwater is typically found around the western and southwestern margins of the study area in locations

outside the influence of the Arroyo Seco. Type 3 water is similar chemically to Colorado River water injected at the Valley Water Company municipal production wells located upgradient of JPL.

Data from water-level measurements in the shallow and deep JPL monitoring wells, along with monthly precipitation data and monthly groundwater extraction data from nearby municipal wells, were used to establish groundwater flow patterns during various times of the year to evaluate the effects outside influences have on the aquifer. The results of these evaluations reveal differences in the responses of the four aquifer layers defined at JPL to external or outside influences.

Throughout the JPL study area, Aquifer Layer 1 comprises the upper 75 to 100 feet of the aquifer and includes the water table. During the RI period, the water table has fluctuated up to 75 feet per year, primarily in response to changes in pumping at nearby production wells and the amount of recharge from the Arroyo Seco spreading basins. The Pasadena production wells, located just east of the Arroyo Seco, clearly have the greatest influence on the water-levels beneath JPL. At times when the Pasadena wells are pumping, water-levels in the study area continually decline until the pumping ceases. Once the pumps are shut off, water-levels immediately begin to rise.

Two general groundwater flow directions were observed in Layer 1 during the course of the OU-1/OU-3 RI. Throughout most of the year, groundwater elevations are typically higher in the wells located along the northern and western margins of the JPL site, resulting in a "normal" east to southeast flow pattern. This pattern corresponds with relatively "dry" periods when the surrounding municipal wells are pumping. During the "wet" season, the Pasadena wells may be either shutoff for a short period of time or producing at a reduced capacity. During these times, when groundwater recharge through the Arroyo Seco spreading basins is significant, groundwater flow can potentially reverse to the west across the JPL site, resulting in a short term "flow reversal" that may last from a few days to a few weeks. However, contaminant analyses from upgradient monitoring wells suggests significant contaminant transport does not occur during these short periods of time.

In addition to the flow patterns in Layer 1, the water-table in the wells located at the mouth of the Arroyo Seco are consistently 80 to 120 feet higher than the water table in other JPL monitoring wells. This indicates the presence of a significant groundwater mound in this area. This mound is present year-round and is likely the result of year-round natural recharge at the mouth of the Arroyo Seco.

Aquifer Layers 2, 3, and 4 are separated from Layer 1 and each other by thin silt-rich intervals, or aquitards, approximately 300, 500 and 800 feet deep, respectively. When nearby municipal wells are pumping, semi-confined aquifer conditions exist in these layers. The nearby Pasadena municipal wells have a significant impact on Layers 2 and 3, where the potentiometric surfaces in these layers as far away as MW-20 (approximately 3,000 feet) are impacted when the Pasadena wells are pumping.

Aquifer Layer 4 is found at the far eastern edge of the study area where it is penetrated by one deep JPL monitoring well (MW-20). Layer 4 is defined by hydraulic-head measurements at well MW-20, screen 5, which is approximately 900 feet deep. Hydraulic head measurements indicate that this part of the aquifer is hydraulically isolated from the effects of nearby municipal pumping.

Groundwater samples collected from the JPL study area were analyzed for a comprehensive suite of analytes including 60 VOCs, 65 SVOCs, 19 metals (excluding cations), perchlorate (ClO_4^-), cyanide (CN), tributyltin (TBT), total petroleum hydrocarbons (TPH), gross alpha/gross beta and general groundwater parameters (major anions and cations). Of these analyses, only three VOCs [carbon tetrachloride (CCl_4), trichloroethene (TCE), and 1,2-dichloroethane (1,2-DCA)], one metal [total chromium (Cr)], and ClO_4^- were detected at levels exceeding state and Federal maximum contaminant levels (MCLs) or interim action levels (IALs). Hexavalent chromium [Cr(VI)] was also detected, however MCLs have not been established for Cr(VI). Aluminum was detected infrequently at levels above its Federal MCL, but conservative risk assessment screening showed the levels were below U.S. Environmental Protection Agency (EPA) Preliminary Remediation Goals (PRGs) and below California's Preliminary Endangerment Assessment hazard levels. Based on the risk screening, the regulating agencies [EPA, Department of Toxic Substances Control (DTSC), and the Regional Water Quality Control Board (RWQCB)] agreed that it no longer needed to be monitored.

CCl_4 appears to have originated on-site and migrated downward and eastward. The resulting plume extends off-site to the east where it has apparently been kept from significant further downgradient migration primarily by the effects of pumping at the Pasadena municipal wells. TCE and ClO_4^- appear to have both on-site and off-site sources. Plumes of these contaminants have also migrated downgradient (eastward) into the vicinity of the Pasadena and Lincoln Avenue Water Company (Lincoln) production wells, where they too appear to have been contained from further significant downgradient migration. 1,2-DCA was only observed in on-site JPL wells and was not detected at any of the off-site monitoring wells during the RI. The presence of 1,2-DCA beneath the JPL facility is possibly the result of bacterial dechlorination of TCE.

Data indicate that VOC and ClO_4^- plume concentrations exceeding respective MCLs or IALs are generally found in monitoring wells located on-site and to the east around the Pasadena and Lincoln Avenue municipal production wells. Overall, VOC concentrations in JPL monitoring wells located within the plumes have generally remained relatively consistent over the course of the RI period. The general lack of significant contaminant plumes east of the Pasadena and Lincoln Avenue municipal wells suggests that these production wells provide a barrier to further significant downgradient migration.

Chromium, both total and hexavalent [Cr(VI)], were detected frequently in a few on-site wells and extremely rarely in scattered off-site monitoring wells, mostly at levels well below MCLs [although

no MCLs have been established for Cr(VI)]. Where Cr [total and Cr(VI)] was detected in on-site wells, concentrations decreased or remained relatively constant during the RI period.

Complex groundwater flow patterns due primarily to pumping of the Pasadena municipal production wells near the JPL site present considerable problems with regard to modeling contaminant transport in groundwater beneath the site and surrounding area. However, with the extensive amount of RI data collected over the last 5 years, the fate and transport of the constituents of concern are generally well known. As a result, limited fate and transport modeling was conducted, focusing on a scoping level type assessment where CCl_4 , TCE and ClO_4^- could migrate downgradient, with natural groundwater gradients typical during periods when the Pasadena and other municipal pumping wells are not operating. Modeling required the establishment of a single source of contamination, or a point source. The point source location for contaminant migration modeling was chosen as off-site well MW-17, Aquifer Layer 2. Aquifer Layer 2 was chosen because this was the only aquifer layer in MW-17 where CCl_4 , TCE and ClO_4^- were detected above drinking water standards during the RI. If the Pasadena and other nearby production wells were to be shut down for an extended period of time, a very unlikely event, contaminant migration from MW-17, Aquifer Layer 2, would be of potential concern.

The fate and transport of CCl_4 , TCE, and ClO_4^- from MW-17 was simulated using the one-dimensional SOLUTE (Version 4.04) analytical contaminant transport model. The results obtained from modeling using actual maximum concentrations for CCl_4 , TCE, and ClO_4^- detected in MW-17 during the RI indicate that even under very conservative assumptions, it will take from 22 to 40 years for these contaminants to migrate from MW-17 and be found in downgradient monitoring well MW-20 above action levels. There is a very low probability this will happen, however, since it is very unlikely nearby municipal wells will stop pumping for the extensive periods of time required for significant migration to occur.

As part of the RI, and pursuant to state and Federal guidance, a baseline risk assessment was conducted to evaluate the theoretical risks to human health associated with hypothetical exposure to untreated groundwater beneath and adjacent to JPL. It is important to note, however, that all groundwater produced near JPL is routinely monitored and treated, if necessary, to assure it meets stringent drinking water standards before it is used by consumers. To ensure adequate protection of human health, conservative values for contaminant concentrations, exposure parameters, and toxicity assumptions were used in estimating the theoretical potential risks (see Section 6.0). For this reason, it must be emphasized that the theoretical risks predicted by this assessment are unlikely to be underestimated. In fact, they more likely represent an overestimate of the actual risk.

The total cancer risk from hypothetical exposure to untreated groundwater at each of the JPL monitoring wells and at each of the nearby municipal production wells was determined by adding the risks calculated for ingestion, inhalation and dermal contact pathways. Results, using conservative assumptions, showed five on-site monitoring wells, two off-site monitoring wells, and one municipal production well had total cancer risk values outside EPA's range for

acceptable risk. The JPL monitoring wells with "elevated" risk extended from the north-central portion of the site towards the City of Pasadena Arroyo well. The only municipal production well with hypothetical "elevated" cancer risk, located approximately ½ mile upgradient to the west of JPL, is outside the known influence of JPL impacted groundwater, and appears to be impacted from commercial activities not associated with JPL. It is important to note that health risks were calculated for hypothetical exposure to untreated groundwater and that all water purveyors are required to monitor water quality and treat groundwater when necessary to meet strict drinking water standards prior to distribution.

The total risk from noncarcinogenic materials, expressed as a hazard index (HI), was also determined for hypothetical exposure to untreated groundwater at each of the JPL monitoring wells and at each of the nearby municipal production wells. Results, again using very conservative assumptions, showed that, based on target organ effects, 10 JPL monitoring wells and three municipal production wells had HI values that exceeded EPA's benchmark value of 1.0. The monitoring wells with "elevated" HI values were primarily located between the north-central portion of the site and Lincoln Avenue Well No. 3 located off-site to the southeast. The three municipal production wells with "elevated" HI values included the City of Pasadena Arroyo well, the City of Pasadena Well 52, and the Lincoln Avenue Well No. 3. It is important to note that the Agency for Toxic Substances and Disease Registry (ATSDR) recently issued a public comment draft of the *Public Health Assessment* for the JPL site (ATSDR, 1998), and concluded that on-site and off-site groundwater do not pose a present or future public health hazard since wellhead treatment and water blending are used by local water purveyors to meet stringent drinking water standards prior to distribution of the water for public use. Unlike state and Federal guidance that require exposures to untreated groundwater be evaluated in baseline risk assessments, the ATSDR evaluated whether or not residents are actually being exposed, or may in the future actually be exposed, to hazardous substances. The ATSDR conclusion represents a more realistic estimate of human health concerns.

An initial scoping assessment of ecological risks was completed to determine if a quantitative ecological assessment of the potential risks to biota (plant and animal) associated with contamination found at the site was required. The scoping assessment qualitatively evaluated potential ecological receptors, constituents of concern, and potentially complete exposure pathways.

The ecological scoping assessment used a habitat approach as the basis for identifying potentially complete pathways between areas of groundwater contamination and biota that occupy or potentially occupy the site. Due to the depth of JPL groundwater, exposure to untreated groundwater was found not to be plausible and, therefore, no complete exposure pathways from groundwater to biota were identified. It was concluded that full characterization of ecological risks due to groundwater contamination was not warranted.

Through the groundwater investigation conducted at JPL, it was concluded that the primary objectives of the RI were met as summarized below:

- Contaminants of potential concern were identified in groundwater beneath and downgradient of JPL, and were well characterized in terms of their horizontal and vertical extent.
- The RI data allowed for an understanding of the fate and transport processes for the contaminants of potential concern in the JPL aquifer. It was concluded that further significant downgradient migration of contaminants is unlikely due to the influence of the nearby municipal production wells.
- The risks from hypothetical exposure to untreated groundwater were conservatively evaluated for each JPL monitoring well and each nearby municipal production well. Results indicated there may be potential human-health risks associated with carcinogenic and noncarcinogenic constituents located in the groundwater near the north-central portion of the site and extending a short distance off-site towards the southeast. However, groundwater is treated by local water purveyors to meet stringent drinking water standards prior to distribution for domestic use, thus effectively protecting public health.
- The nature and extent of contamination and the fate and transport parameters are adequately characterized for the purpose of evaluating potential remedial alternatives for the OU-1/OU-3 Feasibility Study.

1.0 INTRODUCTION

This report contains the results of the Remedial Investigations (RIs) for Operable Units 1 and 3: On-Site (OU-1) and Off-Site (OU-3) Groundwater at the Jet Propulsion Laboratory (JPL) in Pasadena, California. In 1993, during preparation of the RI Work Plan for JPL (Ebasco, 1993a) at the request of the United States Environmental Protection Agency (EPA) Region IX, the groundwater beneath and downgradient of JPL was divided into two operable units. It was believed an RI for on-site groundwater would be completed before an RI for off-site groundwater since several groundwater-monitoring wells already existed on-site. However, after the RI for the on-site groundwater (OU-1) began, additional monitoring wells, unanticipated at the time, were required to be installed. This delayed the completion of the RI for the on-site groundwater and allowed it to coincide with the RI for the off-site groundwater. For this reason the data collected from both the on-site (OU-1) and off-site (OU-3) JPL groundwater monitoring wells have been combined into a single OU-1/OU-3 RI Report.

JPL is a National Aeronautics and Space Administration (NASA) owned facility managed by the California Institute of Technology (CalTech). The term "JPL" is used throughout this document to refer to the facilities located at 4800 Oak Grove Drive in Pasadena, California.

In October 1992, JPL was placed on the National Priorities List and, as a result, JPL is subject to the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, hereafter jointly referred to as CERCLA. Pursuant to CERCLA requirements, the OU-1/OU-3 RI was completed to characterize the nature and extent of contamination in the groundwater beneath and downgradient of the JPL site.

This RI report is one of two to be produced, one associated with the "groundwater" operable units and one associated with the "soils" operable unit at JPL as agreed upon by the EPA, the California State Department of Toxic Substances Control (DTSC), the California Regional Water Quality Control Board (RWQCB), and NASA. The RI for the JPL "soils" (Operable Unit 2), which will be presented in a separate report, pertains to the on-site contaminant source characterization. The activities for each RI have been completed pursuant to applicable state and Federal guidance.

This RI report summarizes the physical and chemical characteristics of the groundwater beneath and surrounding JPL. Information is also presented on the horizontal and vertical extent of contaminants in the groundwater, the fate and transport of these contaminants, and a summary of the risks to actual or potential receptors. The information presented will be used during a Feasibility Study (FS) to identify and evaluate appropriate groundwater remedial technologies to protect human health and the environment.

1.1 PURPOSE OF REPORT

The primary purpose of the JPL OU-1/OU-3 RI is to identify the nature and extent of contaminants in the groundwater. To accomplish this, a large amount of data was collected and evaluated. The purpose of the RI report is to present and organize data to:

- Characterize the nature and extent of contaminants in the groundwater beneath and near the JPL site.
- Assess the fate and transport of contaminants in the groundwater beneath and near the JPL facility based on hydrogeologic and geologic data.
- Provide a baseline risk assessment to evaluate the potential risk from contaminants in the groundwater to human health and the environment.
- Provide sufficient information for the OU-1/OU-3 FS to evaluate technologies for remediation of groundwater.

1.2 REPORT ORGANIZATION

The RI report consists of eight sections as follows:

- Section 1.0: Introduction - This section provides background information regarding site location, physiography, history and operations. The nature and extent of the local groundwater contamination problem as identified through previous investigations are presented.
- Section 2.0: Groundwater Investigation - This section describes the RI field activities including the drilling and installation procedures for groundwater monitoring wells, well development and sampling procedures, as well as aquifer testing protocols.
- Section 3.0: Physical Setting - This section describes the sites' physiography, meteorology, geology and hydrogeology. The information presented in this section is based on data collected during the RI activities as well as information obtained from previous investigations on or near the JPL facility.
- Section 4.0: Nature and Extent of Contamination - This section presents the results of chemical analyses performed on the groundwater samples from the JPL monitoring wells. These results are used to determine the nature and extent of contamination that are critical to identifying appropriate remediation technologies.
- Section 5.0: Contaminant Fate and Transport - This section describes the groundwater contaminant occurrence and distribution, the potential groundwater migration routes for these contaminants, and the characterization of chemical and physical properties of the contaminants to properly define their transport.
- Section 6.0: Baseline Risk Assessment - This section provides an evaluation of contaminants in the JPL groundwater monitoring wells and their potential threat to human health and the environment.

- Section 7.0: Summary and Conclusions - This section provides a summary of the findings from the RI activities.
- Section 8.0: References - This section provides a complete listing of all references used in preparing this report.

1.3 SITE BACKGROUND

This section provides a description of the JPL site, the JPL site history and a summary of previous investigations associated with the groundwater at JPL.

1.3.1 Site Description

JPL is located between the city of La Canada-Flintridge and the unincorporated city of Altadena, California, northeast of the 210 Foothill Freeway. A site location map is included as Figure 1-1. The site is situated on a south facing slope along the base of the southern edge of the east-west trending San Gabriel Mountains at the northern edge of the metropolitan Los Angeles area. The Arroyo Seco, an intermittent streambed, lies immediately to the east and southeast of JPL. Within the Arroyo Seco east of JPL is a series of surface impoundments used to collect surface water for groundwater recharge. Residential development, an equestrian club (Flintridge Riding Club), and a Los Angeles County Fire Department Station borders the site along its southwestern and western boundaries. Residential development is also present to the east of JPL, along the eastern edge of the Arroyo Seco.

JPL is comprised of approximately 176 acres. Of this, a large majority is Federally owned, with the remaining land leased from the City of Pasadena and the Flintridge Riding Club for parking. The main developed area of JPL is located on the southern half of the site, which can be divided into two general areas: the northeastern early-developed area and the southwestern later-developed area. The northern half of the site is not developed because of steeply sloping terrain.

Currently, the northeastern early-developed area is used by JPL for project support, testing, and storage facilities, while the southwestern later-developed area houses most of the personnel, administrative, management, laboratory, and project functions of JPL. Further development of JPL is constrained because of steeply sloping terrain to the north, the Arroyo Seco wash to the south and east, and residential development to the west.

Located at the northern boundary of JPL is the Gould Mesa area (Figure 1-1). This area has widely separated small buildings and is used primarily by JPL for antenna testing. The distance between buildings is a result of the terrain and the need to isolate transmitting and receiving equipment.

The relatively steep mountainside area between Gould Mesa and the well-developed area at JPL is unpopulated. It is accessible to authorized personnel only. The only improvements to this area are water storage tanks and Mesa Road, the road leading to the top of Gould Mesa. Future development in this area is constrained by topography.

Presently, over 150 structures and buildings occupy the JPL facility. Total usable building space is approximately 1,330,000 square feet, of which about 40,164 square feet is occupied by trailers and vans. A site facility map is included as Figure 1-2.

Elevation of the JPL site varies from 1,075 feet in the southern portion to 1,550 feet along the northern portion of the site at Gould Mesa. Surface runoff on JPL is generally from north to south. Surface water runoff from the mountains to the north is collected and transmitted by an underground storm-drain system through the developed southern portion of the site and is then discharged into the Arroyo Seco wash. The storm-drain system includes four major drains (24 to 48 inches in diameter) that extend from the northern slopes of the site and terminate at the Arroyo Seco. Branch lines (12 to 24 inches in diameter) collect localized surface drainage and divert the water to the major drains. Runoff from parts of La Canada-Flintridge join the JPL storm drain system at the western edge of JPL, just north of the main JPL entrance (Building 249, Figure 1-2), before being discharged to the Arroyo Seco. JPL maintains a storm water discharge permit as required by state law and regularly analyzes the discharge during certain storm events.

Previous geologic studies conducted on-site have identified an east-west trending and north dipping thrust fault, referred to as the JPL Thrust Fault, crossing the site separating the San Gabriel Mountains to the north from the alluvial slope to the south. At JPL, the alluvial deposits south of the fault range in thickness from 650 to 850 feet and rest on a crystalline basement complex made up of the same general rock types as those comprising the San Gabriel Mountains north of the fault. The unsaturated alluvium at JPL ranges between approximately 100 to 250 feet in thickness and the saturated alluvium ranges between approximately 550 and 600 feet in thickness. The regional groundwater flow across JPL is generally toward the southeast. Occasionally, however, the groundwater flow direction and gradient across JPL can change significantly. Operation of numerous municipal water production wells near the site and the presence of the Arroyo Seco groundwater recharge basins east of the site can occasionally significantly influence the groundwater flow direction and gradient surrounding JPL.

1.3.2 Site History

The Jet Propulsion Laboratory began in 1936 when Professor Theodore Von Karmen of the California Institute of Technology (CalTech) and a group of students began testing liquid propellant rockets in the Arroyo Seco. At that time the testing was being completed through the Gugenhiem Aeronautical Laboratory at the California Institute of Technology (GALCIT). In 1940, the Army Air Corps provided funding for the first permanent structures built near the present day site. By 1944, the site continued to grow and changed its name to the Jet Propulsion Laboratory, GALCIT. Ultimately, the site became known as the Jet Propulsion Laboratory, or JPL, and became a fully owned Federal facility. In 1958, NASA took over control of JPL. Today, under a prime contract, CalTech performs research and development tasks at facilities provided by NASA which are located at the current site of JPL. CalTech also maintains the facilities as part of its contractual agreement with NASA.

For JPL to accomplish the research and development tasks under their purview, various chemicals and materials have been utilized during the operational history of JPL. The general types of materials used and produced include a variety of solvents, solid and liquid rocket propellants, cooling-tower chemicals, and chemical laboratory wastes. During the 1940s and 1950s, many buildings at JPL maintained a cesspool to dispose of liquid and solid sanitary wastes collected from drains and sinks within the building. These cesspools were designed to allow liquid wastes to seep into the surrounding soil. Present-day terminology for these subsurface disposal areas is "seepage pits". Some of the seepage pits may have received volatile organic compounds (VOCs) and other waste materials that are currently found in the groundwater. In the 1950's, a sanitary sewer system was installed and the use of the cesspools for waste disposal was discontinued.

In 1980, analyses of groundwater from three City of Pasadena water-supply wells (the Ventura Well, Well 52 and the Arroyo Well) located near JPL indicated the presence of trichloroethene (TCE), tetrachloroethene (PCE) and carbon tetrachloride (CCl₄). Since this time, a number of investigations focusing on environmental issues have been conducted at JPL (see Section 1.3.3 below).

1.3.3 Previous Investigations Related to the Groundwater at JPL

Numerous investigations focusing on geotechnical and environmental issues have been conducted at and adjacent to JPL. Studies related to the JPL geology, hydrogeology and groundwater include:

- LeRoy Crandall and Associates (1977a), *Report of Subsurface Investigation, Overall Investigation of Geology, Soils and Seismic Hazard, Seismic Safety Plan, Jet Propulsion Laboratory Site.*
- Agbabian Associates (1977), *Seismic Studies for the Jet Propulsion Laboratory Facilities, Part I, II, and III.*
- LeRoy Crandall and Associates (1977b), *Report of Fault Hazard Study, Jet Propulsion Laboratory.*
- LeRoy Crandall and Associates (1981), *Dewatering Well System, Building 150, Jet Propulsion Laboratory, Pasadena, California.*
- Geotechnical Consultants, Inc. (1982), Draft report and set of notes and correspondence on the drilling and installation of monitoring well MH-01 in the Arroyo Seco for the City of Pasadena.
- Richard C. Slade (1984), *Preliminary Hydrogeologic Assessment of Soil and Groundwater Monitoring at Jet Propulsion Laboratory, Pasadena, California.*
- James M. Montgomery, Inc. (1986), Untitled letter report summarizing hydrogeologic data and contaminant transport predictions.

- Geotechnical Consultants, Inc. (1989), *Interim Report, Evaluation of Groundwater Quality Upgradient of Jet Propulsion Laboratory, Pasadena, California.*
- Ebasco Environmental (1990a), *Expanded Site Inspection Report for NASA-Jet Propulsion Laboratory.*
- Ebasco Environmental (1990b), *Supplemental Information to the Expanded Site Inspection Report on the NASA-Jet Propulsion Laboratory.*
- Jet Propulsion Laboratory (1990), Untitled set of memoranda, laboratory analyses, notes, sketches, and other correspondence associated with the removal of storm drain catch basin and impacted soil.
- Ebasco Environmental (1990c), *Report on Groundwater Elevations at JPL During Start-Up of City of Pasadena Production Wells.*
- Ebasco Environmental (1992a), *Groundwater Model Selection for NASA-Jet Propulsion Laboratory Site.*
- Ebasco Environmental (1993a), Pre-RI Investigation. Reported in *Final Work Plan for Performing a Remedial Investigation/Feasibility Study.*
- JPL Groundwater Sampling Program, 1990-1993. Summary of groundwater sampling events completed at JPL prior to the CERCLA Remedial Investigation/Feasibility Study (RI/FS).
- Ebasco Environmental (1993e), *Draft JPL Groundwater Elevation Data Report Number 1, September 1992 through June 1993*, and Ebasco Environmental (1994a), *Draft JPL Groundwater Elevation Data Report Number 2, July 1993 through December 1993.*
- Foster Wheeler Environmental (1996k), *Report on the Preliminary Evaluation of Groundwater Data Collected at JPL Prior to the CERCLA RI/FS.*
- Multimedia Environmental Technology (1996), *Development and Calibration of the Two-dimensional Groundwater Flow Model of the Jet Propulsion Laboratory, Pasadena, California.*
- Multimedia Environmental Technology (1997), *Development and Calibration of the 3-D Groundwater Flow Model of the Jet Propulsion Laboratory, Pasadena, California.*
- Multimedia Environmental Technology (1998), *Calibration and Refinement of the 3-D Groundwater Flow Model of the Jet Propulsion Laboratory, Pasadena, California.*

Each of these investigations is summarized below.

1.3.3.1 LeRoy Crandall and Associates (1977a). *Report of Subsurface Investigation, Overall Investigation of Geology, Soil and Seismic Hazard, Seismic Safety Plan, Jet Propulsion Laboratory.*

This investigation was completed to identify the depth to crystalline basement rocks at JPL and to identify specific engineering and dynamic properties of soils at JPL for input into a seismic dynamic analysis to be performed later by Agbabian Associates (see Section 1.3.3.2).

During this study three borings were drilled at locations shown on Figure 1-3. Borings 1 and 3 were drilled to 100 feet below grade to provide information on the properties of the relatively shallow alluvium. Boring 2 was drilled to a depth of 680 feet below grade and encountered crystalline basement rocks at 635 feet below grade. All borings were drilled using mud rotary methods. Boring 2 was subsequently completed to 414 feet with 5-inch diameter polyvinyl chloride (PVC) blank casing to allow a down hole seismic survey to be performed. Borings 1 and 3 were backfilled and abandoned after drilling.

Data from this report that is useful for the current groundwater RI include the depth to crystalline basement rocks encountered in Boring 2.

1.3.3.2 Agbabian Associates (1977). *Seismic Studies for the Jet Propulsion Laboratory Facilities, Parts I, II, and III.*

Agbabian Associates completed a three-part seismic study of JPL in 1977. As part of the study, previous geologic and seismologic investigations were summarized, the location of the JPL Thrust Fault was reevaluated and mapped, data from a trench cut across the JPL Thrust Fault at the mouth of the Arroyo Seco by a CalTech research team were examined, and existing seismic data on the subsurface conditions at JPL were reevaluated. A cross section of the trench cut across the JPL Thrust Fault by the CalTech research team is included as Figure 1-4. This trench was 40 feet long and 5 to 8 feet deep, excavated with a backhoe, and located just north of the JPL bridge (see Figure 1-5). In this trench, granitic rocks were found overlying alluvium along a fault contact that dipped to the northeast at an angle between 30 to 40 degrees from horizontal.

As part of the Agbabian study, the trace of the JPL Thrust Fault across the JPL facility was mapped. Agbabian Associate's interpretations of the trace of the JPL Thrust Fault are included in Figure 1-5.

Conclusions of Part I of Agbabian's study related to the geology of the site include:

- The JPL Thrust Fault is part of the Sierra Madre Fault system.
- No evidence was found for, or against, displacement along the JPL Thrust Fault within the past 10,000 to 12,000 years.
- Additional work is required to further evaluate the activity or inactivity of the JPL Thrust Fault and better define its trace in the western half of JPL. Agbabian Associates recommended additional trenching across the fault to address these issues.

Part II of Agbabian Associates' study, "Supplemental Geologic Studies for the Jet Propulsion Laboratory Facilities", reported the results of additional investigations recommended in the Part I study. Included in the additional investigations was further trenching across the JPL Thrust Fault in hopes of finding evidence for dating fault activity. LeRoy Crandall and Associates excavated a trench across the JPL Thrust Fault west of the trench excavated by CalTech (Figure 1-5). The trench was 36 feet long and had a maximum depth of 12 feet. The JPL Thrust Fault, as exposed

along the length of the trench (Figure 1-6), strikes east-west and has an apparent dip to the north of approximately 24 degrees. Due to surface restrictions, the trench was cut oblique (N50 E) to the east-west trace of the fault.

Part III of Agbabian Associates' study, "Implications of Fault Hazard for the Jet Propulsion Laboratory Master Plan", discussed recommendations for the use of existing facilities and for land development within zones of potential earthquake induced surface rupture on the JPL property. These recommendations were based on information obtained during the Part I and Part II studies.

The Agbabian studies were originally intended for earthquake and seismic evaluations only and were not conducted to collect CERCLA RI related information. However, results of Agbabian Associates' work provide insight into the location of the JPL Thrust Fault. This information is used to further understand the nature and history of the study area.

1.3.3.3 LeRoy Crandall and Associates (1977b). *Report of Fault Hazard Study, Jet Propulsion Laboratory.*

This investigation was completed, primarily, to further locate the JPL Thrust Fault along the western portion of JPL so that buildings within the potential rupture zone of the fault could be better identified. In addition, the report discussed potential seismic hazards for a proposed water reservoir and included recommendations for minimizing the rupturing of critical pipelines during fault movement. During this investigation, 11 soil borings were drilled to depths ranging between 33 and 800 feet. The locations and total depths drilled for these borings are shown on Figure 1-7. Listed below is a summary of important geologic data concerning the borings:

Boring No.	Total Depth in Feet	Remarks
1	100	Entirely in alluvium (drilled during Crandall (1977a) investigation)
2	680	Granitic rock at 635 ft. (drilled during Crandall (1977a) investigation)
3	100	Entirely in alluvium (drilled during Crandall (1977a) investigation)
4	800	Entirely in alluvium
5	169.5	Encountered fault at 157 ft.
6	135	Encountered fault at 122 ft.
7	272	Bottom in granitic rock
8	210	Entirely in alluvium
9	259	Encountered fault at 248 ft.
10	110	Bottom in granitic rock
11	323	Entirely in alluvium
12	33	Bottom in granitic rock
13	243	Entirely in alluvium
14	243.5	Encountered fault at 230 ft.

All borings were drilled with mud rotary drilling methods and all soil types were logged during drilling. Soil samples and cores of crystalline basement rock were collected for further evaluation, if necessary. The boring logs were given to a CalTech research team who interpreted the trace of the JPL Thrust Fault and estimated the potential associated rupture zone. The trace of the fault, as developed from the boring logs, is shown on Figure 1-7. The fault plane was penetrated four times during this study and several borings were strategically located to place limits on the possible location of the fault plane. To further define the location of the JPL Thrust Fault, soil boring logs developed during this investigation will be compared to data obtained during the current RI (see Section 3.3).

1.3.3.4 LeRoy Crandall and Associates (1981). *Dewatering Well System, Building 150, Jet Propulsion Laboratory.*

In 1981, LeRoy Crandall and Associates (Crandall) installed and evaluated a soil dewatering system near Building 150 at JPL. During periods of high precipitation, surface water runoff entered the basement of Building 150.

The dewatering system consisted of one 12-inch diameter, 60-foot deep pumping well, and two 4-inch diameter, 40-foot deep observation wells installed at distances of 40 feet and 80 feet, respectively, away from the pumping well (Figure 1-8). During drilling of the 60-foot pumping well, crystalline basement rock was encountered at a depth of approximately 2 feet below grade. Crystalline basement rock was encountered in Observation Well No. 1 at approximately 15 feet below grade and in Observation Well No. 2 at approximately 20.5 feet below grade. Overlying the basement rocks, alluvial soils, consisting of silty sand and sand with gravel and cobbles, were encountered.

Based on performance of the dewatering system, during which the average pumping rate was about 3.2 gallons per minute, the system appeared to be removing significant quantities of water north of the building. However, the entire area was not being dewatered as indicated by water levels in the observation wells. The water level in Observation Well No. 1, located a distance of 40 feet from the pumping well, had declined 3 feet, and the water level in Observation Well No. 2, located 80 feet from the pumping well, had declined less than 0.5 feet. Based on this information, Crandall subsequently recommended modifying the operation of the pumping well to increase its area of influence and recommended converting both observation wells into pumping wells.

This study was conducted for purposes other than CERCLA. However, the shallow nature of the crystalline basement rocks north of the main trace of the JPL Thrust Fault provides further insight on the geologic nature of the site.

1.3.3.5 Geotechnical Consultants, Inc. (1982). Draft report and set of notes and correspondence on the drilling and installation of monitoring well MH-01 in the Arroyo Seco for the City of Pasadena.

In 1982, Geotechnical Consultants, Inc. conducted a preliminary hydrologic assessment of the Arroyo Seco to evaluate potential sources of VOCs in the groundwater for the City of Pasadena. This investigation included the installation and sampling of one groundwater monitoring well. A final report was not submitted to the City of Pasadena because the appropriated budget had been exceeded before a report could be prepared. However, information was obtained on this investigation from a draft copy of the report and a compilation of notes in a City of Pasadena Water and Power Department open file.

This investigation included the installation of the City of Pasadena groundwater monitoring well MH-01 to a depth of 366 feet in the Arroyo Seco approximately halfway between the City of Pasadena's municipal water supply Arroyo Well and JPL Building 103 (Figure 1-9). It was believed that the source of VOCs detected in the City of Pasadena municipal supply wells was from JPL. Monitoring well MH-01 consists of 366 feet of 6-inch diameter blank and slotted PVC casing. The well was screened at nine different intervals between the depths of 145 feet and 355 feet. During well installation, sand was placed continuously in the well's annulus from 366 feet to approximately 55 feet below ground surface. Seals were not placed between screened intervals. The boring was advanced to 399 feet below grade before the well casing was installed to 366 feet.

Standard decontamination procedures were employed to minimize contamination from well construction materials and drilling and sampling equipment. Groundwater samples were collected from the nine different screened intervals in the well using both syringes and a submersible pump. Samples were analyzed by Montgomery Watson Laboratories for VOCs, trihalomethanes/synthetic organics, pesticides, polychlorinated biphenyls (PCBs), and herbicides. Analytical results indicated that concentrations of VOCs including CCl₄, TCE, and PCE were present in the groundwater. The reported concentrations of CCl₄, TCE, and PCE are summarized in Table 1-1. Pesticides, herbicides and PCBs were not detected.

The results of this investigation provided the first evidence that VOCs were present in the groundwater beneath the Arroyo Seco. This investigation was not performed in response to CERCLA, but provided early information on types of contaminants present in the groundwater.

1.3.3.6 Richard C. Slade (1984). *Preliminary Hydrogeologic Assessment of Soil and Groundwater Monitoring at the Jet Propulsion Laboratory.*

Richard C. Slade completed a preliminary assessment of soils and groundwater at JPL in 1984. The purpose of this work was to provide a hydrogeologic assessment based on results of laboratory data generated from soil and groundwater samples collected on and near JPL.

This investigation included the excavation of trenches at two abandoned cesspools (seepage pits) at JPL and the collection of groundwater samples from the City of Pasadena monitoring well MH-01. The seepage pits were located southwest of former Building 59 (Seepage Pit No. 16 in OU-2) and southwest of former Building 65 (Seepage Pit No. 13 in OU-2). Both buildings previously housed chemistry laboratories.

Exploration of these two former seepage pits included the excavation of three to four trenches at each site and the collection of soil samples for laboratory analysis. The trenches ranged in depth from 8 to 13 feet and were excavated using a backhoe equipped with a 2-foot wide bucket. None of the trenches were excavated to the bottom of the seepage pits. Soil samples were collected at depths ranging from 1 to 9.5 feet. Relatively undisturbed samples were obtained from the in-place materials exposed in the trench walls by driving a brass sampling sleeve into the soil and immediately capping both ends of the sleeve. Soil samples were analyzed for CCl₄, TCE, PCE, 1,1,1-trichloroethane (TCA), metals, fluoride (F), and pH.

Laboratory analyses of the relatively undisturbed soil samples did not detect any VOCs. Lead was detected at a concentration of 200 milligrams per kilogram (mg/kg) in the sample collected at a depth of 7 feet from the seepage pit adjacent to former Building 59. The source of this lead was not determined.

The groundwater investigation included collecting water samples, using syringes, from the nine screened intervals in monitoring well MH-01. The report noted that the well was not purged before sampling. The results of this study are impossible to evaluate due to the purging and sampling technique. The results obtained may indicate a variety of potential conditions of which little can be deduced. Laboratory analyses were conducted on each of the samples for priority pollutant metals, F, cyanide, hexane, TCE, PCE, CCl₄, and TCA.

Laboratory results of the groundwater samples from well MH-01 indicated mercury was detected below its Maximum Contaminant Level (MCL) in 6 of the 9 samples and was detected just above its MCL in the 182-foot depth sample (Table 1-2). Fluoride was present above its MCL at concentrations of 13 and 14 milligrams per liter (mg/l) in samples collected from depths of 234 feet and 265 feet, respectively (Table 1-2). Fluoride concentrations in all the other samples were below its MCL. Additional samples were analyzed for fluoride during the RI and the results are discussed in Section 4.0. Cyanide was not detected in any sample analyzed. PCE was found in all samples and ranged in concentration from 0.2 to 0.7 micrograms per liter (µg/l) (Table 1-3). TCE and CCl₄ were found only in samples collected at and below 265 feet (Table 1-3). Reported concentrations of TCE ranged from 1.3 to 7.5 µg/l and reported concentrations of CCl₄ ranged from 0.2 to 2.4 µg/l (Table 1-3).

The Slade investigation was not performed pursuant to the CERCLA investigation. However, it provides information on early laboratory analyses of groundwater samples collected from City of Pasadena monitoring well MH-01 located in the Arroyo Seco.

1.3.3.7 James M. Montgomery, Inc. (1986). Untitled letter report summarizing hydrogeologic data and contaminant transport predictions.

During 1986, James M. Montgomery, Inc. (Montgomery) evaluated VOC contaminant transport in the groundwater beneath the Arroyo Seco for the City of Pasadena using a one-dimensional dispersion model. The objectives of this evaluation were to estimate the following:

- Location of the source of VOC contamination.
- Rate and direction of contaminant plume movement.
- Maximum Expected Contaminant Levels (MECLs) that might be anticipated in the City of Pasadena municipal supply wells.

The analysis was conducted using an analytical one-dimensional dispersion model that assumed no molecular diffusion. The primary transport mechanism was assumed to be hydrodynamic dispersion (groundwater flow velocity together with dispersion).

The model used by Montgomery required the input of an average groundwater velocity and dispersion coefficient for calculating relative concentrations at some distance from a potential source at a given period of time. Groundwater velocities and hydraulic conductivities were estimated based on calculated transmissivities for various municipal wells in the area, and longitudinal dispersion coefficients were estimated based on Montgomery's experience and previous studies in areas having similar subsurface geologic conditions.

It was concluded that the VOC contamination in the City of Pasadena Arroyo Well appeared to originate from a source located to the north-northwest of the well. Based on review of JPL's history, measured VOC concentrations in groundwater, and estimated source distances from the well, Montgomery estimated that the VOCs were derived from a source that originated less than 5,000 feet from the Arroyo Well.

To predict the MECLs, the locations of contaminant sources and a detailed understanding of the subsurface hydrogeology were needed. This information was not available for this study, and therefore, MECL predictions were based on estimated source durations, groundwater flow velocities, and dispersion coefficients. The predictions suggested that MECLs for maximum total VOCs of about 170 µg/l could one day be expected at the City of Pasadena Arroyo Well if current (1986) trends continued. Review of pumping records from water production wells in or near the Arroyo Seco, together with rainfall data, suggested to Montgomery that pumping of the City of Pasadena Arroyo Well was, perhaps, preventing contaminants from migrating to the south and southeast of the well.

This report was not prepared for CERCLA purposes, but did provide some information regarding the potential for VOCs to reach the City of Pasadena municipal wells. The report is of limited value to the current JPL groundwater RI because of the numerous assumptions made and the extent of site specific data obtained since 1986.

1.3.3.8 Geotechnical Consultants, Inc. (1989). *Interim Report, Evaluation of Groundwater Quality Upgradient of the Jet Propulsion Laboratory.*

An evaluation of groundwater quality upgradient of JPL was conducted by Geotechnical Consultants, Inc. for the U.S. Army Corps of Engineers in 1989. The purpose of this investigation was to install two groundwater monitoring wells upgradient and outside the influence of JPL facility activities. These wells were to be sampled and analyzed to establish background water-quality data for JPL.

As part of this study, monitoring well MW-1 was installed just outside the northeast corner of JPL's property near the Arroyo Seco Bridge, and monitoring well MW-2 was installed in the far southwest corner of JPL's west parking lot. Both wells were drilled with mud-rotary methods. Well MW-1 was drilled to a depth of 162 feet and well MW-2 was drilled to a depth of 179 feet. The depth to the groundwater, based on geophysical log interpretation, was estimated to be 85 feet below grade at well MW-1 and 140 feet below grade at well MW-2. Well screens were subsequently installed from 70 to 110 feet in well MW-1 and from 127 to 167 feet in well MW-2. After well development procedures were completed in each well, the water level in well MW-1 was measured at 39 feet below grade, or over 30 feet above the top of the screen, and the screen in well MW-2 was found to be completely above the water table. Well MW-2 was not drilled deeper due to contractual limitations. Due to the depth of the screen in well MW-1, water levels recorded during the RI have consistently been above the screen.

Groundwater samples were subsequently collected from well MW-1 and from previously installed City of Pasadena monitoring well MH-01 (see Section 1.3.3.5). A water sample from well MW-1 was analyzed for volatile and semi-volatile organic compounds (SVOCs), total petroleum hydrocarbons (TPH), five metals (total and dissolved arsenic, lead, mercury, selenium, and silver), pH, and total dissolved solids (TDS). Laboratory results revealed no evidence of organic contamination and no elevated levels of the five target metals. A summary of the laboratory results is presented in Table 1-4. It was concluded that MW-1 was a legitimate upgradient sampling point to JPL and that there was no immediate evidence of groundwater contamination entering the northeast part of the study area along the Arroyo Seco.

The work completed has value to the JPL CERCLA investigation in that it provided at least one upgradient monitoring well for future use. Well MW-1 has been routinely sampled as part of the groundwater characterization effort at JPL (see Section 1.3.3.15).

1.3.3.9 Ebasco Environmental (1990a). *Expanded Site Inspection Report, Jet Propulsion Laboratory.*

Between January and March 1990, field activities for an Expanded Site Inspection (ESI) were conducted at JPL by Ebasco Environmental (Ebasco) (currently known as Foster Wheeler Environmental Corporation) (Ebasco, 1990a). The objectives of the ESI were to obtain additional information on potential contaminants in the groundwater and soils at JPL by installing five groundwater monitoring wells and conducting a limited soil gas survey at suspected waste

disposal sites identified during previous investigations. During the ESI, the five groundwater monitoring wells were installed at the locations shown in Figure 1-9. These data were collected to provide support and documentation for the EPA to provide a final Hazard Ranking System score for JPL to determine whether or not JPL should be included on the National Priorities List (NPL). The monitoring wells were located to obtain water quality information on groundwater near locations where previous waste-disposal activities reportedly occurred, and to obtain groundwater elevations so that gradients and directions of groundwater flow could be identified.

Two of the monitoring wells (MW-3 and MW-4) were drilled to crystalline basement rock, as deep as 730 feet below ground surface, with mud-rotary drilling equipment. Both of these deep monitoring wells were completed with multi-port casing systems, designed by Westbay Instruments Ltd., which allow for the monitoring and sampling of five separate screened intervals within the aquifer from each well.

Three shallow groundwater monitoring wells (MW-5, MW-6, and MW-7), ranging in depth from 140 to 275 feet, were drilled with a dual-wall air percussion drilling rig and were completed as standpipe wells with 50 feet of screen in each well. Total depth of each well was determined in the field based on the location of the water table at the particular location.

Construction details for the five monitoring wells installed during the ESI are summarized in Table 1-5.

Following the installation and development of the monitoring wells, groundwater samples were collected from each screened interval in the deep wells and from each shallow well. This first sampling event of these new JPL monitoring wells is referred to as Event 1 of the pre-RI JPL groundwater monitoring events (see Section 1.3.3.15). Samples collected during Event 1 were analyzed for VOCs (EPA Method 624), SVOCs (EPA Method 625), California Code of Regulations Title 26 metals plus strontium (EPA Method 6010/7000 series), pesticides and PCBs (EPA Method 608), TPH (EPA Method 418.1) and cyanide (EPA Method 9010).

Results of laboratory analyses indicated that the groundwater at JPL, at that time, contained VOCs including CCl₄, TCE, PCE, and 1,1-dichloroethene (1,1-DCE) at concentrations above state and Federal Maximum Contaminant Levels for drinking water. Low levels (below regulatory thresholds) of chloroform, bromodichloromethane, and dibromochloromethane (all trihalomethanes) were also detected in the groundwater at JPL but were also present in the water from the fire-hydrant system at JPL used to mix drilling mud, suppress dust, etc., during drilling activities. Volatile and semi-volatile organic compounds detected in groundwater samples collected from the monitoring wells during the ESI are summarized in Table 1-6.

Cyanide, organochlorine pesticides, and PCBs were not detected in any water sample collected during the ESI at JPL. The analytical results also indicated that metals, including antimony, barium, chromium, cobalt, copper, lead, molybdenum, nickel, zinc, and strontium are present in the groundwater in concentrations normally found in natural waters well below state and Federal

regulatory thresholds established for drinking water. Concentrations of metals and TPH detected in groundwater samples from the five monitoring wells are summarized in Table 1-7.

The ESI work is important to the JPL groundwater CERCLA effort in that it provided the first evaluation of on-site groundwater conditions, identified types and concentrations of VOCs at JPL and provided several monitoring wells for future sampling. Information generated during the ESI provided significant input to the development of the CERCLA RI/FS Work Plan and the OU-1 and OU-3 Field Sampling and Analysis Plans (FSAPs).

1.3.3.10 Ebasco Environmental (1990b). *Supplemental Information to the Expanded Site Inspection Report (ESI) on the NASA-Jet Propulsion Laboratory.*

After the ESI (Ebasco, 1990a) was completed, the Hazard Ranking System scoring methodology was revised by the EPA. The revisions increased the amount and detail of data required by the EPA to evaluate potential threats to public health and the environment while scoring a site for potential inclusion on the NPL. A report, that included additional information not previously obtained was prepared and submitted so the EPA could complete their scoring for JPL with the newly revised system (Ebasco, 1990b).

Discussions and data relating to JPL waste characteristics, the potential groundwater contaminant migration pathways, the potential surface water contaminant migration pathways, the potential air contaminant migration pathways, and the potential on-site soil contaminant exposure pathways were included in this report (Ebasco, 1990b). Brief summaries of the potential groundwater and surface-water pathways from this report are presented below.

Potential Groundwater Migration Pathway

A map was prepared showing the locations of municipal water supply wells within a 4-mile radius of JPL and the population potentially served by each well. Copies of the well logs for the nearby City of Pasadena supply wells and JPL monitoring wells were also included.

Analytical results of water samples collected in November 1989 from four City of Pasadena water supply wells (the Arroyo Well, Well 52, the Ventura Well, and the Windsor Well) were presented. The water samples were analyzed for VOCs (EPA Method 624), SVOCs (EPA Method 625), general water chemistry, nitrates (NO₃), and metals including magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), selenium (Se) and silver (Ag). The VOCs detected in each well are shown in Figure 1-10 and indicate VOCs were present in three of the four wells sampled, but in concentrations generally below state and Federal drinking water standards. However, in the Arroyo Well, CCl₄ and 1,2-dichloroethane (1,2-DCA) were present in concentrations above drinking water standards.

The analytical results of water samples collected in June 1990 during JPL groundwater sampling Event 2 (Section 1.3.3.15), the second round of sampling of existing JPL monitoring wells MW-3 through MW-7, were also included and discussed. The groundwater samples were

analyzed for VOCs using EPA Method 624, and for general water chemistry (sodium (Na), potassium (K), calcium (Ca), Fe, chloride (Cl), sulfate (SO₄), NO₃, carbonate (CO₃), bicarbonate (HCO₃), F, phosphate (PO₄), total organic carbon (TOC)), and TDS. Results of the VOC analyses are summarized in Table 1-8.

Potential Surface Water Migration Pathway

Descriptions were provided on the physical characteristics of the ground surface at JPL, JPL's storm-drainage system, the physical characteristics and uses of the Arroyo Seco, stream-gauge data from the Arroyo Seco, watershed boundaries near JPL and the City of Pasadena's plans at that time for the Arroyo Seco.

Surface runoff on JPL is generally from north to south. Surface water from the mountains to the north of JPL is collected and transmitted across the developed portion of the site by an underground storm-drain system and then discharged into the Arroyo Seco. The storm-drain system, designed to control runoff from a calculated maximum rainstorm within a 50-year period, includes four major drains (24 to 48 inches in diameter) that extend from the northern slopes of JPL and terminate at the Arroyo. Branch lines (12 to 24 inches in diameter) collect localized surface drainage and divert the water to the major drains (Boyle Engineering, 1988). A layout of the existing storm drain system is presented in Figure 1-11.

Surface sediment samples were collected from the stream channel in the Arroyo Seco at the locations shown in Figure 1-12. After 2 to 3 inches of sediment were removed from the surface, sediment samples were collected by driving a 2-inch diameter by 6-inch long stainless steel sample tube into the soil with a hand held, sliding hammer-drive soil sampler. The sediment samples were analyzed for VOCs (EPA Method 8240), SVOCs (EPA Method 8270), California Administrative Code Title 26 metals plus strontium (EPA Method 6010/7000), organochlorine pesticides and PCBs (EPA Method 8080), TPH (EPA Method 418.1), and cyanide (EPA Method 335.2). The analytical results of these analyses are summarized in Table 1-9.

No VOCs, SVOCs, organochlorine pesticides, or PCBs were detected in any near-surface sediment sample. However, some metals, cyanide, and TPH were detected in low concentrations (Table 1-9).

In summary, this study supplied supplemental information to the EPA for Hazard Ranking System scoring purposes. This work contributed to the JPL CERCLA investigation in that the groundwater quality data provided additional insight into the nature of the groundwater near JPL.

1.3.3.11 Jet Propulsion Laboratory (1990). Untitled set of memoranda, laboratory analyses, notes, sketches, and other correspondence associated with the removal of a storm drain catch basin and associated impacted soil.

In November 1990, during a JPL facilities construction project that involved the demolition of six buildings near the east gate (former Buildings 20, 23, 31, 32, 81 and 134) and realignment of

Explorer Road, a construction crew encountered an old catch basin that was part of the site-wide storm-drain system installed over 30 years ago.

The catch basin was located approximately 20 to 25 feet from the front of the east end of Building 107 and was constructed of reinforced concrete. Dimensions of the catch basin were reported to be approximately 6 feet by 6 feet by 10 feet deep. The top of the catch basin was level with the surrounding surface grade and contained an open steel grating that allowed storm-water runoff and associated debris to flow into the basin. Additional runoff flowed into the chamber from an inlet pipe connected to two smaller catch basins located upstream. Solid materials entering the chamber were allowed to settle before water flowed out a discharge line that emptied to the Arroyo.

When the catch basin was uncovered on November 30, 1990, it contained approximately 4 feet of saturated, very dark-gray to black sandy sludge material with about 2 feet of liquid on top. After the catch basin had been broken up, the basin's contents were recognized as being contaminated, and samples of the sludge were collected and sent by JPL personnel to a laboratory for analysis on a "rush" basis. The samples were analyzed for total metals by EPA Method 6010/7000 series, cyanide by EPA Method 8010, TPH by EPA Method 8015 (modified for gasoline), pesticides and PCBs by EPA Method 8080, VOCs by EPA Method 8240, and SVOCs by EPA Method 8270.

Results of these analyses indicated that the materials in the catch basin contained CCl_4 at an estimated concentration of 13,400 mg/kg along with lesser amounts of other solvents. A summary of VOCs and other chemical compounds detected is presented in Table 1-10.

Approximately 60 cubic yards of material were subsequently excavated on December 15, 1990 for off-site disposal. Three confirmation samples were then collected from areas of the excavation that visually appeared to be the most contaminated (darkest discoloration). Based on the analysis of these samples, another 100 cubic yards of soil (including some concrete) were excavated on December 18, 1990 for off-site disposal to ensure removal of impacted soils. All excavated materials (total of 160 cubic yards) were placed in roll-off bins and transported to a Class I landfill at Grassy Mountain, Utah. The catch-basin excavation was backfilled with concrete.

During the JPL OU-2 RI (on-site contaminant source investigation) this area was further investigated for the presence of VOCs. The former catch basin was located above a former seepage pit (seepage pit No. 36, Ebasco 1993a) around which three soil vapor probes (SV-31, SV-32 and SV-33) were installed and sampled for VOCs at 13 feet, 16 feet and 11 feet below grade, respectively. In addition, a multi-port soil vapor well (B-3) was installed nearby with four sampling ports to 52 feet below grade. Soil-vapor sample results indicated the presence of low-levels of carbon tetrachloride and chloroform. For a detailed description of the OU-2 soil investigation in this area see the OU-2 RI report (Foster Wheeler, 1999).

To evaluate potential groundwater contamination in the area, JPL groundwater monitoring well MW-15 was installed downgradient and near this former catch basin (see Section 2-1). VOCs were not detected in the groundwater at this location throughout the OU-1/OU-3 RI (see Section 4.0).

The catch basin was uncovered as a part of routine JPL facilities modification. While the work was not completed as part of the CERCLA process, it provides further insight to the types of constituents present at the site.

1.3.3.12 Ebasco Environmental (1990c). *Report on Groundwater Elevations at JPL During Start-Up of City of Pasadena Production Wells.*

In September 1990, a groundwater treatment plant designed to remove VOCs from groundwater extracted from four City of Pasadena water production wells (Arroyo Well, Well 52, the Ventura Well, and the Windsor Well) was completed and ready for use. The plant is located immediately adjacent to the Ventura well in the Arroyo Seco. The City of Pasadena wells were returned to production after having been shutdown between two to four years. Returning the wells to production provided an opportunity to accumulate well recovery data from short-term well tests conducted by the city before the wells were returned to full-time production. It was hoped the data could be used to attempt to quantify the hydraulic conductivity of the aquifer. In addition, there was an opportunity to monitor the depth of the water table in on-site JPL monitoring wells immediately after the four city wells were returned to production. The purpose of the report was to document the water-level data and provide a basis for interpreting future observations.

Well recovery tests were initiated on August 24, 1990, when City of Pasadena personnel purged two of their municipal production wells, the Arroyo Well and Well 52, in preparation for start-up of the city's groundwater treatment plant. The Arroyo Well was purged for 1 hour 14 minutes and Well 52 was purged for 1 hour 22 minutes. After the well pumps were shut down, recovery of the water levels in each well were monitored with an electric water-level sounder. The turbine pumps used in the city production wells did not contain check valves. Consequently, when the pumps were shut down, the water in the discharge line fell back into each well affecting the early well recovery data. In addition, since the wells are located relatively close to each other, the data from each well was also affected by interference from pumping of the other well. The conditions for the tests were not ideal and the data could not be used to accurately define aquifer characteristics.

In preparation for startup of production of the four City of Pasadena production wells, pressure transducers and computerized data loggers were temporarily installed on August 31, 1990 in JPL monitoring well MW-5 and City of Pasadena monitoring well MH-01 to record water table elevations. The transducers were in place approximately 12 days before the four production wells were returned to production. Water levels from JPL monitoring wells MW-1, MW-6, and MW-7 were manually collected weekly with an electric water level meter. A graph of groundwater elevations versus time during this period is included on Figure 1-13. As shown on Figure 1-13,

the water table beneath JPL was significantly affected by the return to production of the four City of Pasadena municipal wells. The water level in well MH-01 was lowered over 40 feet, and the water level in well MW-6, located over ½ mile from the city production wells, was lowered more than 10 feet soon after the wells were returned to production.

This report was not prepared for any CERCLA related task. However, the data generated furthered the understanding of the aquifer near JPL and its relationship to surrounding municipal supply wells. This data has been of significant importance in understanding the dynamic nature of the aquifer beneath and near JPL.

1.3.3.13 Ebasco Environmental (1992a). *Groundwater Model Selection for NASA-JPL Site.*

The presence of VOCs in municipal water supply wells downgradient from JPL has prompted various investigations. To evaluate the transport mechanisms of organic compounds in JPL groundwater, various numerical models (computer codes) were evaluated as to their capability to model the JPL site for the CERCLA process.

To select an appropriate numerical model for the CERCLA process, issues that were considered included the complexity of site stratigraphy, the required resolution of the model (horizontal and vertical), and the resolution required to evaluate remedial alternatives. Because of the variety of numerical models that could be used to study the JPL site, certain features of the models were used to group them into classes for evaluation. These features included the following criteria:

- Dimensionality (two or three dimensions)
- Finite difference or finite element
- Dynamic or steady state
- Saturated zone or confined flow
- Characteristics of the constituents transported
- Availability in the public domain
- Mass transport compatibility
- Time, money and data availability
- Analytic versus numeric

Selection Criteria

The dimensionality of a model influences its capability to simulate the natural system occurring at a particular site. Based on the known subsurface stratigraphy at JPL, the vertical variation of contaminant concentrations in the groundwater, and the physical hydrogeologic characteristics of the aquifer, it was concluded that a three-dimensional model was preferred for the following reasons:

- Three-dimensional models inherently are more likely to capture the appropriate physical processes, as vertical averaging of contaminant concentrations is not performed.

- A three-dimensional model can potentially be more accurate for evaluating remedial pumping alternatives in terms of selecting both horizontal spacing between wells and elevations of screens for optimal plume capture.

In general, finite-difference models are conceptually simpler and more efficient to operate than a finite-element program. However, finite-element models have the advantage that their grids can be adjusted to fit complex stratigraphy (both horizontally and vertically), and can be configured more efficiently to adapt to areas with high gradients, such as around pumping wells during remediation. Also, finite-difference models can be vertically less accurate than finite-element models.

Most models available for selection could simulate either dynamic or steady state conditions. However, fully dynamic solutions can be very computer intensive and costly. If the water-table conditions are relatively constant, a steady-state solution may provide an adequate description of the groundwater flow. However, if there are distinct water-table variations, such as the variations that occur at JPL, it may be possible to treat each variation as a steady-state event over its duration. Thus, the selected model should be able to simulate both steady state and transient conditions.

At the JPL site, the detected contaminants are in the saturated zone (water-table aquifer). Potential sources are best assessed by assuming vertical migration downward through the unsaturated zone from sources, which is usually sufficient for the needs of groundwater remediation analyses. Therefore, it was concluded that a saturated, unconfined water table program would be adequate to model the groundwater flows beneath the JPL site.

A stated requirement of the model-selection process was that the model selected must be readily available and widely used in the public domain. The model should be available through the agency that developed the model (e.g., the United States Geological Survey (USGS) or EPA), through a clearing house such as the International Groundwater Modeling Center, or readily available through the model developer (e.g., individual, consulting company, or university). Only those models developed in the United States were considered.

Model Comparisons

The aim of the available model review was to select a groundwater-flow program that was in common usage and had a strong history of application that demonstrated sound formulation and flexibility. During the past several years, both the USGS and EPA have published review reports on available groundwater modeling programs.

Approximately 200 different models, including those for saturated and variably-saturated flow programs, were reviewed and discussed in these publications. Because of the large number of programs, only those considered to be "widely used" by "many" under the category of model users, were selected for further comparison.

Following the initial screening, only 15 groundwater flow simulation models remained for further comparison and evaluation. Final selection criteria included the answers to the following six basic questions:

- Is the model readily available in the public domain?
- Is the model widely used by many?
- What is the ease and efficiency of the model (a reflection of the model's cost benefit)?
- Is the model two or three-dimensional?
- Does the flow model have a compatible mass-transport program?
- Can the model be run in both steady state and transient modes?

Answers to these questions for the 15 candidate programs narrowed the selection process to those listed in Table 1-11, in which relative comparisons of availability, usage, documentation, limitations, cost, and other features are tabulated.

Recommended Selection

The review of candidate groundwater-flow models suggested that the following two suites of programs merited further consideration:

- MODFLOW and RAN3D or MT3D
- DYNFLOW and DYNTRACK

MODFLOW is a three-dimensional, finite-difference program that is in the public domain, relatively easy and efficient to use, and in common usage. RAN3D and MT3D are available mass-transport programs that are compatible with MODFLOW. However, RAN3D has been more widely used, and it uses particle tracking to simulate advection and dispersion (an inherently more accurate approach than direct solutions).

DYNFLOW and DYNTRACK are the best selection of three-dimensional, finite-element programs for the study area. However, these proprietary models are currently costly and bound by license restrictions, and are somewhat less efficient to use.

It was recommended and approved by JPL that the MODFLOW program be selected and used in the JPL study for the following reasons:

- MODFLOW is relatively easy to use and is the most widely used program.
- MODFLOW is in the public domain and has a variety of support programs for pre- and post-processing.
- EPA has expressed a preference for non-proprietary models in the public domain.
- MODFLOW is considered to be a "proven" program, whereas DYNFLOW is not in common usage.
- MODFLOW has the features and spatial flexibility to simulate conditions at JPL.

A three-dimensional groundwater flow model has been prepared for the JPL site using MODFLOW. The model was primarily prepared to be used in optimizing various groundwater remedial alternatives and will be discussed in more detail in the FS report for OU-1/OU-3.

1.3.3.14 Ebasco Environmental (1993a). Pre-RI Investigation. Reported in: *Final Work Plan for Performing a Remedial Investigation/Feasibility Study*.

In anticipation of being placed on the NPL by the EPA, a pre-RI investigation was completed at JPL in late 1992 and early 1993 to begin subsurface soil investigations at potential contaminant sources and to obtain additional information on the lateral and vertical extent of VOCs in the groundwater. During this investigation, three additional shallow groundwater monitoring wells and one additional deep multi-port groundwater monitoring well were installed on-site to further characterize the horizontal and vertical extent of contaminants in the groundwater. In addition, a pilot shallow soil vapor survey was completed and five 100-foot soil borings were drilled and sampled. A complete discussion of this investigation is presented in the Final RI/FS Work Plan (Ebasco, 1993a). A discussion of the pre-RI groundwater investigation is summarized below.

The pre-RI groundwater investigation, consisting of installing four additional groundwater monitoring wells, was designed to further define the nature and extent of groundwater contamination beneath JPL. Locations of the four new monitoring wells are presented in Figure 1-14. Monitoring wells MW-8, MW-9, and MW-11 were installed to further assess the areal extent of contamination in the eastern part of JPL, and monitoring well MW-10 was installed in the southwest corner of the site to evaluate the potential for upgradient off-site contaminants contributing to those previously detected. The construction details for the four monitoring wells are summarized on Table 1-12.

The three shallow monitoring wells (MW-8, MW-9, and MW-10) were installed in October, 1992, with 50 feet of stainless steel screen at the bottom of each well to compensate for large fluctuations in water-table elevations previously identified (see Section 1.3.3.12). A dual-wall air percussion drill rig was utilized for drilling and well installation purposes.

MW-11, the deep multi-port monitoring well installed during the pre-RI investigation, was drilled and installed with a mud-rotary drilling rig. After drilling was completed, a suite of wire line geophysical logs including spontaneous potential, electrical resistivity, natural gamma ray, and caliper logs were obtained for use in selecting five zones for well screen placement. The well was constructed with five screened intervals opposite inferred zones of relatively high hydraulic conductivity.

The pre-RI wells (MW-8 through MW-11) were sampled shortly after installation, with the rest of the JPL groundwater monitoring wells, during the eighth groundwater sampling event (Event 8) of the JPL monitoring wells (see Section 1.3.3.15 for results).

The analytical data collected from these four pre-RI monitoring wells were valuable during the development of the JPL RI/FS Work Plan. In addition, data from these wells continue to be valuable in the characterization and monitoring of groundwater conditions at JPL.

1.3.3.15 JPL Groundwater Sampling Program, 1990-1993. Summary of groundwater sampling events completed at JPL prior to the CERCLA RI/FS.

The groundwater beneath JPL has been periodically sampled since the ESI was completed in 1990 and monitoring wells MW-3 through MW-7 were installed (Section 1.3.3.9). The first sampling event, referred to as JPL groundwater sampling "Event 1" was completed as part of the ESI. Subsequent to that first sampling event, and prior to the current CERCLA RI, the groundwater beneath JPL has been sampled 10 times, with the last event, "Event 11", occurring in October, 1993. The overall goal of sampling the JPL monitoring wells was to contribute to the successful characterization of the groundwater quality beneath JPL and the successful completion of the RI and subsequent FS. A summary of the reports prepared presenting the results of each previous groundwater sampling event is presented on Table 1-13, and a summary of the wells sampled, sampling methods used, and the analyses performed during each event is presented on Table 1-14.

Throughout the "pre-RI" groundwater sampling program, the five screens in each of the deep multi-port wells (MW-3, MW-4 and MW-11) (Figure 1-15) were sampled with a Westbay Instruments, Inc. (Westbay) sampling probe. Westbay manufactured the multi-port casing systems installed in each of the deep wells and the equipment required to sample each well. To briefly summarize the deep well sampling procedure, the sampling probe consists of four 250-ml stainless steel tube-shaped containers, linked together with flexible hoses, attached beneath an electrically activated valve opening assembly. The entire apparatus is lowered to a sampling port at the desired screen. The sampling port valve is opened by actuating the sampling probe, allowing groundwater from that port to fill the sample collection tubes. The sampling port is then closed and the sample brought to ground level to be placed in the appropriate sample containers. Throughout sampling of the deep wells, no purging is required before sampling.

The shallow JPL monitoring wells (Figure 1-15) were sampled throughout this period with a stainless steel bailer, Teflon® bailer, or a submersible pump (Table 1-14). Prior to sampling at each well, the well was purged with a submersible pump. The pH, temperature, electrical conductivity, and turbidity (later events primarily) were monitored during purging. Purging continued until the above-mentioned parameters stabilized before samples were collected.

During the course of this groundwater monitoring period, various laboratory analyses were completed (Table 1-14). Analyses for VOCs were performed during all 11 sampling events. Analyses for general water chemistry (major anions and cations) were completed during all events except for the first event, completed in March 1990 during the ESI. Results of water chemistry analyses have been used to produce chemical signatures of the groundwater from the various shallow and deep wells, primarily in hope of gaining a further understanding of

contaminant transport pathways in the aquifer. Analyses for Title 26 metals, strontium, and cyanide were conducted during sampling Events 1, 5, and 8 through 11. Metals were either not detected, or were detected at levels similar to typical natural background levels. Analyses for SVOCs were conducted during Events 1, 5 and 11 as a check for their presence in the groundwater. Throughout the JPL sampling program, other analyses were performed to evaluate whether other constituents were present in the groundwater, including pesticides and PCBs (Events 1 and 5), TPH (Event 1 and in MW-4 during Event 11), gross alpha and gross beta (Event 4), dioxins (Event 5), alcohols and cyclohexanone (Event 8), and hexavalent chromium (Event 11). Data from the first seven (7) sampling events were provided in EPA Contract Laboratory Program (CLP) Level III type formats. Data packages from the last four (4) sampling events included raw data forms, instrument tunes, and calibration records supplying information to satisfy the requirements for EPA CLP Level IV type formats. For a summary of the analyses performed during each event see Table 1-14.

A summary of the VOCs detected during the 11 groundwater sampling events completed at JPL prior to the CERCLA RI is presented on Table 1-15. A review of the results indicate the following generalities for VOCs in the groundwater at JPL:

- Monitoring well MW-7 contained the largest number of VOCs at the highest concentrations relative to all the other wells sampled.
- The predominant VOCs detected on-site included CCl₄, TCE, 1,1-DCE, and 1,2-DCA.

A summary of the Title 26 metals, strontium and cyanide detected during the 11 pre-RI groundwater sampling events at JPL is presented on Table 1-16. A review of the results indicates several metals have been detected in the groundwater beneath JPL but at very low levels. A further evaluation of metals in the groundwater beneath JPL is presented in Section 4.0.

Results of other analyses completed during this monitoring period suggest there are no pesticides or PCBs (Events 1 and 5), no dioxins (Event 5), no alcohols or cyclohexanone (Event 8), and no hexavalent chromium (Event 11) present in the wells sampled. The results of the gross alpha and gross beta analyses (Event 4) and the TPH analyses (Event 1) are presented on Table 1-17. TPH was not detected in well MW-4 during Event 11. The only SVOCs (Events 1, 5 and 11) detected include 17 µg/l bis(2-ethylhexyl)phthalate in screen 2 of well MW-3 (Event 1) and 14 µg/l and 9.9 µg/l of an unknown compound in screen 4 and screen 5, respectively, from well MW-11 (Event 11).

A large amount of water chemistry data has been accumulated from the wells at JPL in an effort to characterize the natural chemistry of the groundwater beneath the site through time. The available water chemistry results from each well for each sampling event were compiled and plotted on Stiff diagrams as a graphical means of illustrating and evaluating the relationships between the general mineral constituents and changes in these relationships over time. The Stiff diagrams are included as Appendix A. The analytical results from the water chemistry analyses performed during each of the 11 groundwater sampling events are presented in the various

reports prepared for each sampling event (Table 1-13). Based on the water chemistry results from the wells present on JPL at this time, the groundwater at JPL was grouped into two basic compositional types. One type (calcium-bicarbonate) was found primarily in the shallow wells (MW-1, MW-5, MW-6, MW-7, MW-8, MW-9 and MW-10), in the upper two screens of multi-port well MW-3 and in the upper three screens of multi-port wells MW-4 and MW-11. The second water type (sodium bicarbonate) was found primarily in the lower three screens of multi-port well MW-3 and in the lower two screens of multi-port wells MW-4 and MW-11. Within these two basic water types some slight variations were observed and evidence suggesting mixing of water types is present. Further discussions on more recent water chemistry data and more recent conclusions are included in Section 3.4.2.

The groundwater sampling program completed at JPL prior to the CERCLA RI (1990-1993) has supplied valuable information on the types and concentrations of various constituents in the groundwater beneath JPL. This data was used to identify requirements for further work for the RI and has been used in contaminate trend analyses along with data collected during the RI (Section 4.0).

1.3.3.16 Ebasco Environmental (1993e and 1994a). *Draft JPL Groundwater Elevation Data Report Number 1, September 1992 through June 1993*; and, *Draft JPL Groundwater Elevation Data Report Number 2, July 1993 through December 1993*.

In September 1992, a groundwater elevation-monitoring program was begun at JPL to better understand the nature of groundwater flow and potential groundwater contaminant transport near the site. The water-level data collected since the program began in September 1992 through June 1993, and between July 1993 and December 1993 were compiled in separate draft reports (Ebasco, 1993e and Ebasco, 1994a). This program consisted of collecting water levels daily from all the shallow monitoring wells on-site and the City of Pasadena monitoring well MH-01 with an automated water-level measurement system. Each automated water level measurement system consisted of a pressure transducer, which measured pressures of water above the transducer relative to atmospheric pressure, and a data logger, which was connected to the pressure transducer with a vented cable and recorded the water pressure at a pre-set time interval. The systems used at JPL were manufactured by Instrumentation Northwest and included a battery powered Aquistar DL-1 data logger and a Model PS9000 30 psi pressure transducer.

In September 1992, the automated water level measurement systems were installed in existing wells MW-1, MW-5, MW-6, MW-7 and MH-01. JPL wells MW-8, MW-9 and MW-10 received water level measurement systems after they were installed in February 1993. Beginning in September 1992, water-level data were recorded every 30 minutes from each well to monitor fluctuations in the water table due to pumping of the nearby City of Pasadena production wells. Beginning in June 1993, following an initial evaluation of the water level data, all the data loggers, except the one in MH-01, was reset to record water-level measurements every 6 hours. In September 1993, the data logger in well MH-01 was reset to record water-level data every hour to monitor the activity of the nearby City of Pasadena production wells. Throughout the

water-level monitoring program data recorded in the data loggers were retrieved approximately every four weeks by uploading the data to a lap top computer. During data retrieval, each data-logger battery was replaced with a fully charged battery and the condition of the water-level measurement system inspected. In addition, several quality assurance/quality control (QA/QC) checks were made in the field to ensure that the water-level measurements were accurate and that the instrumentation was functioning properly.

Although precaution was taken to prevent problems associated with data acquisition, data gaps did occur during the water-level monitoring program. The most prevalent problem plaguing data collection (especially well MW-6) was attributed to water getting into the data logger and vented transducer cable during the rainy season that resulted in inaccurate readings. Other occasional problems resulting in data gaps included data logger-to-transducer linkage problems, battery failure, and software problems. Throughout the water-level monitoring program, however, a very large amount of usable water level data was collected.

The water-level data from the shallow JPL wells collected since the program began in September 1992 through December 1993 have been compiled and summarized on hydrographs. In addition, bar graphs representing precipitation and spreading ground data have been compiled. The water-level data, precipitation data and spreading ground data for all wells, except wells MW-1 and MW-9, are summarized on Figure 1-16, and the data for wells MW-1 and MW-9 are summarized on Figure 1-17.

Review of the water-level hydrographs indicate the following general observations about water level fluctuation at JPL between September 1992 and December 1993:

- Between December 1992 and February 1993, water levels greatly increased because of heavy precipitation during these months (Figure 1-16).
- In early May 1993, water levels dropped relative to the highs recorded between February and March 1993, especially in well MH-01. This was due to the start of pumping of the City of Pasadena municipal wells. Well MH-01, being the closest well to the City of Pasadena wells, was affected the most (Figure 1-16).
- Wells MW-1 and MW-9 exhibited relatively higher, and relatively constant, water-level elevations compared to the other wells at JPL and did not exhibit any immediate noticeable response to local groundwater pumping.
- Wells MW-1 and MW-9 exhibited identical increases in water levels during mid-March and again in late April 1993 (Figure 1-17). This was interpreted to be the result of repairing a small dam located near wells MW-1 and MW-9 that was breached during heavy winter rains. Before the dam was breached, it allowed water to pond near the wells. The sudden decline in water elevations during late March 1993 in these wells was interpreted as being related to the dam being washed out.

- As City of Pasadena wells were pumped for longer periods of time during the months of May and June 1993, water levels showed recovery as an upward “spike” (especially in well MH-01) when one or more of the pumps were turned off for short periods of time (Figure 1-16).
- The end of pumping at the City of Pasadena municipal wells was exhibited with a sudden increase in water levels in the JPL wells, especially well MH-01, when the pumps were turned off on July 1, 1993 (Figure 1-16).
- Water levels rose during November and December 1993 in response to recharge from small amounts of rainfall in November 1993 (Figure 1-16).

1.3.3.17 Foster Wheeler (1996). *Report on the Preliminary Evaluation of Groundwater Data Collected at JPL Prior to the CERCLA RI/FS.*

This report presents a summary of groundwater data collected at the JPL site prior to the CERCLA RI/FS. The report includes an evaluation of groundwater level and groundwater quality data to identify correlations and trends in the data collected at the JPL site, starting with the Expanded Site Inspection in 1990 and ending with the data collected in November 1994. Groundwater quality data evaluated included data from sampling Events 1 (March 1990) through 11 (November 1994), plus data from two OU-1 sampling events completed in 1994 (referred to as Events 12 and 13). Groundwater samples were collected from monitoring wells MW-1 to MW-16. Five of these wells are deep multi-port wells, while the remaining are shallow standpipe wells. Groundwater analyses included VOCs during all sampling events and general mineral analysis for sampling Events 2 through 13. In addition, analysis for Title 26 metals, strontium, and cyanide were conducted for sampling Events 1, 5, and 8 through 13. SVOCs were also analyzed during sampling events 1, 5, 11, 12, and 13.

Water-level data collected since September 1992 was also evaluated. Daily water levels were collected from all shallow JPL monitoring wells and the City of Pasadena monitoring well MH-01. These wells are equipped with automated water level measurement systems.

The report concluded that since 1992, three VOCs (CCl₄, TCE, and 1,2-DCA) have been consistently detected in the groundwater at levels which exceed their respective MCL. The highest concentration of CCl₄ was 320 µg/l found in well MW-7 in September 1992. In general, monitoring well MW-7 contained the highest concentrations of VOCs relative to the other wells at JPL. The highest level of TCE was 90 µg/l in well MW-5 in December 1990. 1,2-DCA was found in highest concentration (8.9 µg/l) in well MW-13 in June 1994.

The water level data has shown that a pronounced groundwater mound is present at the mouth of the Arroyo Seco. This groundwater mound results in a reversal in groundwater flow direction (towards the west) near the eastern part of the site. Water level elevations at the JPL site have fluctuated up to 90 feet during the monitoring period. In contrast, the water levels have varied only as much as 25 feet near the groundwater mound area. The largest fluctuation in piezometric

water levels has been observed in the deep multi-port well screens located below the water table. There does not appear to be consistent correlations between water levels and VOC concentrations.

General mineral analyses suggested that three basic types of groundwater exist at JPL. A calcium-bicarbonate type water is found in the relatively shallow groundwater located in the center and along the eastern end of the JPL site. A sodium-bicarbonate type water is found primarily in the relatively deep groundwater beneath the site. And a third type of water, a calcium-bicarbonate/chloride/sulfate type, is found in relatively shallow groundwater along the western end of the site.

1.3.3.18 Multimedia Environmental Technology (1996). *Development and Calibration of the Two-Dimensional Groundwater Flow Model of the Jet Propulsion Laboratory, Pasadena, California.*

This report described the development and calibration of a preliminary, two-dimensional groundwater flow model of the JPL site. The USGS groundwater flow model, MODFLOW, was used in this study. The objective of developing a calibrated groundwater flow model was to assist in understanding the past and future potential contaminant migration pathways. Hydrogeologic data collected from previous JPL investigations and other basin-wide studies were utilized as input parameters in the development of the preliminary conceptual model. The preliminary JPL flow model encompassed a relatively large area of the northwestern portion of the Raymond Basin.

The groundwater model consisted of a grid of 96 by 101 cells (nodes). The model was established with boundary conditions and recharge areas. A single isotropic layer was used in the initial groundwater model analyses. Both pumping and recharge stresses were applied in the model. A transient period of calibration was established and was divided into 26 monthly stress periods.

Every grid cell was assigned initial values for hydraulic conductivity and storage based on the Raymond Basin study by CH₂M Hill (1990). The hydraulic conductivity values were then refined based on the aquifer test results in JPL monitoring wells. Finally, both the hydraulic conductivity and storage coefficients were calibrated to allow for simulation of target water levels in JPL monitoring wells MH-01 and MW-5, which showed distinct responses to pumping in the nearby Pasadena well field. A 26-month calibration period from August 1992 to September 1994 was selected for calibration of the potentiometric data. Results of the calibration runs of the MODFLOW model provided a good prediction tool of the recent potentiometric-level fluctuations in the shallow monitoring wells. All water levels were simulated within 15 feet of the observed values. Considering that the water levels fluctuated over 100 feet during the calibration period, this represents a good fit of the data. The two-dimensional model was used to establish boundary conditions for a more focused three-dimensional model of the JPL site (see Section 1.3.3.19).

1.3.3.19 Multimedia Environmental Technology (1997). *Development and Calibration of the 3-D Groundwater Flow Model of Jet Propulsion Laboratory, Pasadena, California*

Multimedia Environmental Technology, Inc. prepared this report to describe the development and calibration of a three-dimensional (3-D) groundwater flow model of the JPL site. The JPL flow model encompasses the northwestern portion of the much larger Raymond Basin. The 3-D finite-difference groundwater flow code, MODFLOW (USGS, 1984) was used for this groundwater modeling effort. The objective of the modeling study was to more completely understand the JPL groundwater flow system, especially the area near the eastern border where groundwater mounding occurs.

The 3-D model setup consisted of 96 by 101 grid cells (nodes), six aquifer layers, and five "aquitard" layers. It is important to note that the aquifer layers in the model were chosen for modeling purposes only, and do not directly correlate to the four layers delineated later in this report for data presentation purposes (see Section 3.0). Model input included piezometric levels and hydraulic test data from the JPL multi-port wells to provide estimates of the vertical hydraulic conductivity that may exist in the JPL aquifer system. The same nodal points utilized previously in the 2-D groundwater model were used for this 3-D model simulation.

A quasi-steady state period of February to December 1996 was selected for the initial calibration time period. The beginning time of February 1996 was chosen because all pumping wells had stopped and piezometric levels had recovered to approximately the same level in each well. Once the initial conditions were established, the hydraulic parameters were adjusted to match the piezometric levels in the monitoring wells. Next, calibration of 16 stress periods corresponding to the 16 months of August 1995 to December 1996 was performed. A correlation between recharge and precipitation was developed from the 2-D model period and translated into the 3-D calibration period.

The results of the final calibration showed that water levels in the shallow groundwater monitoring wells were simulated reasonably well. Most of the simulated piezometric levels in the shallow monitoring wells were within 10 feet of the observed levels. The simulated water levels in shallow wells MW-1, MW-9, MW-15 were particularly of interest because the levels in these wells could not be calibrated using the previous 2-D groundwater model. A lag time of about one month was noted between the simulated and observed piezometric levels in the monitoring wells located on the western side of the JPL site. This was due to the relatively high storage coefficient assigned to model aquifer layer 1. This lag time can be fine tuned using variable storage coefficients for all layers.

The final calibration results for the deep multi-port wells showed piezometric levels within 10 feet of observed levels. The coefficient of correlation from regression analysis of the observed versus the simulated piezometric levels was over 0.80 for most of the wells. Results confirm the existence of a layered aquifer system to the east and southeast of the JPL site, with a relatively uniform aquifer to the west of the site. Groundwater mounding at the mouth of Arroyo Seco

appears to be the result of a shallow aquitard in model layer 1. The vertical velocity components in the JPL aquifer system were small compared to the horizontal components.

1.3.3.20 Multimedia Environmental Technology (1998). *Calibration and Refinement of the 3-D Groundwater Flow Model of Jet Propulsion Laboratory, Pasadena, California*

This report summarizes refinements that were made to the JPL 3-D groundwater flow model. Sensitivity analysis and parameter estimation was performed using MODFLOWP (Hill, 1993). After two unsuccessful calibration attempts using MODFLOWP, refinement of the calibration was performed with MODFLOW using conventional trial and error methods. The refined 3-D model provided much better prediction of piezometric-level fluctuations in wells MW-1, MW-9, and MW-15. The model confirmed the existence of a layered aquifer system to the east and southeast of JPL and a relatively uniform aquifer to the west of the site. Horizontal flow components in the groundwater model were determined to be much more significant than vertical flow components.

Simulation of an extreme wet period (an El Niño type winter) and an extreme dry (draught) period were simulated using the 3-D groundwater flow model. These two scenarios were selected to evaluate groundwater conditions during reasonably expected climatological extremes. For the draught simulation, normal recharge was reduced by 66 percent and pumping was increased by 20 percent. As expected, dramatic drops in water levels were simulated during the draught period. For the wet period, the recharge rate was increased by 70 percent and pumping demand was reduced by 40 percent. As expected, dramatic increases in water levels were simulated in all groundwater layers during the wet period. The direction of groundwater flow varied widely in these cases and was generally dependent upon recharge in the mouth of Arroyo Seco and pumping in the Pasadena wells.

The report concluded that in order to make future long-term predictions in water levels, accurate estimates of future recharge and pumping rates are required.

TABLE 1-1

SUMMARY OF CCl₄, TCE, AND PCE CONCENTRATIONS IN
GROUNDWATER FROM CITY OF PASADENA
MONITORING WELL MH-01*, 1982
(Geotechnical Consultants, Inc., 1982)

Sampling Date	Sampling Depth (feet)	Carbon Tetrachloride (µg/l)	Trichloroethene (µg/l)	Tetrachloroethene (µg/l)
12-16-82 (collected with submersible pump)	359	22.0	36.0	1.8
	359	14.0	38.0	1.9
12-17-82 (collected with submersible pump)	212	0.8	2.9	0.4
	212	1.3	4.7	0.5
12-21-82 (collected with submersible pump)	191	1.2	4.4	0.5
	233	1.6	7.7	0.6
	264	7.5	37.0	2.0
	306	17.0	59.0	2.3
	192	1.4	5.2	0.6
	234	2.2	7.6	0.8
	265	7.5	34.0	2.2
	307	12.0	42.0	1.9
12-23-82 (collected with syringe)	182	ND	ND	0.1
	192	ND	ND	0.1
	218	ND	0.3	0.2
	234	0.6	2.2	0.4
	265	7.9	35.0	2.2
	288	16.0	50.0	2.5
	307	16.0	49.0	2.5
	352	14.0	44.0	2.1
California MCL		0.5	5.0	5.0
EPA MCL		5.0	5.0	5.0

µg/l: Micrograms per liter.

ND: Not detected at minimum detection limit of 0.1 µg/l.

MCL: Maximum Contaminant Level.

*: Monitoring well MH-01 is screened across several intervals. Results may represent low estimates due to potential dilution.

TABLE 1-2

**SUMMARY OF ANALYTICAL RESULTS FOR INORGANIC
COMPOUNDS DETECTED IN MONITORING WELL MH-01, 1984
(R.C. Slade, 1984)***

Sample Depth Below Grade (feet)	Metals (Concentrations in mg/l)												Other Constituents (Concentrations in mg/l)		
	Ag	As	Be	Cd	Cr (Total)	Cu	Hg	Ni	Pb	Sb	Se	Tl	Zn	Fluoride	Cyanide
155	ND	ND	ND	0.004	ND	0.008	0.0013	ND	0.014	ND	ND	ND	ND	0.53	ND
182	ND	ND	ND	0.004	ND	ND	0.0022	ND	0.017	ND	ND	ND	ND	0.55	ND
192	ND	ND	ND	ND	ND	ND	ND	ND	0.019	ND	ND	ND	ND	0.5	ND
218	ND	ND	ND	0.004	ND	ND	0.0004	ND	0.021	ND	ND	ND	ND	0.54	ND
234	ND	ND	ND	0.005	ND	ND	ND	ND	ND	0.002	ND	ND	0.007	13.0	ND
265	ND	ND	ND	0.006	ND	ND	0.0005	ND	ND	ND	ND	ND	ND	14.0	ND
288	ND	ND	ND	0.004	ND	ND	0.0012	ND	0.002	ND	ND	ND	0.01	0.79	ND
307	ND	ND	ND	0.003	ND	ND	ND	ND	0.002	ND	ND	ND	ND	0.58	ND
352	ND	ND	ND	0.006	ND	0.011	0.0006	ND	0.005	0.003	ND	ND	ND	0.66	ND
California MCL ¹	0.05	0.05	---	0.01	0.05	1.3 ²	0.002	---	0.05	---	0.01	---	---	1.4 to 2.4 ³	---
Federal MCL	0.10	0.05	0.004	0.005	0.10	1.0	0.002	0.10	---	0.006	0.05	0.002	5.0	4.0	0.2
Detection Limit	0.005	0.001	0.004	0.003	0.029	0.007	0.0002	0.008	0.002	0.002	0.001	0.005	0.007	Not Reported	0.005

mg/l: milligrams per liter.

ND: Not detected.

1: MCL: Maximum Contaminant Level.

2: Action Level.

3: Temperature dependant.

*The results presented here are from groundwater samples collected using methods not normally used in contaminant evaluations.

TABLE 1-3

**SUMMARY OF ANALYTICAL RESULTS
FOR ORGANIC COMPOUNDS DETECTED IN
MONITORING WELL MH-01, 1984
(R. C. Slade, 1984)***

Sample Depth (feet)	Hexane (µg/l)	Trichloroethene (µg/l)	1,1,1-Trichloroethane (µg/l)	Tetrachloroethene (µg/l)	Carbon Tetrachloride (µg/l)
155	ND	ND	ND	0.7	ND
182	ND	ND	ND	0.3	ND
192	ND	ND	ND	0.6	ND
218	ND	ND	ND	0.3	ND
234	ND	ND	ND	0.3	ND
265	ND	1.3	ND	0.3	0.2
288	ND	3.5	ND	0.4	1.1
307	ND	2.9	ND	0.2	0.8
352	ND	7.5	ND	0.3	2.4
California MCL		5.0	200.0	5.0	0.5
Federal MCL		5.0	200.0	5.0	5.0

µg/l: Micrograms per liter.

ND: Not detected at minimum detection limit of 0.1 µg/l.

MCL: Maximum Contaminant Level.

* The results presented here represent samples collected using methods not normally used in contaminant evaluations.

TABLE 1-4

SUMMARY OF ANALYTICAL RESULTS
 FROM MONITORING WELLS MW-1 AND MH-01, 1989
 (Geotechnical Consultants, 1989)

Parameter	Well MW-1	Well MH-01	EPA Method
Semi-volatile Organic Compounds	None Detected	None Detected	625
Total Petroleum Hydrocarbons	None Detected	None Detected	418.1
<u>Metals, Total (mg/l)</u>			
Arsenic	<0.005	<0.005	SM 307A
Lead	<0.05	<0.05	239.1
Mercury	<0.001	<0.001	245.1
Selenium	<0.005	<0.005	SM 323A
Silver	<0.015	0.049	272.1
<u>Metals, Dissolved (mg/l)</u>			
Arsenic	<0.005	<0.005	SM 307A
Lead	<0.05	<0.05	239.1
Mercury	<0.001	<0.001	245.1
Selenium	<0.005	<0.005	SM 323A
Silver	<0.015	<0.015	272.1
pH	7.6	7.6	150.1
Total Dissolved Solids (mg/l)	344	305	160.1
Specific Conductance (µmhos/cm)	518	435	NR

mg/l: milligrams per liter.

µmhos/cm: micromhos per centimeter.

NR: not reported.

TABLE 1-5

SUMMARY OF CONSTRUCTION DETAILS FOR MONITORING WELLS INSTALLED
AT JPL DURING THE EXPANDED SITE INSPECTION
(Ebasco, 1990a)

Well Number	Location	Drilling Method	Total Drilled Depth (feet)	Depth to Bottom of Casing (feet)	Hole Diameter (inches)	Surface Conductor	Elevation Top of 4-inch Casing (feet above mean sea level)	Elevation of Screen Interval (feet above mean sea level)	Multi-port Well Screen Number
MW-3 (Deep Multi-port)	Arroyo Seco	Mud Rotary	730	700	9 $\frac{7}{8}$	22 feet; 10"-dia.	1099.82	919.82-929.82	1
								839.82-849.82	2
								745.82-755.82	3
								534.82-544.82	4
								433.82-443.82	5
MW-4 (Deep Multi-port)	JPL South Parking Lot	Mud Rotary	605	559	12 $\frac{1}{4}$	18 $\frac{1}{2}$ feet; 16"-dia.	1082.72	925.72-935.72	1
								835.72-845.72	2
								754.72-764.72	3
								683.72-693.72	4
								563.72-573.72	5
MW-5 (Shallow Standpipe)	JPL South Parking Lot	Air Percussion	145	140	11	None	1071.60	936.60-986.60	---
MW-6 (Shallow Standpipe)	JPL West Parking Lot	Air Percussion	247	245	11	None	1188.52	943.52-993.52	---
MW-7 (Shallow Standpipe)	JPL Parking Lot Near Buildings 288 and 290	Air Percussion	276	275	11	None	1212.88	937.88-987.88	---

TABLE 1-6

**SUMMARY OF VOLATILE AND SEMI-VOLATILE ORGANIC COMPOUNDS
IN GROUNDWATER, EXPANDED SITE INSPECTION, JPL, 1990
(Ebasco, 1990a)**

Well No. Screen No.	Sample Location (concentrations in µg/l) (only detects included)							Fire Hydrant Water Used at MW-4 and MW-5	Fire Hydrant Water Used at MW-6	California MCLs ^a	Federal MCLs
	MW-3 1	MW-3 1 Dup ^b	MW-3 2	MW-5 Dup	MW-5 Dup	MW-6	MW-7				
Volatile Organic Compounds											
Carbon Tetrachloride	--	--	--	--	--	--	200	--	--	0.5	5.0
Tetrachloroethene	--	--	--	--	--	--	15	--	--	5.0	5.0
Trichloroethene	--	--	--	13	13	--	22	--	--	5.0	5.0
1,1-Dichloroethene	--	--	--	--	--	--	8	--	--	6.0	7.0
Chloroform	7	8	6	--	--	24	23	34	36	c	c
Bromodichloromethane	--	--	--	--	--	6	<5	16	16	c	c
Dibromochloromethane	--	--	--	--	--	--	<5	13	13	c	c
Bromoform	--	--	--	--	--	--	--	<5	<5	c	c
Semi-volatile Organic Compounds											
Bis(2-ethylhexyl) phthalate	--	--	17 ^(B)	--	--	--	--	--	--	NR	NR

a: Maximum Contaminant Level.

b: Duplicate.

c: Total trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform) MCL is 100 µg/l.

--: Not detected.

NR: Not regulated.

(B): Compound also present in laboratory blank.

TABLE 1-7

SUMMARY OF METALS AND TOTAL PETROLEUM HYDROCARBONS
IN GROUNDWATER, EXPANDED SITE INSPECTION, 1990
(Ebasco, 1990a)

Well No.:	Sample Location (concentrations in mg/l) (only detects included)															California MCL ^a	Federal MCL
	MW-3	MW-3	MW-3	MW-3	MW-3	MW-3	MW-4	MW-4	MW-4	MW-4	MW-4	MW-4	MW-4	MW-5	MW-6		
Screen No.:	1	1 Dup ^b	2	3	4	5	1	1 Dup ^b	2	3	4	5					
Antimony	--	--	--	--	--	--	--	--	--	--	--	--	--	0.008	--	NR	0.006
Barium	0.04	0.04	0.03	0.02	0.04	0.02	0.05	0.05	--	0.03	0.02	0.04	0.05	0.02	0.03	1.0	2.0
Chromium (total)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.02	0.05	0.1
Cobalt	--	--	--	--	--	0.01	--	--	--	--	--	--	--	--	--	NR	NR
Copper	--	--	--	--	--	--	--	--	--	--	--	--	0.02	--	0.02	1.3 ^c	1.0
Lead	--	--	--	--	--	--	--	--	--	--	--	--	0.0045	--	--	0.05	1.3 ^c
Molybdenum	--	--	--	0.02	0.02	0.04	--	--	--	--	0.01	0.02	--	--	--	NR	NR
Nickel	0.10	--	--	--	--	--	--	--	0.01	--	--	--	0.02	--	--	NR	0.1
Zinc	--	0.10	0.03	0.02	0.06	0.20	0.06	0.03	0.04	0.11	0.02	0.01	0.23	0.13	0.25	NR	5.0
Strontium	0.53	0.60	0.43	0.21	0.43	0.18	0.42	0.45	0.54	0.27	0.30	0.40	0.50	0.66	0.32	NR	NR
Total Petroleum Hydrocarbons	--	--	--	--	0.5	0.4	--	--	--	--	--	0.5	0.5	2.0	1.1	NR	NR

--: Not detected.

NR: Not regulated.

a: Maximum Contaminant Level.

b: Duplicate

c: Action Level

TABLE 1-8

**VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES
COLLECTED DURING THE JUNE 1990 SAMPLING OF JPL MONITORING WELLS (EVENT 2) (EBASCO, 1990b)**

(Concentrations reported in µg/l)

Well Number		Toluene	Total Xylenes	Carbon Tetrachloride	1,1-Dichloroethene (1,1-DCE)	Trichloroethene (TCE)	Tetrachloroethene (PCE)
MW-3 Screen 1 (top)	44	--	--	--	--	--	--
MW-3 Screen 2	6	--	--	--	--	--	--
MW-3 Screen 3	--	--	--	--	--	--	--
MW-3 Screen 4	--	--	--	--	--	--	--
MW-3 Screen 5	--	--	--	--	--	--	--
MW-4 Screen 1 (top)	--	--	--	--	--	--	--
MW-4 Screen 2	--	--	--	--	--	--	--
MW-4 Screen 3	--	--	--	--	--	--	--
MW-4 Screen 4	--	--	--	--	--	--	--
MW-4 Screen 5	--	--	--	--	--	--	--
MW-5	--	6	11	--	--	--	--
MW-6	--	6	--	--	--	--	--
MW-7	19	5	--	200	6	27	9
California MCL ^a	100 ^b	100 ^c	1,750	0.5	6.0	5.0	5.0
Federal MCL	100 ^b	1,000	10,000	5.0	7.0	5.0	5.0

-- Not detected.

a: Maximum Contaminant Level.

b: Total trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform).

c: Action level.

TABLE 1-9

**ANALYTICAL RESULTS FROM SURFACE SEDIMENT
SAMPLES COLLECTED IN THE ARROYO SECO (EBASCO, 1990b)**

Sample Locations Shown in Figure 1-11

Constituent	Units	Sample Number					California Regulatory Limits	
		SD-01	SD-01D	SD-02	SD-03	SD-04	TTL ¹ (mg/kg)	STLC ² (mg/l)
Metals								
Barium	mg/kg	23	22	41	75	75	10,000	100
Beryllium	mg/kg	ND	ND	ND	ND	0.56	75	0.75
Cadmium	mg/kg	0.5	ND	0.76	1.2	1.2	100	1
Chromium (total)	mg/kg	2.8	2.8	4.6	8.0	8.4	2,500	560
Cobalt	mg/kg	2.6	2.5	3.9	7.2	7.3	8,000	80
Copper	mg/kg	5.3	5.3	13	18	16	2,500	25
Lead	mg/kg	16	5.5	15	36	26	1,000	5
Mercury	mg/kg	ND	ND	ND	0.13	0.12	20	0.2
Nickel	mg/kg	1.2	ND	3.4	4.5	4.3	2,000	20
Vanadium	mg/kg	6.3	5.6	9.6	18	19	2,400	24
Zinc	mg/kg	18	16	37	69	48	5,000	250
Strontium	mg/kg	20	21	21	61	56	NR	NR
Cyanide	mg/kg	ND	ND	ND	ND	0.4	NR	NR
Total Petroleum Hydrocarbons	mg/kg	ND	14	71	56	19	NR	NR

1: TTL¹ - Total Threshold Limit Concentrations, California Code of Regulations, Title 22.

2: STLC² - Soluble Threshold Limit Concentration, California Code of Regulations, Title 22.

mg/kg: milligrams per kilogram.

mg/l: Milligrams per liter.

ND: Not detected.

NR: Not regulated.

TABLE 1-10

**SUMMARY OF DETECTED CHEMICAL COMPOUNDS IN SEDIMENT
FROM STORM DRAIN CATCH BASIN**

(Jet Propulsion Laboratory, 1990)

Analysis	Concentration (mg/kg)	EPA Method
Volatile Organic Compounds:		8240
Acetone	335	
Methylene Chloride	834	
Carbon Disulfide	27	
1,1-Dichloroethane	51	
2-Butanone (MEK)	113	
cis-1,2-Dichlorethene	66	
Chloroform	720	
1,2-Dichloroethane	28	
Carbon Tetrachloride (CCL ₄)	13,400 (est)	
Trichloroethene (TCE)	55	
Toluene	27	
Tetrachloroethene (PCE)	23	
Chlorobenzene	28	
Total Xylenes	76	
Styrene	34	
Semi-Volatile Organic Compounds:		8270
1,4-Dichlorobenzene	9.9	
1,2-Dichlorobenzene	4.6	
Napthalene	5.1	
Di-n-butylphtalate	9.2	
Metals:		
Arsenic	1.8	7061
Cadium	7.3	6010
Chromium (total)	124	6010
Copper	251	6010
Lead	125	6010
Mercury	34	7470
Nickel	724	6010
Zinc	636	8010
Cyanide	0.54	8010
Total Petroleum Hydrocarbons	4,640	8015
Pesticides and PCBs	None Detected	8080

TABLE 1-11

COMPARISON OF GROUNDWATER MODEL PROGRAM FEATURES

(Ebasco, 1992a)

Code Name	Source	Cost	Type and Numerics	Public Availability	Documentation	Previous Use Acceptance	Compatibility	Limitations
MODFLOW	USGS	\$0-\$395	Flow Direct solution	Yes	Good	Many	Good	Few
MT3D	Papadopolus & Assoc.	Low	Mass Direct solution	Yes	Good	Limited	Good	Technically few
RAN3D	Prickett; Engineering Technology, Inc.	Low	Mass Particle tracking	Yes	Good	Moderate	Good	Few
PLASM	Prickett	Low	Flow Direct solution	Yes	Good	Many	Good	Two dimensional program
PLASM3D	Prickett	Low	Flow Direct solution	Yes	Limited	Few	Good	Limited use
DYNEFLOW	Camp Dresser & McKee	(1)	Flow Direct solution	Yes	Good	Moderate(2)	Good	Few
DYNTRACK	Camp Dresser & McKee	(1)	Mass Particle tracking	Yes	Good	Moderate(2)	Good	Few
CFEST	Battelle PNL	Moderate	Flow and Mass Direct solution	Yes	Good	Moderate	Good	Overly complex, needs large computer

TABLE 1-11
COMPARISON OF GROUNDWATER MODEL PROGRAM FEATURES
(Ebasco, 1992a)
(Continued)

Code Name	Parameters	Graphical Output	Output Format	Computer Requirements	Cost per Unit Run	Comments
MODFLOW	Transmissivity Leakances	MODPLOT	Tabular	386	Small	The most widely used flow program
MT3D	Dispersivity Decay rate Retardation Porosity	Yes	Tabular	386	Small	Limited use so far
RAN3D	Dispersivity Decay rate Retardation Porosity	Yes	Tabular	386	Small	Best proven mass transport model for MODFLOW
PLASM	Transmissivity	Yes	Tabular	386	Small	2-D program but widely used
PLASM3D	Transmissivity Leakances	Yes	Tabular	386	Small	Limited use, Prickett uses MODFLOW
DYNEFLOW	Conductivities	DYNPLOT ⁽³⁾	Postprocessor Tabular	386 VAX SUN	Moderate	Relatively easy to use for finite-element program
DYNTRACK	Dispersivity Decay rate Retardation Porosity	DYNPLOT ⁽³⁾	Postprocessor Tabular	386 VAX SUN	Moderate	Relatively easy to use for finite-element program
CFEST	Conductivities Dispersivity Decay rate Retardation Porosity	Yes	Tabular	CRAY Other large machine	High	Overly complex, needs large computer

1: Currently on sale for about \$5000/program.

2: Limited to Camp, Dresser & McKee and some universities.

3: DYNPLOT can be purchased for about \$5000.

TABLE 1-12

CONSTRUCTION DETAILS FOR THE MONITORING WELLS
INSTALLED DURING THE PRE-RI INVESTIGATION

(Ebasco, 1993a)

Monitoring Well	Date Drilled	Drilling Method	Total Depth (feet)	Monitoring Well Diameter (inches)	Screened Interval (feet below ground surface)	Screen Slot Size (inches)	Well Material		Elevation of 4-inch Casing (feet above mean sea level)	Centralizers	Geophysical Survey
							Casing	Screen			
MW-8	Oct. 1992	Air Percussion Hammer	205	4	155-205	0.010	Stainless Steel	Stainless Steel	1139.53	No	Natural Gamma
MW-9	Oct. 1992	Air Percussion Hammer	68	4	18-68	0.010	Sch 40 PVC	Stainless Steel	1106.02	No	Natural Gamma
MW-10	Oct. 1992	Air Percussion Hammer	155	4	105-155	0.010	PVC (0-85') Stainless Steel (85'-105')	Stainless Steel	1087.71	No	Natural Gamma
MW-11	Nov. 1992	Mud Rotary	680	4	1. 140-150 2. 250-260 3. 420-430 4. 515-525 5. 630-640	0.010	Carbon steel	Stainless Steel	1139.35	Yes	Spontaneous Potential Short Normal Resistivity Long Normal Resistivity Single Point Resistivity Natural Gamma Caliper

TABLE 1-13

**SUMMARY OF JPL GROUNDWATER SAMPLING EVENTS
COMPLETED PRIOR TO THE JPL CERCLA RI/FS, 1990-1993**

Sampling Event "Title of Report"	Month Sampling Event Began	Analytical Laboratory
Number 1 "Expanded Site Inspection Report" (Ebasco, 1990a)	March, 1990	Curtis and Tompkins
Number 2 "Groundwater Monitoring Well Resampling, Water Level Measurements and Well Surveying" (Ebasco, 1990d)	June, 1990	Curtis and Tompkins
Number 3 "Analytical Results of Groundwater Samples Collected in December, 1990 from Monitoring Wells at JPL (Ebasco, 1991a)	December, 1990	Curtis and Tompkins
Number 4 "JPL Groundwater Monitoring Report Number 4" (Ebasco, 1991b)	June, 1991	Curtis and Tompkins (Core Laboratories used for water chemistry analyses)
Number 5 "JPL Groundwater Monitoring Report Number 5" (Ebasco, 1992b)	October, 1991	Curtis and Tompkins (Montgomery Laboratories used for water chemistry)
Number 6 "JPL Groundwater Monitoring Report Number 6" (Ebasco, 1992c)	April, 1992	Montgomery Laboratories
Number 7 "JPL Groundwater Monitoring Report Number 7" (Ebasco, 1992d)	September, 1992	Montgomery Laboratories
Number 8 "JPL Groundwater Monitoring Report Number 8" (Ebasco, 1993b)	December, 1992	Montgomery Laboratories
Number 9 "JPL Groundwater Monitoring Report Number 9" (Ebasco, 1993c)	March, 1993	Montgomery Laboratories
Number 10 "JPL Groundwater Monitoring Report Number 10" (Ebasco, 1993d)	July, 1993	Montgomery Laboratories
Number 11 Untitled set of notes and analytical data	October, 1993	Montgomery Laboratories

TABLE 1-14

SUMMARY OF ANALYSES AND SAMPLING METHODS FOR JPL GROUNDWATER
 SAMPLING EVENTS COMPLETED PRIOR TO THE JPL CERCLA RI/FS, 1990-1993

Well No	Well Type	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10	Event 11
		March 1990	June 1990	December 1990	June 1991	October 1991	April 1992	September 1992	December 1992	March 1993	July 1993	October 1993
		VOCs (624) Semi-VOCs (625) Title 26 Metals + Sr TPH (418.1) Pest + PCB's (608) Cyanide (9010)	VOCs (624) Water Chemistry ⁽¹⁾	VOCs (624) Water Chemistry ⁽²⁾	VOCs (524.2) Water Chemistry Gross Alpha/Beta	VOCs (524.2) Water Chemistry Title 26 Metals Select Samples for: ⁽²⁾ Semi-VOCs (8270) Pest + PCBs (8080) Cyanide (335.5) Dioxins (8280) ⁽³⁾	VOCs (524.2) Water Chemistry	VOCs (524.2) Water Chemistry	VOCs (524.2) Water Chemistry Title 26 Metals + Sr Cyanide (335.3) Alcohols Cyclohexanone	VOCs (524.2) Water Chemistry Title 26 Metals + Sr Cyanide (335.3)	VOCs (524.2) Water Chemistry Title 26 Metals + Sr Cyanide (335.3)	VOCs (524.2) Water Chemistry ⁽⁴⁾ Title 26 Metals+Sr ⁽⁴⁾ Cyanide (335.3) Semi-VOCs (8270) Hexavalent Cr. ⁽⁴⁾ TPH (MW-4 only)
MW-1	Shallow standpipe	--	--	--	Pump	Pump	Pump	Pump	-- (road washed out)	Pump	Pump	Pump
MW-2	Shallow standpipe	--	--	--	-- ⁽⁶⁾	-- ⁽⁶⁾	-- ⁽⁶⁾	-- ⁽⁶⁾	-- ⁽⁶⁾	Bailer	Bailer	-- ⁽⁶⁾
MW-3	Deep Multi-port	Westbay Sampler (Dup. Screen 1)	Westbay Sampler	Westbay Sampler (Dup. Screen 3)	Westbay Sampler	Westbay Sampler (Dup. Screen 1)	Westbay Sampler (Dup. Screen 2)	Westbay Sampler (Dup. Screen 2)	Westbay Sampler (Dup. Screen 2)	Westbay Sampler (Dup. Screen 2)	Westbay Sampler (Dup. Screen 2)	Westbay Sampler (Dup. Screen 2)
MW-4	Deep Multi-port	Westbay Sampler (Dup. Screen 1)	Westbay Sampler	Westbay Sampler	Westbay Sampler	Westbay Sampler (Dup. Screen 1)	Westbay Sampler	Westbay Sampler	Westbay Sampler	Westbay Sampler	Westbay Sampler	Westbay Sampler
MW-5	Shallow standpipe	Bailer (Dup. w/bailer)	Bailer	Bailer (Dup. w/pump)	Pump (Dup. w/bailer)	Pump	Pump (Dup. w/bailer)	Pump (Dup. w/bailer)	Bailer	Pump	Pump	Pump
MW-6	Shallow standpipe	Bailer	Bailer	Bailer (Dup. w/pump)	Pump	Pump	Pump	Pump	Bailer (Dup. w/bailer)	Bailer	Pump	Pump
MW-7	Shallow standpipe	Bailer	Bailer	Bailer	Pump (Dup. w/bailer)	Bailer ⁽⁷⁾	Pump (Dup. w/bailer)	Pump (Dup. w/bailer)	Bailer (Dup. w/bailer)	Bailer (Dup. w/bailer)	Pump (Dup. w/pump)	Pump (Dup. w/pump)
MW-8	Shallow standpipe	Wells Were Not Installed Prior to Event 8							Bailer (Dup. w/bailer)	Bailer	Pump	Pump
MW-9	Shallow standpipe								-- (Road washed out)	-- (Road washed out)	Pump	Pump
MW-10	Shallow standpipe								Bailer	Bailer	Pump	Pump
MW-11	Deep Multi-port								Westbay Sampler (Dup. Screen 3)	Westbay Sampler (Dup. Screen 3)	Westbay Sampler (Dup. Screen 3)	Westbay Sampler

Notes:

- (1) Water Chemistry analyses have included major anions, major cations, Total Organic Carbon and Total Dissolved Solids.
- (2) Samples from all shallow wells and upper screen of multi-port wells.
- (3) Dioxins in well MW-7 and upper screen of MW-3 only.
- (4) Samples filtered in field with 0.45 micron filter.
- (5) All JPL shallow wells were equipped with dedicated 2" Grundfos submersible pumps.
- (6) Not enough water in well to sample.
- (7) Not enough water for pump.

TABLE 1-15
(Continued)

Sample Location	Sample Event No.	Sample Date	Depth of Well (feet)	Screened Interval (feet)	Sampling Method	Carbon Tetrachloride	TCE	PCE	Other Volatile Organic Compounds	Total Trihalomethanes ^a (Primarily Chloroform)	Semi-Volatile Organic Compounds
SCREEN 2	6	April 1992	700	250-260	Westbay Sampler	7.6	11	-	-	10	NA
SCREEN 2 - DUP	6	April 1992	700	250-260	Westbay Sampler	10	12	-	-	10	NA
SCREEN 2	7	Sept. 1992	700	250-260	Westbay Sampler	2.3	2.1	-	-	3.7	NA
SCREEN 2 - DUP	7	Sept. 1992	700	250-260	Westbay Sampler	-	-	-	-	-	NA
SCREEN 2	8	Dec. 1992	700	250-260	Westbay Sampler	8.2	5.7	-	-	4.5	NA
SCREEN 2 - DUP	8	Dec. 1992	700	250-260	Westbay Sampler	8.3	6.2	-	-	4.8	NA
SCREEN 2	9	March 1993	700	250-260	Westbay Sampler	-	-	-	-	1.1	NA
SCREEN 2 - DUP	9	March 1993	700	250-260	Westbay Sampler	0.7	0.6	-	-	1.7	NA
SCREEN 2	10	July 1993	700	250-260	Westbay Sampler	-	-	-	-	1.2	NA
SCREEN 2 - DUP	10	July 1993	700	250-260	Westbay Sampler	-	-	-	-	0.9	NA
SCREEN 2	11	Oct. 1993	700	250-260	Westbay Sampler	0.8	1.1	-	-	1.1	-
SCREEN 2 - DUP	11	Oct. 1993	700	250-260	Westbay Sampler	1.4	1.5	-	-	1.1	-
MW-3											
SCREEN 3	1	March 1990	700	344-354	Westbay Sampler	-	-	-	-	-	-
SCREEN 3	2	June 1990	700	344-354	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	3	Dec. 1990	700	344-354	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3 - DUP	3	Dec. 1990	700	344-354	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	4	June 1991	700	344-354	Westbay Sampler	-	-	-	0.6 ETHYLBENZENE 0.9 STYRENE	-	NA
SCREEN 3	5	Oct. 1991	700	344-354	Westbay Sampler	-	-	-	0.5 ETHYLBENZENE 0.8 STYRENE	-	NA
SCREEN 3	6	April 1992	700	344-354	Westbay Sampler	-	-	-	0.6 ETHYLBENZENE 0.7 STYRENE	-	NA
SCREEN 3	7	Sept. 1992	700	344-354	Westbay Sampler	-	-	-	0.8 ETHYLBENZENE 0.8 STYRENE	-	NA
SCREEN 3	8	Dec. 1992	700	344-354	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	9	March 1993	700	344-354	Westbay Sampler	-	-	-	0.6 STYRENE	-	NA
SCREEN 3	10	July 1993	700	344-354	Westbay Sampler	-	-	-	0.5 STYRENE	-	NA
SCREEN 3	11	Oct. 1993	700	344-354	Westbay Sampler	-	-	-	-	-	-
MW-3											
SCREEN 4	1	March 1990	700	555-565	Westbay Sampler	-	-	-	-	-	-
SCREEN 4	2	June 1990	700	555-565	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	3	Dec. 1990	700	555-565	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	4	June 1991	700	555-565	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	5	Oct. 1991	700	555-565	Westbay Sampler	-	-	-	-	-	NA

TABLE 1-15
(Continued)

Sample Location	Sample Event No.	Sample Date	Depth of Well (feet)	Screened Interval (feet)	Sampling Method	Carbon Tetrachloride	TCE	PCE	Other Volatile Organic Compounds	Total Trihalomethanes ^a (Primarily Chloroform)	Semi-Volatile Organic Compounds
SCREEN 4	6	April 1992	700	555-565	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	7	Sept. 1992	700	555-565	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	8	Dec. 1992	700	555-565	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	9	March 1993	700	555-565	Westbay Sampler	-	-	-	0.8 ETHYLBENZENE	-	NA
SCREEN 4	10	July 1993	700	555-565	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	11	Oct. 1993	700	555-565	Westbay Sampler	-	-	-	-	-	-
MW-3											
SCREEN 5	1	March 1990	700	650-660	Westbay Sampler	-	-	-	-	-	-
SCREEN 5	2	June 1990	700	650-660	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	3	Dec. 1990	700	650-660	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	4	June 1991	700	650-660	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	5	Oct. 1991	700	650-660	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	6	April 1992	700	650-660	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	7	Sept. 1992	700	650-660	Westbay Sampler	-	-	-	0.6 CARBON DISULFIDE 0.5 STYRENE	-	NA
SCREEN 5	8	Dec. 1992	700	650-660	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	9	March 1993	700	650-660	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	10	July 1993	700	650-660	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	11	Oct. 1993	700	650-660	Westbay Sampler	-	-	-	-	-	-
MW-4											
SCREEN 1	1	March 1990	560	147-157	Westbay Sampler	-	-	-	-	-	-
SCREEN 1 - DUP	1	March 1990	560	147-157	Westbay Sampler	-	-	-	-	-	NA
SCREEN 1	2	June 1990	560	147-157	Westbay Sampler	-	-	-	-	-	NA
SCREEN 1	3	Dec. 1990	560	147-157	Westbay Sampler	-	8.0	-	-	-	NA
SCREEN 1	4	June 1991	560	147-157	Westbay Sampler	-	-	-	-	-	NA
SCREEN 1	5	Oct. 1991	560	147-157	Westbay Sampler	-	-	-	-	0.7	-
SCREEN 1	6	April 1992	560	147-157	Westbay Sampler	-	-	-	5.2 1,1,1-TRICHLOROETHANE	-	NA
SCREEN 1	7	Sept. 1992	560	147-157	Westbay Sampler	-	-	-	-	-	NA
SCREEN 1	8	Dec. 1992	560	147-157	Westbay Sampler	-	-	-	-	-	NA
SCREEN 1	9	March 1993	560	147-157	Westbay Sampler	-	-	-	-	-	NA
SCREEN 1	10	July 1993	560	147-157	Westbay Sampler	-	-	-	-	-	NA
SCREEN 1	11	Oct. 1993	560	147-157	Westbay Sampler	-	-	-	-	-	-

TABLE 1-15
(Continued)

Sample Location	Sample Event No.	Sample Date	Depth of Well (feet)	Screened Interval (feet)	Sampling Method	Carbon Tetrachloride	TCE	PCE	Other Volatile Organic Compounds	Total Trihalomethanes ^a (Primarily Chloroform)	Semi-Volatile Organic Compounds
<i>MW-4</i>											
SCREEN 2	1	March 1990	560	237-247	Westbay Sampler	-	-	-	-	-	-
SCREEN 2	2	June 1990	560	237-247	Westbay Sampler	-	-	-	-	-	NA
SCREEN 2	3	Dec. 1990	560	237-247	Westbay Sampler	-	-	-	-	-	NA
SCREEN 2	4	June 1991	560	237-247	Westbay Sampler	-	1.7	-	-	-	NA
SCREEN 2	5	Oct. 1991	560	237-247	Westbay Sampler	-	0.9	-	-	-	NA
SCREEN 2	6	April 1992	560	237-247	Westbay Sampler	-	1.5	-	-	-	NA
SCREEN 2	7	Sept. 1992	560	237-247	Westbay Sampler	-	1.7	-	-	0.5	NA
SCREEN 2	8	Dec. 1992	560	237-247	Westbay Sampler	-	1.7	-	-	-	NA
SCREEN 2	9	March 1993	560	237-247	Westbay Sampler	1.0	2.7	-	0.7 1,2-DICHLOROETHANE	2.1	NA
SCREEN 2	10	July 1993	560	237-247	Westbay Sampler	0.8	2.5	-	0.5 1,2-DICHLOROETHANE	1.6	NA
SCREEN 2	11	Oct. 1993	560	237-247	Westbay Sampler	1.3	4.2	-	0.9 1,2-DICHLOROETHANE	2.8	-
<i>MW-4</i>											
SCREEN 3	1	March 1990	560	319-329	Westbay Sampler	-	-	-	-	-	-
SCREEN 3	2	June 1990	560	319-329	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	3	Dec. 1990	560	319-329	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	4	June 1991	560	319-329	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	5	Oct. 1991	560	319-329	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	6	April 1992	560	319-329	Westbay Sampler	-	2.3	2.6	3.4 1,1,1-TRICHLOROETHANE 0.5 TOLUENE	-	NA
SCREEN 3	7	Sept. 1992	560	319-329	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	8	Dec. 1992	560	319-329	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	9	March 1993	560	319-329	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	10	July 1993	560	319-329	Westbay Sampler	-	-	-	-	-	NA
SCREEN 3	11	Oct. 1993	560	319-329	Westbay Sampler	-	-	-	-	-	-
<i>MW-4</i>											
SCREEN 4	1	March 1990	560	389-399	Westbay Sampler	-	-	-	-	-	-
SCREEN 4	2	June 1990	560	389-399	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	3	Dec. 1990	560	389-399	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	4	June 1991	560	389-399	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	5	Oct. 1991	560	389-399	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	6	April 1992	560	389-399	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	7	Sept. 1992	560	389-399	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	8	Dec. 1992	560	389-399	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	9	March 1993	560	389-399	Westbay Sampler	-	-	-	-	-	NA

TABLE 1-15
(Continued)

Sample Location	Sample Event No.	Sample Date	Depth of Well (feet)	Screened Interval (feet)	Sampling Method	Carbon Tetrachloride	TCE	PCE	Other Volatile Organic Compounds	Total Trihalomethanes ^a (Primarily Chloroform)	Semi-Volatile Organic Compounds
SCREEN 4	10	July 1993	560	389-399	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	11	Oct. 1993	560	389-399	Westbay Sampler	-	-	-	2.2 ETHYLBENZENE 0.9 STYRENE 0.5 TOLUENE 0.7 VINYL CHLORIDE	-	-
SCREEN 4 (RESAMPLED)	11	Oct. 1993	560	389-399	Westbay Sampler	-	-	-	-	-	NA
MW-4											
SCREEN 5	1	March 1990	560	510-520	Westbay Sampler	-	-	-	-	-	-
SCREEN 5	2	June 1990	560	510-520	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	3	Dec. 1990	560	510-520	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	4	June 1991	560	510-520	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	5	Oct. 1991	560	510-520	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	6	April 1992	560	510-520	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	7	Sept. 1992	560	510-520	Westbay Sampler	-	-	-	25 ACETONE	-	NA
SCREEN 5	8	Dec. 1992	560	510-520	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	9	March 1993	560	510-520	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	10	July 1993	560	510-520	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	11	Oct. 1993	560	510-520	Westbay Sampler	-	-	-	-	-	-
MW-5	1	March 1990	140	85-135	Bailer	-	13	-	-	-	-
MW-5 - DUP	1	March 1990	140	85-135	Bailer	-	13	-	-	-	-
MW-5	2	June 1990	140	85-135	Bailer	-	13	-	6 TOLUENE 11 TOTAL XYLENES	-	NA
MW-5	3	Dec. 1990	140	85-135	Bailer	-	86	-	-	7	NA
MW-5 - DUP	3	Dec. 1990	140	85-135	Pump	-	90	-	-	6	NA
MW-5	4	June 1991	140	85-135	Pump	0.7	26	-	-	2.4	NA
MW-5 - DUP	4	June 1991	140	85-135	Bailer	0.7	25	-	-	2.6	NA
MW-5	5	Oct. 1991	140	85-135	Pump	-	16	0.6	0.8 1,1-DICHLOROETHANE	2.3	-
MW-5	6	April 1991	140	85-135	Pump	-	4.5	3.8	5.4 cis-1,2-DICHLOROETHENE 0.9 TOLUENE 1.3 TOTAL XYLENES	-	NA
MW-5 - DUP	6	April 1991	140	85-135	Bailer	-	3.3	1.4	0.5 1,1,1-TRICHLOROETHANE 10 cis-1,2-DICHLOROETHENE 1.3 TOLUENE 0.5 TOTAL XYLENES 0.5 BENZENE	-	NA

TABLE 1-15
(Continued)

Sample Location	Sample Event No.	Sample Date	Depth of Well (feet)	Screened Interval (feet)	Sampling Method	Carbon Tetrachloride	TCE	PCE	Other Volatile Organic Compounds	Total Trihalomethanes ^a (Primarily Chloroform)	Semi-Volatile Organic Compounds
MW-5	7	Sept. 1992	140	85-135	Pump	-	1.0(B)	0.8(B)	0.9(B) TOTAL XYLENES	-	NA
MW-5 - DUP	7	Sept. 1992	140	85-135	Bailer	-	-	-	-	-	NA
MW-5	8	Dec. 1992	140	85-135	Bailer	-	-	-	-	-	NA
MW-5	9	March 1993	140	85-135	Pump	-	-	-	-	-	NA
MW-5	10	July 1993	140	85-135	Pump	-	-	-	-	-	NA
MW-5	11	Oct. 1993	140	85-135	Pump	-	-	-	-	-	-
MW-6	1	March 1990	245	195-245	Bailer	-	-	-	-	30	-
MW-6	2	June 1990	245	195-245	Bailer	-	-	-	6 TOLUENE	-	NA
MW-6	3	Dec. 1990	245	195-245	Bailer	-	-	-	-	-	NA
MW-6 - DUP	3	Dec. 1990	245	195-245	Pump	-	-	-	-	-	NA
MW-6	4	June 1991	245	195-245	Pump	-	-	-	-	-	NA
MW-6	5	Oct. 1991	245	195-245	Pump	-	-	-	-	-	-
MW-6	6	April 1992	245	195-245	Pump	-	-	-	-	-	NA
MW-6	7	Sept. 1992	245	195-245	Pump	-	0.8(B)	0.9(B)	0.8(B) TOTAL XYLENES	-	NA
MW-6	8	Dec. 1992	245	195-245	Bailer	-	-	0.5	-	-	NA
MW-6 - DUP	8	Dec. 1992	245	195-245	Bailer	-	-	0.5	-	-	NA
MW-6	9	March 1993	245	195-245	Bailer	-	-	0.6	12 METHYLETHYL KETONE	-	NA
MW-6	10	July 1993	245	195-245	Pump	0.1(B)	0.7(B)	0.5	0.7(B) ISOPROPYLBENZENE	-	NA
MW-6	11	Oct. 1993	245	195-245	Pump	-	-	-	-	-	-
MW-7	1	March 1990	275	225-275	Bailer	200	22	15	8 1,1-DICHLOROETHENE	23	-
MW-7	2	June 1990	275	225-275	Bailer	200	27	9	6 1,1-DICHLOROETHENE 5 TOLUENE	19	NA
MW-7	3	Dec. 1990	275	225-275	Bailer	130	5	28	14 1,1-DICHLOROETHENE	15	NA
MW-7	4	June 1991	275	225-275	Pump	190	7.5	15	6.7 1,1-DICHLOROETHENE	14	NA
MW-7 - DUP	4	June 1991	275	225-275	Bailer	190	7.0	14	7.1 1,1-DICHLOROETHENE	13	NA
MW-7	5	Oct. 1991	275	225-275	Bailer	31	2.0	5.5	3 1,1-DICHLOROETHENE	5.4	-
MW-7	6	April 1992	275	225-275	Pump	260	30	-	-	-	NA
MW-7 - DUP	6	April 1992	275	225-275	Bailer	320	32	-	-	-	NA
MW-7	7	Sept. 1992	275	225-275	Pump	230	39	-	-	19	NA
MW-7 - DUP	7	Sept. 1992	275	225-275	Bailer	200	37	-	-	17	NA
MW-7	8	Dec. 1992	275	225-275	Bailer	120	40	4.8	4 1,1-DICHLOROETHENE 0.9 1,2-DICHLOROETHANE 9.0 FREON 113	17	NA

TABLE 1-15
(Continued)

Sample Location	Sample Event No.	Sample Date	Depth of Well (feet)	Screened Interval (feet)	Sampling Method	Carbon Tetrachloride	TCE	PCE	Other Volatile Organic Compounds	Total Trihalomethanes ^a (Primarily Chloroform)	Semi-Volatile Organic Compounds
MW-7 - DUP	8	Dec. 1992	275	225-275	Bailer	120	32	4.6	4.6 1,1-DICHLOROETHENE 0.9 1,2-DICHLOROETHANE 6.6 FREON 113	15	NA
MW-7	9	March 1993	275	225-275	Bailer	130	48	2.2	2 1,1-DICHLOROETHENE 0.7 1,2-DICHLOROETHANE 11 FREON 113	19	NA
MW-7 - DUP	9	March 1993	275	225-275	Bailer	71	33	-	-	19	NA
MW-7	10	July 1993	275	225-275	Pump	120	31	0.9	1.2 1,1-DICHLOROETHENE 0.5 1,2-DICHLOROETHANE 1.0(B) ISOPROPYLBENZENE 5.6 FREON 113	15.5	NA
MW-7 - DUP	10	July 1993	275	225-275	Pump	120	32	0.8	1.2 1,1-DICHLOROETHENE 0.6 1,2-DICHLOROETHANE 1.2(B) ISOPROPYLBENZENE 5.6 FREON 113	16.6	NA
MW-7	11	Oct. 1993	275	225-275	Pump	230	35 ^g	1.6	2.1 1,1-DICHLOROETHENE 1.1 1,2-DICHLOROETHANE 0.6 FREON 1 6.9 FREON 113	18 ^g	-
W-7 - DUP	11	Oct. 1993	275	225-275	Pump	230	35	1.7	2.1 1,1-DICHLOROETHENE 1.1 1,2-DICHLOROETHANE 0.6 FREON 1 7.1 FREON 113	18 ^g	-
MW-8	8	Dec. 1992	205	155-205	Bailer	-	0.8	-	-	0.8	NA
MW-8 - DUP	8	Dec. 1992	205	155-205	Bailer	0.5	0.9	-	-	0.9	NA
MW-8	9	March 1993	205	155-205	Bailer	3.2	1.4	-	10.0 FREON 113	1.8	NA
MW-8	10	July 1993	205	155-205	Pump	-	-	-	0.8(B) ISOPROPYLBENZENE 0.7 FREON 113	0.5	NA
MW-8	11	Oct. 1993	205	155-205	Pump	-	-	-	1.0 FREON 113	-	-
MW-9	10	July 1993	68	18-68	Pump	-	-	-	0.6(B) ISOPROPYLBENZENE	-	NA
MW-9	11	Oct. 1993	68	18-68	Pump	-	-	-	-	-	-
MW-10	8	Dec. 1992	155	105-155	Bailer	-	15	0.6	0.7 1,1-DICHLOROETHANE 0.7 TOLUENE 2 FREON 113	2	NA
MW-10	9	March 1993	155	105-155	Bailer	-	0.6	-	1.4 1,1,1-TRICHLOROETHANE 1.1 FREON 113	-	NA
MW-10	10	July 1993	155	105-155	Pump	-	-	-	1.2(B) ISOPROPYLBENZENE 0.5 FREON 113	-	NA

TABLE 1-15
(Continued)

Sample Location	Sample Event No.	Sample Date	Depth of Well (feet)	Screened Interval (feet)	Sampling Method	Carbon Tetrachloride	TCE	PCE	Other Volatile Organic Compounds	Total Trihalomethanes ^a (Primarily Chloroform)	Semi-Volatile Organic Compounds
MW-10	11	Oct. 1993	155	105-155	Pump	-	-	-	0.5 1,1,1-TRICHLOROETHANE 1.1 FREON 113	-	-
MW-11											
SCREEN 1	8	Dec. 1992	680	140-150	Westbay Sampler	17	-	-	-	2.3	NA
SCREEN 1	9	March 1993	680	140-150	Westbay Sampler	7.2	-	-	1.4 FREON 113	2.5	NA
SCREEN 1	10	July 1993	680	140-150	Westbay Sampler	8.5	-	-	1.2 FREON 113	1.9	NA
SCREEN 1	11	Oct. 1993	680	140-150	Westbay Sampler	5.5	-	-	2.5 METHYLENE CHLORIDE	1.4	-
MW-11											
SCREEN 2	8	Dec. 1992	680	250-260	Westbay Sampler	8.1	-	-	-	4.7	NA
SCREEN 2	9	March 1993	680	250-260	Westbay Sampler	2.0	-	-	-	3.1	NA
SCREEN 2	10	July 1993	680	250-260	Westbay Sampler	0.6	-	-	-	1.5	NA
SCREEN 2	11	Oct. 1993	680	250-260	Westbay Sampler	0.8	-	-	-	1.6	-
MW-11											
SCREEN 3	8	Dec. 1992	680	420-430	Westbay Sampler	2.8	-	-	-	3.3	NA
SCREEN 3 - DUP	8	Dec. 1992	680	420-430	Westbay Sampler	3.6	-	-	-	3.6	NA
SCREEN 3	9	March 1993	680	420-430	Westbay Sampler	-	-	-	-	0.8	NA
SCREEN 3 - DUP	9	March 1993	680	420-430	Westbay Sampler	-	-	-	-	0.8	NA
SCREEN 3	10	July 1993	680	420-430	Westbay Sampler	-	-	-	-	1.3	NA
SCREEN 3 - DUP	10	July 1993	680	420-430	Westbay Sampler	-	-	-	-	1.4	NA
SCREEN 3	11	Oct. 1993	680	420-430	Westbay Sampler	-	-	-	-	-	-
MW-11											
SCREEN 4	8	Dec. 1992	680	515-525	Westbay Sampler	-	-	-	-	2.9	NA
SCREEN 4	9	March 1993	680	515-525	Westbay Sampler	-	-	-	-	0.8	NA
SCREEN 4	10	July 1993	680	515-525	Westbay Sampler	-	-	-	-	-	NA
SCREEN 4	11	Oct. 1993	680	515-525	Westbay Sampler	-	-	-	-	-	14 UNKNOWN
MW-11											
SCREEN 5	8	Dec. 1993	680	630-640	Westbay Sampler	-	-	-	-	1.2	NA
SCREEN 5	9	March 1993	680	630-640	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	10	July 1993	680	630-640	Westbay Sampler	-	-	-	-	-	NA
SCREEN 5	11	Oct. 1993	680	630-640	Westbay Sampler	-	-	-	-	-	9.9 UNKNOWN

TABLE 1-15
(Continued)

Sample Location	Sample Event No.	Sample Date	Depth of Well (feet)	Screened Interval (feet)	Sampling Method	Carbon Tetrachloride	TCE	PCE	Other Volatile Organic Compounds	Total Trihalomethanes ^a (Primarily Chloroform)	Semi-Volatile Organic Compounds
Practical Quantitation Limit	-	-	-	-	-	0.5 ^d	0.5 ^d	0.5 ^d	- ^e	0.5 ^d	
Regulatory Threshold ^c	-	-	-	-	-	0.5	5.0	5.0	- ^f	100	

NOTES:

(B): Indicates compound also present in laboratory method blank.

EP: Indicates extraneous peak.

NA Indicates not analyzed.

-: Indicates not detected.

a: Total Trihalomethanes include chloroform, bromoform, dibromochloromethane, and dichlorobromomethane.

b: Equipment blank results indicate these VOC values may have resulted from low concentrations remaining in the purge pump.

c: Derived from California Administrative Code, Title 22 Maximum Contaminant Level for Drinking Water or from USEPA Drinking Water Standards and Health Advisories Table.

d: The Practical Quantitation Limit was 5 µg/l in the sampling events which occurred before 1991. Analyses of diluted samples from well MW-7 has resulted in higher detection limits for these analytes since the April 1992 sampling event (25 µg/l in April 1992, 12.5 µg/l in September 1992, 10 µg/l in Jan. 1993, 6.25 µg/l in April 1993). Diluted samples from MW-3, screen 2 were used in April 1992 (1.25 µg/l) and from MW-10 in Jan 1993 (1 µg/l for Trichloroethene).

e: The detection limit for 1,1-dichloroethane, toluene, 1,1,1-trichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, xylenes, cis-1,2-dichloroethene, benzene, carbon disulfide, styrene, and ethylbenzene is 0.5 µg/l. Prior to 1991, the detection limit was 5 µg/l for these compounds (when analyzed for). The detection limit for MEK and acetone is 10 µg/l. No detection limit is given for isopropylbenzene or unknown compounds since their concentrations were arrived at through comparison with similar compounds.

f: Regulatory threshold concentrations for 1,1-dichloroethane is 5 µg/l, for 1,1,1-trichloroethane is 200 µg/l, for 1,1-dichloroethene is 6 µg/l, for 1,2-dichloroethane is 0.5 µg/l, for ethylbenzene is 30 µg/l, for total xylenes is 1750 µg/l, for toluene and acetone is 100 µg/l, and for benzene is 1 µg/l. Styrene, isopropylbenzene, carbon disulfide and unknown compounds are unregulated.

g: Estimated concentration value from undiluted sample.

TABLE 1-16
SUMMARY OF TITLE 26 METALS, STRONTIUM, AND CYANIDE
HISTORICALLY DETECTED IN GROUNDWATER SAMPLES COLLECTED
FROM JPL MONITORING WELLS

Concentrations in mg/l unless otherwise noted
 Results above EPA or California Drinking Water Standards have been shaded

Well Name	Sample Event No.	Sample Date	Sampling Method	As	Ba	Cr	Cu	Hg (µg/L)	Ni	Pb	Sb	Sr	Tl	Other Metals	Zn	Cyanide	Turbidity ^g
<i>MW-1</i>	5	October 1991	Pump ^a	--	0.18	0.020	--	0.020	--	0.024	--	--	--	0.038 V	2.60	--	NA
<i>MW-1</i>	9	March 1993	Pump	--	--	--	--	--	--	--	--	0.31	--	--	0.025(EB)	--	0.7
<i>MW-1</i>	10	July 1993	Pump	--	0.052	--	--	--	--	--	--	0.32	--	--	0.033	--	0.0
<i>MW-1</i>	11	October 1993	Pump ^f	--	0.050	--	--	--	--	--	--	0.30	--	--	0.16	--	NA
<i>MW-2</i>	9	March 1993	Bailer	--	0.069	--	--	--	--	--	--	0.80	--	0.005Cd	0.250	--	9.0
<i>MW-2</i>	10	July 1993	Bailer	--	0.086	0.030	0.01	--	--	0.004	--	1.1	--	--	1.0	0.01	5.7
<i>MW-3</i>																	
Screen 1	1	March 1990 ^a	Westbay Sampler	--	0.04	--	--	--	0.10	--	--	0.53	--	--	--	--	NA
Screen 1-Dup	1	March 1990 ^a	Westbay Sampler	--	0.04	--	--	--	--	--	--	0.60	--	--	0.10	--	NA
Screen 1	5	October 1991 ^a	Westbay Sampler	--	0.048	--	--	--	--	--	--	--	--	--	0.440	--	NA
Screen 1	8	December 1992 ^a	Westbay Sampler	--	--	--	0.047	--	--	--	--	0.29	--	--	0.044	0.006	2.3
Screen 1	9	March 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.33	--	--	0.075(EB)	--	8.8
Screen 1	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.25	--	--	0.026	--	6.0
Screen 1	11	October 1993	Westbay Sampler ^f	--	--	--	--	--	--	--	0.015(EB)	0.22	--	--	--	--	NA
<i>MW-3</i>																	
Screen 2	1	March 1990 ^a	Westbay Sampler	--	0.071	--	--	--	--	--	--	0.43	--	--	0.03	--	NA
Screen	5	October 1991	Westbay Sampler	--	0.060	0.011	--	--	--	--	--	--	--	0.020 Mo	1.80	--	NA
Screen 2	8	December 1992 ^a	Westbay Sampler	--	0.056(EB)	--	0.023	--	--	--	--	0.40	--	--	0.035	0.008	3.7
Screen 2	9	March 1993	Westbay Sampler	--	0.064(EB)	--	--	--	--	--	--	0.35	--	--	0.110(EB)	--	7.5
Screen 2-Dup	9	March 1993	Westbay Sampler	--	--	--	0.020(EB)	--	--	--	--	0.36	--	--	0.170(EB)	--	7.5
Screen 2	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.30	--	--	--	--	3.6
Screen 2-Dup	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.30	--	--	0.026	--	3.6
Screen 2	11	October 1993	Westbay Sampler ^f	--	--	--	--	--	--	--	0.016(EB)	0.33	--	--	--	--	NA
Screen 2-Dup	11	October 1993	Westbay Sampler ^f	--	0.052	--	--	--	--	--	0.014(EB)	0.33	--	--	--	--	NA

TABLE I-16
(Continued)

Well Name	Sample Event No.	Sample Date	Sampling Method	As	Ba	Cr	Cu	Hg (µg/L)	Ni	Pb	Sb	Sr	Tl	Other Metals	Zn	Cyanide	Turbidity ^g
<i>MW-3</i>																	
Screen 3	1	March 1990 ^a	Westbay Sampler	--	0.020	--	--	--	--	--	--	0.21	--	0.02 Mo	0.21	--	NA
Screen 3	5	October 1991 ^a	Westbay Sampler	--	0.018	--	--	--	--	--	--	--	--	0.059 Mo	0.500	--	NA
Screen 3	8	December 1992 ^a	Westbay Sampler	--	--	--	0.010	--	--	--	--	0.23	--	--	0.033	0.007	5.4
Screen 3	9	March 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.17	--	--	0.075(EB)	--	4.0
Screen 3	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.19	--	--	0.032	--	2.3
Screen 3	11	October 1993	Westbay Sampler ^f	--	--	--	0.011	--	--	--	0.11(EB)	0.23	--	--	--	--	NA
<i>MW-3</i>																	
Screen 4	1	March 1990 ^a	Westbay Sampler	--	0.04	--	--	--	--	--	--	0.43	--	0.02 Mo	0.06	--	NA
Screen 4	5	October 1991 ^a	Westbay Sampler	--	0.049	--	--	--	--	--	--	--	--	0.032 Mo	1.90	--	NA
Screen 4	8	December 1992 ^a	Westbay Sampler	0.006	0.076	--	0.052	--	--	--	--	0.23	--	--	0.360	--	NA
Screen 4	9	March 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.19	--	--	0.120(EB)	--	5.3
Screen 4	10	July 1993	Westbay Sampler	--	0.060	--	--	--	--	--	--	0.26	--	--	0.051(EB)	--	3.8
Screen 4	11	October 1993	Westbay Sampler ^f	--	--	--	--	--	--	--	0.017(EB)	0.022	--	--	0.027	--	NA
<i>MW-3</i>																	
Screen 5	1	March 1990 ^a	Westbay Sampler	--	0.02	--	--	--	--	--	--	0.18	--	0.01 Co/0.040 Mo	0.20	--	NA
Screen 5	5	October 1991 ^a	Westbay Sampler	0.015	0.009	--	--	--	--	--	--	--	--	0.030 Mo	0.46	--	NA
Screen 5	8	December 1992 ^a	Westbay Sampler	0.016	--	--	0.019	--	--	--	--	0.07	--	--	0.49	--	NA
Screen 5	9	March 1993	Westbay Sampler	0.010	--	--	0.010(EB)	--	--	--	--	0.06	--	--	0.12(EB)	--	4.6
Screen 5	10	July 1993	Westbay Sampler	0.008	--	--	--	--	--	--	--	0.085	--	--	--	--	2.8
Screen 5	11	October 1993	Westbay Sampler ^f	0.012	--	--	--	--	--	--	0.021(EB)	0.052	--	--	0.18	--	NA
<i>MW-4</i>																	
Screen 1	1	March 1990 ^a	Westbay Sampler	--	0.05	--	--	--	--	--	--	0.42	--	--	0.06	--	NA
Screen 1-Dup	1	March 1990 ^a	Westbay Sampler	--	0.05	--	--	--	--	--	--	0.45	--	--	0.03	--	NA
Screen 1	5	October 1991 ^a	Westbay Sampler	--	0.091	0.012	--	--	--	0.014	--	--	--	0.026 Mo	4.10	--	NA
Screen 1	8	December 1992 ^a	Westbay Sampler	--	--	--	0.043	--	--	--	--	0.28	--	--	0.240	0.009	1.8
Screen 1	9	March 1993	Westbay Sampler	--	--	--	0.014(EB)	--	--	--	--	0.35	--	--	0.059(EB)	--	10.4
Screen 1	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.24	--	--	0.021(EB)	--	4.3
Screen 1	11	October 1993	Westbay Sampler ^f	--	--	--	--	--	--	--	0.011(EB)	0.20	--	--	0.023	--	NA

TABLE 1-16
(Continued)

Well Name	Sample Event No.	Sample Date	Sampling Method	As	Ba	Cr	Cu	Hg (µg/L)	Ni	Pb	Sb	Sr	Tl	Other Metals	Zn	Cyanide	Turbidity ^g
<i>MW-4</i>																	
Screen 2	1	March 1990 ^a	Westbay Sampler	--	--	--	--	--	0.01	--	--	0.54	--	--	0.04	--	NA
Screen 2	5	October 1991 ^a	Westbay Sampler	--	0.078	--	--	--	--	--	--	--	--	--	0.490	--	NA
Screen 2	8	December 1992 ^a	Westbay Sampler	--	0.090	--	--	--	--	--	--	0.63	--	--	0.240	0.012	11.5
Screen 2	9	March 1993	Westbay Sampler	--	0.079	--	0.015(EB)	--	--	--	--	0.55	--	--	0.11	--	20.0
Screen 2	10	July 1993	Westbay Sampler	--	0.081	--	--	--	--	--	--	0.33	--	--	0.029(EB)	--	13.3
Screen 2	11	October 1993	Westbay Sampler ^f	--	0.066	--	--	--	0.024	0.002	0.017(EB)	0.049	--	--	0.023	--	NA
<i>MW-4</i>																	
Screen 3	1	March 1990 ^a	Westbay Sampler	--	0.03	--	--	--	--	--	--	0.27	--	--	0.062(EB)	--	NA
Screen 3	5	October 1991 ^a	Westbay Sampler	--	0.054	--	--	--	--	--	--	--	--	0.015 V	0.640	--	NA
Screen 3	8	December 1992 ^a	Westbay Sampler	0.006	0.054	--	--	--	--	--	--	0.31	--	--	0.22	0.019	4.2
Screen 3	9	March 1993	Westbay Sampler	--	--	--	0.013(EB)	--	--	--	--	0.18	--	--	0.057(EB)	--	7.4
Screen 3	10	July 1993	Westbay Sampler	--	0.14	--	--	--	--	--	--	0.29	--	--	0.15	--	8.0
Screen 3	11	October 1993	Westbay Sampler ^f	--	--	--	0.012	--	--	0.002	0.011(EB)	0.29	--	--	0.19	--	NA
<i>MW-4</i>																	
Screen 4	1	March 1990 ^a	Westbay Sampler	--	0.02	--	0.020	--	0.01	--	--	0.30	--	--	0.02	--	NA
Screen 4	5	October 1991 ^a	Westbay Sampler	--	0.030	0.034	--	--	--	--	--	--	--	0.020 Mo	0.480	--	NA
Screen 4	8	December 1992 ^a	Westbay Sampler	--	--	--	--	--	--	--	--	0.28	--	--	0.210	--	8.0
Screen 4	9	March 1993	Westbay Sampler	--	--	--	0.010(EB)	--	--	--	--	0.25	--	--	0.053(EB)	--	24.0
Screen 4	10	July 1993	Westbay Sampler	--	0.093	--	--	--	--	--	--	0.23	--	--	0.12	--	14.9
Screen 4	11	October 1993	Westbay Sampler ^f	--	--	--	--	--	--	0.004	0.009(EB)	0.27	--	--	0.084	0.005	NA
<i>MW-4</i>																	
Screen 5	1	March 1990 ^a	Westbay Sampler	--	0.04	--	--	--	--	--	--	0.40	--	0.02 Mo	0.01	--	NA
Screen 5	5	October 1991 ^a	Westbay Sampler	--	0.048	--	--	--	--	--	--	--	--	0.022 Mo	1.5	--	NA
Screen 5	8	December 1992 ^a	Westbay Sampler	--	--	--	0.013	--	--	--	--	0.31	--	--	0.240	0.021	2.5
Screen 5	9	March 1993	Westbay Sampler	--	--	0.015(EB)	0.013(EB)	--	--	--	--	0.27	--	--	0.056(EB)	--	5.3
Screen 5	10	July 1993	Westbay Sampler	--	0.13	0.019	--	--	--	--	--	0.26	--	--	0.036(EB)	--	8.0
Screen 5	11	October 1993	Westbay Sampler ^f	--	--	--	0.012	--	--	0.051	0.020(EB)	0.29	--	--	0.20	0.005	NA

TABLE 1-16
(Continued)

Well Name	Sample Event No.	Sample Date	Sampling Method	As	Ba	Cr	Cu	Hg (µg/L)	Ni	Pb	Sb	Sr	Tl	Other Metals	Zn	Cyanide	Turbidity ^g
MW-5	1	March 1990 ^a	Bailer	--	0.05	--	0.02	--	0.02	0.0045	--	0.50	--	--	0.23	--	NA
MW-5	5	October 1991 ^a	Pump	--	0.092	0.013	--	--	--	0.012	--	--	--	--	0.620	--	NA
MW-5	8	December 1992 ^a	Bailer	--	--	--	0.015	--	--	0.007	--	0.23	0.10	--	0.070	--	44.0
MW-5	9	March 1993	Pump	--	--	--	--	--	--	0.012	--	0.26	--	--	0.022	--	3.3
MW-5	10	July 1993	Pump	--	--	--	--	--	--	--	--	0.20	--	--	--	--	4.9
MW-5	11	October 1992	Pump ^f	--	0.072	--	--	--	--	--	--	0.23	--	--	0.024	--	NA
MW-6	1	March 1990 ^a	Bailer	--	0.02	--	--	--	--	--	0.008	0.66	--	--	0.13	--	NA
MW-6	5	October 1991 ^a	Pump	--	0.075	0.018	0.018	--	--	0.006	--	--	--	--	2.50	--	NA
MW-6	8	December 1992 ^a	Bailer	--	0.084	0.24 ^b	0.018	--	--	0.009	--	0.64	--	--	0.180	--	100+ ^b
MW-6	9	March 1993	Bailer	--	0.088	0.42 ^b	0.010	--	0.063	0.010	--	0.70	--	--	0.460	--	100+
MW-6	10	July 1993	Pump	--	0.072	0.027	--	--	0.075	--	--	0.60	--	--	0.065	--	4.0
MW-6	11	October 1993	Pump ^f	--	0.091	--	--	--	0.11	--	--	0.64	--	--	--	--	NA
MW-7	1	March 1990 ^a	Bailer	--	0.03	0.02	0.02	--	--	--	--	0.32	--	--	0.25	--	NA
MW-7	5	October 1991 ^a	Bailer	--	0.079	0.032	--	--	--	0.025	--	--	--	0.015V	0.740	--	NA
MW-7	8	December 1992 ^a	Bailer	--	0.052	0.011	0.012	--	--	--	--	0.37	--	--	0.048	--	32.0
MW-7	9	March 1993	Bailer	--	--	0.059 ^b	0.013	--	0.047	0.022	0.007	0.33	--	--	0.230	--	100+
MW-7-Dup	9	March 1993	Bailer	--	0.057	0.074 ^b	0.020	--	0.058	0.037	0.007	0.34	--	--	0.460	--	100+
MW-7	10	July 1993	Pump	--	--	--	--	--	--	--	--	0.35	--	--	--	--	1.6
MW-7-Dup	10	July 1993	Pump	--	--	--	--	--	--	0.014	--	0.34	--	--	--	--	1.6
MW-7	11	October 1993	Pump ^f	--	0.11	--	--	--	--	--	--	0.34	--	--	0.034	--	NA
MW-7-Dup	11	October 1993	Pump ^f	--	0.051	--	--	--	--	--	--	0.34	--	--	0.020	--	NA
MW-8	8	December 1992 ^a	Bailer	--	0.150	0.025	0.110	0.20	--	0.030	--	0.34	--	--	0.280	--	100+
MW-8	9	March 1993	Bailer	--	0.051	0.049	0.020	--	0.027	0.006	--	0.25	--	--	0.070	--	39.0
MW-8	10	July 1993	Pump	--	0.085	--	--	--	--	--	--	0.22	--	--	0.035	--	0.3
MW-8	11	October 1993	Pump ^f	--	0.097	--	--	--	--	--	--	0.020	--	--	0.19	--	NA
MW-9	10	July 1993	Pump	--	0.051	--	--	--	--	--	--	0.27	--	--	--	--	5.0
MW-9	11	October 1993	Pump ^f	--	0.054	--	--	--	--	--	--	0.29	--	--	0.027	--	NA

TABLE 1-16
(Continued)

Well Name	Sample Event No.	Sample Date	Sampling Method	As	Ba	Cr	Cu	Hg (µg/L)	Ni	Pb	Sb	Sr	Tl	Other Metals	Zn	Cyanide	Turbidity ^g
MW-10	8	December 1992 ^a	Bailer	--	0.280	0.026	0.066	0.30	--	0.017	--	0.94	--	--	0.290	--	100+
MW-10	9	March 1993	Bailer	--	0.059	--	--	--	--	--	--	0.41	--	--	0.029	--	3.8
MW-10	10	July 1993	Pump	--	--	--	--	--	--	--	--	0.33	--	--	0.021	--	0.8
MW-10	11	October 1993	Pump ^f	--	0.091	--	--	--	--	--	--	0.36	--	--	0.024	--	NA
MW-11																	
Screen 1	8	December 1992 ^a	Westbay Sampler	0.011	--	--	0.017	--	--	--	--	0.41	--	--	0.040	--	29.0
Screen 1	9	March 1993	Westbay Sampler	0.008	--	--	0.035	--	--	--	--	0.43	--	--	0.078	--	7.9
Screen 1	10	July 1993	Westbay Sampler	0.010	--	--	--	--	--	--	--	0.45	--	--	--	--	11.5
Screen 1	11	October 1993	Westbay Sampler ^f	0.008	--	--	--	--	--	--	0.014(EB)	0.42	--	--	0.026	--	NA
MW-11																	
Screen 2	8	December 1992 ^a	Westbay Sampler	0.013	--	--	0.064	--	--	--	--	0.35	--	--	0.150	--	4.8
Screen 2	9	March 1993	Westbay Sampler	0.008	--	--	--	--	--	--	--	0.35	--	--	0.058	--	6.9
Screen 2	10	July 1993	Westbay Sampler	0.007	--	--	--	--	--	--	--	0.39	--	--	0.039	--	12.0
Screen 2	11	October 1993	Westbay Sampler ^f	0.010	--	--	--	--	--	--	0.011(EB)	0.41	--	--	0.042	--	NA
MW-11																	
Screen 3	8	December 1992 ^a	Westbay Sampler	--	0.050	--	0.025	--	--	--	--	0.37	--	--	0.140	--	8.0
Screen 3	9	March 1993	Westbay Sampler	--	--	--	--	--	--	0.015	--	0.38	--	--	0.099	--	11.3
Screen 3-Dup	9	March 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.37	--	--	0.110	--	11.3
Screen 3	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.37	--	--	0.023	--	4.5
Screen 3-Dup	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.37	--	--	0.055	--	4.5
Screen 3	11	October 1993	Westbay Sampler ^f	--	--	--	--	--	--	--	0.015(EB)	0.38	--	--	--	--	NA
MW-11																	
Screen 4	8	December 1992 ^a	Westbay Sampler	--	--	--	0.042	--	--	--	--	0.33	--	--	0.074	--	7.5
Screen 4	9	March 1992	Westbay Sampler	--	--	--	--	--	--	--	--	0.31	--	0.075 Mo	0.070	--	3.1
Screen 4	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.36	--	--	0.036	0.008	2.0
Screen 4	11	October 1993	Westbay Sampler ^f	--	--	--	--	--	--	0.003	0.012(EB)	0.34	--	--	0.033	--	NA

TABLE 1-16
(Continued)

Well Name	Sample Event No.	Sample Date	Sampling Method	As	Ba	Cr	Cu	Hg ($\mu\text{g/L}$)	Ni	Pb	Sb	Sr	Tl	Other Metals	Zn	Cyanide	Turbidity ^g
<i>MW-11</i>																	
Screen 5	8	December 1992 ^a	Westbay Sampler	--	--	--	0.029	--	--	--	--	0.20	--	0.050 Mo	0.100	--	22.0
Screen 5	9	March 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.17	--	--	0.070	--	6.5
Screen 5	10	July 1993	Westbay Sampler	--	--	--	--	--	--	--	--	0.22	--	--	0.035	--	11.5
Screen 5	11	October 1993	Westbay Sampler ^f	--	--	--	--	--	--	--	0.007(EB)	0.21	--	--	0.098	--	NA
Practical Quantitation Limit				0.005	0.05 ^e	0.01	0.01 ^e	0.2 ^e	0.002 ^{d,e}	0.002 ^e	0.005 ^d	0.01	0.001 ^{d,c}	0.05 ^e	0.020 ^c	0.005 ^e	--
Regulatory Threshold				0.05	1.0	0.05	1.0	2.0	100 ^c	0.05	0.006 ^c	UR	2.0 ^c	UR/Cd 0.01	5.0	0.2 ^c	--

Regulatory threshold concentrations derived from the California Code of Regulations, Title 26, Maximum Contaminant Levels for Drinking Water unless otherwise noted.

NOTES:

NA: Not applicable (not measured)

--: Not Detected

UR: Unregulated

(EB): Indicates metal also present in field equipment blank.

a: Equipment blanks were not analyzed for metals prior to Event #9.

b: Possibly attributed to particulate rust in sample.

c: EPA Drinking Water Standard.

d: During Event #8 the Practical Quantitation Limit for Tl was 0.10 mg/l for Sb was 0.05 mg/l, and for Ni was 0.04 mg/l.

e: During Event #1, the Practical Quantitation Limit for Ba was 0.01 mg/l, for Cd was 0.001 mg/l, for Co was 0.01 mg/l, for Cu was 0.02 mg/l, for Hg was 0.002 mg/l, for Mo was 0.01 mg/l, for Ni was 0.01 mg/l, for Pb was 0.005 mg/l, for Tl was 0.005 mg/l, for V was 0.02 mg/l, for Zn was 0.01 mg/l and for Cyanide was 0.02 mg/l.

f: Samples filtered in the field with a 0.45 micron filter (Event 11 only).

g: Value in nephelometric turbidity units (NTUs) measured in the field. Values for multi-port screens are average of before and after sampling measurements.

h: Turbidity before sampling at 29 NTUs. Based on previous experience with bailers turbidity was likely 100+ during most of sample collection. Turbidity not checked after sampling due to malfunctioning bailer.

TABLE 1-17

**RESULTS FROM MISCELLANEOUS ANALYSES PERFORMED DURING
THE PRE-RI JPL GROUNDWATER SAMPLING PROGRAM, 1990-1993**

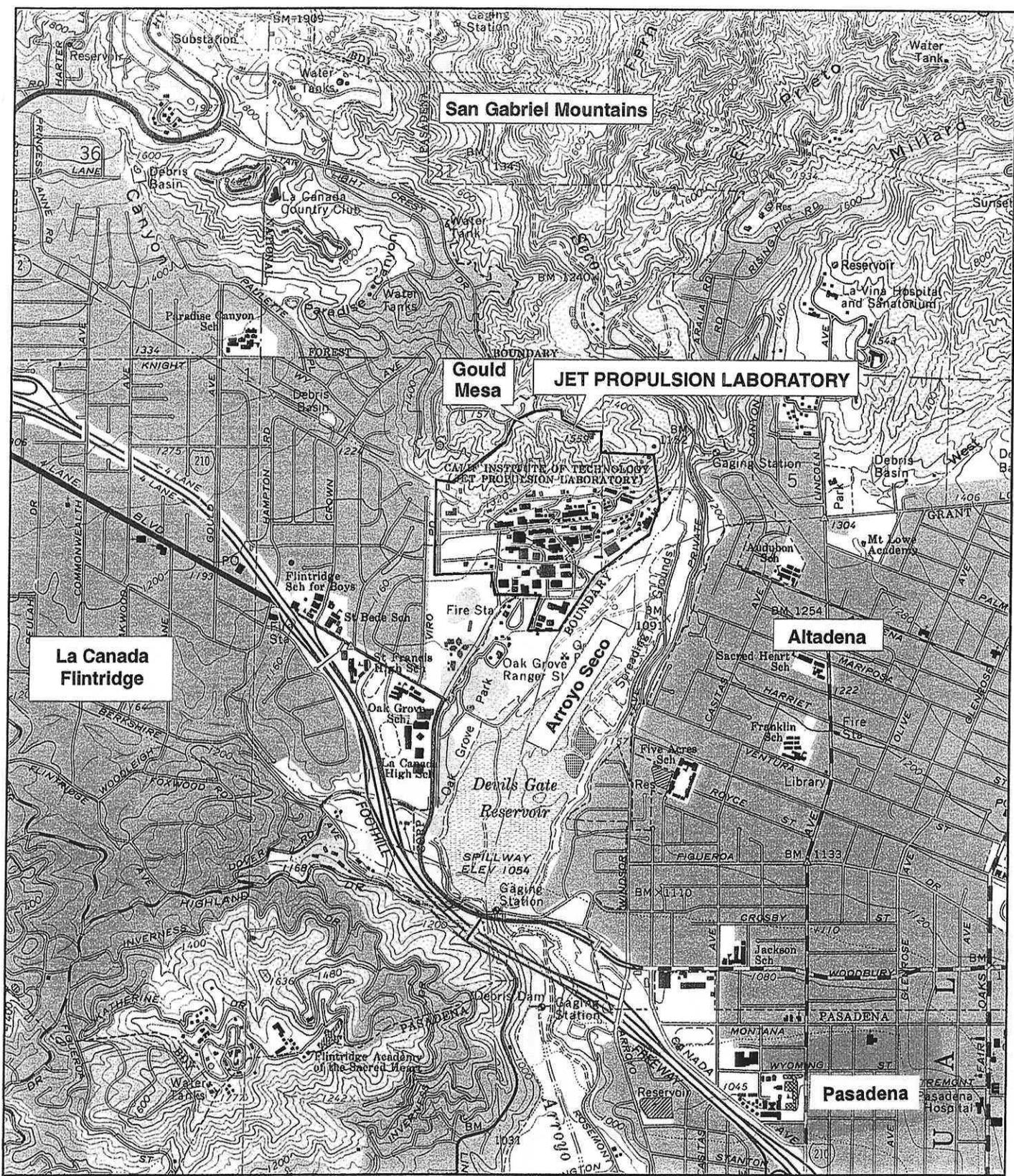
Monitoring Well No	Sampling Event 1	Sampling Event 4	
	Total Petroleum Hydrocarbons (mg/l)	Gross Alpha (pCi / l)	Gross Beta (pCi / l)
MW-1	NA	<11.1	8.6 ± 5.2
MW-3			
Screen 1 (top)	ND	<4.9	7.7 ± 2.8
Screen 2	ND	6.3 ± 4.4	10.1 ± 2.9
Screen 3	ND	<3.9	4.4 ± 2.1
Screen 4	0.5	4.7 ± 3.0	3.5 ± 1.8
Screen 5 (Bottom)	0.4	<1.3	<2.7
MW-4			
Screen 1 (top)	ND	<6.3	7.3 ± 3.4
Screen 2	ND	<7.2	<4.9
Screen 3	ND	<4.4	3.1 ± 2.0
Screen 4	ND	5.9 ± 3.4	3.8 ± 1.9
Screen 5 (Bottom)	0.5	<3.9	3.8 ± 2.1
MW-5	0.5	<9.1	<6.3
MW-5 (Duplicate)	NA	<28.1 ^b	<23.2 ^b
MW-6	2.0	<10.2	<7.1
MW-7	1.1	<6.4	4.6 ± 3.0
MW-7 (Duplicate)	NA	<6.9	<4.8
California MCL ^a	--	15	50
Federal MCL ^a	--	15	4 mrem/yr

ND: Not Detected.

NA: Not Analyzed

a: Maximum Contaminant Level.

b: The relatively high lower limit of detection (LLD) listed is attributed to analytical interference from relatively high suspended solids content in the sample collected by bailer.



San Gabriel Mountains

Gould Mesa

JET PROPULSION LABORATORY

La Canada Flintridge

Altadena

Pasadena

Figure 1-1

0 .5 mile

Scale
1:24,000



Source: USGS 7.5 Minute Topographic
Quadrangle, 1966, Revised 1994

Site Location Map
Jet Propulsion Laboratory

Explanation

Boring 1
 Boring Location and total depth drilled

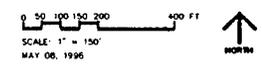
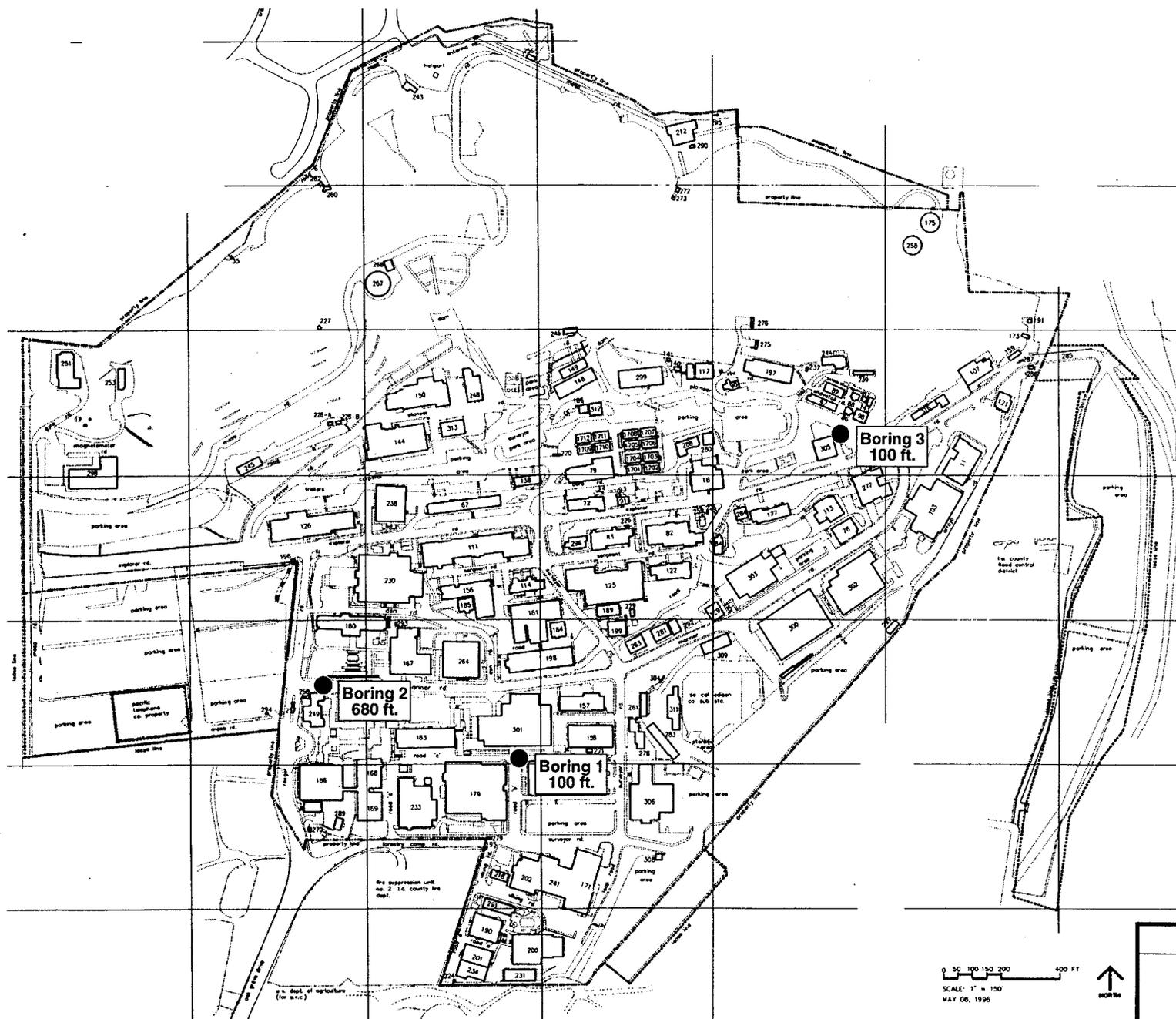
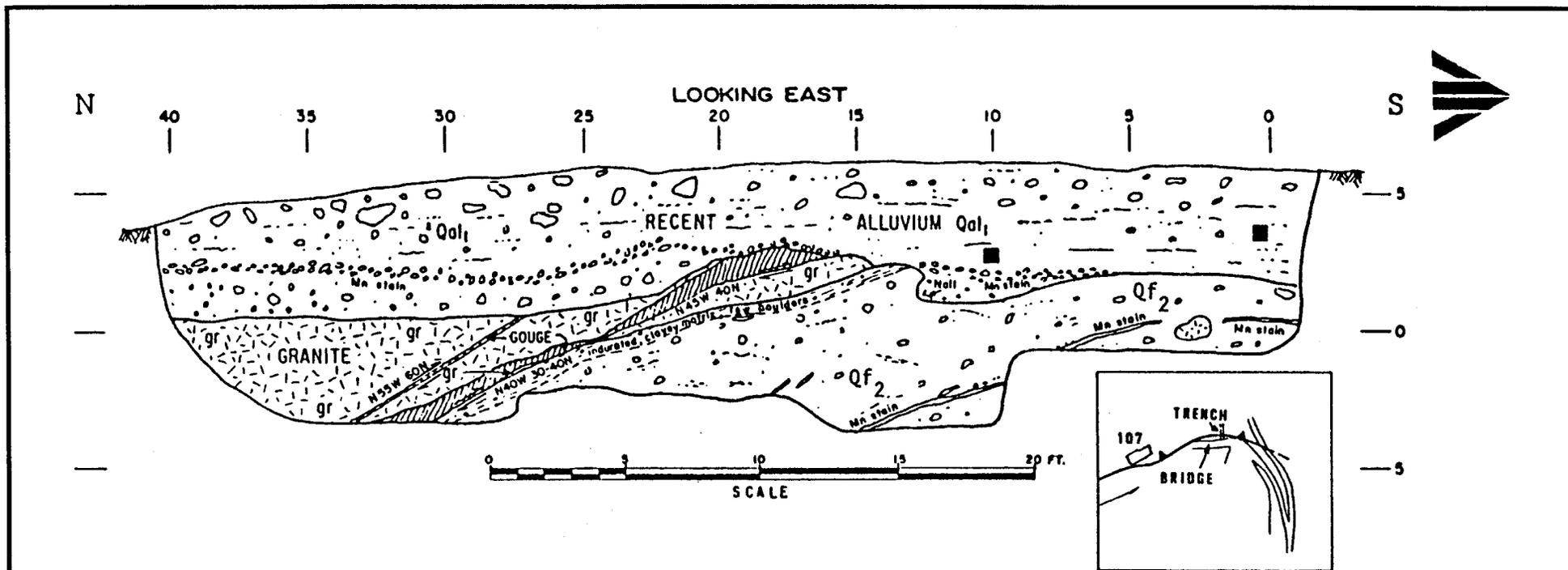


Figure 1-3

**Soil Boring Locations
 Referenced in Crandall and
 Associates (1977a)**

Jet Propulsion Laboratory
 Pasadena, California



SECTION VIEW: BACKHOLE TRENCH CUT IN ARROYO SECO, NORTH OF JPL BRIDGE;
BEARING N30°E; WIDTH, 30 IN.

Qal₁: Gray brown, crudely bedded (flat) pebble-to-boulder conglomerate. Boulders to 3 ft. Contains a distinct ~6-in. boulder bed, the bottom discolored by manganese stains. Two carbon samples (■) collected. Clasts include Lowe Granodiorite, Wilson Diorite, and a dark augen gneiss with porphyroblasts. Boulders are fresh. Large rusty nail found in scoured area at Station 12.

Qf₂: Brown to yellow-brown pebble to boulder fanglomerate. Boulders to 3 ft. Bottom of trench determined by refusal on large boulders. Moderately indurated. Wilson Diorite boulders highly weathered. Lowe Granodiorite fresh. Gneiss fresh. Contains another manganese stain layer. Bedding indistinct to crude,

variable shallow dips. Some diorite clasts appear smeared out. Attitudes of striations in dirt above dislodged boulder at Station 12 are N45E, 20°. A +12-in. well-indurated layer with clayey matrix just below granite contact. Stretched boulders are sub-parallel to faults.

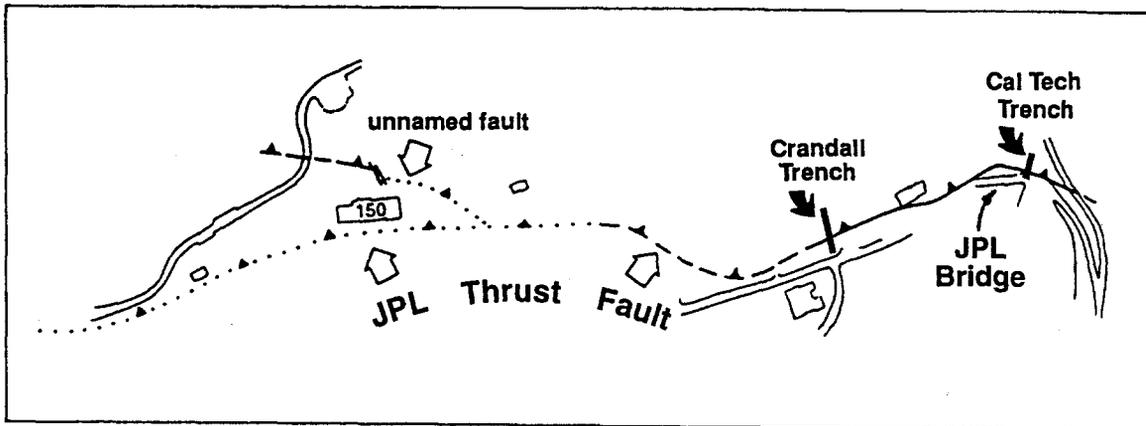
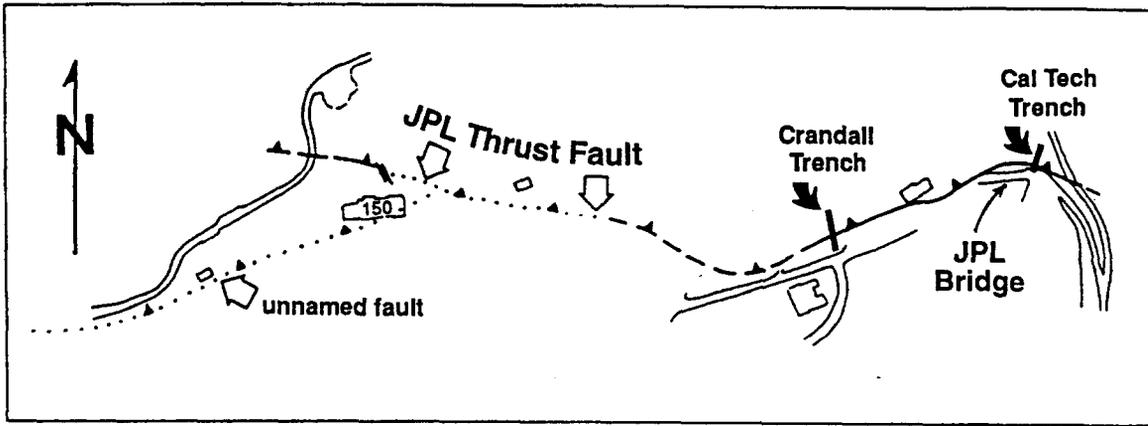
Gouge: Light green, brown, white, and gray clay. Banded in places. Contains some granite pebbles. Upper thin gouge zone is bisected by a plane containing abundant roots.

Granite: Pink to light green, fine-grained granite to quartz monzonite. Highly sheared and decomposed.

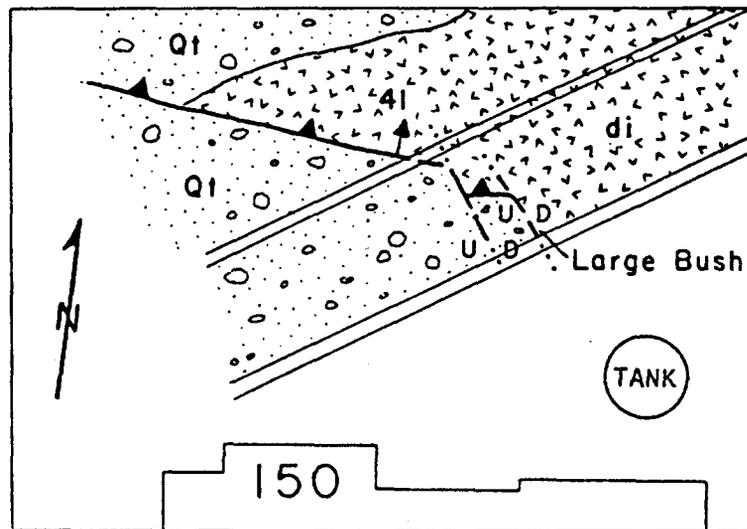
Figure 1-4

Cross Section of CalTech
Trench Across JPL Thrust Fault
(Agbabian1977)

Jet Propulsion Laboratory
Pasadena, California



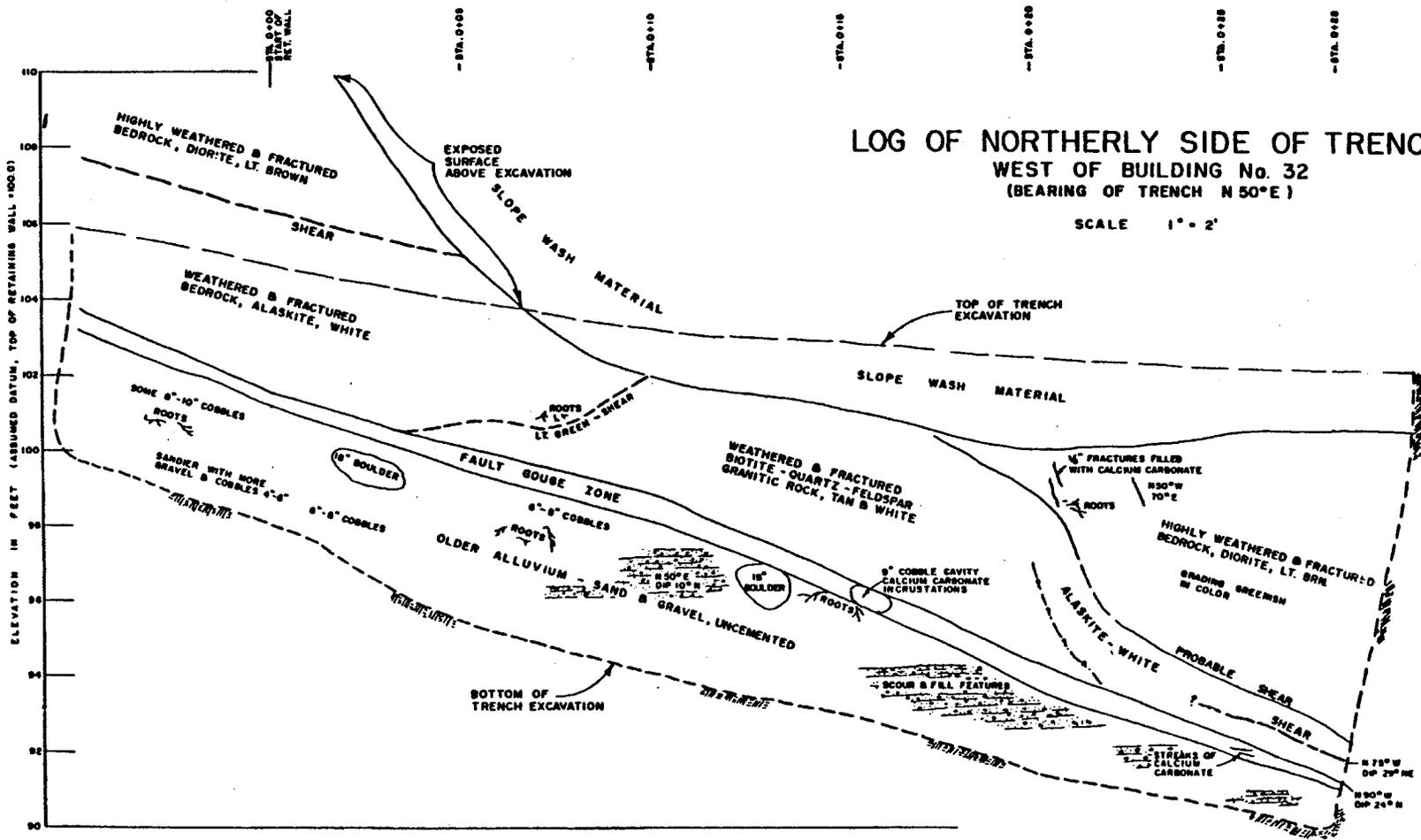
Alternative Interpretations of JPL Fault from Agbabian Associates, 1977.



Geologic Interpretations of Fault Pattern Exposed Behind Building #150; Agbabian Associates, 1977.

Explanation
di : diorite
Qt : Quaternary Terrace deposit
41 : Degrees of Fault Inclination

Figure 1-5
JPL Thrust Fault as Mapped by Agbabian Associates, (1977)
Jet Propulsion Laboratory Pasadena, California

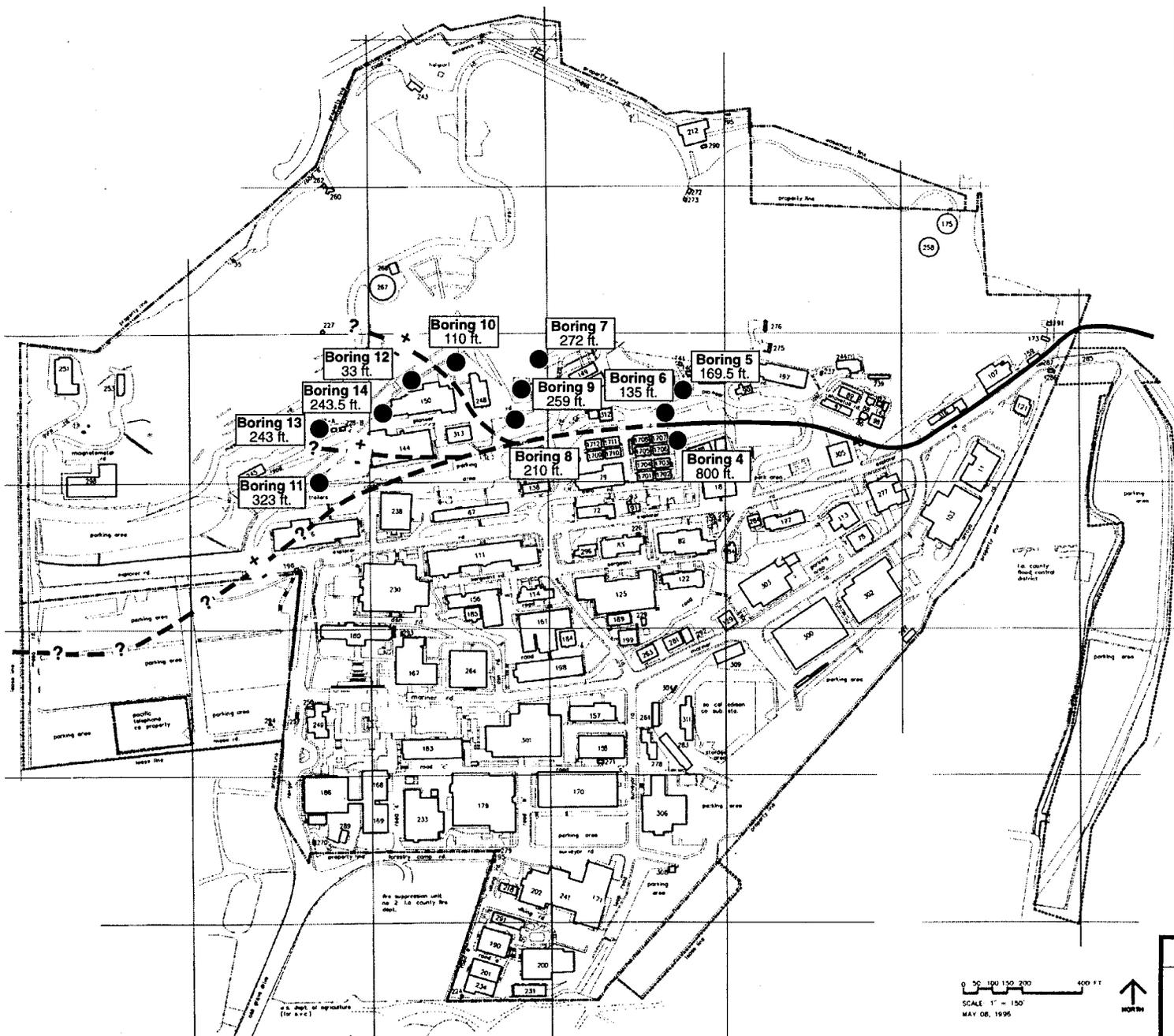


LOG OF NORTHERLY SIDE OF TRENCH
WEST OF BUILDING No. 32
(BEARING OF TRENCH N 50° E)
SCALE 1" = 2'

Figure 1-6
Cross Section of
Crandall and Associates
Trench Across the JPL
Thrust Fault (Agbabian 1977)
Jet Propulsion Laboratory
Pasadena, California

Explanation

- Boring Location and Total Depth Drilled
- ┌ Trace of JPL Thrust Fault (Crandall, 1977b)



0 50 100 150 200 400 FT
SCALE 1" = 150'
MAY OR, 1996



Figure 1-7

JPL Thrust Fault and Soil Boring Locations Referenced in Crandall and Associates, 1977b

Jet Propulsion Laboratory
Pasadena, California

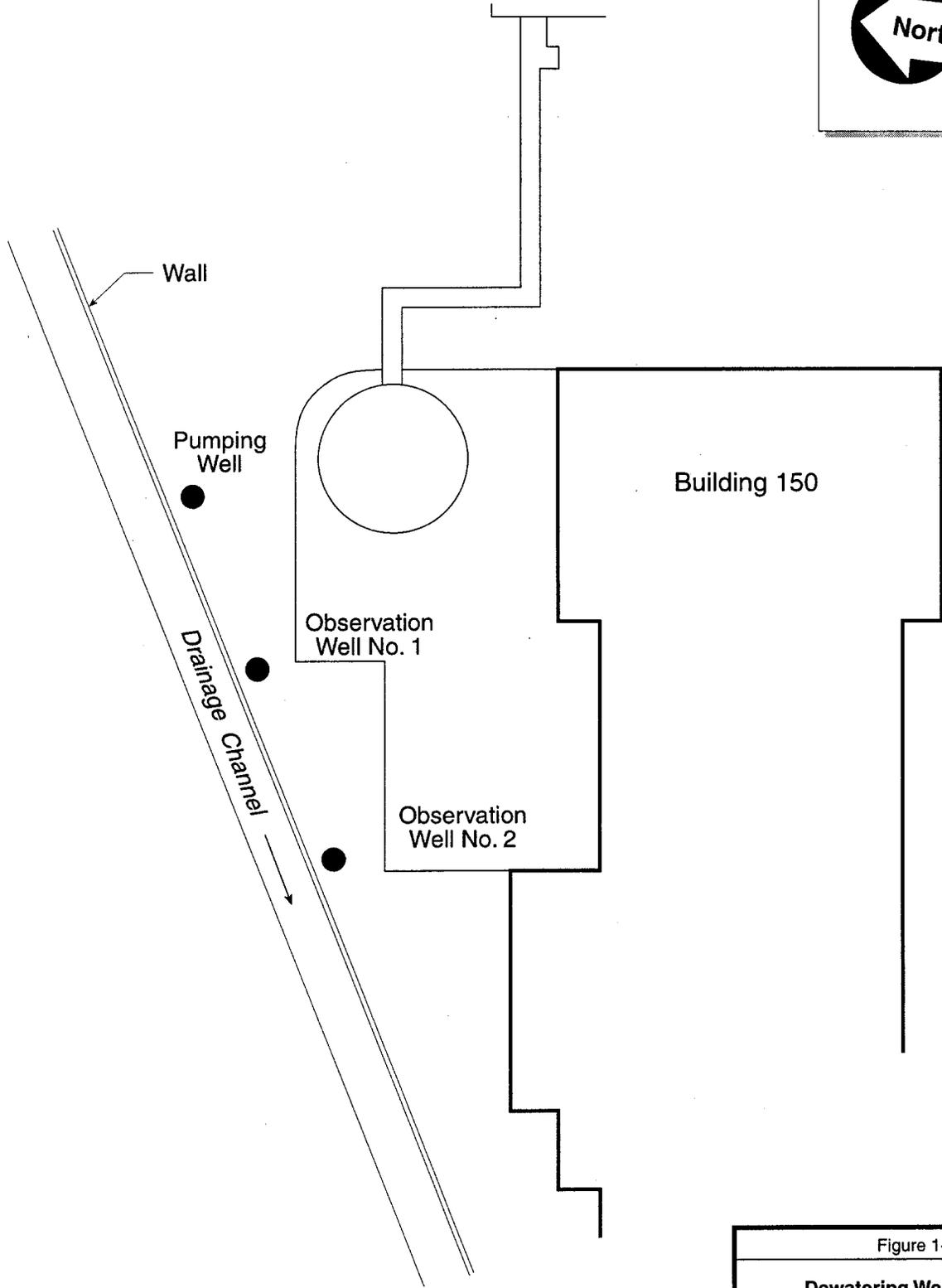
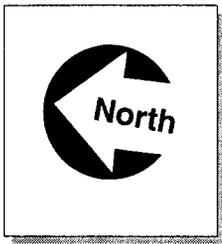
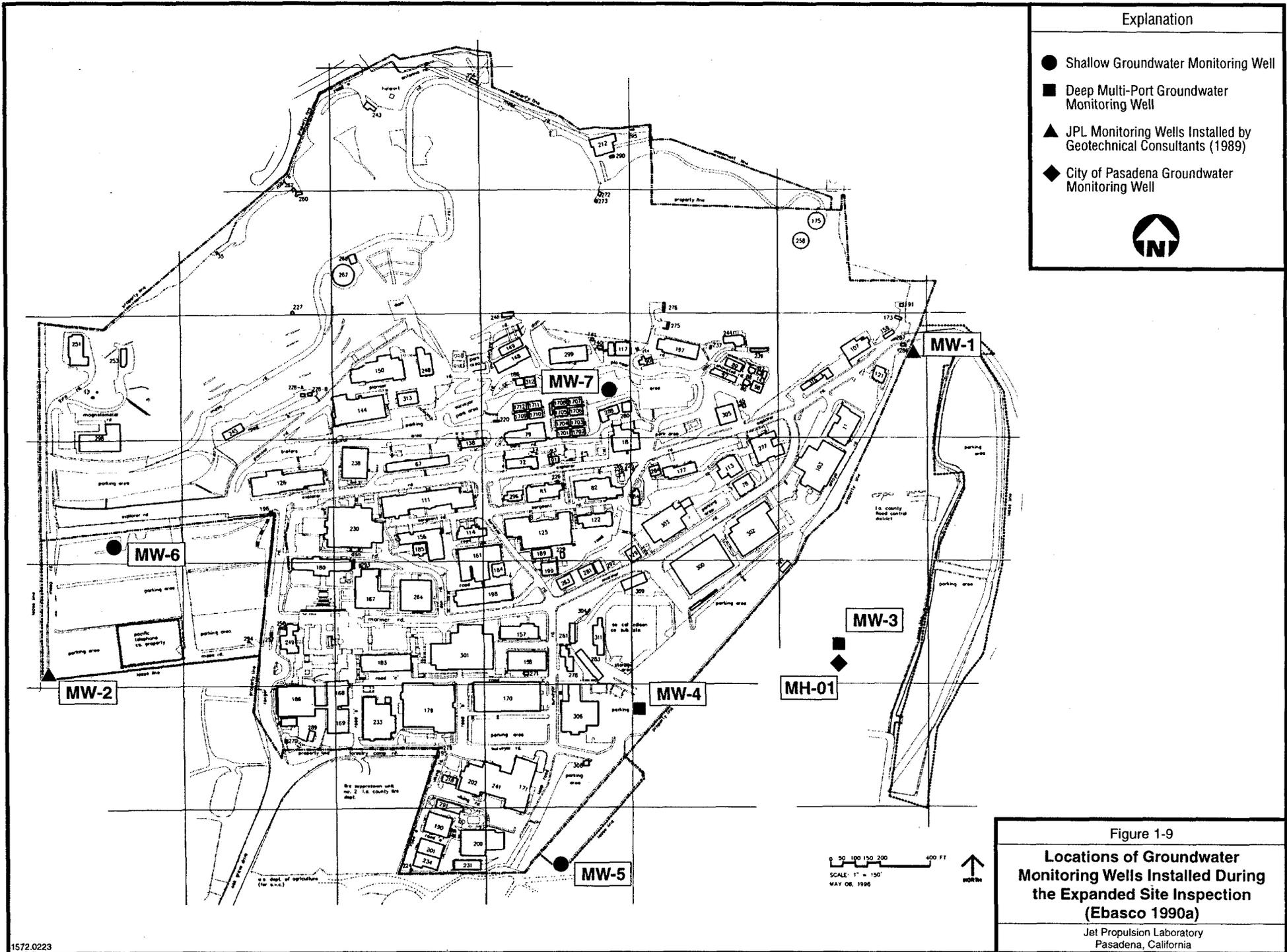


Figure 1-8

**Dewatering Well System
at Building 150
(Crandall, 1981)**

Jet Propulsion Laboratory
Pasadena, California



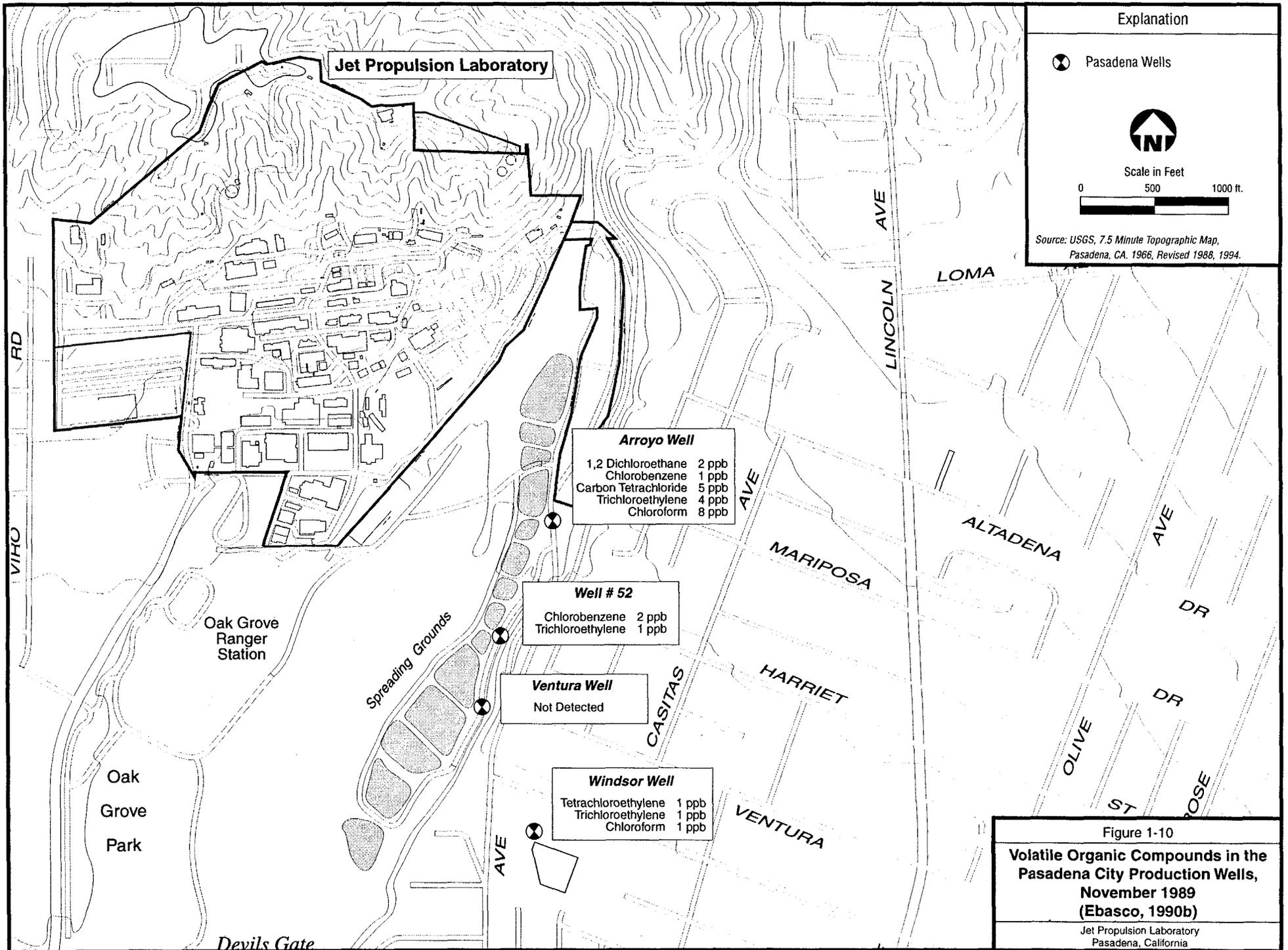
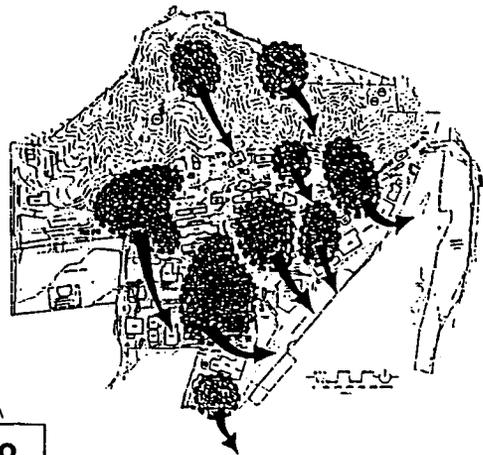
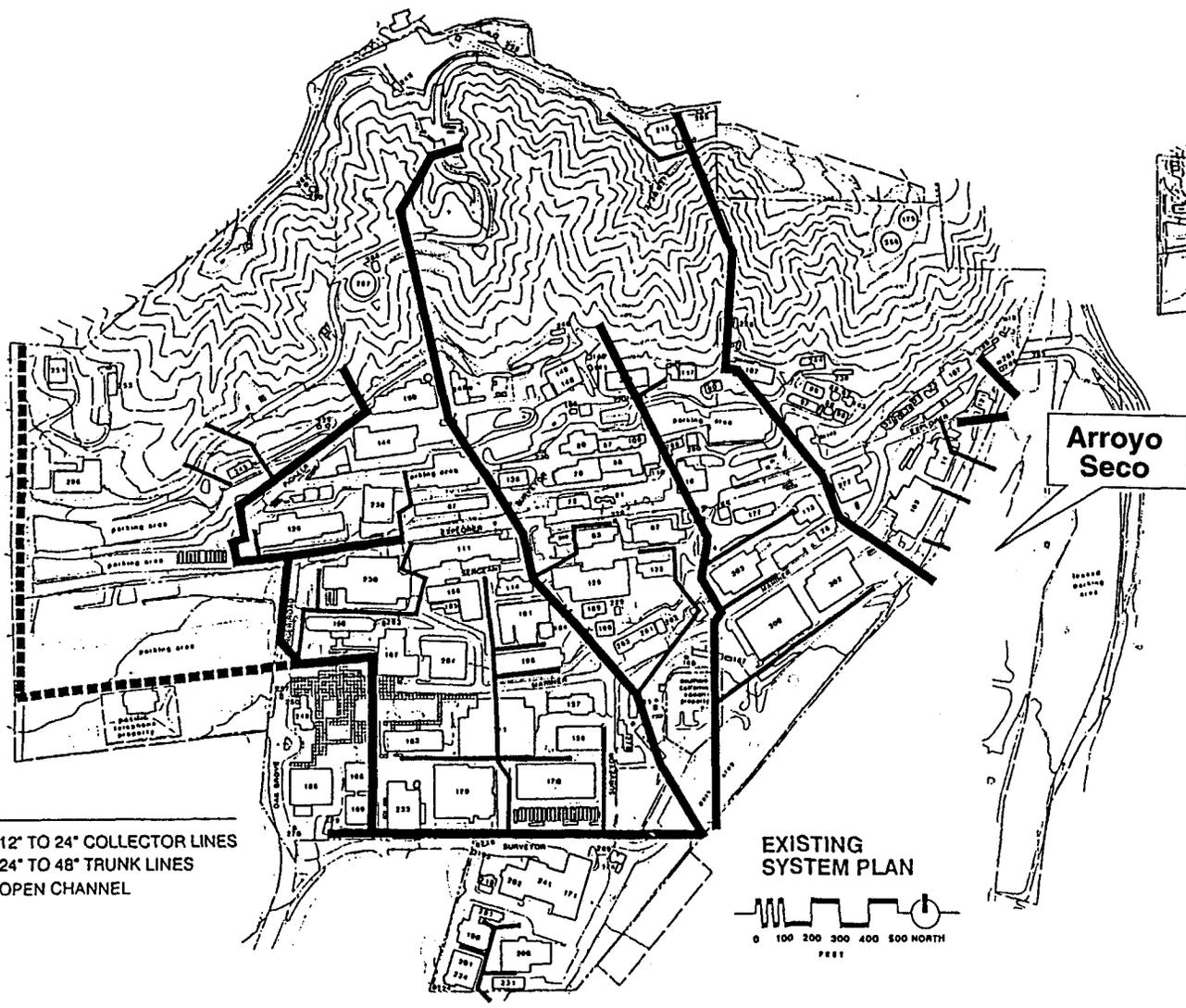


Figure 1-10

Volatile Organic Compounds in the Pasadena City Production Wells, November 1989 (Ebasco, 1990b)

Jet Propulsion Laboratory
Pasadena, California



LEGEND
 ——— 12" TO 24" COLLECTOR LINES
 ——— 24" TO 48" TRUNK LINES
 ■■■■■ OPEN CHANNEL

EXISTING SYSTEM SCHEMATIC LEGEND
 ■■■■■ TRIBUTARY AREA
 → FLOW COMPONENT

EXISTING SYSTEM PLAN
 0 100 200 300 400 500 NORTH
 FEET



From: Supplemental Information to the Expanded Site Inspection Report Dated November 1990

Figure 1-11
Storm Drain System at the Jet Propulsion Laboratory (Ebasco, 1990b)
 Jet Propulsion Laboratory
 Pasadena, California

Explanation

SD-01
● Sediment Sample Location

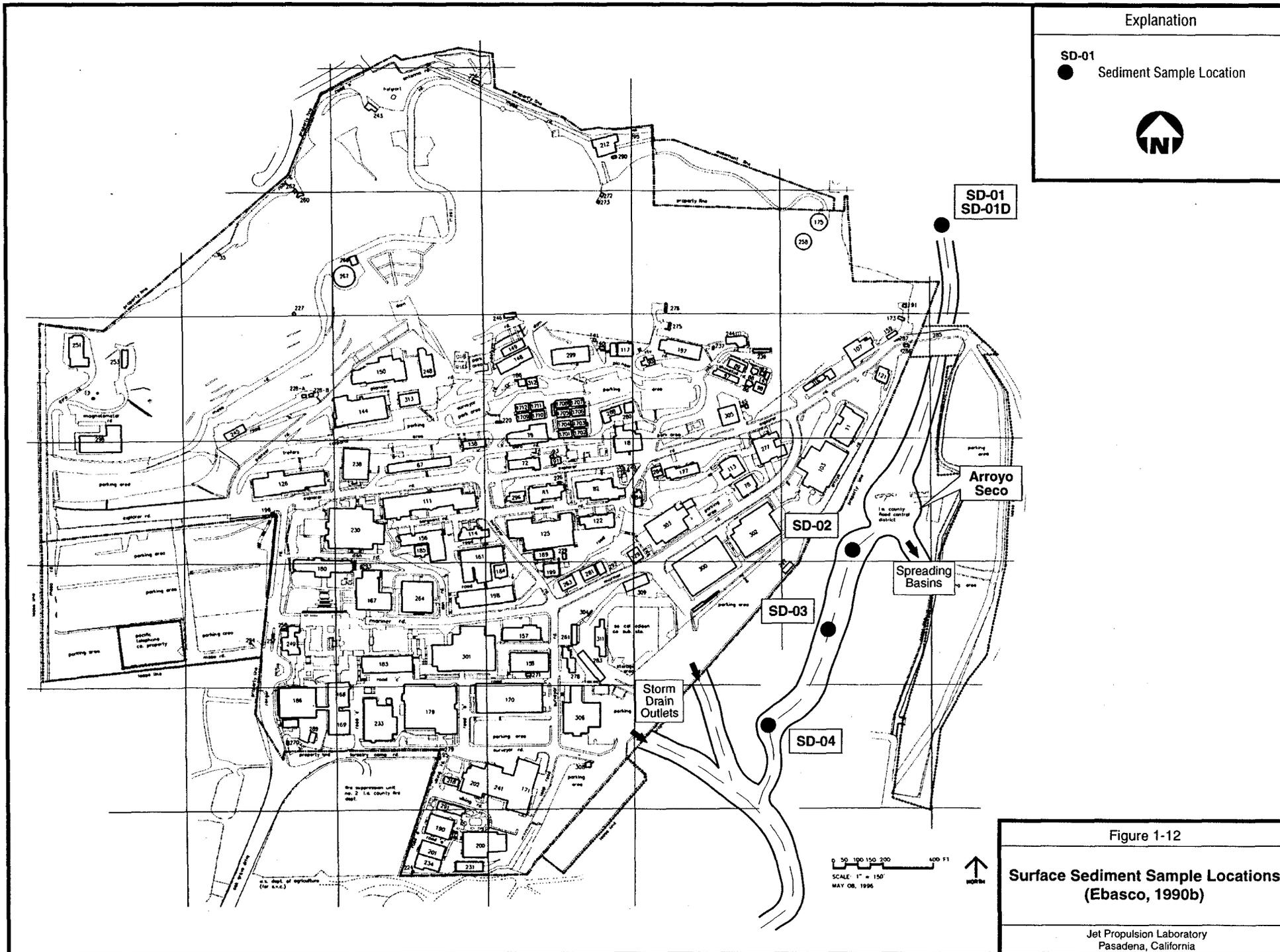
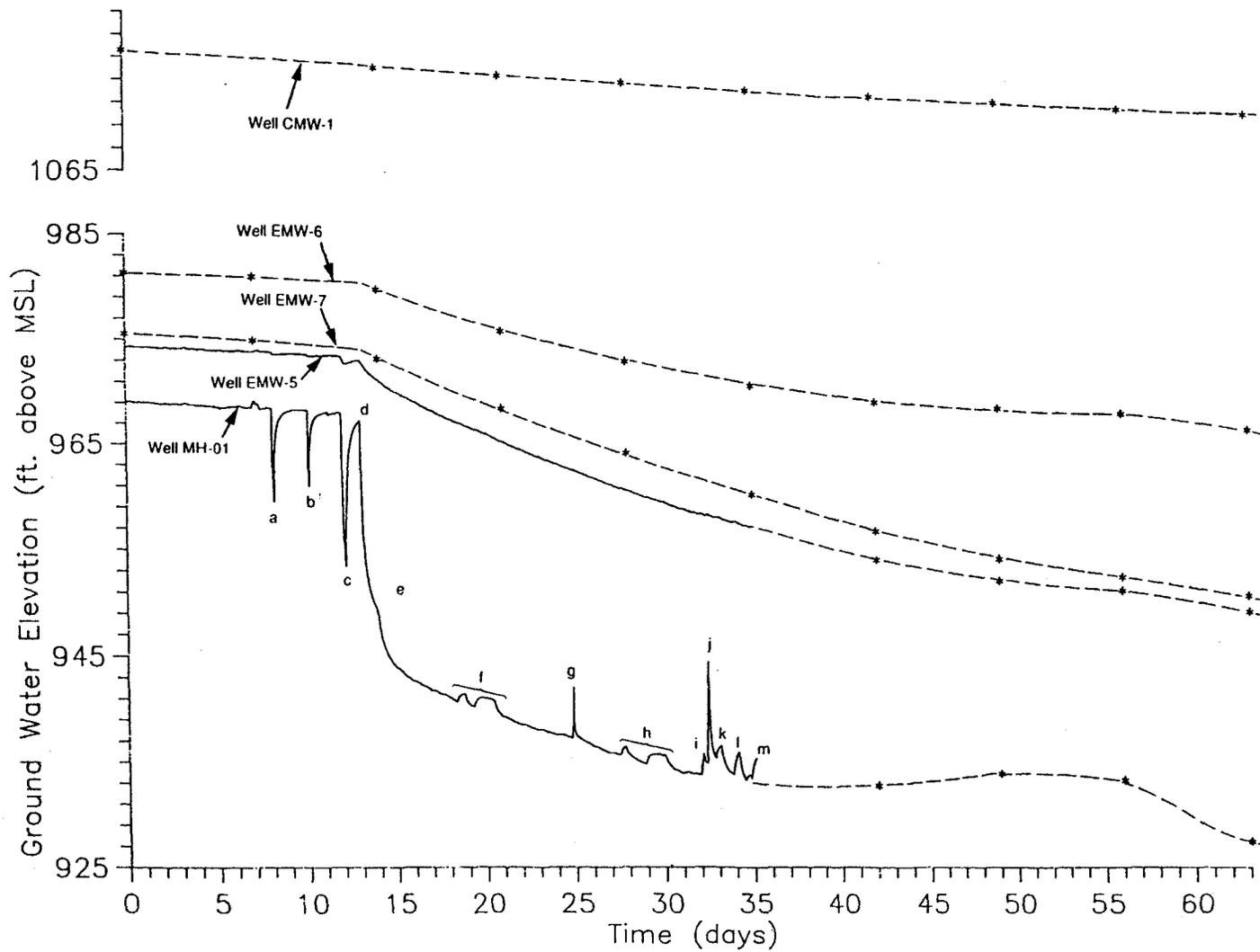


Figure 1-12

Surface Sediment Sample Locations
(Ebasco, 1990b)

Jet Propulsion Laboratory
Pasadena, California



Legend

- Data Collected with Pressure transducer
- * Water Level measurement collected manually
- a: Arroyo Well on/off
- b: Arroyo Well on/off
- c: Arroyo Well, Well #52, Ventura Well, and Windsor Well on/off
- d: Arroyo Well, Well #52, and Windsor Well on
- e: Ventura Well on
- f: Adjusting Flow Rate in Ventura Well
- g: Arroyo Well off/on
- h: Adjusting Flow Rate in Ventura Well
- i: Ventura Well off/on
- j: Arroyo Well, Well #52, Ventura Well, and Windsor Well off/on
- k: Ventura Well off/on
- l: Ventura Well off/on
- m: Ventura Well off

Figure 1-13

Groundwater Elevation vs. Time for Monitoring Wells at JPL During Start-up of City of Pasadena Groundwater Treatment Plant (Ebasco, 1990c)

Jet Propulsion Laboratory
Pasadena, California

Explanation

- Shallow Monitoring Wells
- ◐ Deep Multi-Port Monitoring Wells

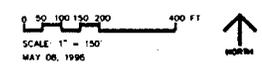
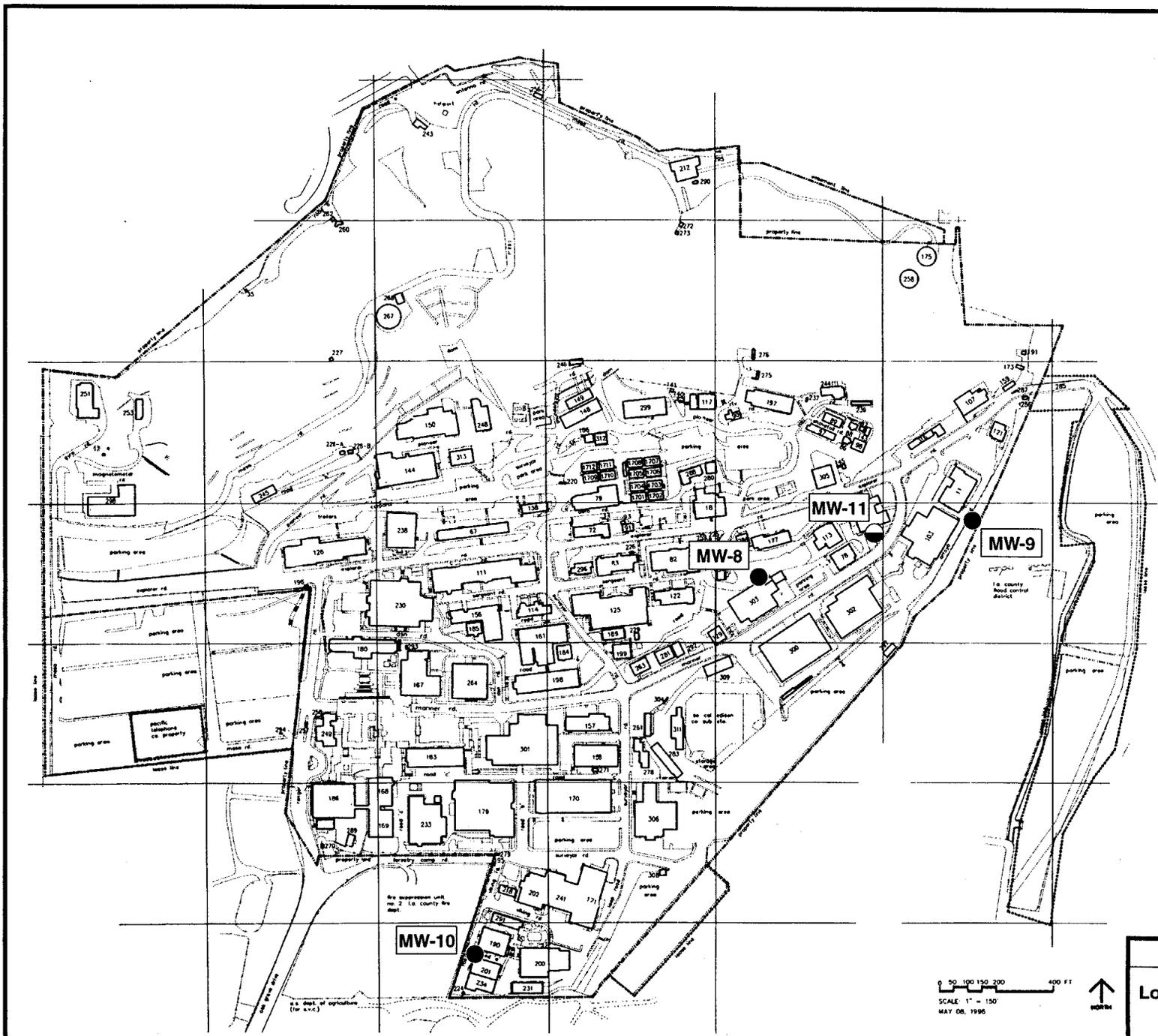


Figure 1-14
Location of Groundwater Monitoring Wells Installed During Pre-RI Investigation (Ebasco, 1993a)
Jet Propulsion Laboratory
Pasadena, California

Explanation

- Shallow Wells Installed by Geotechnical Consultants, Inc. (1989)
- Shallow Wells Installed by Ebasco (1990a)
- Shallow Wells Installed by Ebasco (1993a)
- Deep Multi-Port Wells Installed by Ebasco (1990a)
- Deep Multi-Port Well Installed by Ebasco (1993a)

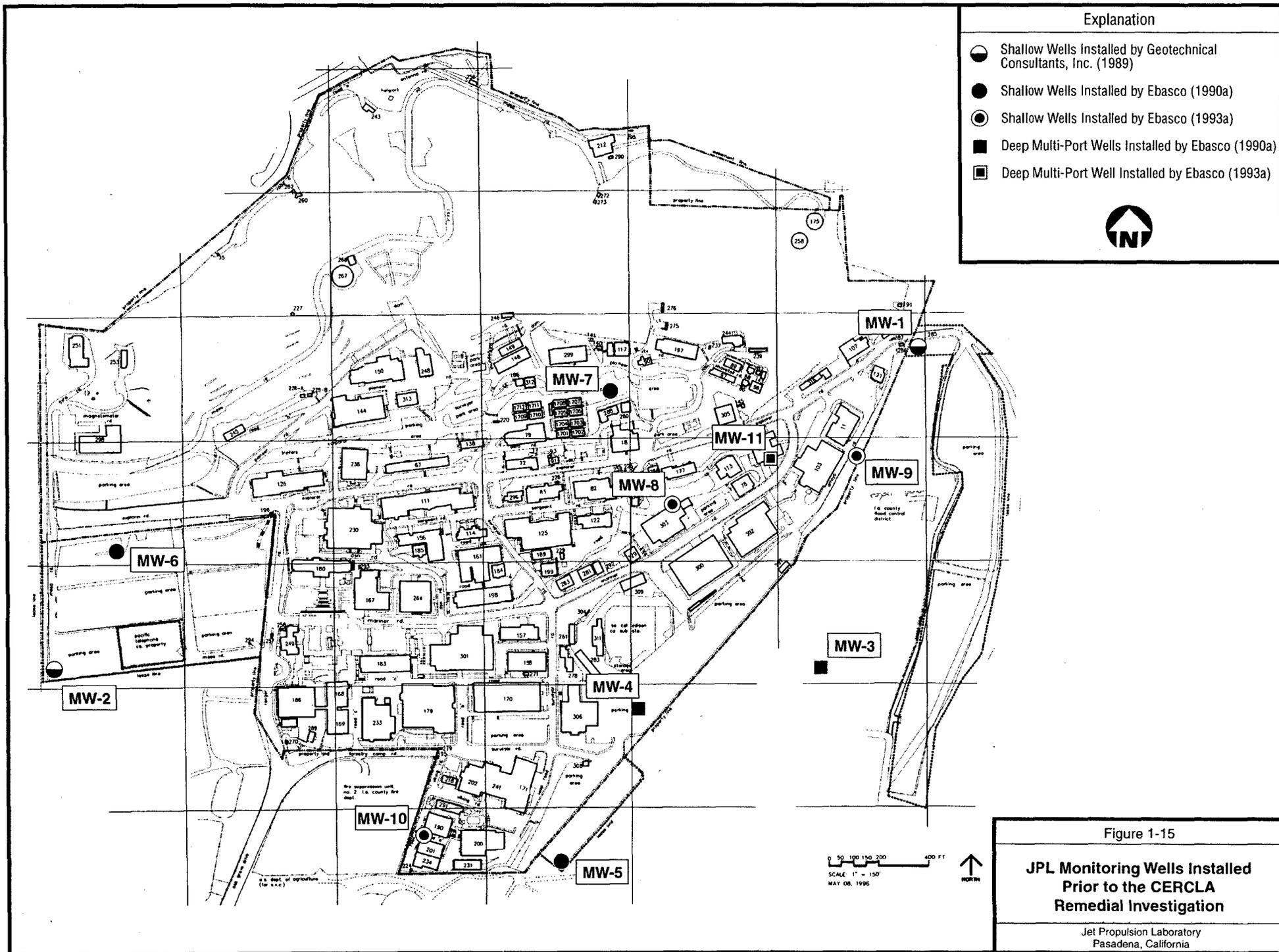


Figure 1-15

**JPL Monitoring Wells Installed
Prior to the CERCLA
Remedial Investigation**

Jet Propulsion Laboratory
Pasadena, California

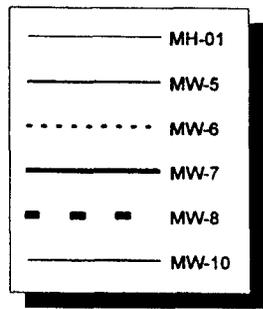
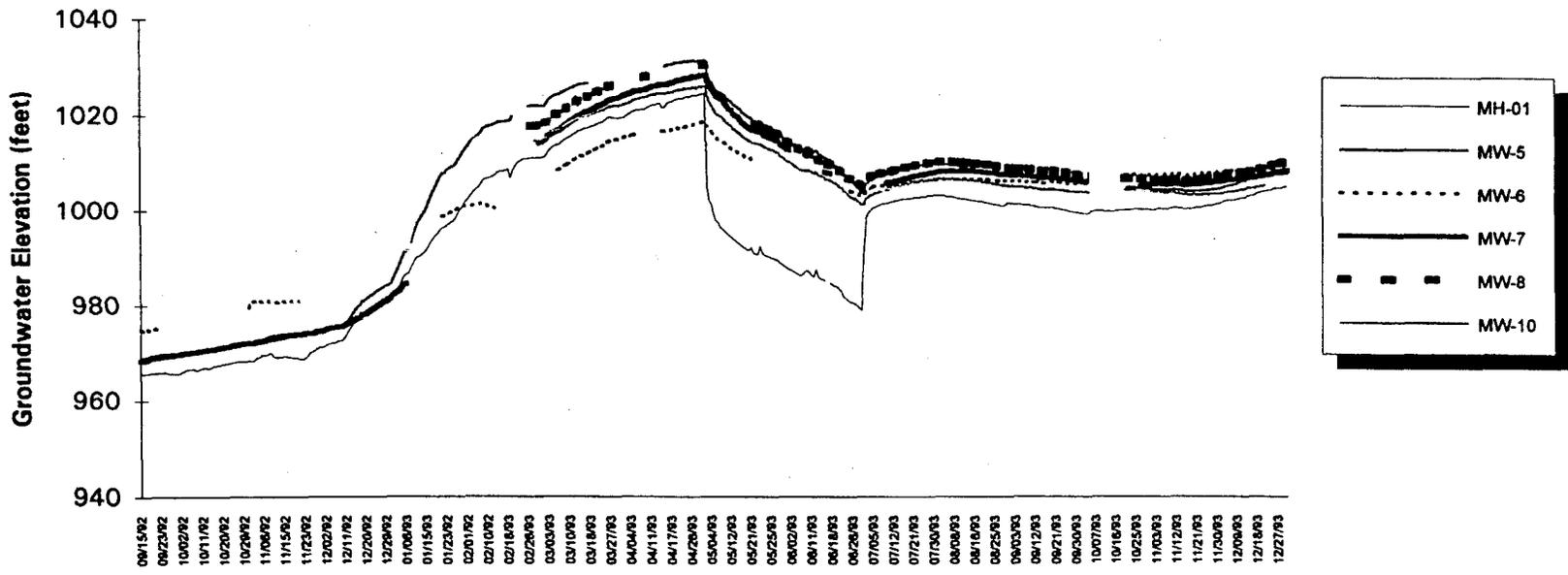
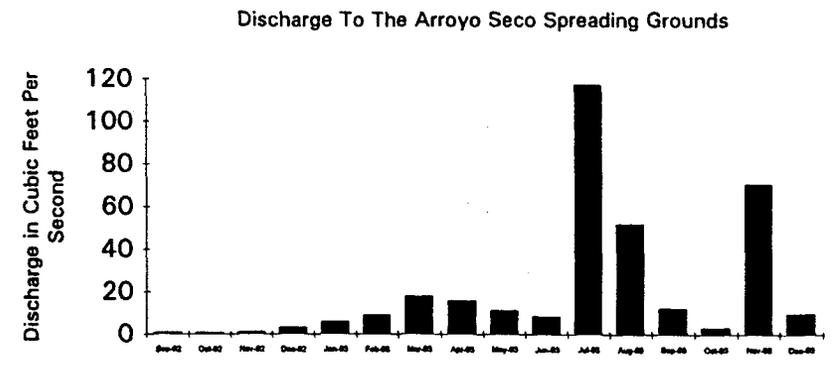
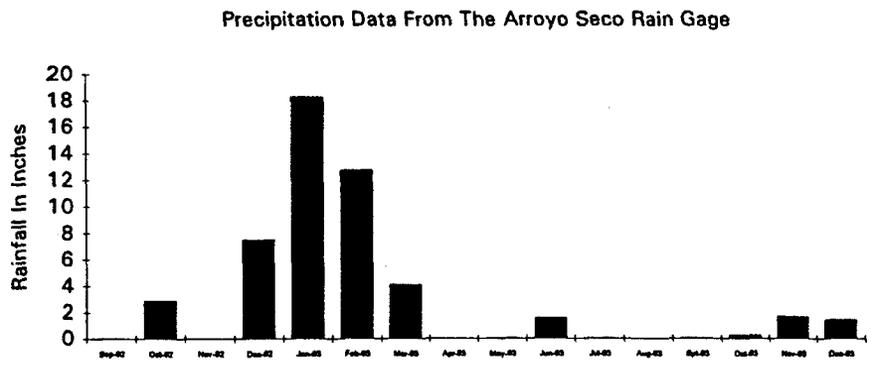
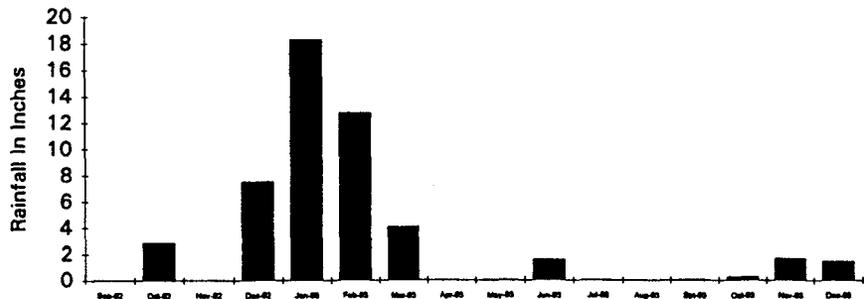
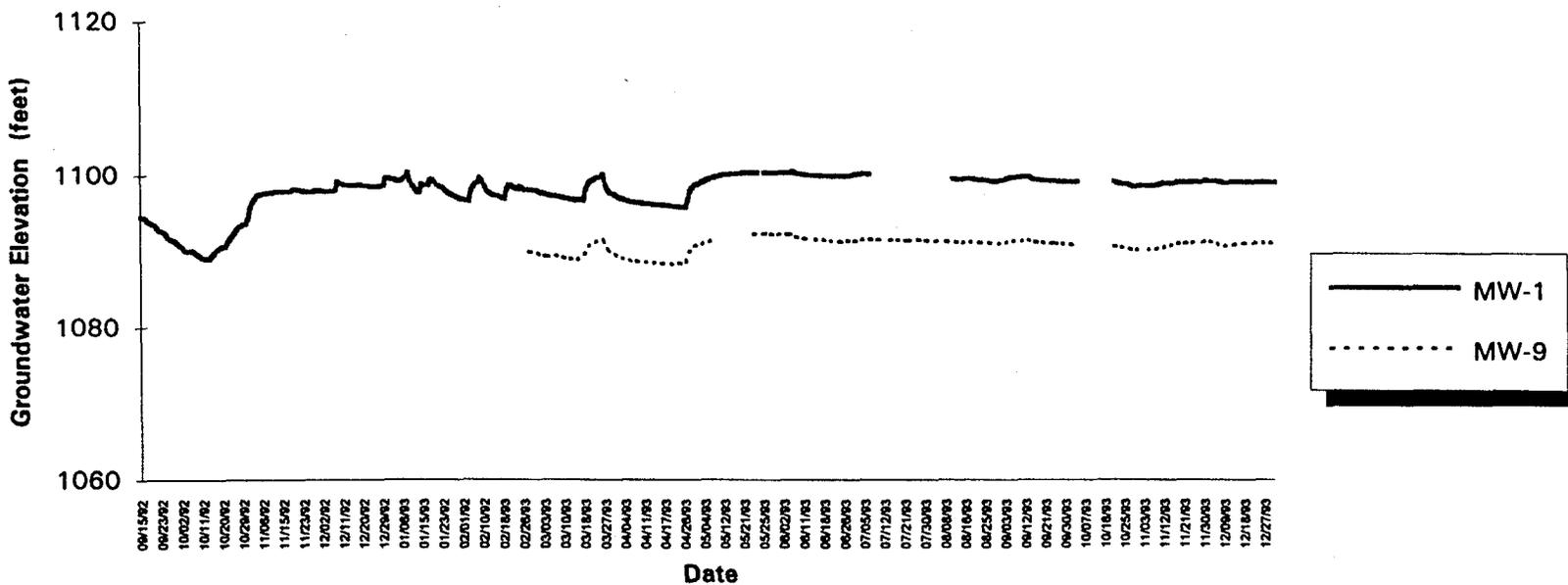
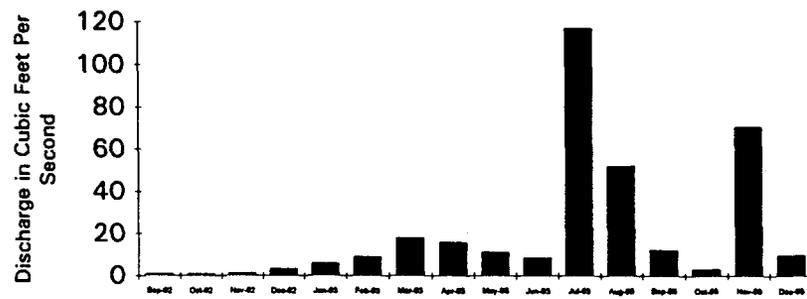


Figure 1-16
 Summary of Water-Level Data, Precipitation Data and Spreading Basin Recharge Data Between September 1992 and December 1993 for Wells MH-01, MW-5, MW-6, MW-7, MW-8 and MW-10
 Jet Propulsion Laboratory
 Pasadena, California

Precipitation Data From The Arroyo Seco Rain Gage



Discharge To The Arroyo Seco Spreading Grounds



— MW-1
 MW-9

Figure 1-17
 Summary of Water-Level Data, Precipitation Data
 and Spreading Basin Recharge Data Between
 September 1992 and December 1993 for
 Wells MW-1 and MW-9
 Jet Propulsion Laboratory
 Pasadena, California

2.0 GROUNDWATER INVESTIGATION

The RI activities were primarily designed to assess the nature and extent of the constituents of concern in the groundwater beneath and downgradient of JPL, provide data required for a baseline human health risk assessment, and obtain information required to complete the groundwater FS. The major components of this program included the following:

- Drill and install eight additional groundwater monitoring wells on-site (wells MW-12, MW-13, MW-14, MW-15, MW-16, MW-22, MW-23, and MW-24) and five groundwater monitoring wells off-site (wells MW-17, MW-18, MW-19, MW-20 and MW-21).
- Perform aquifer tests at each screened interval in each new groundwater monitoring well to assess the characteristics of the aquifer beneath and downgradient of JPL.
- Routinely record water levels in the JPL monitoring wells to further evaluate the groundwater flow system beneath and downgradient of the JPL site.
- Collect and analyze groundwater samples to assess the nature and extent of constituents of concern in the groundwater beneath and downgradient of JPL.

The details of the groundwater investigation field activities are provided in the following sections.

2.1 INSTALLATION OF GROUNDWATER MONITORING WELLS

During the OU-1/OU-3 RI, thirteen additional wells were added to the existing ten (10) well JPL groundwater monitoring well system. The locations of all JPL wells are shown on Figure 2-1 and a summary of construction details for all the JPL monitoring wells is included on Table 2-1. Three of the new wells were shallow completions and ten of the new wells were deep multi-port completions. The wells were constructed in a manner consistent with guidelines in "California Well Standards, Bulletin 74-90" (DWR, 1991) and applicable EPA guidance (EPA, 1986a and 1992a). Prior to initiating field activities, well permits were obtained from the County of Los Angeles Department of Health Services and Notice of Intent cards were submitted to the State of California Department of Water Resources-Southern District. Following the well installation, a well completion report form for each well was submitted to the State of California Department of Water Resources and details of each well installation were submitted to the County of Los Angeles Department of Health Services. Details on the shallow well and deep well installation activities are presented below.

2.1.1 Shallow Monitoring Wells

The following sections describe the drilling methods, well construction details, and well development procedures for the shallow monitoring wells. The three shallow monitoring wells installed during the RI field activities include MW-13, MW-15, and MW-16.

2.1.1.1 Drilling Methods

Shallow monitoring wells MW-15 and MW-16 were drilled with a percussion-hammer drilling rig that utilized dual-wall drive pipe and reversed-air circulation. Well MW-13 was drilled with an air rotary, casing advance, drilling rig. Wells MW-15 and MW-16 were drilled first with the dual-wall air percussion rig. Drilling was extremely difficult due to the abundance of large granitic boulders at well MW-16 and the decision was made to use air rotary drilling for installing well MW-13.

The dual-wall percussion method of drilling consisted of driving a double walled pipe with a diesel operated drive hammer while filtered air was forced downward through the annulus of the double wall drive pipe to the drill bit. The air returned upward through the inside of the drive pipe, bringing with it a continuous discharge of drill cuttings. The drive pipe consisted of two heavy wall pipes joined together (one suspended inside the other). A rubber O-ring was used at each joint to prevent the circulating air from escaping between the two pipes. The external flush jointed drive pipe was not rotated, but rather driven into the ground with the drive hammer which was rated at over 8,000 foot pounds of energy per blow at more than 90 blows per minute. Withdrawal of the dual-wall pipe was accomplished by a pulling system consisting of two 50 ton hydraulic cylinders operating a tapered slip arrangement which gripped the outside of the dual-wall drive pipe.

The air rotary with casing advance drill rig consisted of a retractable drill bit on the end of conventional drill pipe. The borehole was stabilized during drilling with a heavy wall, high tensile strength, threaded casing driven into the ground by a top-hole percussion hammer. Drill cuttings were continuously circulated out of the boring with air circulated down through the drill pipe and up through the annular space between the drill pipe and the drive casing. This drilling system is well suited for boulders, cobbles and gravel commonly encountered when drilling at JPL. Upon completion of drilling, the bit and drill pipe was removed and the well casing was lowered into the boring. The drive casing was slowly extracted by a hydraulic pulling system as well construction proceeded.

The outside diameter of the dual wall drive pipe used in wells MW-15 and MW-16 was 10-inches, and the outside diameter of the drive casing used at well MW-13 was 9 5/8-inches. All drill bits, drive pipe, and casing was steam cleaned before being used in each well boring. Drill cuttings circulated by air out of each boring went through a cyclone device to separate the cuttings from the discharged air before being collected in roll-off bins. The soil cuttings and the discharged air were routinely screened with a flame-ionization detector for organic vapors as required for health and safety purposes (see Health and Safety Plan (HASP) (Ebasco, 1993f)).

Grab samples of drill cuttings were collected from the discharge of the cyclone device after every 10 feet or less of drilling for lithologic descriptions. The lithologic descriptions of the soil cuttings were recorded on boring log forms (Appendix B), based on the Unified Soil Classification System and included the following information:

- Physical characterization and grain-size distribution.
- Stratigraphic boundaries.
- Apparent depth to groundwater.
- Color changes.
- Presence of moisture.
- Thickness of individual units.
- Any other conditions encountered during drilling (i.e., changes in drilling rate, difficulties, etc.).

Grab samples of soil cuttings were collected during drilling and analyzed to evaluate disposal options for the cuttings as described in Section 2.3, and shallow, relatively undisturbed soil samples were collected and analyzed during drilling to evaluate near surface soil conditions as described in Section 2.4.

2.1.1.2 Well Construction

The shallow wells (MW-13, MW-15 and MW-16) were constructed following guidelines in "California Well Standards, Bulletin 74-90" (DWR, 1991) and applicable EPA guidance (EPA, 1992a). Each shallow well is a standard standpipe type well with 50 feet of well screen. The relatively long screen length was required to sample contaminants at the surface of a water table that seasonally fluctuates significantly due to intermittent pumping of the nearby municipal water production wells and recharge from the nearby Arroyo Seco spreading grounds.

The typical design for the shallow monitoring wells is shown in Figure 2-2. The shallow wells were completed according to the following general procedures:

- The total depth of each well was determined by the NASA Authorized Subcontractor Operable Unit Manager (OUM) based on the water level encountered at each particular boring location.
- After drilling was completed at each well, a geophysical logging subcontractor performed a natural-gamma radiation survey (Appendix C) in each well for lithologic characterization and correlation purposes.
- Fifty feet of 4.0-inch diameter, stainless steel, wire wrap screen with 0.010-inch slots along with five feet of 4.0-inch diameter stainless steel blank casing (sand trap) with a bottom cap was lowered into each borehole through the middle of the dual-wall drive pipe, or drive casing, that was advanced during drilling.

The screen was attached to 20 feet of 4.0-inch diameter stainless steel blank transition casing and then to flush threaded 4.5-inch diameter schedule 80 PVC blank casing (MW-16) or 4.0-inch diameter schedules 40 PVC blank casing (MW-13 and MW-15). If the well was less than 250 feet deep, 4.0-inch diameter schedules 40 PVC casing was used. If the well was more than 250 feet, 4.5-inch diameter schedule 80 PVC casing was used. Before each section of screen and casing was lowered into each boring, they were

2.1.2 Deep Multi-Port Wells

The deep multi-port (MP) wells (MW-12, MW-14, and MW-17 through MW-24) were designed so that the aquifer could be sampled at five (5) separate vertical intervals from a single borehole. Identical wells have previously been installed at JPL (wells MW-3, MW-4 and MW-11) (Ebasco, 1990a and 1993a). The drilling methods, well construction details, and well development procedures for the deep wells installed during the OU-1/OU-3 RI are described in the following subsections.

Prior to drilling the wells, clearance of underground utilities was completed at each well location by a subcontracted geophysical company that specialized in providing such services. Four of the five off-site wells were located near residential neighborhoods and, pursuant to the JPL Health and Safety Plan (HASP) (Ebasco, 1993f), sound barriers were placed around each of these wells while site activities were in progress. In addition, when working off-site, soil cuttings were secured or removed from each site each day of drilling and a security guard was contracted to be on each site during all non-working hours.

2.1.2.1 Drilling Method

The new deep multi-port monitoring wells were drilled using either a direct or reverse circulation mud-rotary drilling rig. A pilot hole was augured between approximately 20 to 50 feet initially and a 14- to 20-inch diameter, low-carbon steel conductor casing was cemented in place before mud rotary operations began. Mud rotary drilling typically began with a 12.25-inch diameter tri-cone drill bit and continued to the total depth of each well. The drill bits, drill pipe and drive casing (reverse circulation drilling) were steam cleaned prior to use in each well. During mud-rotary drilling, pure bentonite drilling mud and hydrocarbon-free pipe dope were used.

The bentonite drilling mud was monitored for weight, viscosity, and sand content with a mud scale, marsh funnel and cup, and a sand content kit, respectively. The mud weight was kept below approximately 70-pounds/cubic foot, the viscosity between 40 and 60 seconds, and the sand content less than 4 percent. The mud properties were controlled by the driller to maintain hole stability, fluid loss, and equipment integrity. Mud-property data was recorded on the boring log forms (Appendix B) and any mud property found to be out of tolerance was adjusted back into tolerance.

De-ionized water was used to mix the bentonite drilling mud used during the mud-rotary drilling. The water was delivered to the site in bulk from the Sparkletts Drinking Water Company. Samples of the water were collected after each delivery either directly from the water truck or from the on-site storage tanks used to store the bulk water for analysis for VOCs using EPA Method 524.2. Table 2-3 summarizes the analytical results from these samples. The most common compounds identified were trihalomethanes, which are common by-products of water purification processes. The presence of these compounds in the de-ionized water used during drilling has not impacted the groundwater quality results obtained as part of the RI as reported in Section 4.0.

During drilling operations, the drilling mud was continuously circulated out of the boring to a shaker screen and through a de-sander to separate the drill cuttings from the drilling mud. Drill cuttings were then collected in roll-off bins. Grab samples of drill cuttings were collected during drilling for laboratory analyses to characterize the cuttings for disposal as described in Section 2.3.

Drill cuttings were inspected after every 5 to 10 feet or less of drilling and described to document the soil types and stratigraphy at each location. Lithologic descriptions of the soil cuttings were recorded on boring log forms (Appendix B) and included the following information:

- Physical characterization and grain-size distribution of the sample
- Stratigraphic boundaries
- Color changes
- Thickness of individual units
- Samples of cuttings collected
- Any other conditions encountered during drilling (i.e., changes in drilling rate, difficulties, etc.)

All soil descriptions were based on the Unified Soil Classification System. In addition to completing the boring logs, pertinent information relating to all aspects of well installation was recorded in bound field logbooks.

All drill cuttings and drilling fluids generated during the field investigation were collected and stored. The soil cuttings were placed in roll-off bins and the drilling fluids were stored in large 22,000-gallon Baker® tanks. Results of analyses of these materials were used to determine the proper disposal methods pursuant to EPA guidance on the management of investigation-derived wastes (EPA, 1991a and 1992b) (see Section 2.3).

2.1.2.2 Well Construction

The typical design for the deep monitoring wells is shown in Figure 2-3. The deep, multi-port wells were constructed according to the following general procedures:

- The total depth of each deep well was determined by the OUM and JPL based on the actual or estimated depth of the crystalline basement rocks at each location.
- After each well was drilled, a geophysical logging subcontractor (Welenco, Inc.) recorded an electrical log and a natural gamma radiation log in each open hole to aid in lithologic characterization, stratigraphic correlation, and in determining well screen locations. Copies of the geophysical logs are included in Appendix C.
- The five well screens for each deep well were initially located by evenly distributing them vertically across the aquifer. Then, based on the interpretation of the geophysical logs and the boring log, the screen locations were shifted up or down relatively small distances until they were located adjacent to the sandiest, or "cleanest", and therefore relatively most permeable sections of the aquifer. During previous investigations

(Ebasco, 1990a) it was learned that the resistivity curves most accurately reflect down hole lithologies. The sections of the borehole that appeared to have the best water-yield capabilities (sandiest) appeared to have the highest electrical resistivities. The character of the spontaneous potential curve log was normally subdued due to the fact that fresh-water drilling mud was used in a fresh-water aquifer. The amount of natural-gamma radiation recorded was commonly the result of both the amount of clay present (high potassium content) and the amount of granitic material present (high potassium feldspar and biotite content) rendering lithology determinations from the natural gamma ray log at times unreliable.

- The well casing, consisting of 4.0-inch diameter low-carbon-steel blank casing and five individual 4.0-inch diameter 10-foot lengths of stainless steel wire-wrap screens with 0.010-inch slots, was lowered into each hole. Some sections of the blank casing were cut to specified lengths to place the individual screens at the depths determined from review of the geophysical logs. Before the screens and blank casing were lowered into the boring, each section was measured and steam cleaned. The low-carbon blank casing was sand blasted before it was delivered to the site. Centralizers were used to keep the well casing in the center of the boring and were located above the bottom cap and within 1 to 4 feet of the bottom of each well screen.
- After the casing was lowered in place, bentonite seals and sand packs were tremied into place (Figure 2-3). A grout pump was used to circulate drilling fluid out of the boring and at the same time to pump backfill materials into the boring. The backfill materials consisted of sand, a bentonite seal consisting of 1:1 sand and bentonite mixture, and Volclay® bentonite chips or grout. Opposite the screened intervals, a clean, kiln-dried RMC Lonestar® #2/16 sand was used. Where a bentonite seal was required, a 1:1 mixture of pure bentonite granules and RMC Lonestar® #2/16 sand was placed in the boring. The backfilling procedure was carefully monitored with frequent depth measurements. Above the uppermost bentonite seal the borehole was backfilled with Volclay® bentonite grout or chips which were hydrated in place.
- A traffic box was installed at each well. Concrete was used to secure the traffic box slightly above grade in such a way as to direct surface runoff away from the well.

Initial well development began soon after the 4-inch casing was installed. Time was important at this point in the completion of the deep wells because the five screened intervals in each well had not yet been isolated from each other. Immediately after initial development, as described below in Section 2.1.2.3, the Westbay multi-port (MP) casing system was installed within the 4-inch steel casing. The MP system is a multi-level groundwater monitoring system capable of providing isolated access to each of the five screened intervals within each deep well. Each screened interval was isolated from the others with a minimum of two packers. The MP casing system consists of various components including 1.5- to 2.0-inch-diameter schedule 80 PVC blank casing, PVC couplings used to connect various casing components, PVC measurement-port couplings that allow access to the aquifer for pressure measurements and water sampling, PVC pumping-port couplings that allow access to the aquifer for well purging and hydraulic conductivity testing, and nitrile rubber inflatable packers that seal the annulus on either side of the measurement and pumping ports at each screened interval (Figure 2-4).

The basic concept of the MP system is simple. Valved ports were placed in the 4-inch steel casing opposite the well screens and isolated by packers. A sampling probe, which is lowered into the casing on a cable, is located opposite the desired port and, when activated, collects a groundwater sample from the desired screened interval.

Each MP casing component arrived on-site pre-cleaned with a non-phosphate detergent solution and packed in plastic bags for transport. Before the MP system was installed in each deep well, the components were organized and partly assembled in accordance with a casing installation log. The casing installation log was used to accurately place the packers and measurement ports at the desired depths.

The MP casing string was assembled by lowering the casing segments into the 4-inch steel casing by hand and attaching each successive segment to the adjacent coupling one at a time. Each coupling was pressure tested before it was placed into the hole to verify the integrity of the system during installation. To pressure test each coupling, a probe with two small packers was lowered into the casing so that the packers were located on each side of the coupling. The small packers were inflated and water was then injected under pressure into the casing opposite the coupling. If the coupling did not leak, it was lowered into the well. Once the MP casing was placed in each well, the nitrile rubber packers between screen intervals were inflated. The packers were inflated with water, one at a time, beginning with the lowest packer, using a down hole tool designed for this purpose. After installation, several additional QA/QC checks were performed. These checks included an initial pressure profile to confirm the operation of the measurement ports and to observe piezometric head differences across the packers to confirm that the packers were properly sealing the annulus. A representative of Westbay Instruments supervised the installation and performed the QA/QC checks for each deep well.

2.1.2.3 Well Development Procedures

Prior to the installation of the multi-port casing system in each deep well, initial well development procedures began in the 4-inch casing. The purpose of this initial well development procedure was to rid the screen sections of a majority of fines and drilling fluids, before the MP casing is installed, when relatively large volumes of development water could be obtained.

Each screened interval was swabbed using a rubber-disc swab tool. Sediments that accumulated in the bottom of each well were removed with a bailer. Following swabbing and bailing operations, each screened interval was individually purged, first with an airlift pump system and second with a submersible pump. Pumping was occasionally discontinued to surge the interval being developed. The screened interval being pumped was isolated from the other screened intervals in the well using nitrile rubber packers inflated with compressed nitrogen.

The progress of the development of each screened interval was measured by monitoring the physical and chemical properties of the water produced (pH, electrical conductivity, temperature and turbidity). When these properties approached stability (when two successive measurements

made approximately 3 minutes apart were within approximately 10 percent of each other), the screened interval being developed was considered ready for the installation of the MP casing. All equipment used during development procedures were steam cleaned before use in each well.

After this initial round of well development the MP casing was installed. Each screened interval was subsequently developed further using a small inertial pumping system (flexible plastic tubing with check valve at bottom connected to a reciprocating motor at the surface). Prior to commencing development activities in the MP casing, the piezometric head at each screen interval was measured and the water level inside the casing adjusted to ensure that formation water would flow into the casing when the pumping ports were opened for well development. Under no circumstances was water from inside the casing allowed to flow into the formation. The water level within the MP casing was adjusted by bailing, to assure that this condition was maintained during development activities at each screen interval. Each screened interval was developed by opening the pumping-port valve at that screen and purging water from the screen interval using the inertial pumping system. Pumping was occasionally discontinued to allow the discharge water to fall and lightly surge the formation. The physical and chemical properties of the development water were monitored and recorded on a well development/sampling log form.

The screen interval was considered developed when the pH, conductivity, temperature and turbidity measurements reached stability (when two successive measurements made approximately 3 minutes apart were within approximately 10 percent of each other) and the turbidity was measured near or below 5 NTUs. All pertinent events that occurred during well development activities were entered in bound field logbooks. A summary of the well development for deep wells MW-12, MW-14, and MW-17 through MW-24 are included in Tables 2-4 through 2-13, respectively.

The well development water was contained in 22,000-gallon Baker® tanks, the same tanks used to contain the used drilling mud. The water was stored until the appropriate method of disposal was determined pursuant to EPA guidelines on the management of investigation-derived wastes (EPA, 1991a and 1992b). See Section 2.3 for a discussion on the disposal of well development water.

2.2 GROUNDWATER SAMPLING

For the OU-1/OU-3 RI, groundwater samples have been collected from JPL monitoring wells a total of ten (10) times beginning in 1994. A summary of RI sampling events and analyses performed is included as Table 2-14. During sampling, the monitoring wells were sampled in order of increasing VOC content to minimize the potential for cross-contamination between wells. The shallow wells were sampled with dedicated 2-inch Grundfos Redi-flo2® submersible pumps. This method of sampling is recommended by EPA in "Resource Conservation and Recovery Act (RCRA) Groundwater Monitoring: Draft Technical Guidance" (EPA, 1992a) which updates technical information contained in EPA's Technical Enforcement Guidance Document (EPA, 1986a). The deep MP wells were sampled with specialized equipment provided by Westbay

Instruments, the manufacturer of the multi-port casing systems. The necessary equipment and procedures for the collection of groundwater samples from the groundwater monitoring wells are outlined below.

2.2.1 Equipment Utilized

The primary equipment used to sample the shallow groundwater monitoring wells at JPL included dedicated 2-inch Grundfos Redi-flo2® pumps, a pump controller, and a 220-volt generator. Sampling the deep multi-port monitoring wells required specialized pressure profiling and sampling equipment manufactured by Westbay Instruments, Inc. This equipment included a sampler probe and a pressure-profiling probe with surface control units. The field personnel using this equipment were trained by Westbay personnel to ensure proper equipment use. Copies of the detailed operations manuals for the Westbay sampling probe and pressure probe are included in the OU-1 and OU-3 FSAPs (Ebasco, 1993h and 1994b). A probe battery pack with charger, four 250-milliliter stainless steel sample bottles with fittings and coupling hoses, a reel with 1,000 feet of coaxial cable and appropriate connectors, a 110-volt generator, and a tripod with sheave and cable counter were also required to sample the MP wells.

2.2.2 Decontamination Procedures

All sampling equipment used in the collection of groundwater samples at JPL was decontaminated prior to use. This equipment includes, but is not limited to, 2-inch Grundfos Redi-flo2® pumps and the Westbay sampling equipment.

Pump Decontamination

The shallow groundwater monitoring wells at JPL are sampled with dedicated 2-inch Grundfos Redi-flo2® pumps. Before the installation of dedicated pump systems in new wells MW-13, 15, and 16, each pump was decontaminated and equipment blank was collected from each pump. The pumps were installed in 1994 shortly after the wells were installed.

The following decontamination procedures were used prior to installing the dedicated pumps:

- Clean the exterior surfaces of the pump and discharge hose with a solution of potable water and non-phosphate detergent (Liquinox®) and a solution of potable water and an acid detergent (Citranox®) followed by rinsing in potable water then deionized water.
- Remove the plug at the bottom of the pump and fill the coolant reservoir with fresh deionized water.
- Decontaminate the interior of the pump and discharge hose by first pumping a solution of potable water and non-phosphate detergent (Liquinox®) through the pump and discharge hose for 5 minutes, followed by pumping a solution of an acid detergent (Citranox®) and potable water through the pump and discharge hose for another 5 minutes. Second, rinse the interior of the pump and discharge hose by pumping potable water through the system for 5 minutes. Finally, rinse the interior of the pump and hose a second time by pumping deionized water through the system for 5 minutes.
- Collect equipment blank from the end of the discharge line of the pump.

Equipment blanks collected from the pumps installed in new wells MW-13, MW-15 and MW-16 were analyzed for VOCs (EPA Method 524.2), SVOCs (EPA Method 8270), Title 26 metals plus strontium (EPA Methods 6010/7000), hexavalent chromium (EPA Method 7196), cyanide (EPA Method 335.3), and gross alpha/gross beta (well MW-13 only). The analytical results from the equipment blanks from all three pumps contained very low levels of copper and zinc, and the equipment blank from the pump for well MW-16 also contained very low levels of strontium and chloroform. After reviewing the results of the groundwater sampling program (presented in Section 4.0), the constituents detected in the equipment blanks did not have any influence on the groundwater sample results.

Westbay Sampler Decontamination

The Westbay sampling probe and sample bottles were decontaminated prior to sampling each screened interval in the deep MP wells. In addition, one equipment blank sample was collected from the Westbay sampling bottles each day of sampling. The Westbay stainless steel sample bottles, the Westbay sampling probe, and the valves and Teflon®-lined hoses connecting the sample bottles were decontaminated by the following procedures:

- Wash each 250-ml stainless steel sample bottle in a solution of non-phosphate detergent (Liquinox®) and deionized water followed by washing each bottle in a solution of an acid detergent (Citranox®) and deionized water. The interior surfaces of the bottles were washed by pushing lint-free paper wipes (such as Kim Wipes®) through them with a clean wooden dowel. The exterior surfaces of the bottles were scrubbed using a clean plastic brush.
- Rinse each bottle twice with deionized water.
- The interior surfaces of the Westbay sampling probe, and the hoses and valves associated with the Westbay sample bottles were decontaminated by forcing several volumes of a non-phosphate detergent (Liquinox®) and deionized water solution through them followed by forcing several volumes of an acid detergent (Citranox®) and deionized water solution through them with a clean plastic squeeze bottle used only for this purpose.
- All parts were rinsed by forcing several volumes of deionized water through them using a clean plastic squeeze bottle used only for this purpose.

2.2.3 Well Purging Procedures

Purging before sampling is not required in the deep multi-port monitoring wells because the groundwater is not exposed to the atmosphere. However, the first sampler volume of groundwater retrieved from each screened interval in the multi-port wells was not collected for chemical analyses. This volume of water was used to measure pH, conductivity, temperature and turbidity of the groundwater prior to sampling. The well purging procedures discussed below were used only at the shallow monitoring wells during sampling at JPL.

Prior to sampling each shallow well, the depth to water and the total depth to the bottom of each well was measured and entered on a well development/sampling log form. The depths were measured to the survey mark placed at the top of the casing in each well.

Before groundwater samples were collected in each shallow monitoring well, it was necessary to purge each well. Purging of the shallow wells was completed by pumping with the dedicated pumps. The temperature, pH, electrical conductivity and turbidity of the water removed from each well were continuously monitored during pumping. After the measured temperature, pH, and electrical conductivity of the purged water had stabilized (when two successive measurements made approximately 3 minutes apart were within approximately 10 percent of each other), and the turbidity was less than 5 NTUs, the well was ready for sampling.

The dedicated pump in each well was positioned 3 to 6 feet below the water level prior to purging. This was accomplished by pulling the pump up from the bottom of the well (where it is positioned between sampling events) and anchoring the pump at the appropriate depth. The electrical connections between the pumping system, the pump controller and the generator were then made.

The pump discharge hose was connected to a multi-probe water-monitoring chamber (flow-through box) containing probes from the various field instruments used to monitor the pH, temperature, and conductivity of the purge water. Groundwater samples were not collected downstream from the flow-through box. The groundwater purged from each shallow well was contained in 500 or 1,000 gallon polyethylene storage tanks for later disposal pursuant to EPA guidance on the management of investigation-derived wastes (EPA, 1991a and 1992b) (see Section 2.3).

When all electrical and plumbing connections were made, the pump was turned on. The time at which the pump was turned on and the rate at which water was purged from the well were recorded on a well development/sampling log form. When it was determined that groundwater representative of aquifer conditions was being purged, groundwater samples were collected. During sampling for VOCs, the pump rate was reduced below approximately 100 ml/min (milliliters/minute) (0.03 gal/min (gallons/minute)) to minimize sample agitation. All information concerning sampling was noted on well development/sampling log forms.

2.2.4 Measurement of Field Parameters and Field Instrumentation Calibration

During groundwater purging activities in the shallow monitoring wells, measurements were made of the temperature, pH, specific conductivity and turbidity of the groundwater. Since purging was not required in the deep multi-port monitoring wells, these parameters were measured before and after each sample were collected from these wells. The time and measured value of each of these parameters was recorded on well development sampling log forms.

When using the flow-through box, temperature, pH and specific conductivity probes were installed through the ports in the box to continuously measure these parameters. Aliquots of groundwater were collected routinely from the discharge line of the pump for turbidity measurements.

The instruments used to measure the temperature, pH, specific conductivity and turbidity of the groundwater met the measurement standards specified in the Quality Assurance Program Plan (QAPP) (Ebasco, 1993g). These instruments were all battery powered and appropriate for use in a field environment. For a more complete discussion of the field instruments see the OU-1 and OU-3 FSAPs (Ebasco, 1993h and 1994b).

Periodic maintenance and calibration of field instruments were completed as specified by the instrument manufacturer. Copies of operation manuals, and any calibration certifications, were kept with the instrumentation in the field.

Field calibration, or standardization, of the instruments used was performed at the beginning of each day of sampling and checked again at the end of each day of sampling, and recorded on specific forms. These calibrations, or standardizations, were completed according to manufacturer specifications.

2.2.5 Collection of Groundwater Samples

Ten separate groundwater-sampling events were completed during the OU-1/OU-3 RI during which the analytical suite occasionally changed (Table 2-14). Groundwater samples collected from JPL monitoring wells were either routinely or periodically analyzed for VOCs, SVOCs, all or select Title 26 metals, strontium, hexavalent chromium, aluminum, cyanide, TPH (well MW-4 only), gross alpha/gross beta (well MW-13 only), perchlorate, tributyltin (select wells) and general minerals (major anions and cations). The analytical methods used during the RI by the laboratory are summarized in Table 2-15 along with the containers used, detection limits, and sample preservatives. The sample container requirements were designed by the subcontracted State of California certified laboratory (Montgomery Watson Laboratories) to minimize sample volume required, but at the same time not jeopardize the integrity of the sample or the analyses as required by EPA guidance. Collecting extra, unnecessary volumes of groundwater from the deep multi-port wells is very time consuming and costly.

The order in which samples were collected is specified in "RCRA Groundwater Monitoring Draft Technical Guidance" (EPA, 1992a). Groundwater samples for VOCs were collected first, SVOCs second, TPH (well MW-4 only) third, Title 26 metals, hexavalent chromium, aluminum, tributyltin and strontium (includes major cations) fourth, cyanide fifth, major anions sixth and radioactivity (well MW-13 only) and perchlorate seventh. When samples for VOCs were collected through the 2-inch Grundfos® sampling pump, the flow rate was reduced to approximately 100 ml/min or less to prevent the loss of volatiles. The sampling point on the pump discharge hose was held as close as possible to the sample container, but was not allowed

to contact the sample container. The stream of water from the sampling device flowed smoothly, with no turbulence, onto the inside wall of the sample container to minimize sample agitation. All sample bottles were filled completely and not allowed to overflow, capped, labeled, and placed in a cooler with ice immediately after sample collection. Samples collected for VOCs had zero headspace.

During the initial OU-1 and OU-3 RI sampling events (Table 2-14) one set of samples for metals and hexavalent chromium analyses were sent to the laboratory unfiltered and a second set of samples for metals and hexavalent chromium analyses were sent to the laboratory filtered. To collect the filtered samples, a disposable 0.45-micron cellulose acetate cartridge filter was attached to the end of the discharge hose of the sampling pump, or to the end of the Westbay sampling bottles, before the samples were collected. When the shallow wells were sampled the pump drove the water through the filter, and when the deep multi-port wells were sampled, a manually operated hand pump was used to drive the water through the filter.

2.2.6 Field QA/QC Samples

To verify the quality of the groundwater samples collected from the JPL monitoring wells, field QA/QC samples were collected. The field QA/QC program included the collection of duplicate samples, equipment blanks, field blanks and trip blanks.

One duplicate sample was collected for every 20 groundwater samples collected during each RI sampling event. Each duplicate sample was analyzed for the same constituents of interest as the original sample. These samples were used to verify the accuracy of the analytical laboratory's methods.

Equipment blanks consisted of American Society of Testing Materials (ASTM) Type II organic free water (provided by the analytical laboratory) which was run through the sampling equipment as a final rinse after the equipment had been decontaminated. One equipment blank was collected for each day of sampling from the Westbay sample bottles. Equipment blanks were analyzed for the same constituents of interest being sampled (except for general minerals) to identify potential cross contamination problems due to inadequate decontamination procedures.

One field blank was collected during each RI sampling event. The field blank consisted of sample bottles, filled with ASTM Type II organic free water supplied by the laboratory, placed at the sampling point (well head), typically well MW-7, and left open during all sampling activities. After sampling, the bottles were capped and analyzed for the same constituents of interest as the groundwater sample being collected. This sample helped evaluate the influence that ambient conditions, or sample containers, may have on the analytical results.

Trip blanks, prepared by the laboratory, consisted of laboratory reagent water placed in 40-ml glass vials transported with the sample bottles to and from the field. One trip blank was submitted with each shipment of groundwater samples from the field to the laboratory. Trip

blanks were used to identify any cross contamination of groundwater samples during transport. Additional details of the field QA/QC program are provided in the QAPP (Ebasco, 1993g).

2.3 SAMPLING OF INVESTIGATION DERIVED WASTE

During the drilling of the groundwater monitoring wells at JPL, grab samples of the soil cuttings were collected to characterize the cuttings for disposal purposes only. Similarly, samples of used drilling mud (from deep wells) and well development water were also collected to characterize these materials for disposal purposes only.

Grab samples of soil cuttings were collected during drilling operations from just below the ground surface and after approximately every 50 feet of drilling in the shallow monitoring wells, and from just below the conductor casing and after approximately every 100 feet of drilling in the deep multi-port wells. With the air percussion/air rotary rigs used for drilling the shallow monitoring wells, samples of soil cuttings were collected at the discharge of the cyclone unit immediately above the roll-off bin used to contain the soil cuttings. A wire-screen colander was used to collect the soil cuttings as they were expelled from the cyclone unit. The colander was decontaminated between samples with a non-phosphate detergent (Liquinox®) wash and a double rinse in deionized water.

With the mud rotary drilling rig used for the deep multi-port wells, samples of soil cuttings were collected from the mud discharge pipe immediately above the conductor casing with a wire-screen colander.

All soil cuttings samples were collected in 8-ounce, wide-mouth glass jars, capped, labeled, placed in an ice chest and cooled to 4°C immediately after sampling.

The soil cuttings samples collected from each well were composited by the laboratory and analyzed for VOCs and SVOCs, Title 26 metals plus strontium, cyanide, hexavalent chromium, and total petroleum hydrocarbons solely to determine disposal options for the soil cuttings pursuant to EPA's guidance on the management of investigation-derived wastes (EPA, 1991a and 1992b).

The drilling mud used during the drilling of the deep multi-port wells was placed in large 22,000-gallon Baker® tanks at the completion of drilling operations. Water produced during well development activities was also placed in these tanks. A sample of this fluid was collected from each tank used and submitted for analysis. Each sample was analyzed for VOCs, SVOCs, Title 26 Metals plus strontium, hexavalent chromium, cyanide, TPH and perchlorate (wells MW-22, MW-23 and MW-24) to determine disposal options pursuant to EPA's guidance on the management of investigation-derived wastes (EPA, 1991a and 1992b).

Soil cuttings generated during the OU-1/OU-3 RI were arranged to be disposed of by JPL personnel at Laidlaw Environmental Services' Class II landfill facility in Buttonwillow, California. The drilling fluids generated during the OU-1/OU-3 RI were arranged to be disposed of by JPL personnel at Southwest Processor's facility in Vernon, California.

2.4 SOIL SAMPLING

The OU-1 FSAP (Ebasco, 1993h) included procedures to collect relatively undisturbed soil samples at approximately 10-feet, 20-feet and 30-feet below grade during the drilling of groundwater monitoring wells MW-12 through MW-16. The purpose of this sampling was to add to the knowledge of soil conditions at JPL. As the field program progressed, soil samples were collected from well MW-16 at 9-feet, 19-feet and 25-feet below grade. Drilling and sampling conditions became more difficult at well MW-15 where, after no recovery from a sampling attempt at 8-feet, a sample was collected at 13-feet, and after no recovery from sampling attempts at 18-feet and 23-feet, a sample was collected at 28.5-feet. Drilling and sampling conditions became even more difficult at well MW-12 where after collecting a sample at 11-feet, there was no recovery from sampling attempts at 20-feet, 22-feet, 25-feet, 31-feet, and 35-feet before a very small sample (3-inches of soil) was collected at 45-feet.

Due to the difficult sampling conditions encountered, and the fact that none of the wells, including the two remaining wells to be installed, MW-13 and MW-14, were located near any suspected contaminant sources, approval was received from the regulating agencies (EPA, DTSC, and RWQCB) at a Remedial Project Managers meeting on March 3, 1994, not to attempt to collect shallow soil samples during drilling at wells MW-13 and MW-14.

The soil samples that were obtained were collected with a split-spoon sampler following the procedures described below:

- Drill to the desired sampling depth with the mud-rotary drill rig (deep multi-port wells) or with the air percussion/air rotary rig (shallow standpipe wells). Prior to collecting each sample at the mud-rotary wells, the drill bit and drill pipe was removed from the boring.
- A 2.5-inch (inside diameter) by 18-inch split-spoon sampler containing three decontaminated stainless steel sample tubes (6.0 inches long and 2.5 inches in outside diameter) was lowered on a cable down to the sampling depth. The sampler was driven into the soil a minimum of 18 inches beyond the bottom of the boring using a 140-pound sliding hammer with a 30-inch vertical stroke.
- The sampler was retrieved and opened. Whenever possible, the uppermost sample tube was used for lithologic description purposes and the lowermost tube for laboratory analysis. The ends of the soil sample designated for laboratory analysis were trimmed, covered with Teflon® sheets, and capped with tightly fitting plastic end caps. After the sample was labeled, it was sealed in a self-locking plastic bag and placed on ice in a cooler prior to being transported to the laboratory. Samples used for lithologic descriptions were monitored for the presence of volatile organic vapors with a flame-

ionization detector. During sampling, no soil sample contained organic vapors measurable with the flame-ionization detector.

All soil sampling equipment used in the field was decontaminated prior to each use. The split-spoon sampler and sample tubes were washed with a non-phosphate detergent (Liquinox®) solution followed by a double rinse with deionized water.

The soil samples were sent to Montgomery Watson Laboratories, Inc. (Montgomery), a state-certified laboratory, for analyses. Analyses performed included those for SVOCs (EPA Method 8270), Title 26 Metals plus hexavalent chromium and strontium (EPA Methods 6010/7000), cyanide (EPA Method 9010), TPH (EPA Method 418.1), total solids (EPA Method 160.3), and nitrate (EPA 300.0).

Prior to drilling at each well location, a mobile soil-vapor sampling van was used to collect one soil-vapor sample at each well location from a depth of 20 feet to evaluate whether or not soil samples should be analyzed for VOCs [see OU-1 FSAP (Ebasco, 1993h)]. Each soil vapor sample was analyzed for VOCs in accordance with the RWQCB's guidelines [see FSAP for OU-2 (Ebasco, 1993i)]. During this shallow soil-vapor survey, all data quality objectives, equipment calibration procedures, sample collection and analysis procedures, decontamination procedures, and QA/QC procedures were identical to those used during soil-vapor sampling completed for OU-2 (see FSAP for OU-2). During the vapor sampling, VOCs were not detected and, subsequently, the soil samples were not analyzed for VOCs.

The results of the soil sample analyses are summarized on Table 2-16. As indicated, low levels of metals were found in every soil sample including barium, chromium, copper, mercury, strontium, vanadium and zinc. Low levels of cobalt, nickel and beryllium were also detected at the MW-12 location, and low levels of nickel and beryllium were detected at the MW-16 location. Thallium was detected in one sample, but not its duplicate, from the MW-15 location. These metals were detected at low concentrations similar to levels detected in JPL background soils (Table 2-16, see OU-2 RI for details), and typically lower than ranges of data reported for both California soils and soils across the western United States (Table 2-16).

2.5 SAMPLE HANDLING PROCEDURES

Analyses of all samples (groundwater and soil) were performed by Montgomery Watson Laboratories (Montgomery) located in Pasadena, California. Montgomery is certified by the California Department of Health Services for the analyses performed.

2.5.1 Sample Containers and Preservatives

All containers for water samples were obtained pre-cleaned according to EPA QC procedures (EPA, 1996b) from the laboratory. To achieve optimal sample preservation, Montgomery added the appropriate preservatives to the water sample containers, as necessary, immediately prior to

shipment to the site. The types of containers and preservatives required for specified water analyses are indicated in Table 2-15.

Once opened, a container was used immediately for the collection of a particular sample. Unused, but opened containers were considered contaminated and were discarded. Any unused container, which upon receipt, was found to have a loose cap or missing Teflon® liner (if required for that container) was discarded.

2.5.2 Sample Transport and Custody

Sample labels were attached to each sample container after sample collection. After collection, custody seals and sample tags were also added to each sample container (see QAPP). The sample containers were then sealed in self-locking plastic bags to prevent the loss of labels during shipment. All samples were placed in a cooler with ice to ensure that they remained at a temperature of 4°C until delivery to the laboratory. A thermometer was placed in each ice chest and the temperature was checked periodically. Glass sample containers were packaged with bubble wrap to avoid breakage.

Chain-of-custody procedures were used to maintain and document sample possession for legal purposes. Adherence to strict document control procedures was of prime importance. The principal documents that were used to record possession of the samples were the chain-of-custody forms and the bound field logbooks. A sample was considered to be in a person's custody if: (1) it was in a person's physical possession; (2) it was in view of the person after that person had taken possession; (3) it was secured by that person so that no one could tamper with the sample; and (4) it was secured by that person in an area in which access was restricted.

Chain-of-custody forms were completed and accompanied all samples to the laboratory. The field sampler (originator) was responsible for the care and custody of the samples from the time they were collected until they were transferred to another individual. All samples were transported to the laboratory by a laboratory representative or other authorized personnel, ensuring prompt, secure arrival and meeting the requirements of chain-of-custody procedures. For each sample shipment, the originator completed a chain-of-custody form entering all the requested information. At a minimum the form contained the following:

- Sample number(s)
- Signature of sampler
- Date and time of sample collection
- Sample type
- Signature of persons involved in the chain of possession
- Date and time of relinquishment
- Analyses required

At the transporter's request, authorized sampling personnel were available to open shipping containers for inspection or to modify packaging. Persons relinquishing samples signed the chain-of-custody form in the appropriate box labeled "relinquished by" and retained a copy. The sample recipient cross-checked the sample label and the chain-of-custody form. The recipient also examined the samples and documented any unusual conditions in the "Remarks" section on the chain-of-custody form. The persons relinquishing and receiving the sample signed the chain-of-custody in the appropriate boxes labeled "relinquished by" and "received by" respectively. Along with their signatures they noted the date and time of the exchange. The original chain-of-custody form accompanied all sample shipments. The remaining copies were maintained in a project file.

2.6 AUTOMATED WATER LEVEL MEASUREMENT PROCEDURES

Throughout the OU-1/OU-3 RI, water levels in both the shallow and deep wells have been routinely recorded to evaluate groundwater level fluctuations and groundwater flow directions. The following sections discuss this program for both the shallow and deep wells.

2.6.1 Shallow Monitoring Wells

Throughout the RI, the groundwater level monitoring program described in Section 1.3.3.16 was continued. During this program, water levels were automatically recorded at least one time a day in the shallow standpipe monitoring wells. As new wells were added to the site, new dedicated water-level monitoring equipment was installed in them. The measurements collected were used to monitor the change in the water levels and flow directions of groundwater beneath JPL. The water level data will also be used to evaluate the changes in water levels over time due to the pumping of nearby off-site City of Pasadena municipal production wells and the seasonal recharge from the nearby Arroyo Seco spreading grounds.

The automated water-level measurement systems installed in the JPL shallow wells are manufactured by Instrumentation Northwest and include a battery powered AquiStar DL-1 data logger connected with a vented cable to a Model PS9000 30-psi pressure transducer. The data logger can be programmed to collect pressure readings from the pressure transducer at specified intervals in time. The data logger converts these pressure measurements to feet-of-water above the transducer and stores the result in its internal memory. These measurements are then periodically uploaded to a portable lap top computer. The equipment required to operate these systems, the procedures for their installation, and field QA/QC procedures are summarized below:

2.6.1.1 Required Equipment

To operate the AquiStar DL-1 data loggers and PS9000 pressure transducers installed in the shallow monitoring wells, the following equipment was required:

- An IBM or compatible laptop computer with serial port, graphics adapter and a minimum of 384K random access memory.
- A diskette containing the required software programs supplied by Instrumentation Northwest, the manufacturer.
- A shielded straight-through serial cable with connectors that matched the data logger and computer serial port.
- A set of fully charged 6-volt lead/acid batteries and a battery charger.
- Several desiccant cartridges and moisture indicator pills for the cable's desiccant chamber.
- A water level meter which measured water depth to 0.01 foot.

2.6.1.2 Installation Procedures

Prior to installing a data logger and pressure transducer in a monitoring well for the first time, it was necessary to set the data collection parameters in the data logger memory. The detailed procedures for setting the desired data acquisition parameters are outlined in the OU-1 FSAP.

Once the data acquisition parameters were set in the data logger, the pressure transducer and data logger were installed in the well. This was done using the following procedure:

- Measure the depth to water in the well and enter this value on a transducer data upload form along with the date and time.
- Connect the transducer cable to the data logger. Check the desiccant chamber on the cable to be sure that it contains a fresh desiccant cartridge and moisture indicator pill.
- Connect the computer to the data logger and run the supplied computer program. The computer screen then displays pressure readings converted to feet-of-water above the transducer.
- Lower the transducer carefully into the well while observing the pressure readings converted to feet-of-water above the transducer. When the feet-of-water above the transducer is between 20 to 40 feet, anchor the cable at the surface. The 30-psi pressure transducer can be set to a maximum depth of 69.3 feet below the water surface. Below that depth, damage to the sensor element may occur.
- Note the depth of the transducer below the water surface.
- Start the data logger, disconnect the computer from the data logger and secure the well head.

2.6.1.3 Transducer Data Upload Procedures

The water level data stored in the data loggers was uploaded approximately every 3 to 4 weeks. At the time of uploading, the data logger battery was replaced with a fully charged battery and the condition of the water level measurement system inspected. Procedures used for uploading the water level data and system maintenance are outlined below:

- Gain access to the well head and note any conditions that may impede the water level measurement system's operation (such as flooding).
- Boot up the portable lap top computer and run the supplied computer program.
- Connect the laptop computer to the data logger.
- Upload the data to the portable lap top computer.
- When the upload is complete, verify that the upload was successful.
- When it has been verified that the data has been properly uploaded, clear the data logger memory and record the depth at which the pressure transducer is below the water surface on the transducer data upload form. Replace the battery in the data logger, taking care not to disturb the setting of the data logger before proceeding.
- Inspect the moisture indicator pill in the cable desiccant chamber and replace the pill and the desiccant canister if necessary.
- Alter the length of the cable hanging in the well if necessary to keep the transducer between 20 and 40 feet below the water surface.
- Secure well head.

2.6.1.4 Field QA/QC Procedures

Several QA/QC checks were made in the field to assure that the water level measurements were accurate and that the instrumentation was functioning properly. If any problems were found, action was taken immediately to remedy the situation. The QA/QC checks utilized include:

- Adding the values of depth-to-water to the depth-of-the-transducer below the water surface to get the effective length of the cable. This cable length should not change from one upload event to the next. A difference may be indicative of transducer slippage at the anchoring device, a malfunctioning transducer, or an error in measurement.
- Marking the cable at the base of the anchor so any changes in the location of this mark relative to the anchor will indicate a slipping transducer.
- Checking the transducer baseline pressure reading of the transducer when out of water. Optimally this value should be zero. This value should not change appreciably from one upload event to the next. If the transducer baseline exceeds about 0.25 feet, the transducer may be beginning to drift. If the baseline exceeds 1.0 feet, the transducer may have failed and must be sent to the manufacturer for repair.
- Inspecting data in the field after it had been uploaded to check if data was collected over the entire monitoring period. The date and time of the first record was compared with that of the last record from the previous upload. The date and time of the last record was determined and compared with the date and time of the current data upload. The interval between readings was checked also. Discrepancies in each of these may be indicative of incorrect acquisition parameters, battery failure or instrument malfunction.
- Inspection of data for any large, sudden changes in the water levels, which may be indicative of instrument malfunction or of tampering. Tampering may be verified by inspection of the well head and of the exterior of the data logger.

2.6.2 Deep Multi-Port Monitoring Wells

After each deep multi-port monitoring well was installed, water-level measurements were collected manually at each screened interval on a monthly basis as part of the water-level monitoring program. The water levels were measured by recording water pressure measurements at each screened interval with the Westbay sampling probe pressure transducer. Water-level elevations were then calculated based on the pressure recorded. Water-level elevations are discussed further in Section 3.4.3.

2.7 WELL LOCATION SURVEY

After each groundwater monitoring well was installed, an elevation and location survey was completed. The elevation survey was required to establish a datum elevation for subsurface investigations, and the location survey was conducted to establish an accurate reference point for each well.

The surveys were conducted with a theodolite and electronic distance measuring device by R. Wada and Associates, a licensed surveying company located in Fullerton, California. The accuracy for horizontal and vertical control points was third order and the precision of elevation and distance measurements was to one-hundredth (0.01) of a foot. The well survey data, along with survey data from the existing wells at JPL, have been summarized on Table 2-17.

TABLE 2-1
SUMMARY OF CONSTRUCTION DETAILS FOR ALL JPL GROUNDWATER MONITORING WELLS

Well Number	Well Type	Year Installed	Drilling Method	Depth to Bottom of Casing (feet below ground surface)	Depth of Screened Interval (feet below ground surface)	Elevation Top 4-inch Casing (feet above mean sea level)	Elevation of Screened Interval (feet above mean sea level) ⁽¹⁾	Multi-Port Well Screen Number	Comments
MW-1	Shallow Standpipe	1989	Mud Rotary	120	70-110	1116.7	1006.70-1046.70	-	Installed during upgradient water quality study for U.S. Army Corps of Engineers (see Section 1.3.3.8)
MW-2	Shallow Standpipe	1989	Mud Rotary	177	127-167	1168.85	1001.85-1041.85	-	Installed during upgradient water quality study for U.S. Army Corps of Engineers (see Section 1.3.3.8). Well subsequently replaced by deep well MW-14.
MW-3	Deep Multi-Port	1990	Mud Rotary	700	170-180	1099.82	919.82-929.82	1	Installed during JPL Expanded Site Inspection (see Section 1.3.3.9).
					250-260		839.82-849.82	2	
					344-354		745.82-755.82	3	
					555-565		534.82-544.82	4	
					650-660		433.82-443.82	5	
MW-4	Deep Multi-Port	1990	Mud Rotary	559	147-157	1082.72	925.72-935.72	1	Installed during JPL Expanded Site Inspection (see Section 1.3.3.9).
					237-247		835.72-845.72	2	
					318-328		754.72-764.72	3	
					389-399		683.72-693.72	4	
					509-519		563.72-573.72	5	
MW-5	Shallow Standpipe	1990	Air Percussion	140	85-135	1071.6	936.60-986.60	-	Installed during JPL Expanded Site Inspection (see Section 1.3.3.9).
MW-6	Shallow Standpipe	1990	Air Percussion	245	195-245	1188.52	943.52-993.52	-	Installed during JPL Expanded Site Inspection (see Section 1.3.3.9).
MW-7	Shallow Standpipe	1990	Air Percussion	275	225-275	1212.88	937.88-987.88	-	Installed during JPL Expanded Site Inspection (see Section 1.3.3.9).
MW-8	Shallow Standpipe	1992	Air Percussion	205	155-205	1139.53	934.53-984.53	-	Installed during JPL pre-RI investigation (see Section 1.3.3.14).
MW-9	Shallow Standpipe	1992	Air Percussion	68	18-68	1106.02	1038.02-1088.02	-	Installed during JPL pre-RI investigation (see Section 1.3.3.14).
MW-10	Shallow Standpipe	1992	Air Percussion	155	105-155	1087.71	932.71-982.71	-	Installed during JPL pre-RI investigation (see Section 1.3.3.14).

Notes: (1) All screens, except in wells MW-1 and MW-2, are 4-inch diameter, wire wrap stainless steel with 0.010-inch slot size. Screens in wells MW-1 and MW-2 are 4-inch diameter, schedule 40 PVC with 0.020-inch slot size.

TABLE 2-1
SUMMARY OF CONSTRUCTION DETAILS FOR ALL JPL GROUNDWATER MONITORING WELLS

Well Number	Well Type	Year Installed	Drilling Method	Depth to Bottom of Casing (feet below ground surface)	Depth of Screened Interval (feet below ground surface)	Elevation Top 4-inch Casing (feet above mean sea level)	Elevation of Screened Interval (feet above mean sea level) ⁽¹⁾	Multi-Port Well Screen Number	Comments
MW-11	Deep Multi-Port	1992	Mud Rotary	680	140-150	1139.35	989.35-999.35	1	Installed during JPL pre-RI investigation (see Section 1.3.3.14).
					250-260		879.35-889.35	2	
					420-430		709.35-719.35	3	
					515-525		614.35-624.35	4	
					630-640		499.35-509.35	5	
MW-12	Deep Multi-Port	1994	Mud Rotary	596	135-145	1102.14	957.14-967.14	1	Installed during OU-1 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
					240-250		852.14-862.14	2	
					315-325		777.14-787.14	3	
					430-440		662.14-672.14	4	
					546-556		546.14-556.14	5	
MW-13	Shallow Standpipe	1994	Air Rotary	235	180-230	1183.47	953.47-1003.47	-	Installed during OU-1 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
MW-14	Deep Multi-Port	1994	Mud Rotary	588	205-215	1173.42	958.42-968.42	1	Installed during OU-1 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
					275-285		888.42-898.42	2	
					380-390		783.42-793.42	3	
					453-463		710.42-720.42	4	
					538-548		625.42-635.42	5	
MW-15	Shallow Standpipe	1994	Air Percussion	74	19-69	1120.66	1051.66-1101.66	-	Installed during OU-1 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
MW-16	Shallow Standpipe	1994	Air Percussion	285	230-280	1236.27	956.27-1006.27	-	Installed during OU-1 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
MW-17	Deep Multi-Port	1995	Mud Rotary	774	246-256	1190.99	934.99-944.99	1	Installed during OU-3 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
					366-376		814.99-824.99	2	
					466-476		714.99-724.99	3	
					578-588		602.99-612.99	4	
					723-733		457.99-467.99	5	

Notes: (1) All screens, except in wells MW-1 and MW-2, are 4-inch diameter, wire wrap stainless steel with 0.010-inch slot size. Screens in wells MW-1 and MW-2 are 4-inch diameter, schedule 40 PVC with 0.020-inch slot size.

TABLE 2-1

SUMMARY OF CONSTRUCTION DETAILS FOR ALL JPL GROUNDWATER MONITORING WELLS

Well Number	Well Type	Year Installed	Drilling Method	Depth to Bottom of Casing (feet below ground surface)	Depth of Screened Interval (feet below ground surface)	Elevation Top 4-inch Casing (feet above mean sea level)	Elevation of Screened Interval (feet above mean sea level) ⁽¹⁾	Multi-Port Well Screen Number	Comments
MW-18	Deep Multi-Port	1995	Mud Rotary	732	266-276	1225.34	949.34-959.34	1	Installed during OU-3 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
					326-336		889.34-899.34	2	
					421-431		794.34-804.34	3	
					561-571		654.34-664.34	4	
					681-691		534.34-544.34	5	
MW-19	Deep Multi-Port	1995	Mud Rotary	543	240-250	1143.2	893.20-903.20	1	Installed during OU-3 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
					310-320		823.20-833.20	2	
					390-400		743.20-753.20	3	
					442-452		691.20-701.20	4	
					492-502		641.20-651.20	5	
MW-20	Deep Multi-Port	1995	Mud Rotary	948	228-238	1164.89	926.89-936.89	1	Installed during OU-3 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
					388-398		766.89-776.89	2	
					558-568		596.89-606.89	3	
					698-708		456.89-466.89	4	
					898-908		256.89-266.89	5	
MW-21	Deep Multi-Port	1995	Mud Rotary	416	86-96	1058.99	962.99-972.99	1	Installed during OU-3 RI pursuant to RI/FS Work Plan (Ebasco, 1993a).
					156-166		892.99-902.99	2	
					236-246		812.99-822.99	3	
					306-316		742.99-752.99	4	
					366-376		682.99-692.99	5	
MW-22	Deep Multi-Port	1997	Mud Rotary	634	239-249	1176.81	927.81-937.81	1	Installed during OU-1 RI to fill data gaps pursuant to Addenda to RI/FS Work Plan (Foster Wheeler 1996a, 1996b and JPL 1996).
					324-334		842.81-852.81	2	
					384-394		782.81-792.81	3	
					464-474		702.81-712.81	4	
					584-594		582.81-592.81	5	
MW-23	Deep Multi-Port	1997	Mud Rotary	590	170-180	1108.34	928.34-938.34	1	Installed during OU-1 RI to fill data gaps pursuant to Addenda to RI/FS Work Plan (Foster Wheeler 1996a, 1996b and JPL 1996).
					250-260		843.34-858.34	2	
					315-325		783.34-793.34	3	
					440-450		658.34-668.34	4	
					540-550		558.34-658.34	5	

Notes: (1) All screens, except in wells MW-1 and MW-2, are 4-inch diameter, wire wrap stainless steel with 0.010-inch slot size. Screens in wells MW-1 and MW-2 are 4-inch diameter, schedule 40 PVC with 0.020-inch slot size.

TABLE 2-1

SUMMARY OF CONSTRUCTION DETAILS FOR ALL JPL GROUNDWATER MONITORING WELLS

Well Number	Well Type	Year Installed	Drilling Method	Depth to Bottom of Casing (feet below ground surface)	Depth of Screened Interval (feet below ground surface)	Elevation Top 4-inch Casing (feet above mean sea level)	Elevation of Screened Interval (feet above mean sea level) ⁽¹⁾	Multi-Port Well Screen Number	Comments
MW-24	Deep Multi-Port	1997	Mud Rotary	725	275-285	1200.91	915.91-925.91	1	Installed during OU-1 RI to fill data gaps pursuant to Addenda to RI/FS Work Plan (Foster Wheeler 1996a, 1996b and JPL 1996).
					370-380		820.91-830.91	2	
					430-440		760.91-770.91	3	
					550-560		640.91-650.91	4	
					657-685		515.91-525.91	5	

Notes: (1) All screens, except in wells MW-1 and MW-2, are 4-inch diameter, wire wrap stainless steel with 0.010-inch slot size. Screens in wells MW-1 and MW-2 are 4-inch diameter, schedule 40 PVC with 0.020-inch slot size.

TABLE 2-2
SUMMARY OF WELL DEVELOPMENT PARAMETERS
FROM SHALLOW MONITORING WELLS

Well Number	Final Characteristics of Purge Water				Pump Rate (gpm)	Total Volume Purged (gallons)
	pH	Turbidity (NTU)	Temperature (°C)	Conductivity (µmhos)		
MW-13	6.77	1.7	21.8	573	5	1,100
MW-15	6.98	2.4	16.2	378	10	1,650
MW-16	6.90	1.4	21.6	542	3.5	1,160

TABLE 2-3

**SUMMARY OF VOLATILE ORGANIC COMPOUND ANALYSES OF WATER
USED DURING DRILLING OF DEEP MULTI-PORT WELLS
JET PROPULSION LABORATORY**

Well Number and Sample Description	Sample Date	Volatile Organic Compounds Detected ($\mu\text{g/l}$)			
		Chloroform	Chlorodibromo- methane	Bromodichloro- methane	Other Volatile Organic Compounds
MW-12					
Bulk H ₂ O from Truck	2/22/94	2.8	1.4	2.5	--
Bulk H ₂ O from Tank	2/22/94	1.7	1.1	1.7	--
Bulk H ₂ O from Truck	3/2/94	2.6	1.2	2.4	0.7 Benzene 1.3 Toluene 2.4 Methyl-1-butyl ether
Bulk H ₂ O from Truck	3/7/94	2.3	1.1	2.0	Various compounds listed as unknown extraneous peaks that were also found in laboratory method blank.
MW-14					
Bulk H ₂ O from Tank	3/15/94	3.5	1.7	3.0	1.0 Carbon Tetrachloride
Bulk H ₂ O from Truck	3/16/94	3.5	1.5	3.0	--
Bulk H ₂ O from Truck	3/21/94	3.0	1.4	2.6	--
Bulk H ₂ O from Truck	3/23/94	3.5	1.7	3.1	--
Bulk H ₂ O from Truck	3/25/94	4.2	2.1	3.5	--
MW-17					
Bulk H ₂ O from Truck	3/29/95	6.4	7.2	4.1	6.5 Bromoform
Bulk H ₂ O from Tank	3/29/95	5.5	7.2	3.8	6.2 Bromoform 0.5 Toluene
Bulk H ₂ O from Truck	4/3/95	6.6	3.4	2.4	2.6 Bromoform 2.0 Toluene
Bulk H ₂ O from Truck	4/4/95	10	4.6	3.3	3.6 Bromoform 1.4 Toluene
Bulk H ₂ O from Truck	4/5/95	6.2	3.5	2.5	3.3 Bromoform 1.0 Toluene 7.1 Acetone 1.1 Methyl T-Butyl Ether (B)
Bulk H ₂ O from Truck	4/6/95	6.9	4.1	2.7	3.0 Bromoform 0.5 Toluene 1.3 Decanol 1.4 Methyl T-Butyl Ether (B)
Bulk H ₂ O from Truck	4/12/95	17	9.0	8.8	3.2 Bromoform 1.5 Methyl T-Butyl Ether (B) 1.2 Unknown Scan #1075 1.5 Toluene
Bulk H ₂ O from Truck	4/14/95	23	8.0	10.0	2.1 Bromoform 1.2 Methyl T-Butyl Ether (B) 1.4 Toluene

TABLE 2-3

**SUMMARY OF VOLATILE ORGANIC COMPOUND ANALYSES OF WATER
USED DURING DRILLING OF DEEP MULTI-PORT WELLS
JET PROPULSION LABORATORY**

Well Number and Sample Description	Sample Date	Volatile Organic Compounds Detected ($\mu\text{g/l}$)			
		Chloroform	Chlorodibromo- methane	Bromodichloro- methane	Other Volatile Organic Compounds
<i>MW-18</i>					
Bulk H ₂ O from Truck	4/12/95	16	12	10	5.5 Bromoform 1.0 Toluene 5.1 Acetone (B) 1.6 Methyl T-Butyl Ether (B)
Bulk H ₂ O from Tank	4/13/95	17	7.8	8.5	2.5 Bromoform 1.0 Toluene 6.8 Acetone (B) 1.5 Methyl T-Butyl Ether (B)
Bulk H ₂ O from Truck	4/14/95	20	8.3	11	2.3 Bromoform 1.1 Methyl T-Butyl Ether (B) 0.5 Toluene 5.6 Acetone (B)
Bulk H ₂ O from Truck	4/17/95	44	9.6	18	1.5 Bromoform 1.4 Methyl T-Butyl Ether (B) 1.0 Toluene 8.2 Acetone (B)
Bulk H ₂ O from Truck	4/19/95	34	8.3	14	1.0 Bromoform 0.5 Toluene 7.1 Acetone (B)
Bulk H ₂ O from Truck	4/21/95	37	7.7	14	1.0 Bromoform 0.7 Methyl T-Butyl Ether 0.9 Toluene 6.3 Acetone
Bulk H ₂ O from Truck	4/24/95	47	9.2	17	1.3 Bromoform 0.5 Methyl T-Butyl Ether 0.8 Toluene 6.6 Acetone
Bulk H ₂ O from Truck	4/26/95	76	6.3	14	1.1 Bromoform 1.7 Toluene
Bulk H ₂ O from Truck	4/28/95	50	5.4	14	1.0 Bromoform 0.7 Toluene 8.5 Acetone
Bulk H ₂ O from Truck	4/28/95	48	15	15	1.2 Bromoform 7.0 Acetone
<i>MW-19</i>					
Bulk H ₂ O from Tank	2/16/95	12	5.0	8.0	0.5 Bromoform 7.5 Carbon Disulfide
Bulk H ₂ O from Truck	2/10/95	7.3	4.9	3.8	1.6 Bromoform
Bulk H ₂ O from Truck	2/17/95	8.2	3.5	3.3	3.2 Bromoform
Bulk H ₂ O from Truck	2/22/95	6.5	3.8	2.6	3.1 Bromoform 0.7 Toluene
Bulk H ₂ O from Truck	2/22/95	12	6.9	5.9	5.7 Bromoform
Bulk H ₂ O from Truck	2/24/95	19	6.4	6.7	4.1 Bromoform
Bulk H ₂ O from Truck	2/28/95	20	5.4	6.0	3.6 Bromoform
Bulk H ₂ O from Truck	3/02/95	21	4.9	5.5	3.0 Bromoform

TABLE 2-3

**SUMMARY OF VOLATILE ORGANIC COMPOUND ANALYSES OF WATER
USED DURING DRILLING OF DEEP MULTI-PORT WELLS
JET PROPULSION LABORATORY**

Well Number and Sample Description	Sample Date	Volatile Organic Compounds Detected ($\mu\text{g/l}$)			
		Chloroform	Chlorodibromo- methane	Bromodichloro- methane	Other Volatile Organic Compounds
<i>MW-20</i>					
Bulk H ₂ O from Truck	3/6/95	16	5.1	5.4	2.9 Bromoform 0.9 Toluene
Bulk H ₂ O from Truck	3/14/95	12	3.9	3.0	3.7 Bromoform 2.1 Toluene
Bulk H ₂ O from Truck	3/20/95	14	9.1	5.9	6.1 Bromoform 0.7 Toluene
Bulk H ₂ O from Truck	3/22/95	12	8.6	5.6	5.1 Bromoform
Bulk H ₂ O from Truck	3/27/95	9.8	6.1	4.2	2.9 Bromoform 0.8 Toluene 1.8 Unknown Hydrocarbon
Bulk H ₂ O from Truck	3/28/95	7.5	6.1	3.4	3.8 Bromoform 0.5 Toluene
Bulk H ₂ O from Truck	3/30/95	6.6	3.8	2.3	2.9 Bromoform 0.6 Toluene 2.1 2-Butanone
Bulk H ₂ O from Truck ⁽¹⁾	4/3/95	9.3	4.2	2.8	3.6 Bromoform 1.2 Toluene
Bulk H ₂ O from Truck	4/5/95	5.1	4.1	2.5	3.2 Bromoform 0.6 Toluene 1.2 Methyl T-Butyl Ether
<i>MW-21</i>					
Bulk H ₂ O from Truck	1/27/95	4.4	2.9	3.6	17 Acetone 16 Methyl T-Butyl Ether
Bulk H ₂ O from Tank	1/27/95	5.0	3.2	3.9	12 Acetone 13 Methyl T-Butyl Ether
Bulk H ₂ O from Truck	1/30/95	13	5.8	8.4	0.5 Bromoform 1.1 Methyl T-Butyl Ether
Bulk H ₂ O from Truck	2/1/95	14	6.6	9.9	0.6 Bromoform 1.0 Methyl T-Butyl Ether
<i>MW-22</i>					
Bulk H ₂ O from Truck	7/23/97	4.5	1.0	0.6	0.6 Bromoform
Bulk H ₂ O from Truck	7/25/97	3.0	0.7	--	--
Bulk H ₂ O from Truck	7/25/97	3.9	--	--	--
Bulk H ₂ O from Truck	7/29/97	3.8	0.7	0.5	1.1 Unknown (RT=2.48) (B)
Bulk H ₂ O from Truck	7/30/97	3.7	0.6	--	--
<i>MW-23</i>					
Bulk H ₂ O from Truck	7/10/97	9.7	2.2	1.4	1.5 Bromoform
Bulk H ₂ O from Truck	7/11/97	5.3	0.6	--	--
Bulk H ₂ O from Truck	7/15/97	6.2	1.3	0.8	0.9 Bromoform 1.2 Unknown (RT=7.76) (B)
Bulk H ₂ O from Truck	7/18/97	4.1	--	--	1.3 Benzene

TABLE 2-3

**SUMMARY OF VOLATILE ORGANIC COMPOUND ANALYSES OF WATER
USED DURING DRILLING OF DEEP MULTI-PORT WELLS
JET PROPULSION LABORATORY**

Well Number and Sample Description	Sample Date	Volatile Organic Compounds Detected ($\mu\text{g/l}$)			
		Chloroform	Chlorodibromo- methane	Bromodichloro- methane	Other Volatile Organic Compounds
<i>MW-24</i>					
Bulk H ₂ O from Truck	6/20/97	11.0	0.6	0.5	--
Bulk H ₂ O from Tank	6/20/97	8.3	--	--	3.1 1-Methyl-4-(1-Methyl ethenyl) cyclohexene
Bulk H ₂ O from Truck	6/25/97	11.0	1.3	1.1	0.7 Bromoform
Bulk H ₂ O from Truck	6/26/97	8.0	0.7	0.5	--
Bulk H ₂ O from Truck	6/28/97	9.2	0.7	0.6	--
Bulk H ₂ O from Truck	6/30/97	8.3	1.2	1.0	0.5 Bromoform

(B) Denotes that compound was detected in the laboratory Method Blank.

(1) Half of bulk H₂O delivery was used at MW-17.

--: Not Detected.

TABLE 2-4

SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORIT WELL MW-12

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top) (135-145 feet bgs)						
Air lift pump in 4-inch casing (no packers)	8.38	35	18.8	470	2.0	844
Air lift pump in 4-inch casing		Not enough water above screen for adequate air lift				
Submersible pump in 4-inch casing	7.03	1.7	16.6	378	7.5	9,130
Westbay Development	6.85	2.8	18.2	362	1.0	450
Screen #2 (240-250 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	7.94	23	18.6	484	15.0	3,435
Air lift pump in 4-inch casing	8.05	50	17.0	445	4.0	4,191
Submersible pump in 4-inch casing	7.03	4.6	17.5	401	6.0	6,785
Westbay Development ⁽¹⁾	7.17	13	18.9	447	--	391
Screen #3 (315-325 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	7.99	21	18.9	495	10.0	2,490
Air lift pump in 4-inch casing	8.33	22	24.0	450	5.0	3,436
Submersible pump in 4-inch casing	7.24	4.4	18.0	392	4.5	4,129
Westbay Development ⁽¹⁾	7.18	7.92	17.6	387	--	511
Screen #4 (430-440 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	8.01	30	21.0	489	9.4	3,053
Air lift pump in 4-inch casing	8.15	58	19.8	298	2.5	5,791
Submersible pump in 4-inch casing	7.29	6.7	17.8	390	5.0	14,226
Westbay Development ⁽¹⁾	7.66	6.5	20.1	430	--	946
Screen #5 (Bottom) (546-556 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	7.93	32	19.2	480	11.1	12,913
Air lift pump in 4-inch casing	8.08	55	19.5	201	6.0	10,168
Submersible pump in 4-inch casing	7.11	6.4	19.4	350	5.0	8,470
Westbay Development	7.62	4.7	22.0	430	1.0	1,500
TOTAL						92,859

Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen unless otherwise noted.

(1): Final purge water collected with Westbay sampling equipment.

TABLE 2-5

SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORT WELL MW-14

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top)						
Air lift pump in 4-inch casing	8.43	56.9	22.0	1,100	0.2	81
Submersible pump in 4-inch casing	6.69	4.7	20.0	1,110	4.0	13,692
Westbay Development	6.71	4.18	18.4	1,112	1.0	720
Screen #2						
Air lift pump in 4-inch casing	8.15	15.8	21.0	1,010	3.8	1,964
Submersible pump in 4-inch casing	7.09	2.1	19.5	1,000	5.0	325
Westbay Development ⁽¹⁾	7.02	4.92	18.8	971	--	1,290
Screen #3						
Air lift pump in 4-inch casing	8.17	11.8	19.5	780	7.0	1,644
Submersible pump in 4-inch casing	7.28	4.6	19.0	790	4.5	501
Westbay Development	8.69	2.72	19.5	643	1.0-0.5	555
Screen #4						
Air lift pump in 4-inch casing	8.08	19.6	20.2	400	14.0	6,410
Submersible pump in 4-inch casing	7.41	4.4	20.1	490	5.0	710
Westbay Development	8.09	4.69	19.8	405	1.3	286
Screen #5 (Bottom)						
Air lift pump in 4-inch casing	8.14	44.4	20.0	355	9.0	5,806
Submersible pump in 4-inch casing	7.40	7.2	24.0	378	4.0	4,373
Westbay Development ⁽¹⁾	8.64	2.13	19.6	334	--	174
TOTAL						38,351

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen.

(1) Final purge water collected with Westbay sampling equipment.

TABLE 2-6

SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORIT WELL MW-17

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top) (245-255 ft. bgs)						
Air lift pump in 4-inch casing	--	14.9	--	--	11.0	2,431
Submersible pump in 4-inch casing	7.02	4.0	18.7	287	5.0	160
Westbay Development	6.8	1.03	21.4	265	0.8	295
Screen #2 (365-375 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	1.5-4.0	2,148
Submersible pump in 4-inch casing	7.00	8.0	18.8	281	6.0	2,160
Westbay Development ⁽¹⁾	6.84	4.23	18.9	313	1.0	195
Screen #3 (466-476 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	3.3	3,503
Submersible pump in 4-inch casing	7.05	1.5	17.5	265	6.7	871
Westbay Development ⁽¹⁾	6.89	5.51	19.1	320	1.0	835
Screen #4 (578-588 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	21.0	2,310
Submersible pump in 4-inch casing	7.02	4.0	18.7	282	5.0	1,144
Westbay Development ⁽¹⁾	7.48	4.86	19.4	398	0.55	429
Screen #5 (Bottom) (723-733 ft. bgs)						
Air lift pump in 4-inch casing	--	17.0	--	--	7.0	10,240
Submersible pump in 4-inch casing	7.25	5.0	18.2	283	1.7	1,326
Westbay Development	7.67	6.5	19.8	372	0.80	706
					TOTAL	28,753

* Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen.

(1) Final purge water collected with Westbay sampling equipment.

-- Data not collected.

TABLE 2-7

SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORT WELL MW-18

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top) (266-276 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	1.2	684
Submersible pump in 4-inch casing	7.12	2.8	18.0	400	5.0	525
Westbay Development	7.05	0.74	20.7	407	0.8	120
Screen #2 (326-335 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	2.4	1,296
Submersible pump in 4-inch casing	7.50	1.8	18.0	390	5.0	825
Westbay Development ⁽¹⁾	7.09	0.94	19.3	399	0.6	126
Screen #3 (421-431 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	8.5	3,442
Submersible pump in 4-inch casing	7.3	3.0	17.0	400	4.5	270
Westbay Development ⁽¹⁾	7.09	3.65	21.2	435	0.5	90
Screen #4 (560-571 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	8.5	5,880
Submersible pump in 4-inch casing	7.31	2.5	17.0	400	3.3	710
Westbay Development ⁽¹⁾	7.36	4.93	21.7	478	0.4	192
Screen #5 (Bottom) (681-691 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	7.5	7,260
Submersible pump in 4-inch casing	7.27	6.8	17.0	400	2.0	1,875
Westbay Development	7.44	4.7	19.5	424	0.66	238
TOTAL						23,533

* Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen.

(1) Final purge water collected with Westbay sampling equipment.

-- Data not collected.

TABLE 2-8
SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORT WELL MW-19

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top) (240-250 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	--	--	--	--	2.5	25
Air lift pump in 4-inch casing	7.93	28.5	15.5	306	3.5	420
Submersible pump in 4-inch casing	7.52	3.0	16.6	305	5.0	1,105
Westbay Development	6.97	2.15	16.5	319	1.9	133
Screen #2 (310-320 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	--	--	--	--	7.8	78
Air lift pump in 4-inch casing	--	4.0	16.5	810	8.5	3,780
Submersible pump in 4-inch casing	7.26	1.0	17.5	800	5.6	252
Westbay Development ⁽¹⁾	6.38	0.60	18.3	842	1.5	705
Screen #3 (390-400 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	--	--	--	--	7.0	70
Air lift pump in 4-inch casing	7.98	4.5	17.7	668	8.0	3,360
Submersible pump in 4-inch casing	7.31	3.3	17.0	680	5.0	270
Westbay Development	6.90	0.82	19.7	727	1.8	70
Screen #4 (442-452 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	--	--	--	--	11.0	110
Air lift pump in 4-inch casing	8.01	5.0	17.6	555	8.0	3,636
Submersible pump in 4-inch casing	7.26	3.3	16.5	700	3.3	396
Westbay Development ⁽¹⁾	7.36	4.32	19.2	526	0.86	430
Screen #5 (Bottom) (492-502 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	--	--	--	--	5.0	50
Air lift pump in 4-inch casing	7.63	7.0	19.0	600	7.0	630
Submersible pump in 4-inch casing	7.70	5.3	17.0	540	3.3	1,980
Westbay Development	7.10	4.5	19.0	603	1.0	823
					TOTAL	17,689

* Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen unless otherwise noted.

(1) Final purge water collected with Westbay sampling equipment.

-- Data not collected.

TABLE 2-9

SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORT WELL MW-20

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top) (228-238 ft. bgs)						
Air lift pump in 4-inch casing	--	20.0	--	--	8.0	540
Submersible pump in 4-inch casing	7.22	1.0	17.7	638	6.3	221
Westbay Development	7.27	4.1	20.8	697	1.6	924
Screen #2 (388-398 ft. bgs)						
Air lift pump in 4-inch casing	--	10.3	--	--	10.0	4,500
Submersible pump in 4-inch casing	7.15	3.0	17.4	399	6.3	315
Westbay Development	7.35	4.94	18.4	397	1.77	319
Screen #3 (558-568 ft. bgs)						
Air lift pump in 4-inch casing	--	13.0	--	--	5.0	510
Submersible pump in 4-inch casing	7.06	3.5	18.5	614	5.0	185
Westbay Development	7.44	4.9	20.0	480	1.5	300
Screen #4 (698-708 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	7.0	2,880
Submersible pump in 4-inch casing	6.90	4.2	19.0	500	4.3	296
Westbay Development	--	4.4	--	--	1.0	444
Screen #5 (Bottom) (898-908 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	2.0	2,520
Submersible pump in 4-inch casing	7.98	5.9	17.9	317	1.6	1,584
Submersible pump in 2-inch Westbay casing	8.20	4.3	21.9	344	2.3	2,241
Westbay Development	--	61.0	--	--	2.0	2,101
					TOTAL	19,880

* Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen unless otherwise noted.

-- Data not collected

TABLE 2-10
SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORIT WELL MW-21

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top) (228-238 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	7.80	20.0	20.5	1,067	2.4	653
Air lift pump in 4-inch casing	6.41	4.4	19.1	843	5.0	6,084
Submersible pump in 4-inch casing	--	--	--	--	--	--
Westbay Development	6.63	3.96	19.5	763	2.5	40
Screen #2 (388-398 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	7.75	12.5	20.1	1,050	12.3	4,950
Air lift pump in 4-inch casing	6.52	4.25	19.2	1,165	2.0	180
Submersible pump in 4-inch casing	--	--	19.4	--	--	475
Westbay Development ⁽¹⁾	6.53	4.6	19.4	1,034	2.5	391
Screen #3 (558-568 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	7.73	95.5	19.6	1,124	11.4	18,832
Air lift pump in 4-inch casing	6.52	4.0	19.8	1,149	2.0	120
Submersible pump in 4-inch casing	--	--	--	--	--	--
Westbay Development	6.70	4.2	19.6	975	2.8	891
Screen #4 (698-708 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	7.73	4.5	18.8	1,119	22.1	15,360
Air lift pump in 4-inch casing	7.90	4.1	19.8	1,137	6.1	3,540
Submersible pump in 4-inch casing	--	0.83	--	--	2.5	1,512
Westbay Development ⁽¹⁾	7.04	4.1	19.5	605	2.5	1,951
Screen #5 (Bottom) (898-908 ft. bgs)						
Air lift pump in 4-inch casing (no packers)	7.80	5.0	19.8	999	25.0	12,000
Air lift pump in 4-inch casing	6.62	4.0	19.4	1,137	2.0	6,630
Submersible pump in 4-inch casing	6.89	1.0	21.4	764	1.9	177
Westbay Development	--	1.32	--	--	3.4	3,588
					TOTAL	76,556

* Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen unless otherwise noted.

(1) Final purge water collected with Westbay sampling equipment.

-- Data not collected.

TABLE 2-11

SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORT WELL MW-22

Screen/Task	Final Characteristics of Purge Water					
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	Total Volume Purged (gals.)
Screen #1 (Top) (239-249 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	--	--
Submersible pump in 4-inch casing	7.31	4.0	25.7	969	2.0	500
Westbay Development	6.86	1.77	21.9	896	1.0	100
Screen #2 (324-334 ft. bgs)						
Air lift pump in 4-inch casing	8.37	3.65	23.0	792	4.0	939
Submersible pump in 4-inch casing	7.44	4.05	24.2	731	2.0	192
Westbay Development	7.35	3.00	23.5	729	0.8	60
Screen #3 (384-394 ft. bgs)						
Air lift pump in 4-inch casing	8.46	4.1	18.9	543	5.1	848
Submersible pump in 4-inch casing	7.93	3.7	23.1	501	2.0	508
Westbay Development	7.79	0.76	24.3	479	0.75	72
Screen #4 (464-474 ft. bgs)						
Air lift pump in 4-inch casing	8.33	10.8	24.8	386	5.3	10,826
Submersible pump in 4-inch casing	7.91	2.56	23.4	486	1.7	607
Westbay Development	7.74	1.07	22.2	361	1.0	566
Screen #5 (Bottom) (584-594 ft. bgs)						
Air lift pump in 4-inch casing	7.78	27.6	25.8	540	10.1	6,992
Submersible pump in 4-inch casing	7.83	4.5	23.1	486	2.25	1,201
Westbay Development	7.96	4.98	23.7	493	0.8	641
					TOTAL	24,052

* Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen.

-- Data not collected.

TABLE 2-12

SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORT WELL MW-23

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top) (170-180 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	--	--
Submersible pump in 4-inch casing	7.14	2.37	23.3	1,024	3.0	719
Westbay Development	6.51	3.7	23.1	1,075	0.6	132
Screen #2 (250-260 ft. bgs)						
Air lift pump in 4-inch casing	--	16.2	24.9	1,114	4.1	847
Submersible pump in 4-inch casing	7.38	1.38	22.8	924	2.5	593
Westbay Development	6.80	4.5	22.2	955	1.2	108
Screen #3 (315-325 ft. bgs)						
Air lift pump in 4-inch casing	--	19.5	25.1	--	3.2	2,632
Submersible pump in 4-inch casing	7.78	3.32	22.7	794	2.0	847
Westbay Development	7.56	2.15	22.8	442	0.8	131
Screen #4 (440-450 ft. bgs)						
Air lift pump in 4-inch casing	--	10.40	24.5	--	6.2	3,582
Submersible pump in 4-inch casing	7.28	1.23	22.1	839	1.8	559
Westbay Development	7.14	3.5	22.3	365	1.1	440
Screen #5 (Bottom) (540-550 ft. bgs)						
Air lift pump in 4-inch casing	8.35	170	22.6	721	0.75	15,443
Submersible pump in 4-inch casing	7.76	78	23.3	486	0.75	2,306
Westbay Development	7.96	7.3	22.4	452	0.5	1,106
					TOTAL	29,445

* Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen.

-- Data not collected.

TABLE 2-13

SUMMARY OF WELL DEVELOPMENT FOR MULTI-PORT WELL MW-24

Screen/Task	Final Characteristics of Purge Water					Total Volume Purged (gals.)
	pH	Turbidity* (NTU)	Temperature (°C)	Conductivity (µmhos)	Pump Rate (gpm)	
Screen #1 (Top) (275-285 ft. bgs)						
Air lift pump in 4-inch casing	--	--	--	--	--	--
Submersible pump in 4-inch casing	7.76	1.26	21.6	398	3.2	192
Westbay Development	6.68	0.75	23.9	423	0.7	158
Screen #2 (370-380 ft. bgs)						
Air lift pump in 4-inch casing	8.57	4.43	24.3	471	6.5	1,542
Submersible pump in 4-inch casing	7.43	0.28	22.3	469	3.0	232
Westbay Development	6.90	1.04	25.8	510	0.6	130
Screen #3 (430-440 ft. bgs)						
Air lift pump in 4-inch casing	8.20	18.6	24.0	419	10.5	3,129
Submersible pump in 4-inch casing	8.12	0.89	22.1	408	3.4	496
Westbay Development	7.90	0.78	24.7	419	0.8	129
Screen #4 (550-560 ft. bgs)						
Air lift pump in 4-inch casing	8.22	19.2	22.6	377	10.5	6,500
Submersible pump in 4-inch casing	7.75	0.71	22.6	418	4.5	567
Westbay Development	7.76	0.91	23.5	417	0.8	193
Screen #5 (Bottom) (675-685 ft. bgs)						
Air lift pump in 4-inch casing	8.20	8.34	24.3	416	9.0	8,301
Submersible pump in 4-inch casing	8.26	4.53	22.2	396	2.1	1,346
Westbay Development	8.10	4.45	23.8	406	0.5	547
					TOTAL	23,462

* Lowest recorded value.

Note: Purging with air lift and submersible pump completed with a packer inflated above and below each screen.

-- Data not collected.

TABLE 2-14

**SUMMARY OF OU-1/OU-3 RI SAMPLING EVENTS
JET PROPULSION LABORATORY**

Analyses Performed	RI Sampling Event									
	OU-1 June 1994 MW-1, MW-3 thru MW-16	OU-1 Nov. 1994 MW-1, MW-3 thru MW-16	OU-3 July 1995 MW-17 thru MW-21	OU-3 Dec. 1995 MW-17 thru MW-21	OU-1/OU-3 Aug. 1996 MW-1, MW-3 thru 21	OU-1/OU-3 Oct. 1996 MW-1, MW-3 thru 21	OU-1/OU-3 Feb. 1997 MW-1, MW-3 thru 21	OU-1/OU-3 June 1997 MW-1, MW-3 thru 21	OU-1/OU-3 Sept. 1997 MW-1, MW-3 thru 24	OU-1/OU-3 Jan. 1998 MW-1, MW-3 thru 24
VOCs (Method 524.2)	X	X	X	X	X	X	X	X	X	X
SVOCs (Method 8270)	X	X	X	X	MW-12-2 only					
SVOCs (Method 525.1) ¹		X	X	X						
Title 26 Metals plus Strontium	X (plus filtered)	X (plus filtered)	X (plus filtered)	X (plus filtered)						
Aluminum		X (plus filtered)	X (plus filtered)	X (plus filtered)	X					
Chromium, Lead and Arsenic					X	X	X	X	X	X
Hexavalent Chromium	X (plus filtered)	X	X (plus filtered)	X (plus filtered)	X	X	X	X	X	X
Cyanide	X	X	X	X						
Gross Alpha/Gross Beta	MW-13 only	MW-13 only								
Total Petroleum Hydrocarbons	MW-4 only	MW-4 only								
Perchlorate								X	X	X
Tributyltin					MW-12-1, MW-12-2, MW-13 only	MW-12-2, MW-13 only	MW-12-1, MW-12-2, MW-13 only	MW-4-1, MW-4-2, MW-12-1, MW-12-2, MW-13 only	MW-8 only	
General Minerals	X	X	X	X	X	X	X	X	X	X

1: Analyses for benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, di(2-ethylhexyl)phthalate, hexachlorobenzene, and pentachlorophenol only.

TABLE 2-15

**SUMMARY OF LABORATORY ANALYSES AND SAMPLE
CONTAINERS FOR GROUNDWATER SAMPLES
JET PROPULSION LABORATORY**

Parameter	Method	Container	Preservative	Maximum Holding Time	Detection Limits
Volatile Organic Compounds	EPA 524.2	3x40 ml amber vial	4 drops HCl to pH <2; Cool to 4°C	7 days	
Benzene					0.5 µg/l
Vinyl chloride					0.5 µg/l
Carbon tetrachloride					0.5 µg/l
1,2-Dichloroethane					0.5 µg/l
Trichloroethylene					0.5 µg/l
1,4-Dichlorobenzene					0.5 µg/l
1,1-Dichloroethylene					0.5 µg/l
1,1,1-Trichloroethane					0.5 µg/l
Bromobenzene					0.5 µg/l
Bromodichloromethane					0.5 µg/l
Bromoform					0.5 µg/l
Bromomethane					0.5 µg/l
Chlorobenzene					0.5 µg/l
Chlorodibromomethane					0.5 µg/l
Chloroethane					0.5 µg/l
Chloroform					0.5 µg/l
Chloromethane					0.5 µg/l
o-Chlorotoluene					0.5 µg/l
p-Chlorotoluene					0.5 µg/l
Dibromomethane					0.5 µg/l
1,3-Dichlorobenzene					0.5 µg/l
1,2-Dichlorobenzene					0.5 µg/l
trans-1,2-Dichloroethylene					0.5 µg/l
cis-1,2-Dichloroethylene					0.5 µg/l
Dichloromethane					0.5 µg/l
1,1-Dichloroethane					0.5 µg/l
1,1-Dichloropropene					0.5 µg/l
1,2-Dichloropropane					0.5 µg/l
1,3-Dichloropropane					0.5 µg/l
cis-1,3-Dichloropropene					0.2 µg/l
trans-1,3-Dichloropropene					0.5 µg/l
2,2-Dichloropropane					0.5 µg/l
Ethyl benzene					0.5 µg/l
Styrene					0.5 µg/l
1,1,2-Trichloroethane					0.5 µg/l
1,1,1,2-Tetrachloroethane					0.5 µg/l
1,1,2,2-Tetrachloroethane					0.5 µg/l
Tetrachloroethylene					0.5 µg/l
1,2,3-Trichloropropane					0.5 µg/l
Toluene					0.5 µg/l
m,p-Xylenes					0.5 µg/l
o-Xylene					0.5 µg/l
Bromochloromethane					0.5 µg/l

TABLE 2-15
SUMMARY OF LABORATORY ANALYSES AND SAMPLE
CONTAINERS FOR GROUNDWATER SAMPLES
JET PROPULSION LABORATORY

Parameter	Method	Container	Preservative	Maximum Holding Time	Detection Limits
n-Butylbenzene					0.5 µg/l
Dichlorodifluoromethane					0.5 µg/l
Fluorotrichloromethane					0.5 µg/l
Hexachlorobutadiene					0.5 µg/l
Isopropylbenzene					0.5 µg/l
p-Isopropyltoluene					0.5 µg/l
Naphthalene					0.5 µg/l
n-Propylbenzene					0.5 µg/l
sec-Butylbenzene					0.5 µg/l
tert-Butylbenzene					0.5 µg/l
1,2,3-Trichlorobenzene					0.5 µg/l
1,2,4-Trichlorobenzene					0.5 µg/l
1,2,4-Trimethylbenzene					0.5 µg/l
1,3,5-Trimethylbenzene					0.5 µg/l
2-Butanone (MEK)					5.0 µg/l
4-Methyl-2-Pentanone					5.0 µg/l
Trichlorotrifluoroethane					0.5 µg/l
Title 26 Metals + Strontium (Sr) + Aluminum (Al)		500 ml Polyethylene	2 ml HNO ₃ to pH <2; Cool to 4°C		
Silver (Ag)	6010			6 months	10 µg/l
Aluminum (Al)	200.7			6 months	25 µg/l
Arsenic (As)	206.2			6 months	5 µg/l
Barium (Ba)	6010			6 months	50 µg/l
Beryllium (Be)	6010			6 months	4 µg/l
Cadmium (Cd)	6010			6 months	5 µg/l
Chromium (Cr)	6010			6 months	10 µg/l
Cobalt (Co)	6010			6 months	50 µg/l
Copper (Cu)	6010			6 months	10 µg/l
Mercury (Hg)	245.1			28 days	2 µg/l
Molybdenum (Mo)	6010			6 months	50 µg/l
Nickel (Ni)	6010			6 months	40 µg/l
Lead (Pb)	239.2			6 months	2 µg/l
Antimony (Sb)	204.2			6 months	6 µg/l
Selenium (Se)	270.2			6 months	5 µg/l
Thallium (Tl)	279.2			6 months	2 µg/l
Vanadium (V)	6010			6 months	50 µg/l
Strontium (Sr)	6010			6 months	10 µg/l
Zinc (Zn)	6010			6 months	20 µg/l
Major Cations					
Calcium (Ca)	215.1			6 months	1000 µg/l
Magnesium (Mg)	242.1			6 months	1000 µg/l
Sodium (Na)	273.1			6 months	1000 µg/l
Potassium (K)	258.1			6 months	1000 µg/l
Iron (Fe)	200.7/6010			6 months	100 µg/l

TABLE 2-15

**SUMMARY OF LABORATORY ANALYSES AND SAMPLE
CONTAINERS FOR GROUNDWATER SAMPLES
JET PROPULSION LABORATORY**

Parameter	Method	Container	Preservative	Maximum Holding Time	Detection Limits
Chromium (Hexavalent)	7196	125 ml polyethylene	Cool to 4°C	24 hours	5 µg/l
Cyanide	335.3	125 ml Polyethylene	0.5 ml of 50% NaOH to pH >12; Cool to 4°C	14 days	5 µg/l
Major Anions		500 ml Polyethylene	Cool to 4°C		
Alkalinity	310.1			14 days	2 mg/l
Chloride	300			28 days	1000 µg/l
Sulfate	300			28 days	2000 µg/l
Nitrate (as N)	300			48 hours	100 µg/l
Total Dissolved Solids	160.1			7 days	10 mg/l
Perchlorate	300.0 (Modified)	250 ml Polyethylene	Cool to 4°C	28 days	4 µg/l
Tributyltin	GC/FPD	3x1000 ml glass	Cool to 4°C	35 days	0.002 µg/l
Radioactivity					
Gross Alpha/Beta	9310	1 liter Polyethylene 125 ml Polyethylene	2 ml HNO ₃ to pH <2; Cool to 4°C Cool to 4°C	6 months	-
Total Petroleum Hydrocarbons	EPA 418.1	1000 ml glass	2 ml HCl to pH <2; Cool to 4°C	28 days	1 mg/l
Semi-Volatile Organic Compounds	EPA 8270	2x1000 ml glass	Cool to 4°C	Extraction w/in 14 days; Analysis w/in 40 days	
Phenol					10 µg/l
bis(2-chloroethyl)ether					10 µg/l
2-Chlorophenol					10 µg/l
1,3-Dichlorobenzene					10 µg/l
1,4-Dichlorobenzene					10 µg/l
Benzyl Alcohol					10 µg/l
1,2-Dichlorobenzene					10 µg/l
2-Methylphenol					10 µg/l
bis(2-chloroisopropyl)ether					10 µg/l
4-Methylphenol					10 µg/l
N-nitroso-di-n-dipropylamine					10 µg/l
Hexachloroethane					10 µg/l
Nitrobenzene					10 µg/l
Isophorone					10 µg/l
2-Nitrophenol					10 µg/l
2,4-Dimethylphenol					10 µg/l
Benzoic Acid					50 µg/l
bis(2-chloroethoxy)methane					10 µg/l
2,4-Dichlorophenol					10 µg/l
1,2,4-Trichlorobenzene					10 µg/l
Naphthalene					10 µg/l
4-Chloroaniline					10 µg/l
Hexachlorobutadiene					10 µg/l
4-Chloro-3-methylphenol					10 µg/l

TABLE 2-15

**SUMMARY OF LABORATORY ANALYSES AND SAMPLE
CONTAINERS FOR GROUNDWATER SAMPLES
JET PROPULSION LABORATORY**

Parameter	Method	Container	Preservative	Maximum Holding Time	Detection Limits
2-Methylnaphthalene					10 µg/l
Hexachlorocyclopentadiene					10 µg/l
2,4,6-Trichlorophenol					10 µg/l
2,4,5-Trichlorophenol					50 µg/l
2-Chloronaphthalene					10 µg/l
2-Nitroaniline					50 µg/l
Dimethylphthalate					10 µg/l
Acenaphthylene					10 µg/l
2,6-Dinitrotoluene					10 µg/l
3-Nitroaniline					50 µg/l
Acenaphthene					10 µg/l
2,4-Dinitrophenol					50 µg/l
4-Nitrophenol					50 µg/l
Dibenzofuran					10 µg/l
2,4-Dinitrotoluene					10 µg/l
Diethylphthalate					10 µg/l
4-Chlorophenyl-phenyl ether					10 µg/l
Fluorene					10 µg/l
4-Nitroaniline					50 µg/l
4,6-Dinitro-2-methylphenol					50 µg/l
N-nitrosodiphenylamine					10 µg/l
4-Bromophenyl-phenylether					10 µg/l
Hexachlorobenzene					10 µg/l
Pentachlorophenol					50 µg/l
Phenanthrene					10 µg/l
Anthracene					10 µg/l
Di-n-butylphthalate					10 µg/l
Fluoranthene					10 µg/l
Pyrene					10 µg/l
Butylbenzylphthalate					10 µg/l
3,3-Dichlorobenzidine					20 µg/l
Benzo(a)anthracene					10 µg/l
Chrysene					10 µg/l
bis(2-ethylhexyl)phthalate					10 µg/l
Di-n-octylphthalate					10 µg/l
Benzo(b)fluoranthene					10 µg/l
Benzo(k)fluoranthene					10 µg/l
Benzo(a)pyrene					10 µg/l
Indeno(1,2,3-cd)pyrene					10 µg/l
Dibenzo(a,h)anthracene					10 µg/l
Benzo(g,h,i)perylene					10 µg/l

TABLE 2-15

**SUMMARY OF LABORATORY ANALYSES AND SAMPLE
CONTAINERS FOR GROUNDWATER SAMPLES
JET PROPULSION LABORATORY**

Parameter	Method	Container	Preservative	Maximum Holding Time	Detection Limits
Semi-Volatile Organic Compounds	EPA 525.1	2x1000 ml glass	Cool to 4°C	Extraction w/in 7 days; Analysis w/in 40 days	
Hexachlorobenzene					0.05 µg/l
Pentachlorophenol					1.0 µg/l
Benz(a)anthracene					0.05 µg/l
Benzo(b)fluoranthene					0.02 µg/l
Benzo(a)pyrene					0.02 µg/l
Di(2-ethylhexyl)phthalate					0.6 µg/l

Notes: Method detection limits are highly matrix-dependent and may vary slightly. The detection limits listed herein are provided for guidance.

TABLE 2-16
SUMMARY OF ANALYTICAL RESULTS FROM SOIL SAMPLES COLLECTED DURING OU-1 WELL INSTALLATION

Sample Location	Sample Number	Sample Date	Semivolatile Organic Compounds EPA 8270 (mg/kg)	Title 26 Metals plus Hexavalent Chromium and Strontium (mg/kg) (EPA 6010/7000)												Cyanide EPA 335.3/9010 (mg/kg)	TPH EPA 418.1 (mg/kg)	Nitrate EPA 300.0 (mg/kg)	Total Solids EPA 160.3 (%)		
				Pb	Hg	Ba	Cr	Cr (VI)	Cu	Sr	V	Zn	Co	Ni	Be					Th	
Soil Sample MW-12 (11 ft. bgs)	Soil-01	2-23-94	ND	ND	0.1	110	6.4	ND	9.5	26	42	45	5.1	4.7	ND	ND	ND	ND	94		
			<u>Extraneous Peaks</u>																		
			1,1,2,2-Tetrachloroethane	0.27B ⁽¹⁾																	
			Decamethylcyclopentasiloxane	0.59B																	
			Dodecamethylcyclohexasiloxane	0.38B																	
			Ethyl Benzene	0.22B																	
			Unknown Phthalate	0.14																	
Soil Sample MW-12 (45 ft. bgs)	Soil-02	2-24-94	ND	ND	0.14	89	12	ND	19	48	39	47	5.1	9	0.61	ND	ND	ND	80		
			<u>Extraneous Peaks</u>																		
			1,1,2,2-Tetrachloroethane	0.40B																	
			Ethyl Benzene	0.24B																	
Soil Sample MW-15 (13 ft. bgs)	Soil-03	2-26-94	ND	ND	0.03	140	5.2	ND	5.3	31	23	48	ND	ND	ND	ND	ND	2.7	99		
			<u>Extraneous Peaks</u>																		
			1,1,2,2-Tetrachloroethane	0.26B																	
			Decamethylcyclopentasiloxane	0.58B																	
			Dodecamethylcyclohexasiloxane	0.35B																	
			Ethyl Benzene	0.20B																	
			Unknown Phthalate	0.14																	
Soil Sample MW-15 (29 ft. bgs)	Soil-04	2-26-94	ND	ND	0.05	89	4.3	ND	9.2	16	31	34	ND	ND	ND	15	ND	ND	ND	89	
			<u>Extraneous Peaks</u>																		
			1,1,2,2-Tetrachloroethane	0.29B																	
			Decamethylcyclopentasiloxane	0.54B																	
			Dodecamethylcyclohexasiloxane	0.33B																	
			Ethyl Benzene	0.16B																	
			Unknown Hydrocarbon	0.15																	
Dup. Soil Sample MW-15 (28.5 ft. bgs)	Soil-05	2-26-94	ND	ND	0.04	93	3.5	ND	11	21	27	30	ND	ND	ND	ND	ND	ND	ND	89	
			<u>Extraneous Peaks</u>																		
			1,1,2,2-Tetrachloroethane	0.33B																	
			Decamethylcyclopentasiloxane	0.52B																	
			Dodecamethylcyclohexasiloxane	0.32B																	
			Ethyl Benzene	0.23B																	
			Unknown Hydrocarbon	0.15																	
			Unknown Hydrocarbon	0.17																	
Soil Sample MW-16 (9.0 ft. bgs)	Soil-06	2-28-94	ND	ND	0.03	100	8.8	ND	10	24	38	47	ND	7.3	0.56	ND	ND	100	ND	97	
			<u>Extraneous Peaks</u>																		
			1,1,2,2-Tetrachloroethane	0.23B																	
			Decamethylcyclopentasiloxane	0.38B																	
			Dodecamethylcyclohexasiloxane	0.25B																	
			Ethyl Benzene	0.43B																	
			Unknown hydrocarbon	0.14																	
			Unknown hydrocarbon	0.15																	
Unknown hydrocarbon	0.16																				
			Unknown phthalate	0.27																	

TABLE 2-16
SUMMARY OF ANALYTICAL RESULTS FROM SOIL SAMPLES COLLECTED DURING OU-1 WELL INSTALLATION

Sample Location	Sample Number	Sample Date	Semivolatile Organic Compounds EPA 8270 (mg/kg)	Title 26 Metals plus Hexavalent Chromium and Strontium (mg/kg) (EPA 6010/7000)												Cyanide EPA 335.3/9010	TPH EPA 418.1	Nitrate EPA 300.0	Total Solids EPA 160.3
				Pb	Hg	Ba	Cr	Cr (vi)	Cu	Sr	V	Zn	Co	Ni	Be	Th	(mg/kg)	(mg/kg)	(mg/kg)
Soil Sample MW-16 (19.0 ft. bgs)	Soil-07	2-28-94	ND <u>Extraneous Peaks</u> 1,1,2,2-Tetrachloroethane 0.32B Decamethylcyclopentasiloxane 0.75B Dodecamethylcyclohexasiloxane 0.48B Ethyl Benzene 0.23B	ND	0.1	46	4.4	ND	4.8	25	22	23	ND	ND	ND	ND	ND	ND	96
Soil Sample MW-16 (28.0 ft. bgs)	Soil-08	2-28-94	ND <u>Extraneous Peaks</u> 1,1,2,2-Tetrachloroethane 0.34B Decamethylcyclopentasiloxane 1.2B Dodecamethylcyclohexasiloxane 0.88B Ethyl Benzene 0.21B Unknown hydrocarbon 0.13 Unknown hydrocarbon 0.13 Unknown hydrocarbon 0.19 Unknown scan #833 0.18B	ND	0.08	46	3	ND	5.2	20	23	33	ND	ND	ND	ND	ND	ND	97
Typical Metals Background: Western Conterminous United States Soils ⁽²⁾	--	--	--	<10 to 700	<0.01 to 4.6	70 to 5000	3 to 2000	NA	2 to 30	10 to 3000	7 to 500	<20 to 1500	<3 to 50	<5 to 700	<1 to 15	NA	--	--	--
Typical Metals Background: California Soils ⁽³⁾	--	--	--	12 to 97	0.05 to 0.09	130 to 1400	23 to 1600	NA	9.1 to 96	20 to 270	39 to 290	88 to 240	2.7 to 47	9.0 to 510	0.26 to 2.7	0.17 to 1.1	--	--	--
Metals Background: JPL Soils ⁽⁴⁾	--	--	--	2.2 to 6.2	0.04 to 0.09	38 to 180	4.4 to 12	ND	4.5 to 12	20 to 30	20 to 51	25 to 54	3.2 to 8.2	2.0 to 6.9	0.35 to 0.58	5.2 to 5.2	--	--	--

(1): "B" indicates compound was also detected in laboratory method blank.

(2): Shacklette and Boerger, 1984: *Element Concentrations and Other Surficial Materials of the Conterminous United States*.

(3): University of California, March 1996: *Background Concentrations of Trace and Major Elements in California Soils*.

(4): Range of detections from OU-2 RI (5 samples).

NA: Not available.

TABLE 2-17

SUMMARY OF WELL ELEVATION AND LOCATION SURVEY DATA
JET PROPULSION LABORATORY

Well Number	Well Location ⁽¹⁾		Elevation in Feet			
	Northing (Meters)	Easting (Meters)	Top Traffic Box	Top 4-inch Well Casing	Top Westbay Casing	Top Dedicated Pump Assembly
MW-1	3,785,253.87	392,506.83	1,115.84 ⁽²⁾	1,116.70	NI	1,116.72
MW-2	3,784,878.83	391,448.64	1,169.47	1,168.85	NI	NI
MW-3	3,784,893.00	392,394.48	1,099.59	1,099.82	1,100.34	NI
MW-4	3,784,814.98	392,170.24	1,083.69	1,082.72	1,082.84	NI
MW-5	3,784,637.09	392,063.66	1,072.20	1,071.60	NI	1,071.62
MW-6	3,785,031.55	391,541.07	1,189.09	1,188.52	NI	1,188.54
MW-7	3,785,211.01	392,128.64	1,213.43	1,212.88	NI	1,212.90
MW-8	3,785,086.61	392,220.28	1,140.22	1,139.53	NI	1,139.55
MW-9	3,785,113.00	392,441.64	1,104.78 ⁽²⁾	1,106.02	NI	1,106.04
MW-10	3,784,670.25	391,893.97	1,088.27	1,087.71	NI	1,087.73
MW-11	3,785,123.56	392,340.01	1,139.63	1,139.35	1,139.30	NI
MW-12	3,785,004.97	392,338.86	1,102.42	1,102.14	1,102.14	NI
MW-13	3,785,063.23	391,935.86	1,184.02	1,183.47	NI	1,183.49
MW-14	3,784,898.62	391,452.43	1,174.05	1,173.42	1,173.47	NI
MW-15	3,785,177.91	392,444.96	1,121.34	1,120.66	NI	1,120.68
MW-16	3,785,192.89	391,976.59	1,236.66	1,236.27	NI	1,236.29
MW-17	3,784,428.18	392,675.34	1,191.65	1,190.99	1,191.21 ⁽⁴⁾	NI
MW-18	3,784,907.38	392,825.38	1,225.66	1,225.34	1,225.41 ⁽⁴⁾	NI
MW-19	3,783,949.77	392,375.82	1,143.68	1,143.20	1,142.94 ⁽⁴⁾	NI
MW-20	3,783,826.19	393,186.03	1,165.51	1,164.89	1,165.05 ⁽⁴⁾	NI
MW-21	3,784,268.36	391,582.89	1,059.36	1,058.99	1,059.10 ⁽⁴⁾	NI
MW-22	3,785,041.07	391,762.83	1,177.28	1,176.81	1,176.98	NI
MW-23	3,784,851.24	391,845.47	1,109.02	1,108.34	1,108.84	NI
MW-24	3,785,151.62	392,077.66	1,201.28	1,200.91	1,200.94	NI
MH-01	3,784,885.04	392,474.98	NI	1,099.78 ⁽³⁾	NI	NI

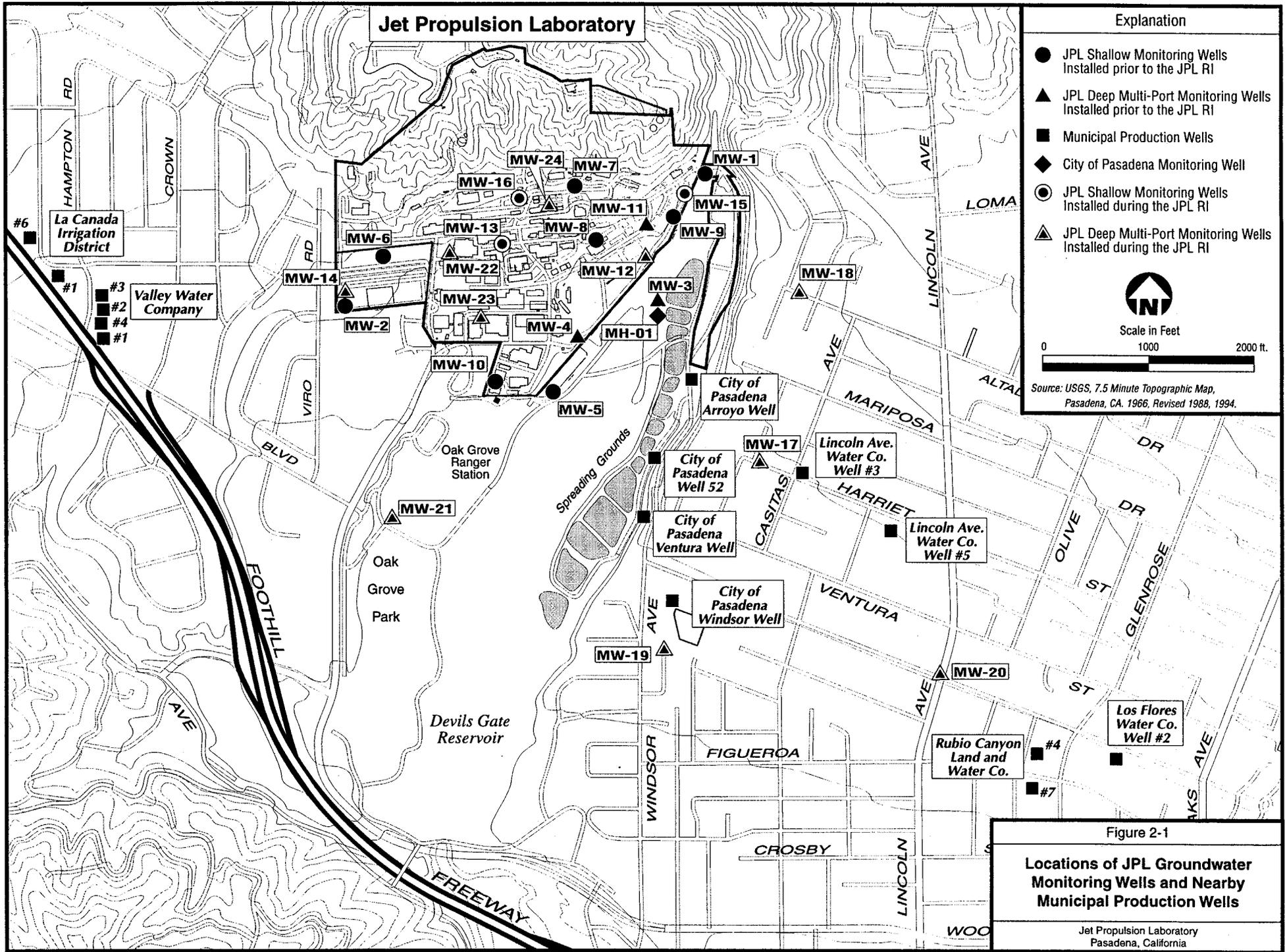
(1) Universal Transverse Mercator coordinator Zone 11 (based on North American Datum 83).

(2) Top concrete pad north of rising monument cover.

(3) 6-inch well casing.

(4) 2-inch Westbay Casing.

NI: Not Installed.



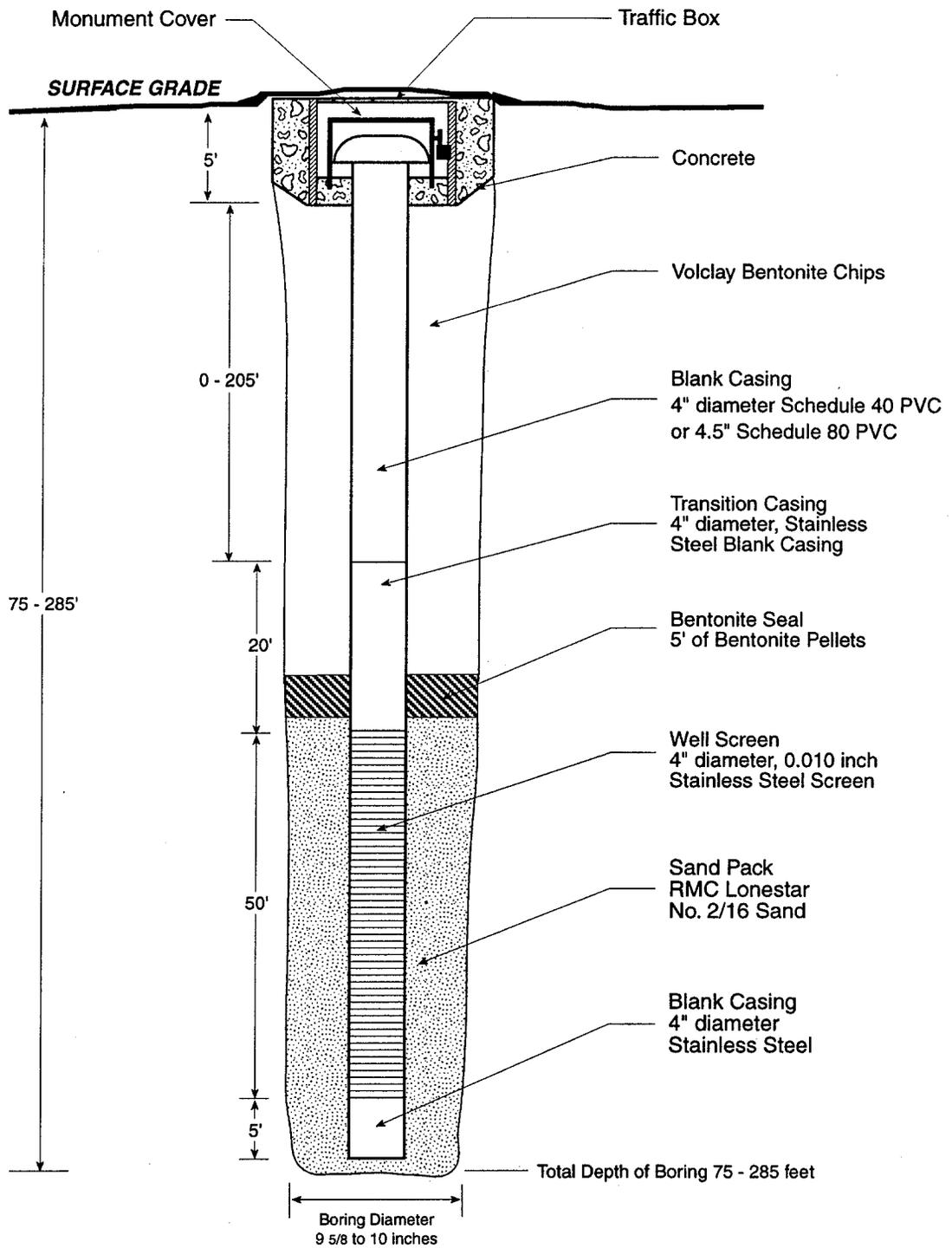
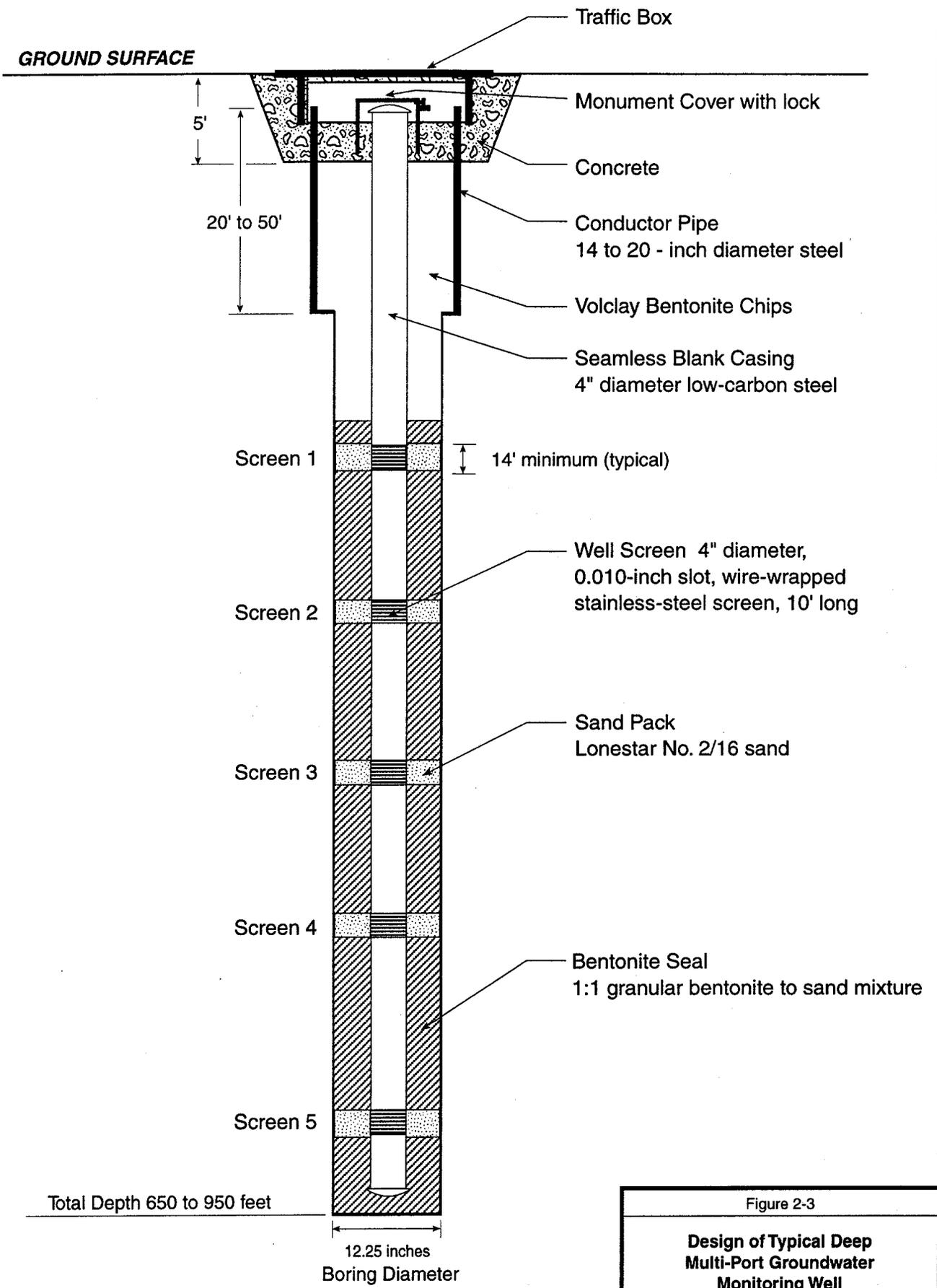


Figure 2-2

**Design of Typical Shallow
Groundwater Monitoring Well**

Jet Propulsion Laboratory
Pasadena, California



GROUND SURFACE

Traffic Box

5'

Monument Cover with lock

Concrete

20' to 50'

Conductor Pipe
14 to 20 - inch diameter steel

Volclay Bentonite Chips

Seamless Blank Casing
4" diameter low-carbon steel

Screen 1

14' minimum (typical)

Well Screen 4" diameter,
0.010-inch slot, wire-wrapped
stainless-steel screen, 10' long

Screen 2

Sand Pack
Lonestar No. 2/16 sand

Screen 3

Screen 4

Bentonite Seal
1:1 granular bentonite to sand mixture

Screen 5

Total Depth 650 to 950 feet

12.25 inches
Boring Diameter

Figure 2-3

**Design of Typical Deep
Multi-Port Groundwater
Monitoring Well**

Jet Propulsion Laboratory
Pasadena, California

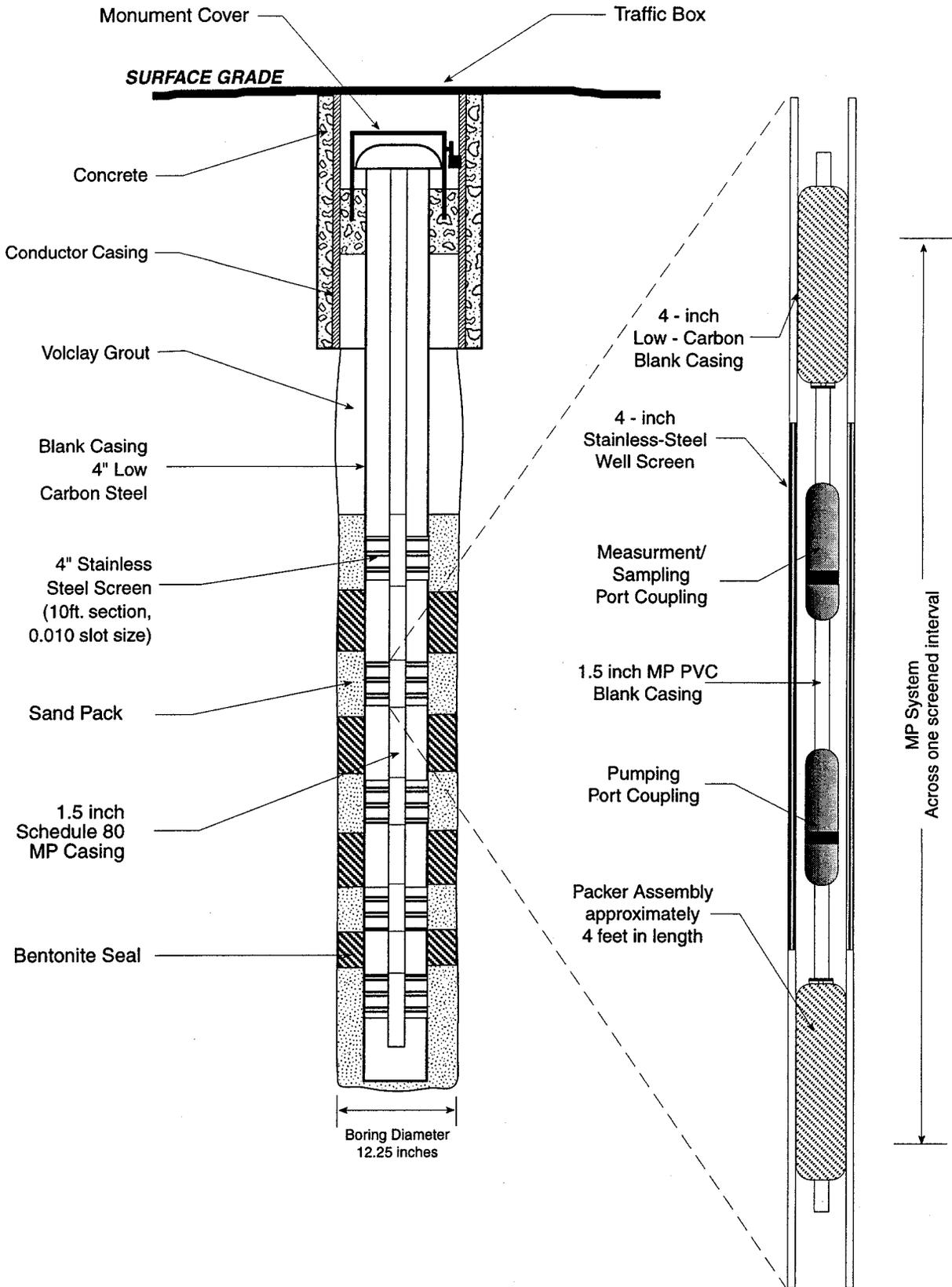


Figure 2-4

**Typical Multi-Port (MP)
Monitoring Well Casing Installation**

Jet Propulsion Laboratory
Pasadena, California

3.0 PHYSICAL SETTING

The description of the physical setting of the study area is based on field observations, information from previous investigations and analytical data. The site features discussed in the following sections include physiography, meteorology, geology and hydrogeology.

3.1 PHYSIOGRAPHY/TOPOGRAPHY

The JPL site is located within the San Gabriel Valley in the eastern portion of Los Angeles County. The San Gabriel Valley is bounded on the north by the San Gabriel Mountains, which consist of relatively steep, rocky ridges and numerous canyons. It is bound to the south, southwest, and southeast by a series of east-west trending hills that include the Repetto, Merced, Puente, and San Jose Hills (Figure 3-1). This system of relatively low hills rises about 500 feet from the valley floor to form a crescent shape, separating the southern edge of the San Gabriel Valley from the coastal plain of Los Angeles. A break in these hills, approximately 1.5 miles wide and located northwest of Whittier, is referred to as the Whittier Narrows.

The San Gabriel Mountains range from about 900 feet in elevation along their base to a maximum elevation of more than 10,000 feet above sea level. The San Gabriel Valley itself forms a broad plain that slopes generally to the south, downward from the base of the San Gabriel Mountains. The average slope of the valley floor is about 65 feet per mile.

The rivers and tributaries that traverse the valley floor generally flow in a southerly direction. Almost all natural surface outflow from the San Gabriel Valley passes through Whittier Narrows (Figure 3-1).

3.2 METEOROLOGY

The San Gabriel Valley has a semi-arid Mediterranean climate that is characterized by mild, rainy winters and warm, dry summers. Average rainfall in the area is variable and averages approximately 20 inches per year. The rainfall is greater than that in the City of Los Angeles as a result of orographic effects of the nearby San Gabriel Mountains. The majority of the annual precipitation in the San Gabriel Valley (80 percent) occurs between the months of November and April.

Temperatures in the San Gabriel Valley are relatively mild, with August typically the warmest month and January the coolest. Extremes for the area range from about 30°F in winter to 105°F during the summer months.

Wind patterns change seasonally in both strength and direction in response to normal seasonal variations in barometric pressure systems. Generally, winds are mild throughout the year, characterized by ocean breezes (onshore) during the day and land breezes (offshore) at night.

Occasionally during the fall, the area is affected by "Santa Ana" winds. These winds occur as the result of strong high-pressure systems moving into parts of Nevada and Utah creating strong, hot and dry winds originating from the northeast. Near the mouth of canyons oriented along the direction of airflow, these winds can be particularly strong. Winds resulting from Santa Ana conditions have been recorded at speeds in excess of 100 miles per hour down the Arroyo Seco (Boyle Engineering, 1988).

3.3 GEOLOGY

The geology in the study area is discussed in this section. A generalized discussion of the local and regional geology of the area has been included in the RI Work Plan (Ebasco, 1993a). However, a more detailed discussion based on information obtained during the OU-1/OU-3 RI is included below.

3.3.1 Stratigraphy

The stratigraphy beneath the study area was evaluated by reviewing a published surface geologic map (Figure 3-2) and by constructing five geologic cross sections (Figures 3-3 through 3-7). The cross sections were constructed by correlating lithologic logs and geophysical logs along with reviewing historical water levels and hydraulic heads in the deep multi-port wells (see below).

A surface geologic map of the north half of the Pasadena quadrangle, which includes the study area, was produced by the California Division of Mines and Geology (Smith, 1986). The geologic formations present within the subject area, as described by the California Division of Mines and Geology, are included on the geologic map in Figure 3-2. Also shown on Figure 3-2 are the locations of the cross sections.

The lithologic columns and geophysical logs depicted on the cross sections accurately represent the boring logs and geophysical logs included in Appendices B and C. As anticipated, correlation between wells was, in some cases, difficult due to the variable nature of alluvial fan-type deposits. Correlations of generally similar lithologic sequences at similar depths were made whenever possible as opposed to attempting to correlate individual sand and silt layers. Correlations were also made between sections of the aquifer that had similar responses to pumping of nearby municipal production wells (similar amounts of "drawdown"). Historical hydrographs from each well are included on the cross sections for reference. Throughout the aquifer, silt-rich intervals are present that appear to inhibit the vertical migration of groundwater during periods of pumping of the nearby production wells. Well screens located between silt-rich intervals that are similarly affected, or show similar amounts of drawdown during periods of pumping, were correlated with each other.

Based on the above criteria, four primary "hydrogeologic layers" of the aquifer, or "aquifer layers", were delineated in the study area above the crystalline basement complex. The geophysical log that can be considered a "type log" for the study area is from well MW-19 (Figure 3-5). Based on a somewhat unique electrical resistivity curve character and similar

response to nearby pumping, three of the four “aquifer layers” in the study area are present in this well. After evaluating descriptions of geologic formations in the study area published by the California Division of Mines and Geology (Smith, 1986) and the USGS (Crook, et. al., 1981), the primary aquifer layers present in the study area were identified with geological formations (Figures 3-3 through 3-7).

The four aquifer layers in the study area include the upper and lower sections of the Older Fonglomerate Series (aquifer Layers 1 and 2, respectively), the Pacoima Formation (aquifer Layer 3) and the Saugus Formation (aquifer Layer 4). The fourth aquifer layer is represented by one well screen, the deepest screened interval in the well furthest downgradient of JPL (MW-20). Further discussion and description of the four aquifer layers is included below.

Descriptions of each of the soil/rock types beneath the study area as defined by the California Division of Mines and Geology (Smith, 1986) are presented below, beginning with the oldest first.

Leucocratic Granodiorite (gl)

The oldest rocks in the subject area include igneous intrusive rocks that comprise the crystalline basement complex beneath the subject area (Figures 3-2 through 3-7). The dominant crystalline rock type is a light gray to buff, fine to medium grained leucocratic granodiorite (map unit gl) with a hypidiomorphic texture (Smith, 1986). Its typical composition is: plagioclase, 60% to 75%; potassium-feldspar, 5% to 15%; quartz, 10% to 15%; biotite, 2% to 10%, and a trace of magnetite. This rock type is widely distributed and recognized by its light color and resistance to chemical weathering. The age of this rock is probably Cretaceous (Smith, 1986).

Saugus Formation (TQs)

The Saugus Formation (map unit TQs) lies on top of the crystalline basement rocks at the far eastern edge of the subject area (Figures 3-4 and 3-5). For the purpose of this RI, the Saugus Formation will be referred to as the fourth aquifer layer (Layer 4). In the study area, it is represented by screen 5 in well MW-20 (see Section 3.4), the only screen in the study area assumed to be located in the Saugus Formation.

The Saugus Formation is typically composed of arkosic sand, pebbly arkosic sand, and conglomeratic arkosic sand that range from light-brown to light-gray in color. Lithic clasts in the Saugus Formation were likely derived from the granitic and metamorphic terrain located in the adjacent San Gabriel Mountains. However, some easily recognizable and distinctive clasts of monzonite and augen gneiss, are abundant in all of the sedimentary units younger than the Saugus Formation, but are not found in the Saugus Formation (Smith, 1986). The formation appears to have been deposited primarily in a fluvial floodplain environment (Smith, 1986). This is in contrast to “high energy” fanglomerate depositional environment that exists today along the southern edge of the San Gabriel Mountains. However, the clast sizes and bedding styles of the Saugus Formation are sufficiently variable to indicate a range of depositional environments (Smith, 1986).

The age of the Saugus Formation is uncertain, as no fossil evidence has been found in this area. However, the formation may be late Pliocene to early Pleistocene in age, based on comparison to similar deposits in the Ventura basin that contain fossils of that age (Smith, 1986).

The three principal criteria that can be used to identify the Saugus Formation include: 1) the combination of lithic clast types in the Saugus Formation is different from that of younger units, 2) the Saugus beds are typically not as well graded as those of younger units, and 3) the Saugus beds have generally resulted from a relatively low energy floodplain depositional environment compared to younger formations (Smith, 1986).

Pacoima Formation (Qp)

The Pacoima Formation (Map unit Qp) lies unconformably on the crystalline basement complex beneath most of the subject area and on the Saugus Formation at the far eastern edge of the study area (around MW-20). For the purpose of this RI, the Pacoima Formation will be referred to as the third aquifer layer, or Layer 3, in the study area. It is represented by a number of well screens (Section 3.4). This unit is typically composed of fluvial conglomeratic arkosic sand that contains significant amounts of gravel and some boulders. Its color is light brown where unaffected by weathering, but can range from orange to dark reddish-orange with significant weathering.

The gravel and boulders in the Pacoima Formation are generally of the same lithology as the basement rock types that are found in the adjacent San Gabriel Mountains. In a general sense, the Pacoima lithic clast assemblage is identical to that of the modern stream deposits that emerge from the San Gabriel Mountains (Smith, 1986). The Pacoima Formation was likely deposited in a fanlomeratic to stream channel type environment (Smith, 1986) that is generally assumed to have had a higher energy than the environment in which the older Saugus Formation formed (Smith, 1986).

The greatest exposed stratigraphic thickness of the Pacoima Formation is approximately 300 feet on the east side of Gould Mesa, approximately 1 mile north of JPL (Smith, 1986). There, a continuous section is exposed from the bottom of the Arroyo Seco Canyon to the top of the mesa. Beneath the subject area, it is estimated that the Pacoima Formation is approximately 200 to 300 feet thick. The Pacoima Formation does not differ lithologically much from younger strata, making distinction between them difficult. The easiest way to differentiate the Pacoima Formation from younger units in surface exposures is the characteristic way the Pacoima Formation weathers to a red or orange color (Smith, 1986). However, during the mud rotary drilling for the OU-1/OU-3 RI at JPL, this color change, if present, was not apparent.

Older Fanlomerate Series (Qo1 to Qo4)

Overlying the Pacoima Formation throughout the study area is the Older Fanlomerate Series (map units Qo1 to Qo4). This series is composed of light-brown to gray to dark-brown fluvial arkosic sands with abundant gravel and boulders. Smith (1986) divided the series into four stratigraphic members, in a somewhat arbitrary manner, on the basis of apparent age. Overall, there are no local compositional differences between the oldest (Qo1) and youngest strata (Qo4) within this series. The predominant source of the Older Fanlomerate series is clearly the

crystalline rock complex exposed in the present day San Gabriel Mountains, although some reworked material from the Pacoima Formation is found in these sediments (Smith, 1986).

The maximum exposed thickness of the Older Fanglomerate Series is about 150 feet along the east side of the Arroyo Seco near JPL (Smith, 1986). The age of this series ranges from late Pleistocene through Holocene. The age of the oldest strata is not precisely known because no fossil evidence has been found (Smith, 1986).

For the purpose of this RI, the Older Fanglomerate Series has been divided into an upper and lower section, each representing an aquifer layer, or Layers 1 and 2. The division of the Older Fanglomerate Series was primarily based on how screens in each layer were affected by nearby pumping. The "upper" and "lower" Older Fanglomerate Series layers are both represented by a number of well screens (Section 3.4).

Recent Fanglomerate and Stream Channel Deposits (Qr and Qsc)

The Recent Fanglomerate (map symbol Qr) mapped in the subject area is material of Holocene age that is present on alluvial fan surfaces still subject to deposition (Smith, 1986). Stream Channel Deposits (map symbol Qsc) represent material within confined water courses that is subject to present day reworking by stream action (Smith, 1986). The lithologic characteristics of these deposits are essentially the same as those of the youngest of the Older Fanglomerate Series (Qo4) described above.

Artificial Fill (af)

The mapping of artificial fill (map symbol af) in the area of JPL (Smith, 1986) is restricted to fills of significant size or unusual occurrence.

3.3.2 Structure

The JPL study area lies within the San Gabriel Valley, immediately south of the southern edge of the San Gabriel Mountains. The San Gabriel Mountains, together with the San Bernardino Mountains to the east and the Santa Monica Mountains to the west, make up a major portion of the east-west trending Transverse Range geologic province of California. This province is dominated by east-west trending folds, reverse faults and thrust faults, indicating a history of extensive north-south compressional deformation.

The San Gabriel Mountains are primarily composed of Cretaceous to Tertiary crystalline rocks, including diorites, granites, monzonites, and granodiorites, with a complex history of intrusion and metamorphism. Episodic pulses of tectonic uplift of the San Gabriel Mountains has produced the present topography of the area (Smith, 1986). Most of this uplift has occurred along a system of north- to northeast-dipping reverse faults and thrust faults located along the southern edge of the San Gabriel Mountains referred to as the Sierra Madre Fault system. The Sierra Madre Fault system separates the San Gabriel Mountains to the north from the San Gabriel Valley to the south.

A significant component of the Sierra Madre Fault system crosses the JPL site in the form of the JPL Thrust Fault. This fault is the only positively identified structural feature present on the JPL site, although there is no surface expression of the JPL Thrust Fault east of the Arroyo Seco Canyon (Smith, 1986). The known and inferred locations of the JPL Thrust Fault are shown on Figure 3-2.

Several previous investigations at JPL have provided information on the actual and inferred location of the JPL Thrust Fault. These studies include those by Crandall and Associates (1977a and 1977b) and Agabian Associates (1977) (see Section 1.3.3) during which boreholes were drilled and trenches excavated to obtain information on the location of the fault. Data obtained indicate the fault dips approximately 40 degrees to the north and has over 800 feet of vertical displacement on the JPL site. The northernmost splay of the fault observed on the hillside north of JPL (Figure 3-2) appears to have a displacement on the order of approximately 20 to 40 feet. The location of the fault is clearly defined where older crystalline basement rocks have been thrust over the younger alluvial deposits. In other locations where alluvial sediments have been thrust over similar alluvial sediments, it is more difficult, if not impossible, to distinguish the fault.

Data on the depth to the crystalline basement complex from deep JPL monitoring wells and nearby municipal production wells have been compiled showing the crystalline basement complex generally dips to the north and east beneath JPL. A contour map of the top of the crystalline basement around the JPL area is shown on Figure 3-8 and a more detailed contour map of the top of the basement complex beneath the JPL site is shown on Figure 3-9. As shown on both figures, a second fault has been inferred on-site trending east-west along the southern section of the site. This relatively minor fault was inferred based on the elevations of the basement complex encountered in nearby wells. There are no indications that this inferred fault has any influence on groundwater flow patterns.

3.4 HYDROGEOLOGY

The San Gabriel Valley has been divided into distinct groundwater basins, one of which is the Raymond Basin where JPL is located. The Raymond Basin lies within the far northwest portion of the San Gabriel Valley and is bordered on the north by the San Gabriel Mountains, on the west by the San Rafael Hills, and on the south and east by the Raymond Fault. The Raymond Basin covers approximately 40 square miles and slopes to the south with elevations ranging from approximately 2,000-feet above mean sea level (msl) at the base of the mountains to approximately 600 feet above msl at the Raymond Fault.

The alluvial deposits in the subject area comprise the groundwater reservoir. These alluvial deposits range in thickness up to about 1,100 feet (CH₂M Hill, 1989). As shown on Figure 3-10, groundwater elevations for the basin, in the fall of 1997, ranged from 500 feet above msl in the southeastern portion of the basin to 1400 feet above msl in the northwestern portion (Raymond Basin Management Board, 1998). However, it should be noted that groundwater elevations in the basin do change in response to pumping and natural recharge.

The Raymond Basin provides an important source of potable groundwater for many communities in the area including Pasadena, La Cañada-Flintridge, San Marino, Sierra Madre, Altadena, Alhambra, and Arcadia. The aquifer yields water readily at rates ranging from a few hundred to several thousand gallons per minute (gpm), providing approximately 36,163 acre feet to users in 1997 (Raymond Basin Management Board, 1998).

The Raymond Basin is further divided into three separate hydrologic subbasins, the Pasadena Subarea, the Santa Anita Subarea, and the Monk Hill Subbasin. Groundwater in the basin flows in somewhat different directions depending on where one is located. JPL is located in the Monk Hill Subbasin (Figure 3-10). The boundaries between the three subdivisions, although somewhat arbitrary, represent general locations of changing groundwater gradient or groundwater divides.

On a regional scale, a confluence of groundwater flow regimes occurs in the Monk Hill Subbasin. At the western end of the Monk Hill Subbasin, upgradient of JPL, the groundwater flow is predominantly to the southeast, and at the eastern end of the Monk Hill Subbasin, downgradient of JPL, the groundwater flow is predominantly to the south (Figure 3-10). Groundwater elevation contour maps generated since the 1930's (Department of Public Works, 1954) indicate that regional groundwater flow has predominantly been to the southeast upgradient of JPL. In the Monk Hill Subbasin, the City of Pasadena and several other local water companies have installed a number of municipal water production wells to extract groundwater strictly from the saturated sections of these alluvial deposits. The presence of municipal groundwater production wells near JPL and the presence of groundwater recharge basins (spreading grounds) near JPL in the Arroyo Seco significantly influences the local groundwater flow directions.

Underlying the alluvium in the subject area is the crystalline basement complex, comprised of the same general rock types that are exposed in the San Gabriel Mountains to the north. Because of their crystalline nature, groundwater can only occur in fractures or joints. As a result, the crystalline bedrock is treated as non-water bearing.

The aquifer below the site is generally considered to be an unconfined, or water-table aquifer. However, vertical hydraulic head differences with depth are observed between screens in deep JPL multi-port monitoring wells located near production wells when the production wells are pumping, which indicates the presence of other than completely unconfined conditions. This is due to the presence of relatively thin, silt-rich layers located throughout the alluvial aquifer that inhibit vertical flow of groundwater. In general, primarily based on historical hydrographs from the deep JPL wells, the aquifer has been divided into four "hydrogeologic" layers based on how silt-rich intervals influence the hydraulic heads in the aquifer during periods of pumping of the nearby municipal wells.

The groundwater table has been measured in the JPL monitoring wells at depths ranging from approximately 22 to 270 feet below ground surface. This wide range of depth to groundwater can primarily be related to the relatively steep topography present around JPL, but can also be related to effects from seasonal groundwater recharge at the nearby spreading grounds and affects from groundwater production from the nearby municipal production wells.

The following sections describe the results of the aquifer testing performed in the JPL monitoring wells, results of the general water chemistry analyses from the JPL wells, and a discussion on the groundwater flow patterns around JPL in each aquifer layer.

3.4.1 Hydraulic Characteristics

The hydraulic characteristics of the aquifer were evaluated by performing simple aquifer tests at each shallow monitoring well at JPL and at each screen interval in the deep multi-port monitoring wells. The goal was to collect data for estimating the horizontal hydraulic conductivity of the aquifer material surrounding each monitoring well casing. Two different types of aquifer tests were performed, one in the shallow wells and one in the deep wells, to accommodate the construction design differences between the well types. The shallow wells were subjected to in-situ slug/bail tests performed by displacing a quantity of water and monitoring the water level recovery in each well. Rising-head tests were performed within each screened interval in each of the deep wells. Descriptions of these test procedures and the results of analyses of the data are presented in the following sections.

3.4.1.1 Slug/Bail Test Procedure

The slug/bail tests were designed to monitor the relationship between water level elevations and time in each of the shallow wells. This relationship is indicative of how quickly water can be transported from the well to the adjacent formation or from the formation to the well. The data collected from the tests in combination with the geometric characteristics of the wells were used to estimate the hydraulic conductivity of the aquifer material in the proximity of each well screen.

For purposes of water displacement, a 15-foot section of 3-inch diameter Schedule 80 PVC casing with threaded end caps was assembled. Prior to testing, the casing was filled with deionized water to increase its density or weight to assure submergence. The casing was carefully assembled to prevent leakage in the wells. This water-filled blank casing is referred to as the "solid casing" in this report.

Initially, the depth to the static (undisturbed) water level in each well was measured using a water-level sounder. Subsequently, a pressure transducer probe was lowered into the well and fixed at a depth below the static water level. The probe was positioned at a sufficient depth to be located below the solid casing during the tests. The pressure transducer was connected to a data logger to record the measurements taken by the transducer. The data logger recorded water pressure that reflected the height of the water column above the transducer probe. The water displacements in the wells were obtained by calculating the deviations from the static water height.

During the tests, the lowering and raising of the solid casing into and out of the wells was accomplished by using a hydraulic winch. The solid casing was initially lowered to near the top of static water in the test well. Upon initiating the test, the solid casing was quickly lowered into

the well and submerged under water. This sudden submergence of the solid casing resulted in a rise of water level or pressure increase in the well as recorded by the pressure transducer. Subsequently, the water level gradually recovered to the static water level and the recovery recorded by the data logger. The water level data was used to provide a relationship for water level displacement with time. Accordingly, one set of data was obtained from this test which is referred to as the slug test, because it simulated an addition of a "slug" of water to the well.

Upon reaching a stage of stabilized water level, the aquifer test was repeated in each well, except this time the solid casing was removed and the data logger recorded the water-level displacement. Sudden removal of the solid casing resulted in an initial fall in the water level in the test well simulating removal of water from the well with a bailer. This test, referred to as the "bail" test, also provided a relationship for water level displacement with time.

The slug/bail tests were conducted in the JPL shallow monitoring wells MW-1, MW-5 through MW-10, MW-13 and MW-15. Well MW-16 is slightly deviated from vertical so that the cable holding the solid casing became entangled with the transducer cable during all attempts to complete the tests. The tests were repeated in some of the wells to provide additional sets of data. The results are summarized in Section 3.4.1.3.

3.4.1.2 Rising-Head Test Procedure

Rising-head tests were performed at each screen interval in the deep multi-port wells. These tests are conceptually similar to the "bail-type" tests described above. The tests were repeated at each screened interval and provided the required data to estimate the hydraulic conductivity of the formation material adjacent to each particular screen section.

Each multi-port well at the site includes pumping port couplings which can be used to provide hydraulic connection between the interior of the Westbay® casing and the test zone. The pumping port couplings contain a valve that can be opened to allow groundwater to flow between the surrounding formation and the Westbay® casing. Once a valve is open, the Westbay® casing becomes a screened standpipe piezometer similar to the shallow monitoring wells.

To conduct the rising head test at a particular multi-port well screen, all pumping ports were initially closed. Accordingly, the interior of the Westbay® casing is watertight and not connected to any of the monitoring zones. Subsequently, the following steps were followed:

- Step 1** - The water level in the Westbay® casing was measured using a water level sounder.
- Step 2** - Water was bailed from the well to reduce the water level inside the casing below that of the aquifer.
- Step 3** - A pressure transducer was lowered into the well and placed below the current water level in the Westbay® casing; the transducer was connected to a data logger to record the water level changes.

Step 4 - The pumping port at an individual screened interval was opened to the outside formation.

Step 5 - The hydraulic pressure, or water level, in the Westbay® casing was monitored until recovery to a static condition; measurement recordings were initiated immediately prior to opening the pumping port and continued throughout the test.

The rising-head tests were conducted in each of the multi-port wells. The data obtained from the rising-head tests provided a relationship between the water level changes with time for each screen section. This relationship was used to estimate the hydraulic conductivity as described in Section 3.4.1.3.

3.4.1.3 Aquifer Testing Results

The aquifer tests described in Sections 3.4.1.1 and 3.4.1.2 above provided the data required for estimation of the formation hydraulic conductivities. The aquifer test data from each aquifer test are represented on hydraulic head versus time graphs in Appendix D.

The method used for calculation of hydraulic conductivities was developed by Bouwer and Rice (1976) and described in Bouwer (1978, 1989). The method provides an estimate of the hydraulic conductivity of the formation material surrounding a well, based on the geometry of the well and the water-level displacement data. This method is suitable for analysis of test data from partially penetrating wells in unconfined or semi-confining aquifers, which is consistent with the general conditions encountered in the shallow and deep monitoring wells at JPL.

To apply the Bouwer and Rice method to the JPL site, it was assumed that the formation surrounding each well screen was homogeneous, isotropic and infinite in areal extent. Certainly, conditions at the site deviated from these ideal conditions but it was assumed that any deviation had only a minor effect on the estimated conductivities.

When the Bouwer and Rice method was applied to the JPL shallow monitoring wells, two different cases were encountered. In the first case, which was encountered in wells MW-1 and MW-9, the height of the static water level was above the top of each of the well's screen section. In this case, no special provision was applied to the Bouwer and Rice method. In the second case, encountered in the remaining shallow wells at the site, the static water level was below the top of the screen section of each well. In this case, the flow of water from the well to the adjacent formation occurred through both the screen section below and above the water table. Accordingly, the rate of water fall in the well during slug tests was increased, and when data was analyzed by the Bouwer and Rice method, the estimated hydraulic conductivities were potentially overestimated. To alleviate this problem, in this case, the casing radius was corrected to account for this increased water transfer rate (Bouwer, 1986).

In application of the Bouwer and Rice method to the deep monitoring wells, the height of the static water level was at an adequate distance above the top screen for all wells except well MW-12. For this well, the test data for the top screen (Screen 1) could not be analyzed because the static water level was too close to the measurement port. Additionally, for purposes of using