



BP OIL

URGENT
95 JAN 13 PM 3:40

BP Oil Company
Environmental Resources Management
Building 13, Suite N
295 SW 41st Street
Renton, Washington 98055-4931
(206) 251-0667

January 11, 1995

Ms. Juliet Shin
Alameda County Department of Environmental Health
1131 Harbor Bay Parkway
Alameda, CA 94502

*Conclusions: SVE + GWE would be
effective remediation alternative for
site.*

**RE: BP OIL FACILITY #11104
1716 Webster Street
Alameda, CA**

*5/5/95 spoke w/ S. Hooton - He will put
out to bid to have system designed,
permitted + installed. Expected to select bids
end of May - should receive p/cy by
end of June (date).*

Dear Ms Shin:

Attached please find our **REMEDIAL INVESTIGATION REPORT DATED
DECEMBER 5, 1994** for the above referenced facility.

If you should have any questions regarding this site, I may be reached at (206) 251-0689.

Respectfully,

*Margot Unger
for*

Scott T. Hooton
Environmental Resources Management
Group Leader

STH:mu msword\RIR11104

cc: Mr. Kevin Graves, CRWQCB, San Francisco Bay Region, 2101 Webster Street,
Suite 500, Oakland, CA 94612

Hydro Environmental Technologies, 2363 Mariner Square Drive, Suite 243,
Alameda, California 94501

Mr. Larry Silva, TOSCO Northwest Co., 601 Union Street, Suite 2500, Seattle,
WA 98101

Site File

**REMEDIAL INVESTIGATION
REPORT**

**BP Service Station No. 11104
1716 Webster Street
Alameda, California**

Prepared For:

**BP OIL COMPANY
16400 Southcenter Parkway, Suite 301
Tukwila, Washington 98188**

Prepared By:

**HYDRO-ENVIRONMENTAL TECHNOLOGIES, INC.
2363 Mariner Square Drive, Suite 243
Alameda, California 94501
HETI Project No. 9-038.2**

December 5, 1994

DEC 12 1994

**BP OIL CO.
ENVIRONMENTAL DEPT.
WEST COAST REGION OFFICE**

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- Appendix B: Boring Log and Well Construction Diagram/ACDHS Well Permit
- Appendix C: Aquifer Test Equations and Calculations
- Appendix D: Soil Vapor Extraction Pilot Test Equations and Calculations
- Appendix E: Official Laboratory Reports and Chain-of-Custody Records

1.0 INTRODUCTION AND PURPOSE

The purpose of this report is to present the results of Hydro-Environmental Technologies, Inc.'s (HETI's) continued investigative activities at BP Oil Company (BP) Service Station No. 11104 located at 1716 Webster Street in Alameda, California (Figure 1). Subsurface investigative work conducted by HETI during this phase of activity included installing a ground water and soil vapor recovery well and ~~two~~ vapor extraction points, performing a step-discharge aquifer ~~test~~ a constant-discharge aquifer test and a soil vapor extraction pilot test.

The work was performed to evaluate soil vapor extraction and ground water extraction as potential remedial alternatives at the site. Air sparging was not evaluated as a potential remedial option because the ground water table is too high to allow vapor extraction alone or in combination with air sparging without ground water extraction. Air sparging could cause the water table to mound in the area of the air sparging injection well, which would further reduce the unsaturated soil thickness available for vapor extraction.

2.0 BACKGROUND

A detailed background was presented in HETI's Problem Assessment Report dated June 10, 1993. Relevant background information is summarized below:

- In September 1990, Kaprelian Engineering, Inc. (KEI) supervised the removal of the dispenser islands and associated product piping at the site as part of BP's service station reimaging program. Hydrocarbons were detected in soil samples collected from the side walls of the excavation and in a water sample from the ground water which accumulated in the excavation.
- At the request of the Alameda County Department of Health Services (ACDHS), in late 1990 KEI supervised the excavation of soil in the vicinity of the former dispensers. Soil sampling after excavation activities indicated hydrocarbons in the soil.
- In June 1992, HETI installed three on-site monitoring wells to assess the presence of hydrocarbons in both the soil and ground water, and to determine subsurface lithology and ground water flow direction. Hydrocarbons were detected in soil and water samples from one of the three wells installed. Ground water was encountered at approximately five feet below grade. Soil types encountered during drilling were predominantly fine, silty sands. Ground water flow was estimated to be towards the north-northeast. Results were presented in HETI's report dated August 21, 1992.
- In March 1993, HETI installed two off-site monitoring wells to assess the extent of hydrocarbons in both soil and ground water. Sampling results indicated that

the two off-site wells, when combined with sample results from an existing off-site well to the north, served to delineate the extent of the hydrocarbon plume. Results were presented in HETI's report dated June 10, 1993.

3.0 FIELD ACTIVITIES

Field activities included installation of a ground water and soil vapor recovery well and two soil vapor monitoring points, performance of step-discharge and constant-discharge aquifer tests, and performance of a soil vapor extraction pilot test. All field work was performed according to standard HETI protocol, which is consistent with ACDHS and Regional Water Quality Control Board (RWQCB) guidelines and procedures. A copy of HETI's protocols for drilling, well installation, sampling and pilot testing is attached as Appendix A.

3.1 Recovery Well and Vapor Point Installation

On August 5, 1993, Soils Exploration Services, Inc. of Benicia, California used a Mobile B-55 hollow stem auger drill rig to install one six-inch diameter recovery well designated RW-1. The location of RW-1 is shown on the Site Plan (Figure 2). RW-1 was installed according to standard HETI protocol. Refer to the Soil Boring and Well Construction Log in Appendix B for well completion details. No soil samples were collected during drilling, as this area of the site has been characterized previously. Following installation, the elevation of the top-of-well casing was surveyed, and the well was developed until relatively free of turbidity.

On that same day, two soil vapor monitoring probes were hydraulically driven into place using the drill rig. One probe, designated VP-1, was installed approximately 15 feet southwest of RW-1, and the other probe, designated VP-2, was installed approximately 10 feet east of RW-1. Each probe was constructed of 1.25-inch inside diameter steel pipe, with the lower 18 inches screened to permit vapor entry. Each probe was driven to a depth of 4.9 feet below grade. Locking, protective covers were cemented in place over each probe, flush with the surrounding pavement.

3.2 Aquifer Tests

Step Discharge Test

A step-discharge aquifer test was performed on August 17, 1993. The purpose of the step-discharge test was to determine the highest possible sustainable ground water flow rate from well RW-1. This information was to be used to determine a flowrate for the constant discharge test and vapor extraction field test, and to ensure that the constant discharge test would stress the aquifer as much as possible without completely dewatering RW-1. An electric submersible pump was used, and pumped water was stored in a portable storage tank on-site. Drawdown in RW-1 was monitored using a pressure transducer connected to a data logger and portable

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computer. Flow rate was monitored using an analog totalizing flow meter and manual methods. The depth to water in nearby MW-1 was monitored using an interface probe.

During the step-discharge test, RW-1 was pumped at 0.3 gallons per minute (gpm) for approximately 16 minutes, at approximately 0.8 gpm for 13 minutes, at 1.2 gpm for 21 minutes, and then at 1.9 gpm for 47 minutes. The pumping stopped for approximately 20 minutes due to a blown fuse, and then was restarted at 1.25 gpm for a period of 21 minutes, after which time the test was stopped.

Constant Discharge Test

The purpose of the constant discharge aquifer test was to estimate aquifer properties such as transmissivity (T), storativity (S) and hydraulic conductivity (K), and to estimate the capture zone of the pumping well. Drawdown in RW-1 and MW-1 was monitored using a pressure transducer, datalogger and portable computer. Depth to water in other surrounding monitoring wells (MW-2 and MW-3) was monitored using an interface probe. Flow rate and total gallons pumped during the test were monitored using an analog flowmeter/totalizer and manual methods.

The test was performed on August 24, 1993. Well RW-1 was initially pumped at a rate of 1.8 gpm for a period of 15 minutes, then, the flow rate was reduced to 1.6 gpm because drawdown in the pumping well was approaching the level of the intake of the pump. The pumping rate of approximately 1.6 gpm was maintained for 8.5 hours, the remainder of the test. The flow rate varied occasionally from 1.1 to 2.0 gpm during the test, for example when silt filters became clogged or were changed. Pumped water was stored in a portable holding tank on-site.

The analytical method selected to evaluate the aquifer test data was the modified non-equilibrium method developed by Cooper and Jacob (1946) for aquifer tests conducted using a partially penetrating well in a confined aquifer. This method uses time-drawdown data to calculate T and K values. Drawdown data (decreases in water table elevations) from those monitoring wells which experienced significant drawdown were plotted using the computer graphing program Cricket Graph®. The best-fit logarithmic equation was determined by the program, and the slope (Δs) of the resulting straight line across one time log cycle was calculated. The Δs values were then plugged into the Cooper and Jacob equations to estimate T, S and K for each of these wells. Detailed calculations and time-drawdown graphs are presented in Appendix C.

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At the end of the test, a water sample was collected from the extracted ground water stream, transferred into laboratory-provided samples containers, and placed on ice for transport to the laboratory. The water sample was analyzed for total petroleum hydrocarbons, calculated as gasoline (TPHg) by EPA method 8015/8020 (modified) and benzene, toluene, ethylbenzene and xylenes (BTEX) by EPA method 8020 (modified). The analyses were performed by Pace, Inc. a state-certified analytical laboratory located in Novato, California.

3.3 Soil Vapor Extraction Pilot Test

On August 26, 1993 HETI conducted a combined soil vapor extraction test and ground water extraction test using recovery well RW-1. The Bay Area Air Quality Management District was informed of the proposed test in a notification letter dated August 25, 1993. Well RW-1 was pumped at approximately 1.6 gpm, and a vacuum was applied to the well using a six-cylinder industrial internal combustion (IC) engine. Vacuum was monitored in the surrounding vapor points VP-1 and VP-2, and monitoring well MW-1.

Vacuum was applied to RW-1 using the (IC) engine. The engine also destroyed any hydrocarbons before releasing the vapors to the atmosphere. Sensitive air pressure gauges with a range of zero inches of water column (in. WC) to 2 in. WC were used to monitor vacuum at the monitoring points. A combined lower-explosive-limit and oxygen (LEL/O₂) instrument was used to monitor hydrocarbon vapor and oxygen concentrations in the extracted vapor stream. A vapor sample for laboratory analysis was also collected for comparison. A thermal anemometer was used to measure the extracted vapor flow rate. Water levels in RW-1 and MW-1 were monitored using a pressure transducer, data logger and portable computer.

Prior to the beginning of the test, ground water was present in recovery well RW-1 at approximately five feet below the ground surface, making the top of the screened interval approximately two feet above the static water level. To expose the well screen even further for the vapor extraction portion of the pilot test, the pump test was started first. RW-1 was pumped at approximately 1.6 gpm for approximately 2.5 hours before a vacuum was applied to the well. A vacuum of 20 in. WC was applied for 30 minutes, then the vacuum was decreased in 5 in. WC increments to a minimum of 5 in. WC, to obtain data regarding the relationship between applied vacuum and flow rate. The vacuum was then increased to 20 in. WC, and increased in varying increments to the maximum sustainable vacuum of approximately 70 in. WC over 1.5 hours. This vacuum was maintained for the duration of the test. The ground water flow rate was increased to 3.0 gpm to compensate for the upwelling of ground water in the well.

The vapor sample collected from the extracted soil vapor stream and was stored in a dark container for transport to the analytical laboratory. The sample was analyzed for Non-Methane Hydrocarbons, as n-octane, (TPHo) by EPA method 8015/8020 (modified) and for BTEX by EPA method 8020 (modified) by Pace, Inc.

4.0 RESULTS OF INVESTIGATION

4.1 Aquifer Test Results

The step discharge test indicated that RW-1 could sustain a flowrate of 1.9 gpm or less for an extended period. The drawdown at this pumping rate was approximately 8 feet.

The following table summarizes the results of the constant-discharge aquifer test on well RW-1, as calculated from drawdown data in each of the following wells:

<u>Well No.</u>	<u>Transmissivity T (cm²/sec)</u>	<u>Hydraulic Conductivity K (cm/sec)</u>	<u>Storativity S (dimensionless)</u>
MW-1	4.3	7.9×10^{-3}	5.3×10^{-4}
MW-2	6.4	1.2×10^{-2}	6.4×10^{-4}
MW-3	13	2.4×10^{-2}	9.8×10^{-4}
AVERAGE	7.9	1.5×10^{-2}	7.2×10^{-4}

The average value of hydraulic conductivity is 1.5×10^{-2} cm/sec is indicative of a **medium** sand. The soil types encountered during boring installations were composed of fine sand and silty sand.

The average storativity is 7.2×10^{-4} . The storativity values calculated from the constant-discharge test are indicative of a confined water-bearing zone, which normally has storativity values ranging from 10^{-5} to 10^{-3} , while unconfined aquifers typically have storativity values ranging from 0.01 to 0.3. **Boring log information does not indicate that ground water beneath the site is under confined conditions.**

Capture zone analysis of the pump test data indicated that pumping well RW-1 at 1.6 gpm would create a ground water flow stagnation point at approximately 2.2 meters (7.3 feet) downgradient from RW-1. The capture zone is shown graphically on Figure 3, the Pilot Test Areas of Influence Map. The results of the most recent quarterly water sampling are shown on Figure 4, the Hydrocarbon Distribution Map. A detailed explanation of the analysis and calculations of the aquifer test data are included in Appendix C.

TPHg was detected in the water sample collected from RW-1 during the aquifer test at a concentration of 11,000 parts per billion (ppb). Benzene was detected at a concentration of 3,900 ppb. The laboratory report is presented in Appendix E.

4.2 Soil Vapor Extraction Pilot Test Results

The data from the vapor extraction pilot test using RW-1 were used to estimate a radius of influence for vapor extraction. The data were also analyzed to evaluate the air permeability of soil surrounding the well, and to assess vapor flow rate as a function of applied vacuum. The extracted hydrocarbons and oxygen concentrations were used to predict the expected composition of extracted soil vapor from a remediation system at the site. All equations and calculations used to analyze the vapor extraction pilot test data are presented in Appendix D.

Vacuum influence in the vapor monitoring probes that showed an influence were plotted versus their distance from RW-1. The **calculated radius of influence at 65 in. WC was approximately 27 feet**. This radius is also shown on Figure 3.

The flow rates per unit screen length were used to calculate air permeability of the subsurface soil by inserting ranges of permeabilities into governing equations, until the flow rates most closely approximated the data collected during the pilot test. The flow rates observed during the test indicate an air permeability range between 1 and 10 darcy, which is typical of a fine sand. Fine sand was encountered in the upper five feet of the soil borings drilled for MW-1 and RW-1.

To predict the relationship between applied vacuum and flow rate per length of screen, a graph was produced which shows the observed relationship and a best-fit approximation of the relationship. This graph is included in Appendix D.

To provide information necessary for the design of a vapor extraction system, hydrocarbon concentrations in extracted soil vapor were analyzed. Vapor sample RW-1A, collected in the early portion of the pilot test, indicated a TPHo concentration of 2500 micrograms per liter ($\mu\text{g/L}$) and BTEX concentrations of 11 $\mu\text{g/L}$, 30 $\mu\text{g/L}$, 55 $\mu\text{g/L}$ and 340 $\mu\text{g/L}$, respectively. Vapor sample RW-1B, collected near the end of the test, indicated a TPHo concentration of 1400 $\mu\text{g/L}$ and BTEX concentrations of 5 $\mu\text{g/L}$, 21 $\mu\text{g/L}$, 32 $\mu\text{g/L}$ and 190 $\mu\text{g/L}$, respectively. A copy of the laboratory report is attached in Appendix E.

5.0 SUMMARY OF RESULTS

The aquifer test and soil vapor extraction pilot test results are summarized below:

- Data analysis of the aquifer test results indicated average transmissivity, hydraulic conductivity and storativity values of 7.9 cm^2/sec , $1.5 \times 10^{-2} \text{ cm/sec}$ and 7.2×10^{-4} (dimensionless), respectively. The transmissivity and hydraulic conductivity values are fairly consistent from well to well. The storativity value is indicative of a confined water-bearing zone. **At a pumping rate of 1.6 gpm from RW-1, a capture zone with a radius of approximately 7.3 feet was established.**

- The vapor extraction pilot test indicated a radius of influence of 27 feet. This radius of influence is large enough to include monitoring well MW-1, which was the only well in which hydrocarbons were detected in soil samples collected during drilling. The calculated air permeability of the soil was in the range of 1 to 10 darcy, which correlates well with observed soil types beneath the site.
- The aquifer test and vapor extraction pilot test results may have been affected by an area of higher permeability associated with the underground storage tank complex backfill, and the lack of surface seals on the vapor monitoring probes.
- Based on the results of this test, soil vapor extraction combined with ground water extraction would be an effective remediation alternative for this site.

6.0 REFERENCES

- Cooper, H. H., Jr. and Jacob, C. E., 1946. A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History, *Transactions, American Geophysical Union*, Vol. 27, No. 4.
- Driscoll, Fletcher G., 1986. *Ground Water and Wells*, Johnson Filtration Systems Inc., St. Paul, MN, p. 1089.
- Freeze, R. A. and Cherry, J. A., 1979. *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, N.J., p. 604.
- Johnson, P.C., et al, 1990. A Practical Approach to the Design, Operation, and Monitoring of in Situ Soil Venting Systems, *Ground Water Monitoring Review*, Spring 1990.
- Keely, J. F. and Tsang, C. F., 1983. Velocity Plots and Capture Zones of Pumping Centers for Ground Water Investigations, *Ground Water*, Vol. 21, p. 701-714.

7.0 CERTIFICATION

This report was prepared under the supervision of a registered professional engineer. All statements, conclusions and recommendations are based solely upon field observations and laboratory analyses performed by a state-certified laboratory related to the work performed by Hydro-Environmental Technologies, Inc.

It is possible that variations in the soil or ground water conditions exist beyond the points explored in this investigation. Also, site conditions are subject to change at some time in the future due to variations in rainfall, temperature, regional water usage or other factors.

The service performed by Hydro-Environmental Technologies, Inc. has been conducted in a manner consistent with the level of care and skill ordinarily exercised by members of our profession currently practicing under similar conditions in the area of the site. No other warranty, expressed or implied, is made.

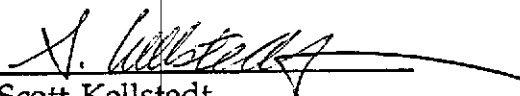
Hydro-Environmental Technologies, Inc. includes in this report chemical analytical data from a state-certified laboratory. These analyses are performed according to procedures suggested by the U.S. EPA and the State of California. Hydro-Environmental Technologies, Inc. is not responsible for laboratory errors in procedure or result reporting.


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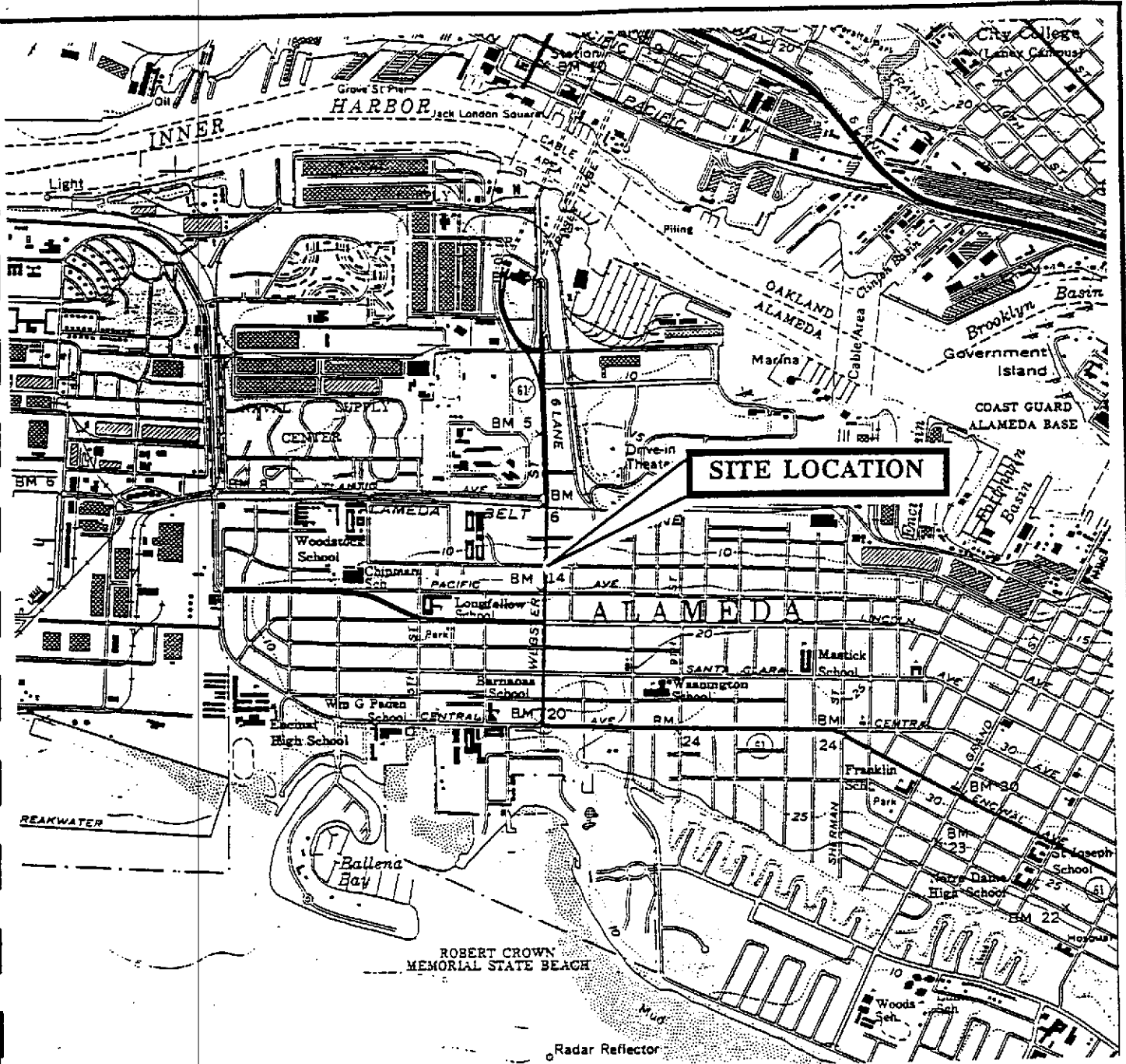
Prepared by:

Reviewed by:



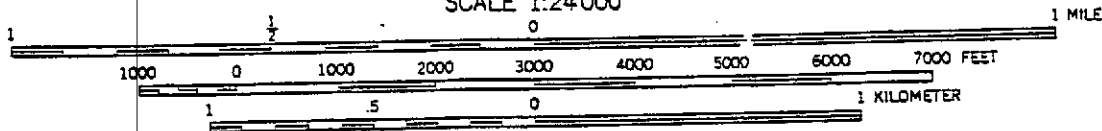

Scott Kellstedt
Project Manager


Thomas E. Lindemuth, P.E.
Western Regional Manager



Source:
USGS 7.5' Quadrangle
Oakland, East

SCALE 1:24 000



North

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SITE LOCATION MAP
BP Oil Facility No. 11104
1716 Webster Street
Alameda, California

Job No.
9-038
Figure
1

BUENA VISTA AVENUE

WEBSTER STREET



MW-1

RW-1

VP-2

VP-1

UNDERGROUND
GASOLINE STORAGE
TANKS

DISPENSER ISLANDS
AND
CANOPY

STATION
BUILDING

E

MW-2

SERVICE BAY

MW-3

SERVICE BAY





SERVICE BAY

UNDERGROUND
USED OIL TANK

6' HIGH WOOD FENCE

PLANTER

LEGEND

- MW-1  = MONITORING WELL (2-INCH DIAMETER)
- RW-1  = RECOVERY WELL (6-INCH DIAMETER)
- VP-2  = VAPOR POINT
-  = PROPERTY BOUNDARY

PLANTER

6' HIGH WOOD FENCE



SCALE IN FEET

HYDR -
ENVIR -
TECHN -
ENVIRONMENTAL
LOGIES, INC.

SITE PLAN

BP Oil Facility No. 11104
1716 Webster Street
Alameda, California

Job No.
9-038
Figure
2

8/25/93

BUENA VISTA AVENUE

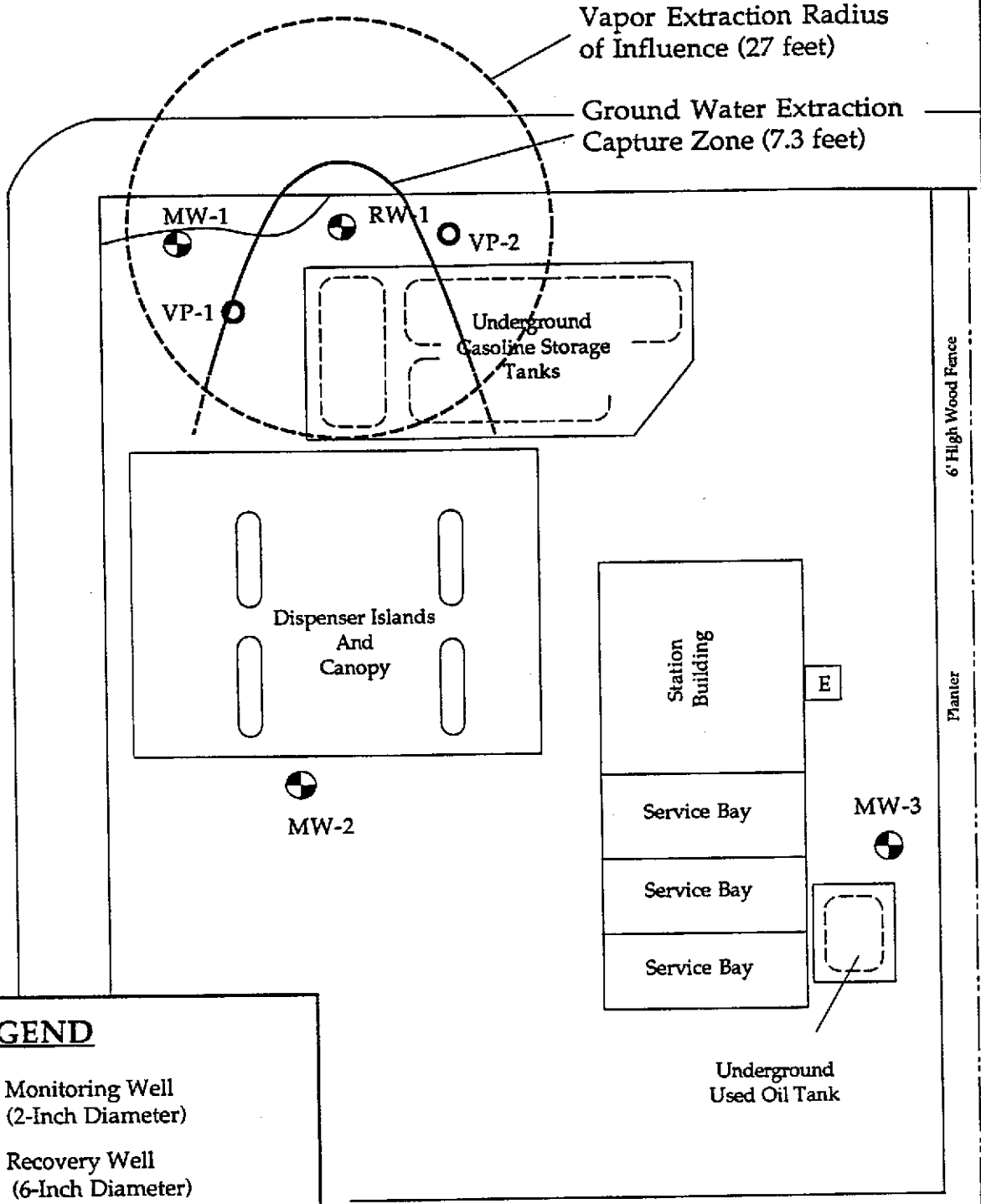
North



Vapor Extraction Radius of Influence (27 feet)

Ground Water Extraction Capture Zone (7.3 feet)

WEBSTER STREET



6' High Wood Fence

Planter

LEGEND

- MW-1 = Monitoring Well (2-Inch Diameter)
- RW-1 = Recovery Well (6-Inch Diameter)
- VP-2 = Vapor Point
- = Property Boundary

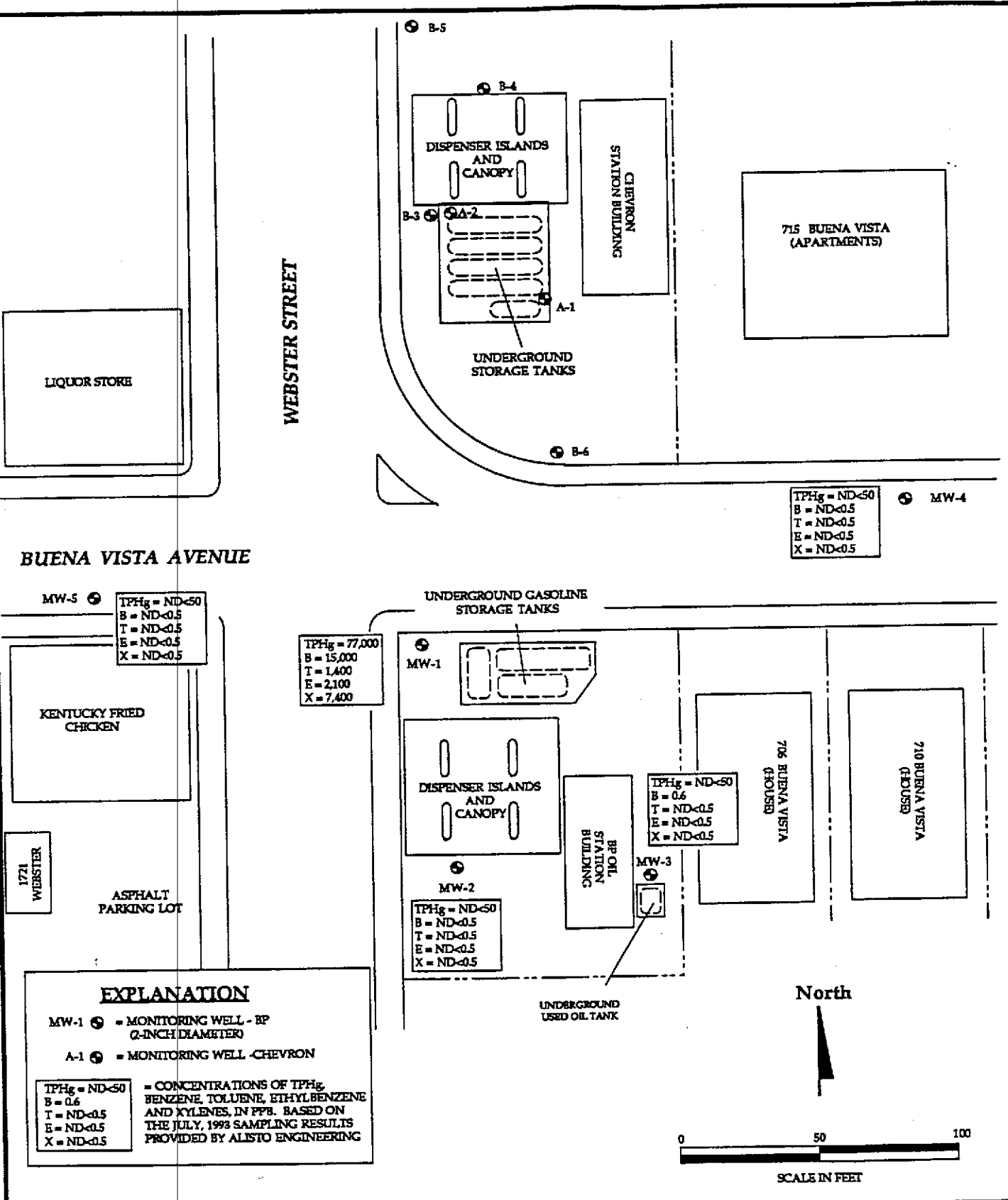
Planter
6' High Wood Fence



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TECHN **LOGIES, INC.**

**PILOT TEST AREAS
OF INFLUENCE**
BP Oil Facility No. 11104
1716 Webster Street
Alameda, California

Job No.
9-038
Figure
3
11/3/93



TPHg = ND<0.5
 B = ND<0.5
 T = ND<0.5
 E = ND<0.5
 X = ND<0.5

MW-4

BUENA VISTA AVENUE

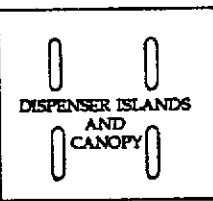
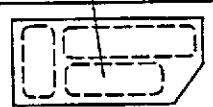
MW-5

TPHg = ND<0.5
 B = ND<0.5
 T = ND<0.5
 E = ND<0.5
 X = ND<0.5

UNDERGROUND GASOLINE STORAGE TANKS

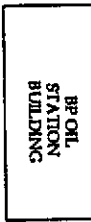
TPHg = 77,000
 B = 15,000
 T = 1,400
 E = 2,100
 X = 7,400

MW-1



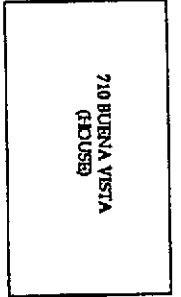
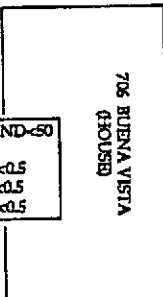
MW-2

TPHg = ND<0.5
 B = ND<0.5
 T = ND<0.5
 E = ND<0.5
 X = ND<0.5



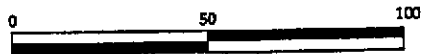
MW-3

TPHg = ND<0.5
 B = 0.6
 T = ND<0.5
 E = ND<0.5
 X = ND<0.5



UNDERGROUND USED OIL TANK

North



SCALE IN FEET

EXPLANATION

- MW-1 = MONITORING WELL - BP (2-INCH DIAMETER)
- A-1 = MONITORING WELL - CHEVRON

TPHg = ND<0.5
 B = 0.6
 T = ND<0.5
 E = ND<0.5
 X = ND<0.5

= CONCENTRATIONS OF TPHg, BENZENE, TOLUENE, ETHYL BENZENE AND XYLENES, IN PPM. BASED ON THE JULY, 1993 SAMPLING RESULTS PROVIDED BY ALISTO ENGINEERING

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HYDROCARBON DISTRIBUTION
 BP Oil Facility No. 11104
 1716 Webster Street
 Alameda, California

Job No. 9-038
 Figure 4
 11/3/93

**HYDRO-ENVIRONMENTAL TECHNOLOGIES, INC.
CALIFORNIA**

**DRILLING
WELL CONSTRUCTION
AND
SAMPLING PROTOCOLS**

November 1992

DRILLING, WELL CONSTRUCTION, AND SAMPLING PROTOCOLS

Drilling Protocol

Prior to any drilling activities, Hydro-Environmental Technologies, Inc. (HETI) will verify that necessary drilling permits have been secured.

Prior to drilling, underground and above ground utilities will be located using Underground Service Alert (USA) and site reconnaissance. To the extent possible, drilling will be conducted so that disruptions of normal business activities at the project site are minimized. HETI shall obtain and review available public data on subsurface geology and, if warranted, the location of wells within a quarter mile of the project site will be identified. Drilling equipment will be inspected for suitability and integrity prior to performing work.

Subsurface investigations are typically performed to assess the lateral and vertical extent of petroleum hydrocarbons or other contaminants which may be present in soils and groundwater. Drilling methods will be selected to optimize field data requirements and to be compatible with known or suspected subsurface geologic conditions.

Shallow soil borings will be drilled dry using a truck-mounted hollow-stem auger drilling rig, unless site conditions favor a different drilling method. Drilling and sampling methods will be consistent with ASTM Method D-1452-80. The auger size will be a minimum of 3-inches nominal outside diameter (O.D.) for borings not to be completed as wells. The auger size will be a minimum of 8-inches nominal O.D. for borings to be completed as wells. No drilling fluids will be used during this drilling method. All augers and drill rods will initially be thoroughly steam cleaned before arriving on-site, to prevent the introduction of contaminants from off-site, and augers and drill rods which are used will be steam cleaned between borings away from boring locations. Working components of the drilling rig (subs, collars and all parts of the rig chassis near the borehole) will also be steam cleaned. Cleaned augers, rods and other tools, if required, will be stored and covered when not in use. Decontamination of drilling equipment will consist of steam cleaning, and/or trisodium phosphate wash. Cleaning operations will be observed and supervised by a representative of HETI. The drilling rig will also be inspected by a representative of HETI to ensure that no fluids (hydraulic or lubricant) are leaking from the equipment.

Soil Sampling Protocol

Soil samples are typically collected at 5-foot intervals, from the ground surface to the total depth of the boring, with a California Modified split-spoon sampler driven 18 to 24 inches ahead of the lead auger by a 140-pound hammer falling a minimum of 30 inches. The sampler will be lined with clean brass or stainless steel tubes. The number of blows necessary to drive the sampler will be recorded on the boring log and well construction diagram (Plate A-1) to help evaluate the consistency of the materials encountered. Additional soil samples may be collected based on significant lithologic changes and/or potential chemical content. All equipment that contacts soil samples will be thoroughly cleaned prior to arrival at the project site and between each individual sample collection point on-site. New and used split-spoon samplers will be steam cleaned or washed with a trisodium phosphate or Alconox solution, rinsed with tap water, air dried or wiped dry with a clean towel. Soil removed from the top two liners (typically each 4 to 6 inches in length) and the end cone will be used for visual logging purposes and disposed with cuttings produced during the drilling operations. The bottom liner, if suitable, will be preserved for laboratory analysis. Soil samples from each sampling interval will be lithologically described, consistent with the Unified Soil Classification System, by a HETI geologist. The exact depth of all borings to the nearest 1/2-

foot will be determined in the field. Exploratory boring logs shall be prepared under the direction of a Registered Geologist or Professional Engineer.

Head-space analysis will be performed in the field to check for the presence of volatile organic compounds. Head-space analysis will be performed using an organic vapor meter (either flame-ionization or photo-ionization). The method used will be consistent with the method described by Fitzgerald (1989). Organic vapor concentrations will be recorded on the HETI Soil Boring Log (Figure 1). The selection of soil samples for chemical analysis are typically based on the following criteria:

- a. Soil discoloration
- b. Soil odors
- c. Visual confirmation of chemical in soil
- d. Depth with respect to underground tanks
- e. Depth with respect to groundwater
- f. Organic vapor meter reading

The soil sampler and liners will be cleaned with a trisodium-phosphate or Alconox solution, rinsed with clean tap water and air dried or wiped dry with a clean towel prior to each sampling event. Soil samples (full liners) selected for chemical analyses will be covered with aluminum foil or teflon tape and the ends will be sealed with plastic end caps. The end caps will then be taped to ensure a more secure seal. The samples will then be labeled and entered onto a Chain-of-Custody document, and placed in a cooler on blue ice (hard shell) for transport to a state certified analytical laboratory.

Where copper and zinc contamination are the subject of the investigation, stainless steel liners will be used in lieu of brass liners. Stainless steel liners will also be used when the client, additional sampling protocol or regulatory agencies require.

Soil borings will be backfilled (sealed) to the ground surface using either a neat cement or cement-bentonite grout mixture in accordance with appropriate local regulations.

Pending the outcome of the results of the laboratory analyses, excess drill cuttings will remain on-site and, when deemed necessary, covered with a plastic tarp or drummed. Confirmed uncontaminated soils may be appropriately disposed of on-site by the client. Soils found to contain concentrations of contaminants above applicable local or state limits will be placed in appropriately labeled 55-gallon D.O.T. drums or in a hazardous materials drop bin and left on-site for proper disposal by the client. At the clients request, HETI will act as the client's agent by assisting in the disposal of the contained material. In no case will HETI personnel sign a Hazardous Waste Manifest.

Well Construction

Monitoring wells shall be installed using a truck-mounted hollow-stem auger drilling rig or an air or mud-rotary drilling rig. Typically, the hollow stem rig will be used for the installation of wells up to 100 feet deep, if subsurface conditions prove favorable. Wells greater than 100 feet in depth will typically be drilled using air or mud-rotary equipment. Mud-rotary equipment will typically be used when alternate methods have failed or proven ineffective.

Monitoring well casing and screen shall be constructed of a minimum of Schedule 40, flush joint, threaded, polyvinylchloride (PVC) pipe. The well screen will be factory mill-slotted. The screen length shall be determined in the field and shall be placed with the intent of setting the screened interval adjacent to the aquifer material. The screen length shall also be set with the intent of placing the top of the screened interval a minimum of 2 feet above the static water

level. All screens and casings used will be in a contaminant-free condition when placed in the ground. No thread lubrication shall be used, other than teflon tape or distilled water, during the connection of individual lengths of screened and solid well casing. Screen shall not be placed in a borehole that creates hydraulic interconnection of two or more distinctly separate aquifer units. Screen slot size will be chosen to be compatible with the encountered aquifer materials. The screen slot size will be chosen to retain a high percentage of the filter pack or natural formation. The remainder of the well casing, above the screened interval, shall be of solid riser casing. A sand pack shall be placed in the remaining annular space surrounding the well casing to a minimum of 1 foot above the screened interval. Sand pack shall not be placed such that it interconnects two or more distinctly separate aquifer units. Sand pack shall be chosen to be compatible with both the aquifer materials and the screen slot size. Sand pack shall consist of clean, washed, kiln dried silica sand. A minimum 1-foot thick bentonite pellet or bentonite slurry seal shall be placed above the sand pack. All bentonite shall be hydrated by either formation water or steam-distilled water. The remaining annular space above the bentonite seal shall be grouted with a neat cement or bentonite-neat cement mixture and shall be placed from the top of the bentonite pellet seal to within 6 inches of the top of the well. If used, the bentonite content of the mixture shall not exceed 5 percent by weight. Sand pack, bentonite, and cement seal levels will be confirmed during construction by measuring the remaining annular space with a calibrated weighted tape. If shallow water table conditions prevail, the screen interval will be placed such that the screen height above the static water level is reduced and a maximum possible surface seal can be achieved. A field boring log and well construction diagram (Plate A-1) shall be prepared by a representative of HETI for each well completed. Monitoring and extraction wells shall be constructed with Class-A cement/bentonite grout or bentonite pellets tremied into position as a base for the well casing if necessary. The well casing will be set within the aquifer according to the proposed function of the well and the chemistry of the potential contaminants.

In the event a monitoring well is required to be installed in an aquifer unit underlying an existing, shallower aquifer, the well will be completed in the lower aquifer such that only water from the lower aquifer is drawn into the well. The upper aquifer will be sealed by installing a steel conductor casing which extends to the base of the shallow aquifer. The steel casing will be tremied into position with an annular neat cement or cement-bentonite grout seal placed between the outside wall of the casing and the wall of the borehole. The cement grout will be allowed a minimum of 72 hours to set prior to advancing the boring beyond the sealed conductor casing and into the next aquifer. After 72 hours, the boring will be advanced below the seal and completed as a well as described above but within the steel conductor casing.

The tops of all well casings will be sealed and placed in a vandal resistant, traffic rated box to prevent entry of surface contamination, unauthorized entry and tampering.

Monitoring wells will be surveyed to obtain north-end casing elevations to the nearest ± 0.01 foot. Water level measurements will be recorded with an interface probe to the nearest ± 0.01 foot and referenced to either a project datum or mean sea level (MSL). A project site datum is typically chosen such that it will remain in the event the project site undergoes a physical change as a result of construction or other cultural disturbance. Where required, the wells will be surveyed by a licensed land surveyor relative to the nearest bench mark and relative to mean sea level. Typically, the establishment of a known, on-site reference by a licensed survey, is enough to allow for the remaining well top elevations to be determined using a survey level and rod. Unless directed otherwise by local regulatory agencies, the well top elevations will be established in this manner.

Well Development

After installation, all monitoring wells shall be developed to remove fine grained sediments from the well and to stabilize sand, gravel and disturbed aquifer materials in the annular area around the screened interval. Well development will be accomplished by air-lift pump, suction-lift pump, submersible pump, bladder pump, surge block, bailer or any combination of the above. All well development equipment will be decontaminated prior to development using a steam cleaner and/or trisodium-phosphate solution wash, clean water rinse, and steam distilled water rinse. Well development will continue until each well is relatively free of turbidity. The adequacy of well development will be assessed by a HETI geologist. Where appropriate, indicator parameters (pH, specific conductance, temperature, and turbidity) will be monitored during well development. Field instrument calibrations will be performed prior to use according to manufacturers specifications.

Well Head Completion and Site Clean-up

Monitoring wells shall be completed below grade unless special conditions exist that require above grade design. Monitoring well casing (including the well locking seal and cap) will be completed approximately two inches below the vandal resistant traffic rated road box cover. Except in areas where snow plows might be used, the road box cover shall be completed approximately one inch above the existing grade surface to allow for precipitation runoff. All concrete work, both inside and outside the road box, shall be completed with a smooth finish.

Above ground completions will be set inside a 2 to 3 foot tall locking steel protective casing. If traffic conditions dictate, three 4-inch diameter steel pipes will be set in concrete in a triangular pattern to act as bumper posts. The posts will be set 2 feet deep and will be filled with concrete. A four foot square, 3-inch thick concrete pad which slopes away from the well will be set around each well. Both the protective steel well casing and the bumper posts will be painted yellow.

The project site shall be left as clean as possible. All soils and excess concrete produced from each monitoring well will be placed in appropriate areas to be disposed as previously described. All monitoring well locations will either be broomed or washed down such that staining of the existing surface cover is minimized.

GROUNDWATER SAMPLING AND ANALYSIS

Quality Assurance/Quality Control Objectives

The sampling and analysis procedures employed by HETI for groundwater sampling and monitoring follow specific Quality Assurance/Quality Control (QA/QC) guidelines. Quality Assurance (QA) objectives have been established by HETI to develop and implement procedures for obtaining field data and evaluating water quality in an accurate, precise and complete manner so that sampling procedures and field measurements provide information that is comparable and representative of the actual field conditions. Quality Control (QC) is maintained by HETI by using specific field protocols and requiring the analytical laboratory to perform internal and external QC checks. It is the goal of HETI to provide data that are accurate, precise, complete, comparable, and representative. The definitions for accuracy, precision, completeness, comparability, and representativeness are as follows:

1. Accuracy - the degree of agreement of a measurement with an accepted reference or true value.
2. Precision - a measure of agreement among individual measurements under similar conditions. Usually expressed in terms of standard deviation.
3. Completeness - the amount of valid data obtained from a measurement system compared to the amount that was expected to meet the project data goals.
4. Comparability - the confidence with which one data set can be compared with another.
5. Representativeness - the degree to which a sample or group of samples reflect the characteristics of a media at a given sampling point. Also includes the degree to which a sampling point represents the actual parameter variations which are under study.

As part of the HETI QA/QC program, applicable federal, state and local reference documents are to be followed. The procedures outlined in these regulations, manuals, handbooks, guidance documents and journals are incorporated into the HETI sampling procedures to assure that: (1) groundwater samples are properly collected, (2) groundwater samples are identified, preserved, and transported in a manner such that they are representative of field conditions, and (3) chemical analyses of samples are accurate and reproducible.

**GUIDANCE AND REFERENCE DOCUMENTS USED
TO COLLECT GROUNDWATER SAMPLES**

U.S.E.P.A. - 339/9-51-002	NEIC Manual for Groundwater/ Subsurface Investigation at Hazardous Waste Sites
U.S.E.P.A. - 503/SW611	Procedures Manual for Groundwater Monitoring at Solid Waste Disposal Facilities (August, 1977)
U.S.E.P.A. - 600/4-79-020	Methods for Chemical Analysis of Water and Wastes (1983)
U.S.E.P.A. - 600/4-82-029	Handbook for Sampling and Sample Preservation of Water and Wastewater (1982)
U.S.E.P.A. - SW-846#, 3rd Edition	Test Methods for Evaluating Solid Waste - Physical/Chemical Methods (November, 1986) and latter additions
40 CFR 136.3e Table II	Required Containers, Preservation Techniques, and Holding Times
Resources Conservation and Recovery Act (OSWER 9950.1)	Groundwater Monitoring Technical Enforcement Guidance Document (September, 1986)
California Regional Water Quality Control Board (Central Valley Region)	A Compilation of Water Quality Goals (September, 1988); Updates (October, 1988)
California Regional Water Quality Control Board (North Coast, San Francisco Bay, and Central Valley)	Regional Board Staff Recommendations for Initial Evaluations and Investigation of Underground Tanks: Tri-Regional Recommendations (June, 1988)
California Regional Water Quality Control Board (Central Valley Region)	Memorandum: Disposal, Treatment, and Refuse of Soils Contaminated with Petroleum Fractions (August, 1986)
State of California Department of Health Services	Hazardous Waste Testing Laboratory Certification List (March, 1987)
State of California Water Resources Board	Leaking Underground Fuel Tank Control (LUFT) Field Manual (May, 1988), and LUFT Field Manual Revision (April, 1989)

State of California Water Resources
85), Control Board

Title 23 (Register #85.#33-8-17-
Subchapter 16: Underground Tank
Regulations; Article 3, Sections 2632
and 2634; Article 4, Section 2647
(October, 1986)

Santa Clara Valley Water District

Guidelines for Investigating Fuel
Leaks (March, 1989)

Santa Clara Valley Water District

Guidelines for Preparing or Reviewing
Sampling Plans for Soil and
Groundwater Investigation of Fuel
Contamination Sites (January, 1989)

Alameda County Water District

Groundwater Protection Program:
Guidelines for Groundwater and Soil
Investigations at Leaking
Underground Fuel Tank Sites (most recent

revision)

American Public Health
Association

Standard Methods for the Examination
of Water and Wastewaters, 16th
Edition

Analytical Chemistry (journal)

Principles of Environmental Analysis
Volume 55, pages 2212-18, December,
1983

American Petroleum Institute
Environmental Affairs Dept.,
June, 1983

Groundwater Monitoring & Sample Bias

The Bay Area Air Quality
Management District

Regulation 8 - Rule 40 & Rule 48

Because groundwater samples collected by HETI are analyzed in the parts per billion (ppb) range for many analytes, care is exercised to prevent contamination of samples. When volatile or semivolatile organic compounds are included for analysis, HETI sampling crew members will adhere to the following precautions in the field:

1. A new pair of clean, disposable, latex (or comparable material) gloves are to be worn for each well to be sampled.
2. When possible, samples will first be collected from wells known or suspected to contain the fewest contaminants, followed by wells in increasing order of degree of contamination.
3. All sample bottles and equipment are to be kept away from fuels and solvents. When possible, gasoline (used in generators and water pumps) is to be shipped to the project site in separate compartments of the same vehicle or in a separate vehicle as that in which sample bottles are shipped.

4. Sampling bailers are to be composed of polyethylene (when dedicated to the well), Teflon or stainless steel. Other materials, such as acrylic, may contain phthalate esters which can interfere with gas chromatography (GC) analyses. Well purging may be performed with PVC bailers.
5. Volatile organic groundwater samples are collected so that air passage through the sample does not occur or is minimal (to prevent volatiles from being stripped from the samples). Sample bottles are filled by slowly running the sample down the side of the bottle until there is a positive convex meniscus over the neck of the bottle. The Teflon side of the septum (in cap) is positioned against the meniscus and the cap is screwed on tightly. The sample is then inverted and lightly tapped while the sampler inspects the contents of the bottle for an air bubble. The absence of an air bubble indicates a successful seal. If a bubble is evident, the cap is removed and more water is added to the sample. The inspection procedure is repeated and if bubbles persist, the vial is discarded in a container designated for used and broken vials and bottles and the sample filling procedure is repeated with another vial.
6. Extra vials shall be available for use in the event of dropped bottles and/or caps. Any bottle which has come in contact with the ground shall be considered contaminated and shall not be used. When replacing septa, or if septa become inverted, care shall be taken to assure that the Teflon seal faces the interior of the bottle.
7. All preservatives shall be provided by the contract analytical laboratory.

Laboratory and field handling procedures of samples may be monitored by including QC samples for analysis with sample lots from a project site. QC samples may include any combination of the following:

1. Trip Blank - Used for purgable organic compounds only; QC samples shall be collected in 40 milliliter (ml) sample vials filled in the analytical laboratory with organic free water. Trip blanks should be sent to the project site, and travel with the samples from the project site. Trip blanks are not opened, and are returned from the project site with the samples from the project site for analysis.
2. Field Blank - Prepared in the field using steam-distilled water. Field blank QC samples shall accompany project site samples to the laboratory and shall be analyzed for the same chemical parameters as those samples taken from the project site.
3. Equipment Blank - Equipment Blank QC samples shall be prepared in the field using field equipment rinsate between two different wells after the equipment has been washed and rinsed. The equipment blank will consist of deionized water retained in the sampling equipment. These QC samples will only be taken when a dedicated bailer is not used for sampling.
4. Duplicates - Duplicate QC samples shall be collected "second samples" from a selected well and project site. Duplicates shall be collected as either split samples or second-run samples (i.e. later date) from the same well.

The number and types of QC samples shall be determined by HETI on a site-specific basis.

GROUNDWATER SAMPLE COLLECTION

This section describes the routine procedures followed by HETI while collecting groundwater samples for chemical analysis. These procedures include decontamination, water level measurements, well purging, physical parameter measurements, sample collection, sample preservation, and sample handling. Critical sampling objectives for HETI are to:

1. Collect groundwater samples which are representative of the sampled matrix.
2. Maintain sample integrity from the time of sample collection to delivery to the analytical laboratory.

Sample analyses, methods, containers, preservation, and holding times are presented in Table A-1.

Decontamination Procedures

All physical parameter measuring and sampling equipment shall be decontaminated prior to measurement and sample collection using a trisodium phosphate or Alconox solution wash, followed by two separate rinses in tap water, followed by one rinse in steam-distilled water. Any sampling equipment surfaces or parts that might absorb specific contaminants, such as plastic pump valves, impellers, etc., are to be cleaned in the same manner.

Sample bottles, bottle caps, and septa used for sampling volatile organics are thoroughly pre-cleaned in either the laboratory or the factory. All appropriate measures shall be taken to assure continued sterility of the containers issued by the contract laboratory prior to usage at the project site.

During field sampling, equipment which has been placed in a well shall be decontaminated by washing with a trisodium-phosphate or Alconox solution followed by two rinses in tap water and one rinse in steam-distilled water.

Water Level Measurements

Prior to purging and sampling any wells, the static-water level shall be measured by use of an electronic sounder and/or calibrated portable oil-water interface probe. Both static water level and separate phase product thickness shall be measured and noted to the nearest ± 0.01 foot. Interface probe results shall be confirmed by sampling the top of the water column with a clear bailer and measuring any floating product thickness to the nearest ± 0.01 foot with an engineers scale tape. In all cases a clear bailer sample will be taken from each well to check for color, sheen and undetected floating product. If floating product of any measureable thickness is observed, no sampling will be performed for that well. If visible product sheen is observed, sampling shall proceed under normal protocols.

The line used to lower the bailer shall be discarded after each use to preclude the possibility of cross contamination. Field observations (e.g., well integrity, product odor, turbidity, water color, odors, etc.) shall be recorded on the HETI Purge/Sample Sheet (Plate A-2). Before and after the use of the electric sounder, interface probe, non-dedicated bailer, or any other down well equipment, each will be decontaminated by washing in a trisodium phosphate or Alconox solution, followed by a double rinse with tap water, followed by a rinse with steam-distilled water.

Well Purging

Before sampling commences, well casing storage water and interstitial water in the artificial sand pack shall be purged from the well using: (1) a positive displacement bladder pump constructed of inert non-wetting Teflon and stainless steel; (2) a pneumatic-airlift pumping system; (3) a centrifugal pumping system; or (4) a PVC, Teflon or stainless steel bailer. Methods of purging will be assessed based on the well size, location, depth, accessibility, and known chemical conditions. Individual well purge volumes are calculated from the casing volumes. In general, a minimum of 3 to 5 casing volumes will be purged. Wells which dewater or demonstrate slow recharge capacities (i.e., low yield wells which only recover to 70 percent of initial water column height after 1 hour) during purging activities may be sampled after fewer than 3 to 5 purging cycles. If a low yield well is to be sampled, sampling shall not take place until at least 70 percent of the previously measured water column has been replaced by recharge. Monitoring wells shall be purged according to the protocol flowchart presented in Plate A-3. Water removed from the wells will either be disposed or stored in 55-gallon DOT drums for future disposal according to procedures outlined for contaminated soil cuttings in the Soil Sampling Protocol section above. Where appropriate, physical parameters (pH, specific conductance, and temperature) will be monitored by HETI field crew during well purging operations. If necessary, purging may continue until all three physical parameters have stabilized. Stability shall be defined as a change of less than 0.2 pH units, less than 10 percent in micro mhos, and less than 1.0 degree Centigrade. The pH meters shall be read to the nearest ± 0.1 pH units. Specific conductance meters shall be read to the nearest ± 10 micro-mhos per centimeter. Both types of meters shall be calibrated daily to manufacturer's specifications. Temperature shall be read to the nearest ± 0.1 degree centigrade. Field data collected while developing, purging and sampling the wells will be entered onto the HETI Purge/Sample Sheet (Plate A-2). Copies of the Purge/Sample Sheets will be reviewed for accuracy and completeness for each well sampled.

DOCUMENTATION

Sample Container Labels

Each sample container shall be labeled immediately after the sample is collected and sealed. The label shall include:

- Company Name (HETI)
- Source (i.e., well number or code)
- Sampler's identification
- Project number
- Date and time of collection
- Type of preservation (if any) used

Field Sampling Data Sheets

In the field, the HETI sampling crew will record the following information on the Purge/Sample Sheet (Plate A-2) for each well sampled:

- Project number
- Client
- Location
- Source (i.e., well number or code)
- Time and date of development, purging and sampling
- Well accessibility and integrity
- Pertinent well data (e.g., total depth, product thickness, static water level)
- Physical parameters when appropriate (e.g., specific conductance, pH, temperature) - may be more than one reading
- Gallons and well casing volumes purged

Chain-of-Custody

A chain-of-custody record shall be completed and will accompany every shipment of samples to the analytical laboratory in order to establish documentation tracing sample possession from the time of collection until delivery to the laboratory. The record will contain the following information:

- Sample or station number or code (ID)
- Signature of the collector, sampler, or recorder
- Date and time of collection
- Place of collection (project address and name of business)
- Sample type (soil or water)
- Type of analysis requested
- Signatures of persons involved in chain of possession (in chronological order)
- Dates and times of individual possession (inclusive)
- Laboratory comments regarding the sample receptacle conditions

Samples will always be accompanied by a Chain-of-Custody record. When transferring the samples, the individuals relinquishing and receiving the samples will sign, date and note the time on the Chain-of-Custody record.

Sample Collection, Handling, Storage and Transport

All water samples will be collected in an order such that those parameters most sensitive to volatilization will be sampled first. A general order of collection for some common groundwater parameters is as follows:

- Volatile Organic Compounds (VOC's)
- Total Organic Halogens (TOH)
- Total Organic Carbon (TOC)
- Extractable Organics
- Total Metals
- Dissolved Metals
- Phenols
- Sulfate and Chloride
- Nitrate and Ammonia
- Turbidity

All samples from the same well shall be collected immediately after purging or when the well recovers to 70 percent of the original water column height. All samples from one sampling set from a single well should be collected on the same day.

All chemical sample handling and storage will be conducted under the direction of HETT's consulting analytical chemist. All laboratory chemical testing will be accomplished by a state approved analytical laboratory.

All water samples will be held at 4°C by packing them in a water-tight container inside an ice chest and covering with hard shelled "blue ice™". In no event shall the time between sample collection and delivery to the contract laboratory be greater than 72 hours. Preservatives will not be added to any sample by the sampling crew, unless instructed by the consulting analytical chemist. If added in the field, preservatives shall be supplied by the contract analytical laboratory. No one will open the samples other than laboratory personnel who will perform the specified chemical analyses.

If it is necessary for samples or sample ice chests to leave the immediate control of the sampling crew prior to delivery to the laboratory or laboratory courier, such as shipment by a common carrier (e.g., UPS™), a custody seal will be placed on each sample container and/or sample chest. Custody seals will be placed to ensure that the samples have not been tampered with during shipment and will contain the samplers signature, the date and time the seal was emplaced.

TABLE A-1

SAMPLE ANALYSIS METHODS, CONTAINERS, PRESERVATIVES, AND
HOLDING TIMES

<u>Parameter</u>	<u>Analytical Method</u>	<u>Reporting Units</u>	<u>Container*</u>	<u>Preservation†</u>	<u>Maximum Holding Time</u>
Total Petroleum Hydrocarbons (low to med. b.p. i.e. gasoline)	EPA 8015 (DHS modified)	ppb ug/l	40ml glass vial, Teflon lined septum	4°C HCl to pH<2**	14 days
Benzene Toluene Ethylbenzene Xylenes (BTEX)	EPA 8020	ppb ug/l	40ml glass vial, Teflon lined septum	4°C HCl to pH<2**	7 days(w/o preservative) 14 days (w/preservative)
Oil & Grease	SM 503A&E	ppb ug/l	1L glass jar, Teflon lined cap	4°C H2SO4 to pH<2	28 days
Total Petroleum Hydrocarbons (high. b.p. i.e. diesel)	EPA 8015 (DHS modified)	ppb ug/l	1L glass jar, Teflon lined cap	4°C	14 days
Halogenated Volatile Organics (chlorinated solvents)	EPA 8010	ppb ug/l	40ml glass vial, Teflon lined septum	4°C	14 days
Non-Chlorinated Solvents	EPA 8020	ppb ug/l	as above	4°C	14 days
Volatile Organics (GC/MS)	EPA 8240	ppb ug/l	as above	4°C	14 days
Semi-Volatile Organics (GC/MS)	EPA 8270	ppb ug/l	as above	4°C	14 days
Metals	ICP-EPA 200.7 or A.A.EPA-	ppb ug/l	100 ml	4°C HNO3 to pH<2	6 months

* Containers listed are for water - soil containers are to be brass or stainless steel tubes with plastic end caps.

† Applies only to liquid samples.

** May vary depending on lab requirements.

**HYDRO-ENVIRONMENTAL TECHNOLOGIES, INC.
CALIFORNIA**

**SOIL VAPOR EXTRACTION TEST
PROTOCOL**

July 1993

SOIL VAPOR EXTRACTION TEST PROTOCOL

Successful design of a Soil Vapor Extraction (SVE) system requires knowledge of the following:

- Contaminant composition
- Soil plume definition
- Vapor concentration and composition
- Flow rate vs applied vacuum
- Radius of Influence

The last three of these components are found by testing. The particular aspects of these items are expanded as follows:

Vapor Concentration and Composition

The determination of vapor concentration in the extracted air stream is important for two reasons: to calculate the removal efficiency of the test extraction well and to provide information necessary to specify the off-gas treatment equipment. Vapor samples should be taken at the beginning and end of the SVE test, which should be conducted for a long enough time to extract at least one pore volume of vapor from the contaminated soil zone. The initial vapor concentration is representative of the initial equilibrium vapor concentration, while the concentration measured after one pore volume has been extracted gives an indication of realistic removal rates.

The initial and final concentration measurements during the VET should be done using State DHS-certified laboratory analysis of vapor samples using methods 8015/8020 (modified). Samples will be collected in evacuated, one-liter Tedlar® bags from the undiluted vapor stream using a sample pump. The sample data will be entered onto a Chain-of-Custody form and each sample labeled with a unique designation. Following collection, the sample bag will be placed immediately into an opaque cooler to minimize exposure to light. Chilling is not required. Samples will be analyzed as soon as possible, but no more than 72 hours from collection.

A Gastech 1214S LEL/O₂ meter, or equivalent, should be used for intermediate measurements to follow progress. However, these instruments must be calibrated to an appropriate gas such as hexane or heptane.

The oxygen concentration in the extracted vapor stream must be taken, as this affects designs using a thermal or catalytic oxidizer, or internal combustion (IC) engine. A Gastech 1214S LEL/O₂ meter, or equivalent, should be used.

Flow Rate vs Applied Vacuum

To properly specify the vapor extraction blower, the actual flow rate and vacuum during the test must be known. The vapor flow rate should be measured using a Kurz Model 443 thermal anemometer, or equivalent.

Anemometers should be installed with 10 pipe diameters of straight pipe upstream and 5 diameters downstream. The upstream straight pipe may be shortened by installing straightening vanes. They should be mounted through a tight-fitting hole in the side of the pipe. Use of a tee fitting would disrupt flow, causing additional inaccuracy.

Since VETs are often conducted using existing monitoring wells, water table upwelling within the well must be considered when determining screen height. In a monitoring well, approximately one inch of screen height will be lost for every inch of vacuum applied.

The absolute atmospheric pressure should be assumed as the day's barometric reading obtained from the local newspaper and corrected for altitude.

Radius of Influence

Determining soil permeability and radius of influence (R_I) requires that we measure induced vacuum vs distance or induced vacuum vs time for several points. Induced vacuum vs time for several monitoring points is preferable because soil permeability may vary with direction. The data can be entered into Shell Oil Company's HyperVentilate[®] computer program to determine the soil air permeability.

Radial pressure from an extraction well can be simplified for a fixed P_w , P_{Atm} , R_w and R_I to the following form:

$$P(r) = Ar^b \quad (5)$$

Where A and b are constants.

Plot $P(r)$ vs r using a program such as Cricket Graph[®], which will do a logarithmic curve fit, to determine an average A and b. Then solve for $r = R_I$ where $P(r) = P_{Atm}$.

Vapor Extraction Testing

Vapor extraction testing should be conducted using the attached Vapor Extraction Test Setup and Log sheets. Completion of these forms will provide a checklist for collection of all required information.

Vapor Well Installation Guidelines

Prior to any drilling activities, Hydro-Environmental Technologies, Inc. (HETI) will verify that necessary drilling permits have been secured.

Prior to drilling, underground and above ground utilities will be located using Underground Service Alert (USA) and site reconnaissance. To the extent possible, drilling will be conducted so that disruptions of normal business activities at the project site are minimized. Drilling equipment will be inspected for suitability and integrity prior to performing work.

Wells selected or installed for testing should, if possible, be wells that would be used for remediation. At least one well should be installed and screened in the heart of the plume. Wells screened through clean soils decrease the overall effectiveness of the system unless they will be used for air induction wells. Multiple wells are required for vapor extraction testing to allow measurement of induced pressure as a function of distance.

Well spacing is a function of soil type. Some guidelines for well spacing are:

Gravel	30 to 100 ft
Sand	25 to 75 ft
Silt	15 to 50 ft
Clay	5 to 40 ft

Each pair of wells used for measurements should be screened in the same horizon. The vertical permeability in undisturbed soils can be as little as 10% of the horizontal permeability. Care must be taken near the surface to prevent "short circuiting" of air flow either from the surface, tank field or through paving base rock.

Dedicated vapor extraction wells are normally screened with 2-inch or 4-inch diameter, 0.030-inch slotted casing. A coarse sand pack is used to minimize resistance to air flow. Typical air flow rates from a single well are 25 to 100 scfm.

Well installation protocols are found in HETI's "Drilling, Well Construction and Sampling Protocols." These will be followed.

Conducting The Test

Prior to any testing activities, HETI will verify that necessary air discharge permits have been secured or notifications made. To the extent possible, testing will be conducted so that disruptions of normal business activities at the project site are minimized. Testing equipment will be inspected for suitability and integrity prior to performing work.

1. Extracted soil vapor will be treated with an internal combustion engine before being discharged to the atmosphere. The engine will be rented from a third party that has specifically modified the engine to treat extracted soil vapor.
2. A Gastech 1214S LEL meter, or equivalent, will be used to measure the vapor concentration in each well. These readings will be recorded. Testing will begin with the well with the highest concentration.
3. The depth to water (and product) in each extraction and observation well will be measured and recorded.
4. A Magnehelic® or manometer will be connected to each observation well using the previously assembled wellhead risers. These instruments will be vented prior to beginning the test.
5. After applying vacuum to the extraction well, the vacuum and flow rate will be recorded. Within 5 minutes, a vapor sample will be collected from the well. Corresponding O₂ and LEL readings will be recorded.
6. A second person will record vacuum vs time in the nearest observation wells. Initial readings will be taken as frequently as possible until vacuum stabilizes. Vacuum may stabilize within the nearest observation well within minutes.
7. Readings of flow, vacuum, extraction well temperature, O₂ and vapor concentration from the extraction well will be recorded until one pore volume has been removed.
8. After one pore volume has been removed, a second vapor sample from the extraction well will be collected. A corresponding O₂ and LEL reading will be recorded.
9. Steps 4 through 8 may be repeated on other extraction wells, especially if screened at different vertical intervals.

HETI Vapor Extraction Test Setup

Client: _____ HETI Job Number: _____

Site Address: _____

Tester(s): _____ Date: _____

Items To Be Completed Prior to Test

1. Determine wells to be tested. They are: _____
2. Calculate one pore volume on page 5. Calculate the time to remove one pore volume at:
25 scfm _____
50 scfm _____
100 scfm _____
 If the time to remove one pore volume will be over 4 hours, schedule someone for overtime to continue test on a second shift.
3. Schedule internal combustion engine delivery. Use for multi-day or multi-site tests. Will fuel delivery be required? Do we know how to operate it?
4. Complete known well data on sheet 5. Only depth to water should be measured in field.
5. Schedule sample analysis with lab. Not all labs can do air samples. If we use other than the normal lab, a purchase order may be required. Air samples must be analyzed within 72 hours. Labs don't like to get samples on Friday afternoon. Confirm courier pickup or plan to deliver samples.
6. Complete Sketch of Test Setup on Sheet 4. This should be drawn as a Piping and Instrumentation Diagram (P&ID). Have it reviewed.
7. Do you have all of the fittings to piece together what you've sketched?
8. Calibrate sample equipment (O₂/LEL). Calibrate LEL to heptane in nitrogen.
9. Check the calibration of pressure test equipment.
10. Plan layout of equipment at station. Consider traffic patterns and potential noise complaints.
11. Notify station owner of test schedule, if applicable.

HETI Vapor Extraction Test Setup

Client: _____ HETI Job Number: _____

Site Address: _____

12. ___ Make up wellhead riser test connections for each well. These utilize socket couplings and silicone stop-cock grease (Remember chemistry lab?) to connect to the well.
13. ___ Charge the test equipment batteries.
14. ___ Complete the Site Safety Plan.

Equipment and Supplies to Bring to the Test

- ___ Interface probe
- ___ Tape measure
- ___ Wellhead risers from Item 12, above
- ___ Well lock keys
- ___ All the piping, hoses and fittings from Item 7, above.
- ___ Teflon® pipe thread tape
- ___ Pipe assembly tools
- ___ Pitot tube (with Magnehelic® and tubing), Kurz meter or venturi meter (with Magnehelic® and tubing).
- ___ Straight length of pipe for flow meter. See text for minimum length.
- ___ Drill and 1/8-inch or 1/4-inch pipe tap to install Pitot tube, Kurz meter and pressure gauges
- ___ Tedlar® air sample bags in cooler (Ice is not required, but samples must be kept in dark.)
- ___ Chain of custody forms
- ___ Magnehelic® for each observation well, including fittings and tubing to connect. Range should be 0 to 2.0 inches of water (in. WC).
- ___ LEL/O₂ meter
- ___ Vacuum gauge, 100 to 0 in. WC
- ___ Pager
- ___ Test setup forms
- ___ Test logs

Conducting The Test

1. Set up the internal combustion engine. Inspect testing equipment for suitability and integrity prior to performing work.
2. Use an LEL meter to measure the vapor concentration in each well. Record these readings. Start with the well with the highest concentration.
3. Measure the depth to water (and product) in each extraction and observation well.

HETI Vapor Extraction Test Setup

Client: _____ HETI Job Number: _____

Site Address: _____

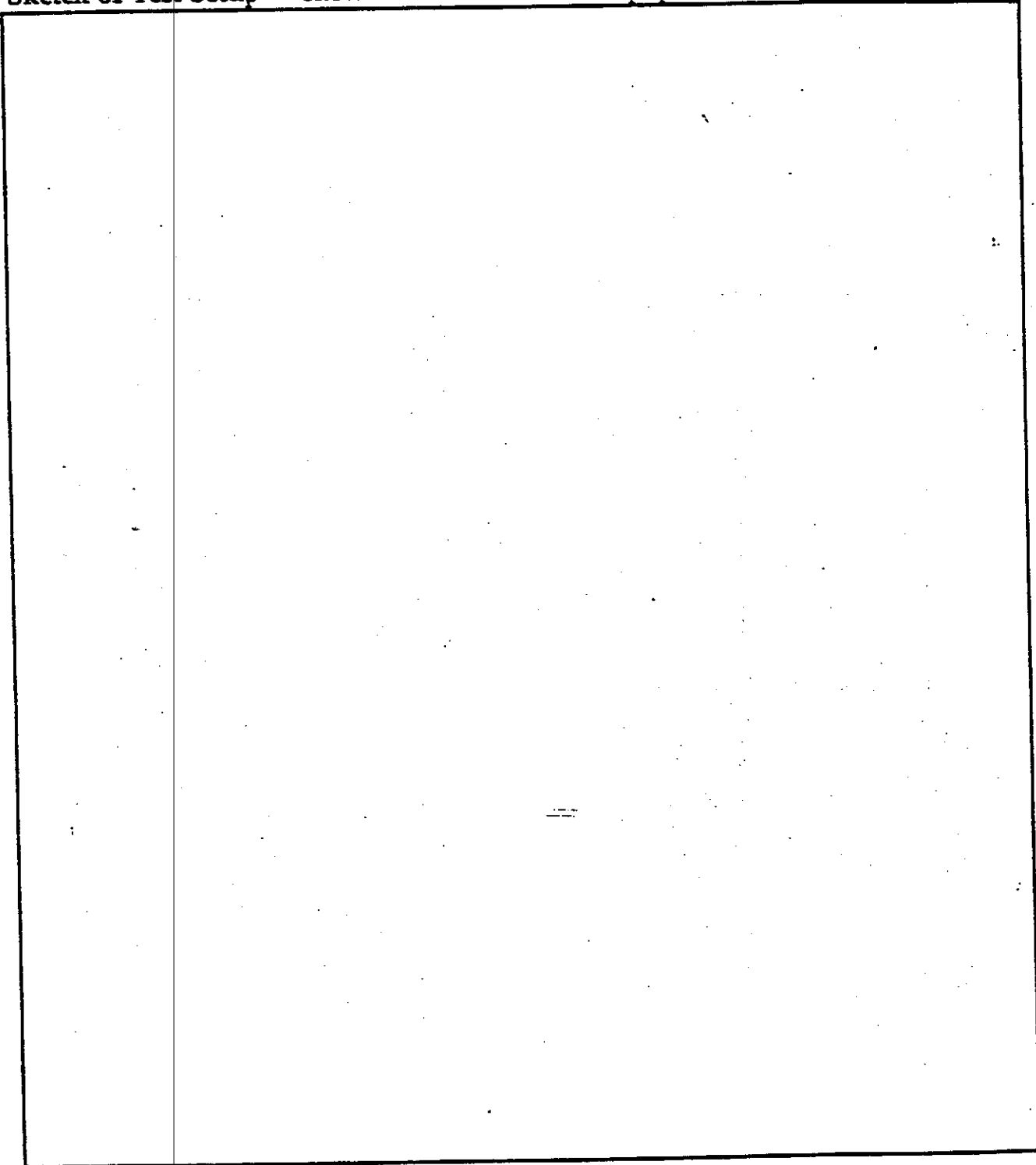
4. Connect a Magnehelic® or manometer on each observation well using the previously assembled wellhead risers. Vent these prior to beginning the test.
5. Apply vacuum to the extraction well. Record the vacuum and flow rate. Within 5 minutes, collect a vapor sample from the well. Also collect an O₂ and LEL reading.
6. A second person should record vacuum vs time in the nearest observation wells. Initial readings should be taken as frequently as possible until vacuum stabilizes. Vacuum may stabilize within the nearest observation well within minutes.
7. Continue taking readings of flow, vacuum, extraction well temperature, carbon inlet temperature, O₂ and vapor concentration (using the LEL) from the extraction well until one pore volume has been removed.
8. After one pore volume has been removed, collect a second vapor sample from the extraction well.
9. If possible, operate on the extraction well at a second or third vacuum reading. Record the vacuum, flow rate and vapor concentration (using the LEL).
10. Repeat Steps 4 through 9 on other extraction wells, especially if screened at different intervals.

HETI Vapor Extraction Test Setup

Client: _____ HETI Job Number: _____

Site Address: _____

Sketch of Test Setup — show all instruments and equipment.



HETI Vapor Extraction Test Setup

Client _____ HETI Job Number: _____

Site Address: _____

Vacuum Source: _____

Flow Measuring Instrument: _____

Barometer Reading: _____ Source: _____ Site Elevation _____

Pore volume: $V_p = \epsilon_A \pi R^2 H$
 = _____
 = _____

Where:

- ϵ_A = the air-filled void fraction. If unknown, assume 0.3.
- R = radius of the zone of contamination
- H = the vertical thickness of the zone of contamination or the screen height, whichever is greater

Well No.	Well Dia. in.	Slot Width in.	Slot Spacing in.	Depth to Screen ft	Depth to Water ft	Depth to Bottom ft	Screened Interval ft

HETI Vapor Extraction Test Log

Client: _____ HETI Job Number: _____

Site Address: _____ Date: _____

Tester(s): _____

Extraction Well: _____

Time	Applied Vacuum in. WC	Extract'n. Rate	Sample - Type & Source	Mon. Pt. _____ Vac, " WC	Mon. Pt. _____ Vac, " WC	Mon. Pt. _____ Vac, " WC	Mon. Pt. _____ Vac, " WC	Comments
Distance from Extraction Well, ft								

DATE/LOCATION 8/5/93 1716 Webster St, Alameda, CA	BEGIN 8/5/93	BORING DIAMETER 12 Inches	ANGLE/BEARING 90 Degrees	BORING NO RW-1
DRILLING CONTRACTOR Soils Exploration Services, Inc.	COMPLETED 8/5/93	FIRST ENCOUNTERED WATER DEPTH 5 feet	BOTTOM OF BORING 25 Feet	
OPERATOR Morris Peterson	LOGGED BY F. Maroni	STATIC WATER DEPTH/DATE 5 feet	WELL NO. RW-1	
DRILL MAKE & MODEL Mobile Drill B-55	SAMPLING METHOD Not Applicable	BOTTOM OF WELL 23 Feet		
WELL MATERIAL 6" SCH 40 PVC	SLOT SIZE 0.020"	FILTER PACK #3	WELL SEAL Neat cement with 5% bentonite over hydrated pellets	PLANNED USE Recovery Well

DEPTH FOOT	PID FIELD HEADSPACE (ppm)	DEPTH	SAMPLE	WATER LEVEL	WELL CONSTR.	GRAPHIC LOG	MATERIAL CLASSIFICATION & PHYSICAL DESCRIPTION
1							ASPHALT
2							BASEROCK
3							SAND (SM); yellow-brown; poorly-graded, fine sand; trace silt; moist.
4							same as above; color change to olive-gray; increase in silt content to 15%.
5							
6							silty SAND (SM); olive; poorly-graded, fine-grained; 25% silt; wet.
7							
8							
9							
10							silty SAND (SM); light yellow-brown; fine to medium grained; trace silt; wet.
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

HYDR - ENVIRONMENTAL TECHNOLOGIES, INC.

DATE: August 10, 1993

APPROVED BY: John H. Turney, P.E.

SOIL BORING LOG RW-1 AND WELL CONSTRUCTION RW-1

BP Service Station No. 11104
1716 Webster Street
Alameda, CA

PLATE
C-2

SHEET 1 OF 1

JOB NO.
9-038



ZONE 7 WATER AGENCY

5997 PARKSIDE DRIVE

PLEASANTON, CALIFORNIA 94588

VOICE (510) 484-2600

FAX (510) 462-3914

DRILLING PERMIT APPLICATION

FOR APPLICANT TO COMPLETE

FOR OFFICE USE

LOCATION OF PROJECT BP OIL COMPANY
710 WEBSTER STREET
ALAMEDA, CA

PERMIT NUMBER 93376
LOCATION NUMBER _____

CLIENT
Name BP OIL COMPANY
Address 16400 SOUTHCENTRAL EXPRESS Phone 206-394-5246
City BUCKLE WA Zip 98188
SUITE 301

PERMIT CONDITIONS

Circled Permit Requirements Apply

APPLICANT
Name HYDRO-ENVIRONMENTAL TECH.
Address 2303 MARINERS Phone 510-521-2084
City ALAMEDA, CA Zip 94501
SUITE 243

A. GENERAL

1. A permit application should be submitted so as to arrive at the Zone 7 office five days prior to proposed starting date.
2. Submit to Zone 7 within 60 days after completion of permitted work the original Department of Water Resources Water Well Drillers Report or equivalent for well Projects, or drilling logs and location sketch for geotechnical projects.
3. Permit is void if project not begun within 90 days of approval date.

B. WATER WELLS, INCLUDING PIEZOMETERS

1. Minimum surface seal thickness is two inches of cement grout placed by tremie.
2. Minimum seal depth is 50 feet for municipal and industrial wells or 20 feet for domestic and irrigation wells unless a lesser depth is specially approved. Minimum seal depth for monitoring wells is the maximum depth practicable or 20 feet.

C. GEOTECHNICAL. Backfill bore hole with compacted cuttings or heavy bentonite and upper two feet with compacted material. In areas of known or suspected contamination, tremied cement grout shall be used in place of compacted cuttings.

D. CATHODIC. Fill hole above anode zone with concrete placed by tremie.

E. WELL DESTRUCTION. See attached.

TYPE OF PROJECT

Well Construction	Geotechnical Investigation
Cathodic Protection _____	General _____
Water Supply _____	Contamination _____
Monitoring <u>X</u>	Well Destruction _____

PROPOSED WATER SUPPLY WELL USE

Domestic _____	Industrial _____	Other <u>N/A</u>
Municipal _____	Irrigation _____	

DRILLING METHOD:

Mud Rotary _____ Air Rotary _____ Auger X
Cable _____ Other _____

DRILLER'S LICENSE NO. CS7-582696 SOILS EXPLORATION

WELL PROJECTS

Drill Hole Diameter	<u>12</u> in.	Maximum
Casing Diameter	<u>6</u> in.	Depth <u>23</u> ft.
Surface Seal Depth	<u>2</u> ft.	Number <u>1</u>

GEOTECHNICAL PROJECTS

Number of Borings	<u>2</u>	Maximum
Hole Diameter	<u>6</u> in.	Depth <u>23</u> ft.

ESTIMATED STARTING DATE 8.9.93
ESTIMATED COMPLETION DATE 8.13.93

Approved Wyman Hong Date 15 Jul 93
Wyman Hong

I hereby agree to comply with all requirements of this permit and Alameda County Ordinance No. 73-68.

APPLICANT'S
SIGNATURE FRANCES MARON Date 7.13.93

APPENDIX C

DRAFT

Equations Used to Calculate Aquifer Properties and Capture Zones BP Station No. 11104 Alameda, California

Use of Cooper and Jacob (1946) non-equilibrium equations, as presented by Driscoll (1986):

$$T = Q(0.183)/\Delta s \qquad K = T/b \qquad S = (2.25)Tt_0/r^2$$

where:

T = transmissivity (cm²/sec) Q = pumping rate (cm³/sec)

Δs = drawdown over one log cycle (cm)

K = hydraulic conductivity (cm/sec)

b = water bearing zone thickness = 18 feet (estimated) = 549 cm

t₀ = zero drawdown intercept (sec) r = distance between wells (cm)

Factors t₀ and Δs calculated from time vs. drawdown plots.

MW-1 (pumping RW-1)

Q = 1.6 gpm = 100 cm³/sec
t₀ = 0.13 min = 7.78 sec

Δs = 0.14 feet = 4.31 cm
r = 8.2 ft. = 378 cm

Results:

T = 4.3 cm²/sec K = 7.9 x 10⁻³ cm/sec S = 5.3 x 10⁻⁴

MW-2 (pumping RW-1)

Q = 1.6 gpm = 100 cm³/sec
t₀ = 3.9 min = 234 sec

Δs = 0.10 feet = 2.9 cm
r = 75.1 ft. = 2290 cm

Results:

T = 6.4 cm²/sec K = 1.2 x 10⁻² cm/sec S = 6.4 x 10⁻⁴

MW-3 (pumping MW-2)

Q = 1.6 gpm = 100 cm³/sec
t₀ = 5.0 min = 297 sec

Δs = 0.19 feet = 5.8 cm
r = 97.9 ft. = 2980 cm

Results:

T = 13 cm²/sec K = 2.4 x 10⁻² cm/sec S = 9.8 x 10⁻⁴

The average hydraulic conductivity value of 1.5×10^{-2} cm/sec is indicative of a medium sand. The soil encountered during boring installations was composed of fine sand and silty sand.

The average storativity value is 7.2×10^{-4} . A storativity value of less than 10^{-3} is normally indicative of a confined aquifer. Boring log information does not show that the ground water is under confined conditions.

Influence of UST complex

The drawdown data from the extraction well RW-1 is plotted versus time on the attached graph. The drawdown did not increase at the same rate after 25 minutes as it had up to that point. Stabilization of drawdown in a pumping well typically occurs when the zone of influence of the pumping well reaches an area of recharge. The area of recharge in this case is most probably the backfill of the UST complex.

Recharge from the UST complex would decrease the amount of drawdown in the observation wells, and this influence would have a consequent effect on the calculation of hydraulic conductivity and storativity. This effect would cause the calculated hydraulic conductivity to be increased, and storativity to be decreased. If pumping is maintained for an extended period of time, the influence of the UST complex would decrease as the backfill became dewatered.

Determination of Stagnation Point

The downgradient stagnation point was analyzed by a method developed by Keely and Tsang (1983). The method provides for the estimation of downgradient stagnation point from an extraction well, which is the furthest point downgradient at which water will be induced to flow back toward the extraction well. The method assumes that transmissivity, T , hydraulic gradient, i , and pumping rate, Q , are known. The equation is as follows:

$$X_s = Q/2\pi Ti$$

where

X_s = Distance from extraction well to stagnation point (cm.)

Q = Flowrate = $100 \text{ cm}^3/\text{sec}$

T = Transmissivity = $7.9 \text{ cm}^2/\text{sec}$

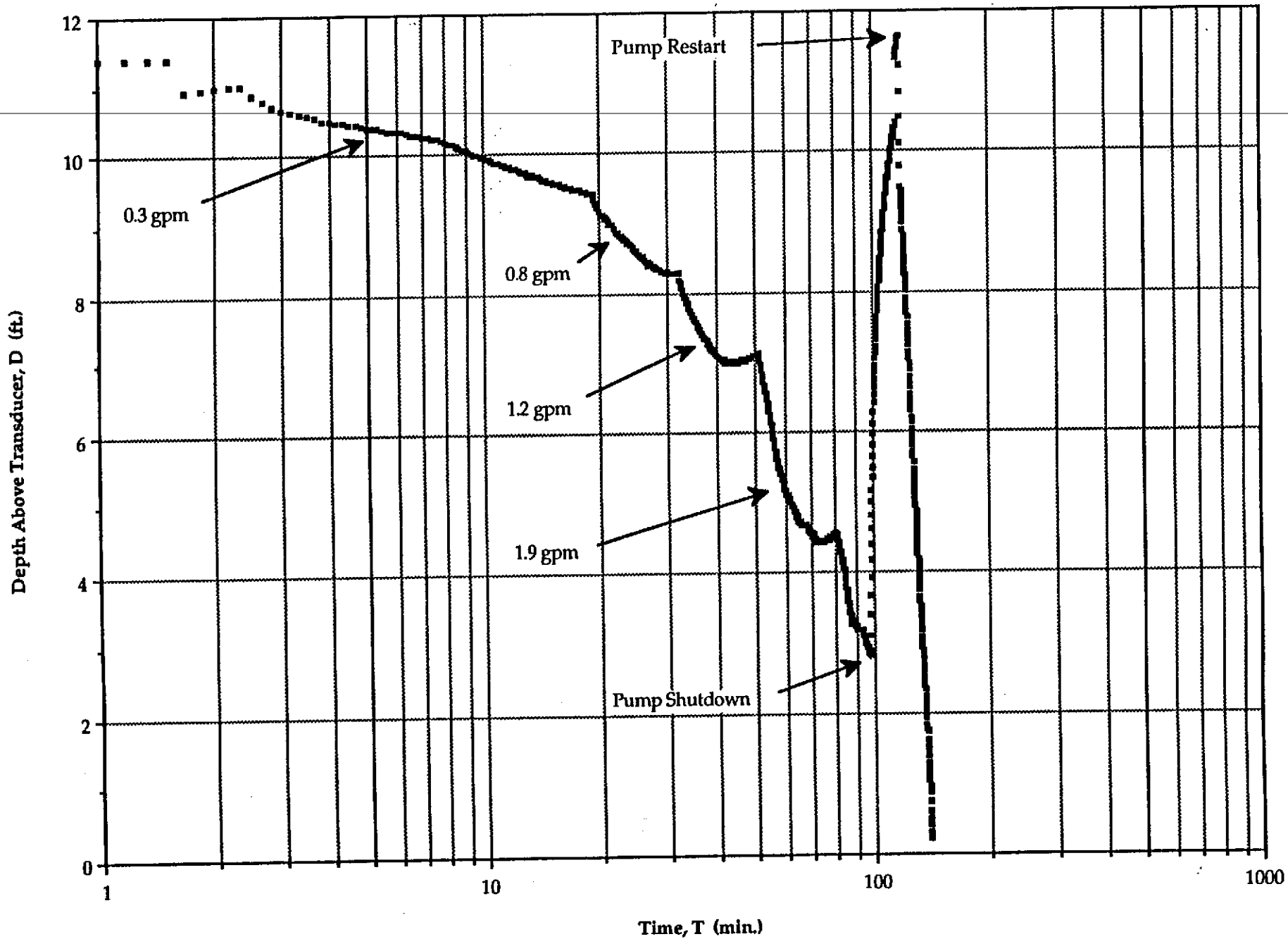
i = Gradient = 0.009 cm/cm

yields:

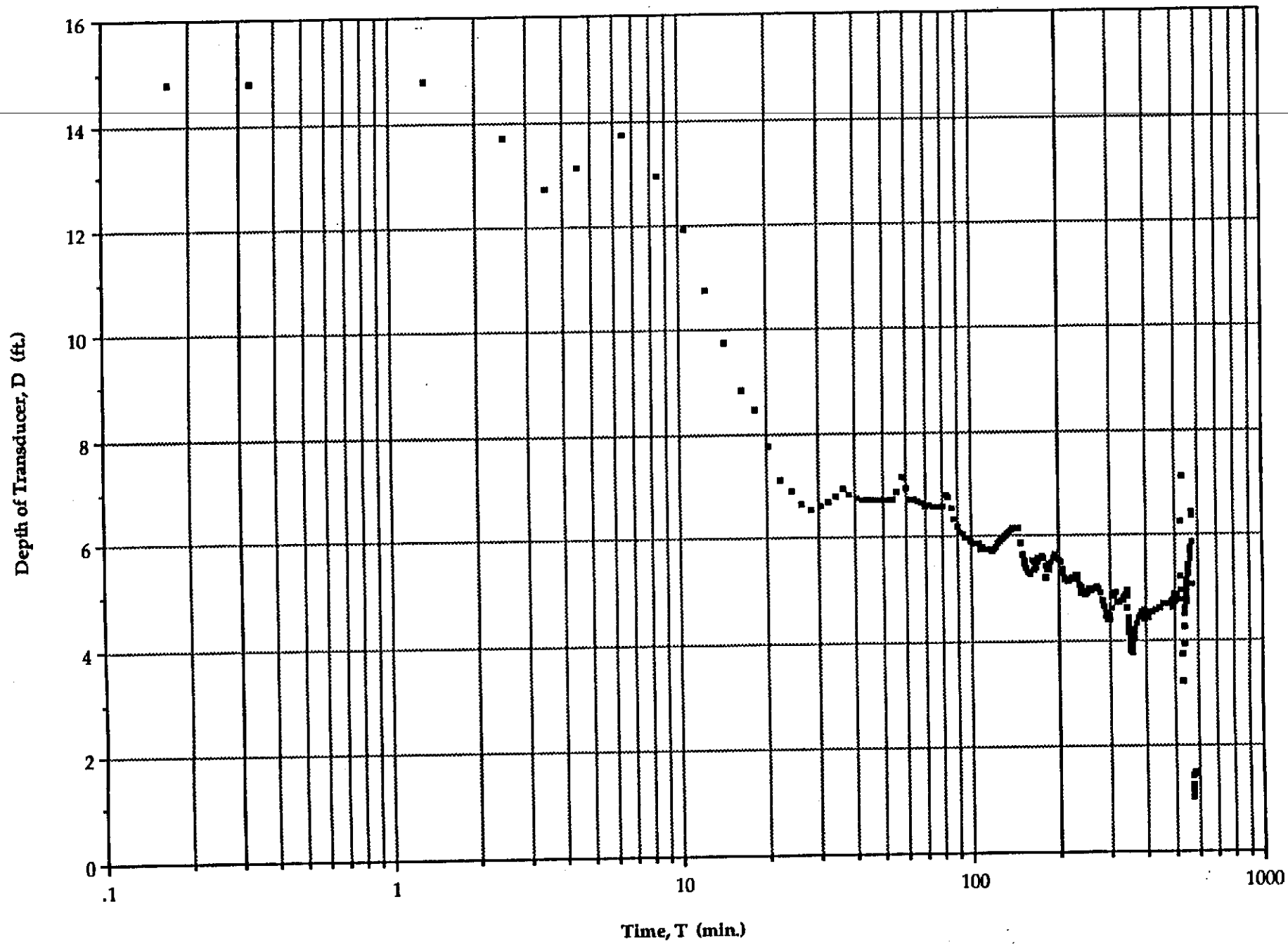
$$X_s = 220 \text{ cm} = 2.2 \text{ meters}$$

The stagnation point is probably less than that which would be encountered for long term pumping system because of an artificially high transmissivity value, most probably caused by the influence of the tank complex.

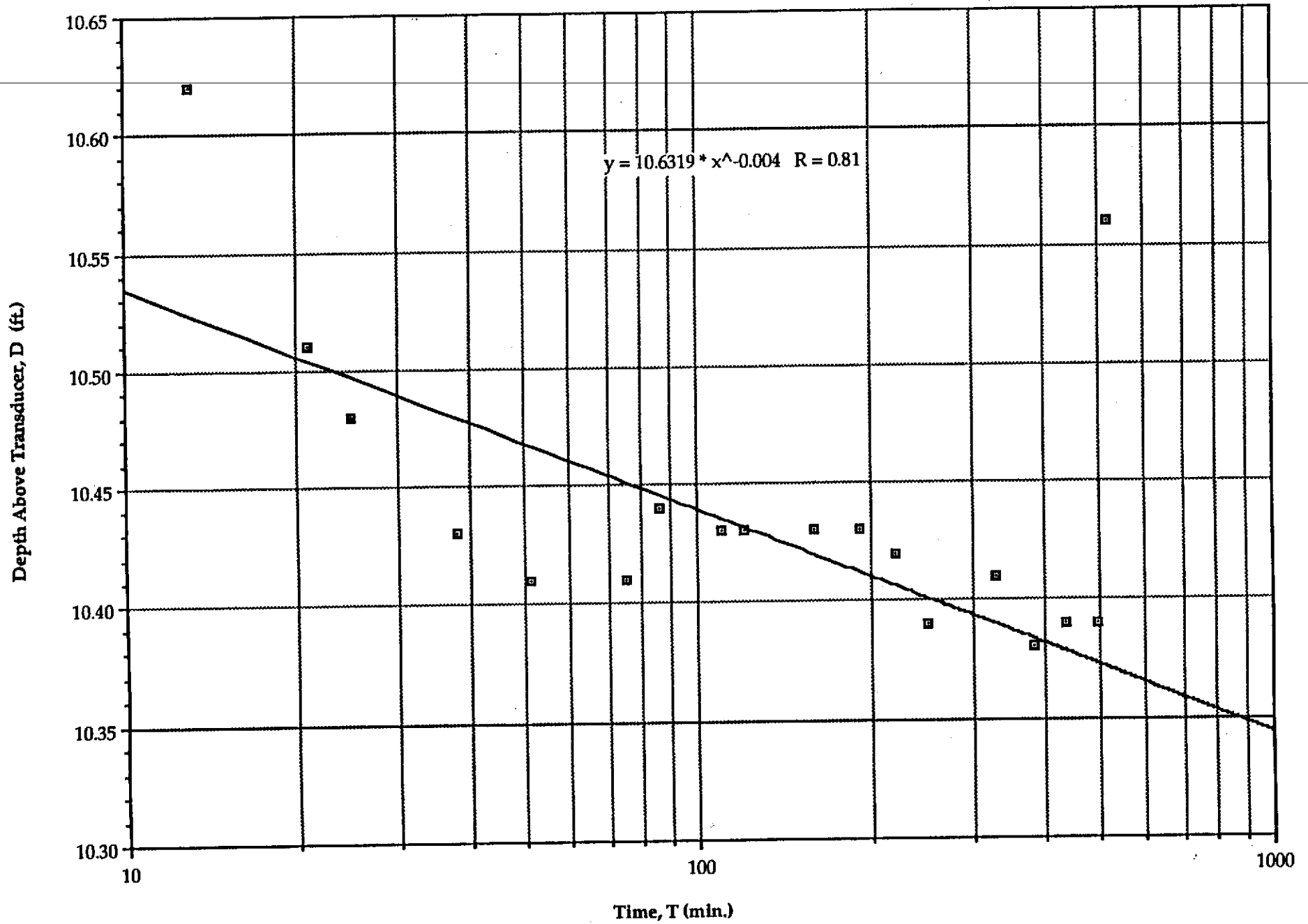
Time vs. Drawdown in RW-1, Step Discharge Test



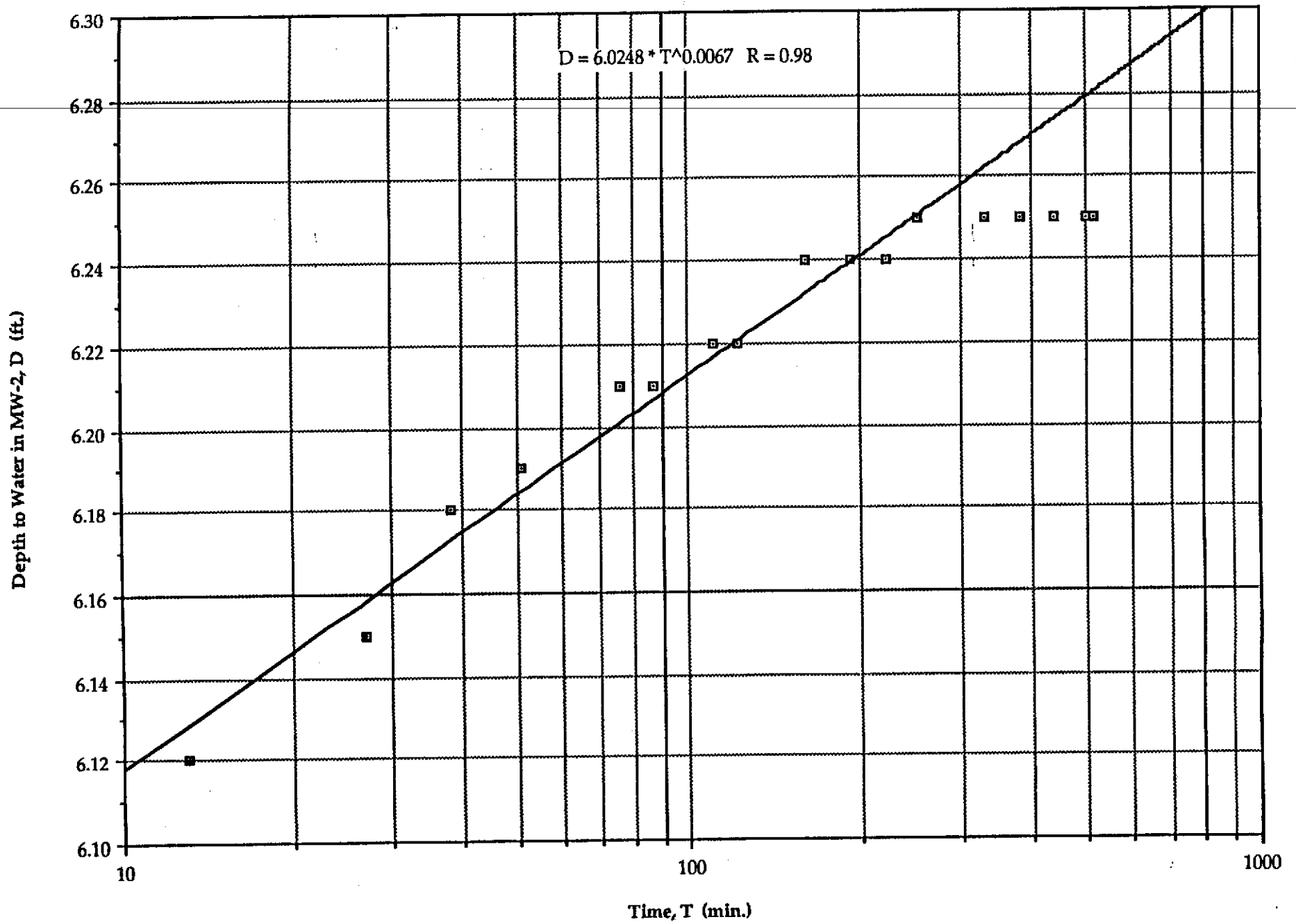
Constant Discharge Test, Time vs. Drawdown in RW-1



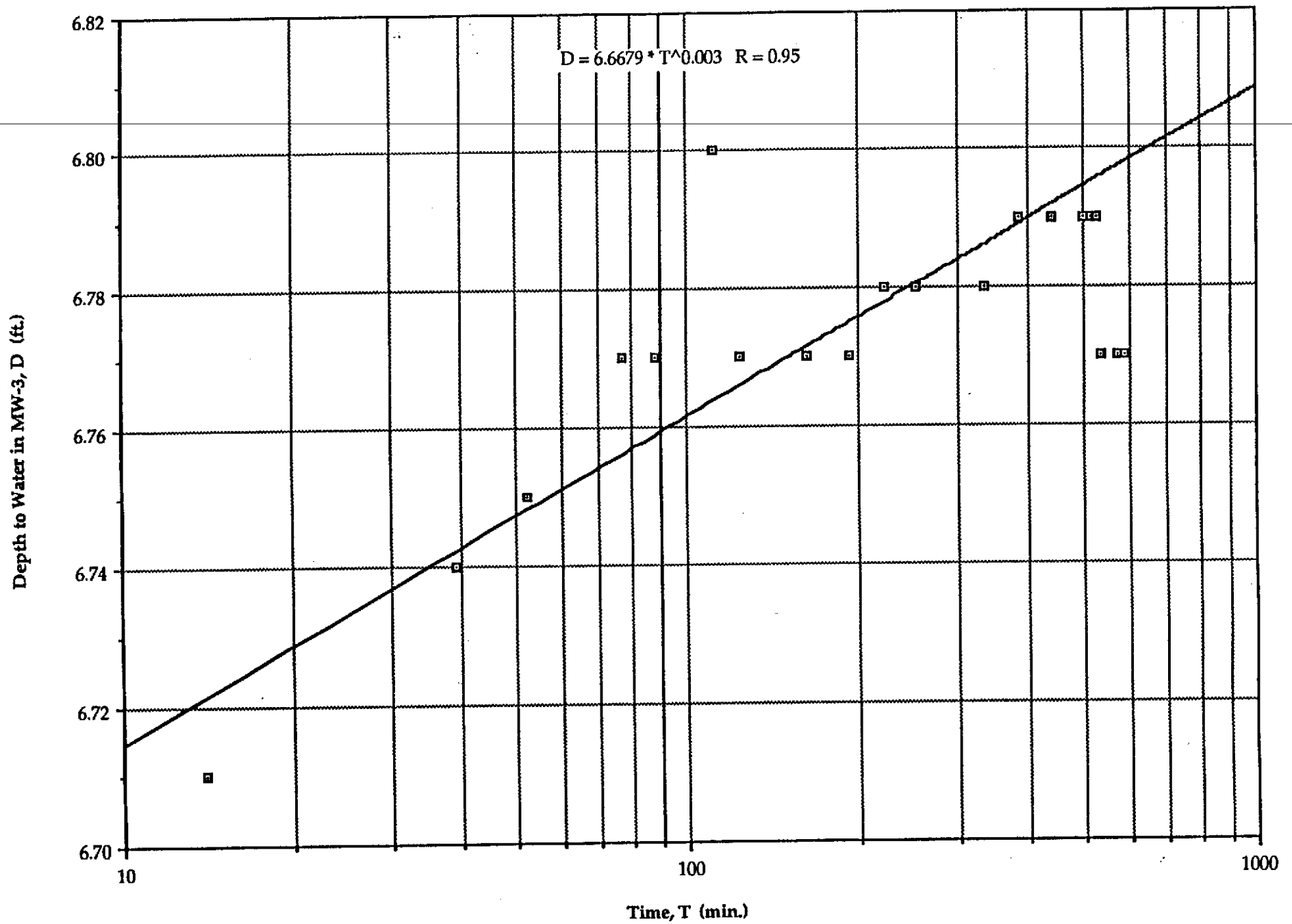
Constant Discharge Test - Time vs. Drawdown in MW-1



9-038 - Constant Discharge Test - Depth to Water in MW-2



9-038 - Constant Discharge Test - Depth to Water in MW-3



APPENDIX D**Soil Vapor Extraction Pilot Test
Equations and Calculations
BP Station No. 11104
Alameda, California****Test Methods**

The tests were carried out according to HETT's Protocol for Soil Vapor Extraction Tests.

On August 26, 1993, HETI conducted a vapor extraction pilot test (VE test) by extracting soil vapor and ground water from well RW-1, and monitoring the vacuum influence in vapor points VP-1, VP-2, and well MW-1, and the change in that influence over time at various extraction flow rates.

Soil Vapor Extraction Test Results

The data from the VE test on RW-1 were used to calculate a radius of influence for vapor extraction. The data were also analyzed to evaluate the permeability to air of soil surrounding the well and to determine vapor flow rate as a function of vacuum. The extracted concentrations of hydrocarbons and oxygen were used to predict the makeup of extracted soil vapor to be expected for a long term system.

Determination of Radius of Influence

Vacuum influence was noted in VP-2 (8.2 ft. from RW-1) at all vacuum levels. Vacuum influence was not noted in VP-1 (25.8 ft. from RW-1) at vacuum levels less than 58 in. WC. No vacuum influence was noted in well MW-1 during the entire test.

The low vacuum influences noted in the vapor points may have been partially due to faulty surface seals. Higher permeability backfill in the UST complex may have reduced the spread of vacuum influence by causing short-circuiting of soil vapor. The screens were submerged in MW-1 throughout the test, which is probably the reason that no influence was noted in that well during the test.

The distances versus monitoring well absolute pressure in the monitoring points at a vacuum of 65 in. WC were plotted on a semi-log graph, and the graphical result is shown on Figure C1. The radius of influence was estimated by using a curve fit to determine an equation for monitoring well pressure as a function of distance and solving that equation for the distance where subsurface pressure remains at atmospheric. Atmospheric pressure is 406.8 in. WC. The graph shows the radius of influence at 65 in. WC was approximately 27 feet.

Determination of Soil Permeability

The vapor flow per unit length of well screen, Q/H , is described by the equation (Johnson, et al [1990]):

$$\frac{Q}{H} = \pi \frac{k P_v}{\mu} \frac{[1 - (P_{Atm} / P_v)^2]}{\ln (R_v / R_l)}$$

The flow rates per unit screen length were used to calculate air permeability of the subsurface soils by inserting ranges of permeabilities into the above equation until the flow rates most closely approximated the data gathered during the field test. These equations were solved with the aid of the computer program called "Hyperventilate®" (Johnson, et al).

The flow rates observed during the test match the permeability of a fine sand. The permeability range was between 1 and 10 darcy. A fine sand was observed in the upper five feet of the borings for MW-1 and RW-1.

Vapor Flow Rate

The data from the test on VW-1 were used to determine the relationship between extracted vapor flow rate and vacuum level. The vacuum versus flow rate for RW-1 was plotted and appears as Figure C2.

Vapor Concentrations

The concentration of hydrocarbons and oxygen in the extracted vapor stream was measured using a Gastech combined LEL and O₂ meter. The results were:

Well No.	Fraction of LEL ¹ %	Calculated Concentration ppmv*	Oxygen Concentration ² %
RW-1	20	2,600	17

- Note: 1 - LEL is the lower explosive limit of hydrocarbons in air, assumed to be 13,000 parts per million by volume (ppmv).
2 - The oxygen concentration is that observed at the end of the test. The initial oxygen concentration was 5%, and rose steadily throughout the test.

Vapor sample RW-1A, taken during the VE test, yielded a TPHo concentration of 2500 µg/L and BTEX concentrations of 11 µg/L, 30 µg/L, 55 µg/L, and 340 µg/L, respectively. Vapor sample RW-1B, taken at the end of the test, yielded a TPHo concentration of 1400 µg/L and BTEX concentrations of 5.0 µg/L, 21 µg/L, 32 µg/L, and 190 µg/L, respectively.

Conclusions

The VE test yielded a relatively small radius of influence of 27 feet. This radius of influence is large enough to influence MW-1, which is the only well that had detectable levels of hydrocarbons in subsurface soils.

The radius of influence and vacuum influence may have been negatively affected by an area of higher permeability in the UST complex backfill and ineffective surface seals on the vapor wells, so the radius of a permanent system with improved surface seals should be larger. The relatively high vapor flow rates observed during the test also shows that vapor extraction will be effective.

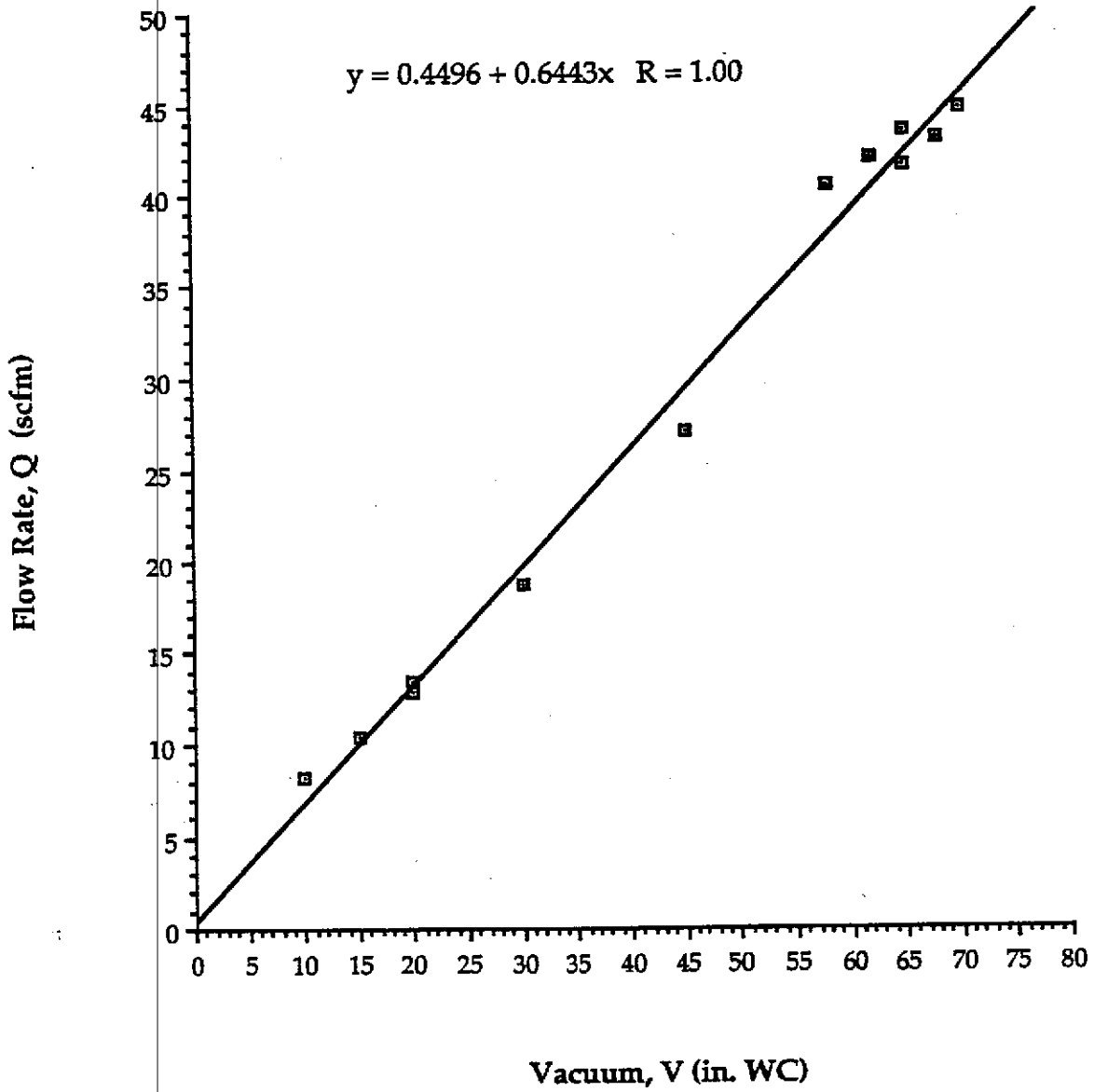
Based on the results of this test, soil vapor extraction combined with ground water extraction would be an effective remediation technology for this site. The low total flow rate that is required makes a regenerative blower the most reasonable choice for a vacuum pump. These pumps are effectively limited to a maximum vacuum of 50 in. WC. System design parameters would be as follows:

Number of vapor and ground water extraction wells:	One
Initial vapor extraction flow rate (based on observations during the test - limited by vacuum pump)	30 scfm total
Initial extraction vacuum at wellhead: (limited by vacuum pump)	50 in. WC
Initial extracted hydrocarbon concentration:	1400 µg/L*
Initial extracted benzene concentration:	5 µg/L*
Initial extracted oxygen concentration: (based on test data)	17 %
Initial vapor extraction radius of influence: (based on test)	27 feet
Ultimate vapor extraction flow rate: (based on vacuum pump)	30 scfm total
Ultimate extraction vacuum at wellhead: (based on vacuum pump)	50 in. WC

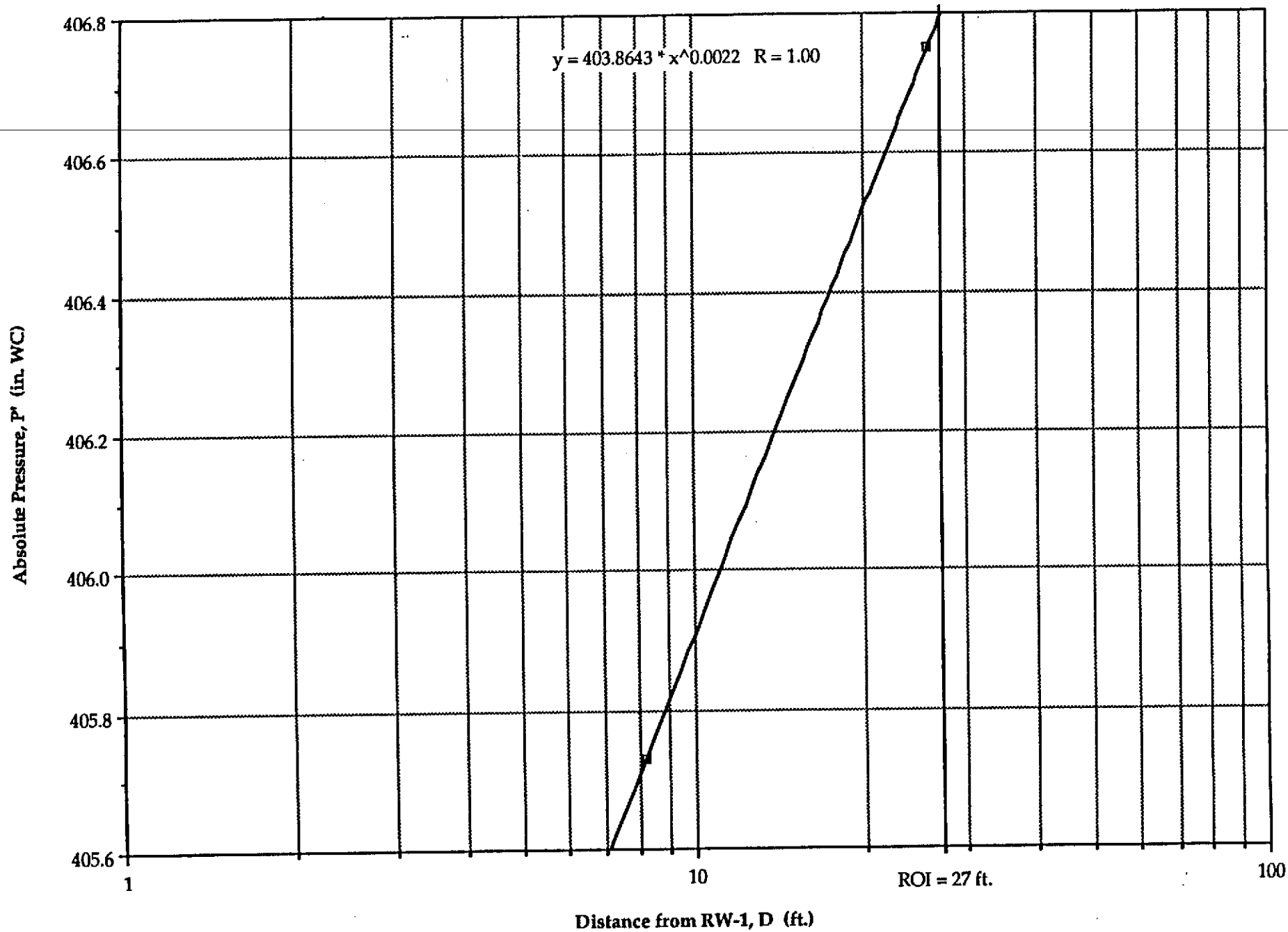
* Note: Concentrations of hydrocarbons in extracted soil vapor did not reduce to a stable level during the tests. The initial concentrations of hydrocarbons are assumed to be the concentrations measured in the air sample RW-1B taken at the end of the VE test.

FIGURE C? 9-038.2

Vacuum vs. Flow Rate, RW-1



Pressure vs. Distance: VE at 65 in. WC vacuum





REPORT OF LABORATORY ANALYSIS

Hydro-Environmental Tech.
363 Mariner Sq. Dr. # 243
Alameda, CA 94501

September 03, 1993
PACE Project Number: 430825509

Attn: Ms. Frances Maroni

Client Reference: BP Station # 11104

PACE Sample Number: 70 0140447
Date Collected: 08/24/93
Date Received: 08/25/93
Client Sample ID: RW-1

<u>Parameter</u>	<u>Units</u>	<u>MDL</u>	<u>DATE ANALYZED</u>
------------------	--------------	------------	----------------------

ORGANIC ANALYSIS

PURGEABLE FUELS AND AROMATICS

TOTAL FUEL HYDROCARBONS, (LIGHT):		-	09/01/93
Purgeable Fuels, as Gasoline (EPA 8015M)	ug/L	500	11000
PURGEABLE AROMATICS (BTXE BY EPA 8020M):		-	09/01/93
Benzene	ug/L	5.0	3900
Toluene	ug/L	5.0	510
Ethylbenzene	ug/L	5.0	540
xylenes, Total	ug/L	5.0	670

These data have been reviewed and are approved for release.

Darrell C. Cain
Regional Director

REPORT OF LABORATORY ANALYSIS

Ms. Frances Maroni
Page 2

FOOTNOTES
for page 1

September 03, 1993
PACE Project Number: 430825509

Client Reference: BP Station # 11104

MDL Method Detection Limit

REPORT OF LABORATORY ANALYSIS

No. Frances Maroni
 Page 3

QUALITY CONTROL DATA

September 03, 1993
 PACE Project Number: 430825509

Client Reference: BP Station # 11104

URGIBLE FUELS AND AROMATICS

Batch: 70 24227
 Samples: 70 0140447

METHOD BLANK:

Parameter	Units	MDL	Method Blank
TOTAL FUEL HYDROCARBONS, (LIGHT):			-
Urgible Fuels, as Gasoline (EPA 8015M)	ug/L	50	ND
URGIBLE AROMATICS (BTXE BY EPA 8020M)			-
Benzene	ug/L	0.5	ND
Toluene	ug/L	0.5	ND
Ethylbenzene	ug/L	0.5	ND
Methyl tert-Butyl Ether (MTBE)	ug/L	5.0	ND
Xylene (total)	ug/L	0.5	ND

LABORATORY CONTROL SAMPLE AND CONTROL SAMPLE DUPLICATE:

Parameter	Units	MDL	Reference Value	Recv	Dupl Recv	RPD
Urgible Fuels, as Gasoline (EPA 8015M)	ug/L	50	1000	97%	85%	13%
Benzene	ug/L	0.5	40	102%	103%	0%
Toluene	ug/L	0.5	40	102%	103%	0%
Ethylbenzene	ug/L	0.5	40	104%	106%	1%
Methyl tert-Butyl Ether (MTBE)	ug/L	5.0	40	95%	94%	1%
Xylene (total)	ug/L	0.5	120	107%	110%	2%

Ms. Frances Maroni
Page 4

FOOTNOTES
for page 3

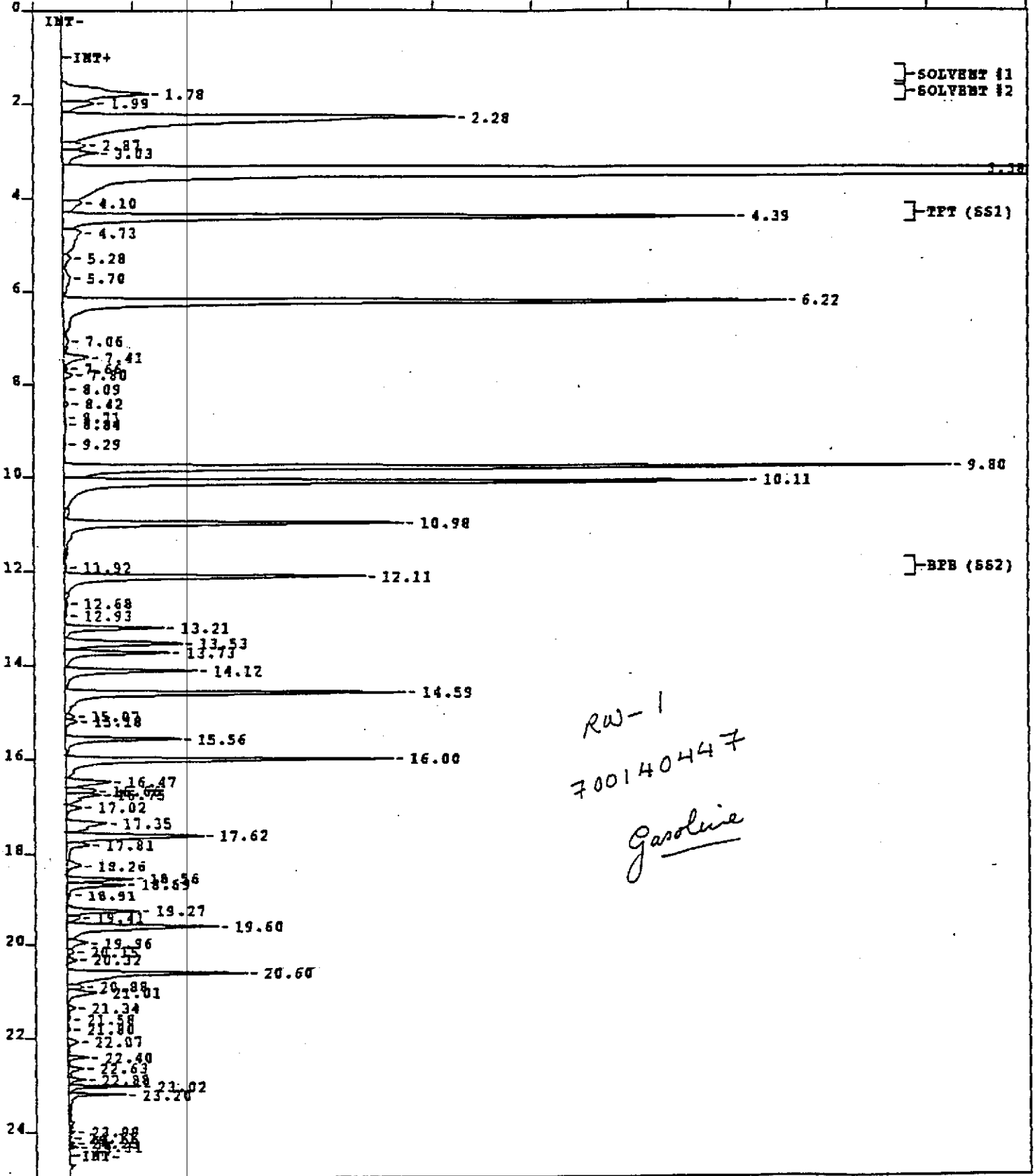
September 03, 1993
PACE Project Number: 430825509

Client Reference: BP Station # 11104

MDL Method Detection Limit
ND Not detected at or above the MDL.
RPD Relative Percent Difference

Sample Name=14044.7R,10,2/3

0 to 25.0 min. Low Y=56.0 High Y=150.0 mv Span=394.0



RW-1
700140447
Gasoline

CHAIN-OF-CUSTODY RECORD
Analytical Request

Client HYDRO-ENVIRONMENTAL TECH
Address 2303 MARINER SQ DR #243
ALAMEDA, CA 94501
Phone 510-521-2084

Report To: F. MARONI
Bill To: BPOIL CO.
P.O. # / Billing Reference _____
Project Name / No. 9-058.2

Pace Client No. _____
Pace Project Manager _____
Pace Project No. 430825.009
Requested Due Date: 5/7

Sampled By (PRINT):
FRANCES MARONI 82493
Sampler Signature _____ Date Sampled _____
FRANCES MARONI

NO. OF CONTAINERS	PRESERVATIVES				ANALYSES REQUEST	REMARKS
	UNPRESERVED	H ₂ SO ₄	HNO ₃	VOA HCL		
					<u>TRG/BTEX</u>	

ITEM NO.	SAMPLE DESCRIPTION	TIME	MATRIX	PAGE NO.
1	<u>RW-1</u>	<u>6op</u>	<u>140</u>	<u>14044.7</u>
2				
3				
4				
5				
6				
7				
8				

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COOLER NOS.	BAILERS	SHIPMENT METHOD		ITEM NUMBER	RELINQUISHED BY / AFFILIATION	ACCEPTED BY / AFFILIATION	DATE	TIME
		OUT / DATE	RETURNED / DATE					

FRANCES MARONI 82493
End talk the
8/25/11
8/25/13

Additional Comments



REPORT OF LABORATORY ANALYSIS

Hydro-Environmental Tech.
363 Mariner Sq. Dr. # 243
Alameda, CA 94501

September 02, 1993
PACE Project Number: 430827515

Attn: Ms. Frances Maroni

Client Reference: BP Station # 11104

PACE Sample Number:

70 0141885

Date Collected:

08/26/93

Date Received:

08/27/93

Client Sample ID:

RW-1A

Parameter

Units

MDL

DATE ANALYZED

ORGANIC ANALYSIS

GASOLINE AND AROMATICS-AIR (M8015/8020)

Non-Methane Hydrocarbons, as n-octane

ug/L

120

2500

08/31/93

Volatile Aromatic Compounds (EPA M8020)

ug/L

1.2

-

08/31/93

Benzene

ug/L

1.2

11

08/31/93

Toluene

ug/L

1.2

30

08/31/93

Ethylbenzene

ug/L

1.2

55

08/31/93

Xylenes, Total

ug/L

1.2

340

08/31/93

REPORT OF LABORATORY ANALYSIS

Ms. Frances Maroni
 Page 2

September 02, 1993
 PACE Project Number: 430827515

Client Reference: BP Station # 11104

PACE Sample Number:
 Date Collected:
 Date Received:
 Client Sample ID:
 Parameter

70 0141893
 08/26/93
 08/27/93
 RW-1B

Units MDL _____ DATE ANALYZED

ORGANIC ANALYSIS

GASOLINE AND AROMATICS-AIR (M8015/8020)				
n-Non-Methane Hydrocarbons, as n-octane	ug/L	50	1400	08/31/93
Volatile Aromatic Compounds (EPA M8020)			-	08/31/93
Benzene	ug/L	0.5	5.0	08/31/93
Toluene	ug/L	0.5	21	08/31/93
Ethylbenzene	ug/L	0.5	32	08/31/93
Xylenes, Total	ug/L	0.5	190	08/31/93

These data have been reviewed and are approved for release.

Darrell C. Cain
 Darrell C. Cain
 Regional Director

Ms. Frances Maroni
Page 3

FOOTNOTES
for pages 1 through 2

September 02, 1993
PACE Project Number: 430827515

Client Reference: BP Station # 11104

MDL Method Detection Limit

REPORT OF LABORATORY ANALYSIS

Ms. Frances Maroni
 Page 4

QUALITY CONTROL DATA

September 02, 1993
 PACE Project Number: 430827515

Client Reference: BP Station # 11104

ASOLINE AND AROMATICS-AIR (M8015/8020)
 Batch: 70 24012
 Samples: 70 0141885, 70 0141893

METHOD BLANK:

Parameter	Units	MDL	Method Blank
Non-Methane Hydrocarbons, as n-octane	ug/L	50	ND
Volatile Aromatic Compounds (EPA M8020)			-
Benzene	ug/L	0.5	ND
Toluene	ug/L	0.5	ND
Ethylbenzene	ug/L	0.5	ND
Xylenes, Total	ug/L	0.5	ND

LABORATORY CONTROL SAMPLE AND CONTROL SAMPLE DUPLICATE:

Parameter	Units	MDL	Reference Value	Recv	Dupl Recv	RPD
Non-Methane Hydrocarbons, as n-octane	ug/L	50	241	90%	93%	3%
Benzene	ug/L	0.5	32	84%	86%	2%
Toluene	ug/L	0.5	38	85%	87%	2%
Ethylbenzene	ug/L	0.5	43	85%	88%	3%
Xylenes, Total	ug/L	0.5	128	87%	91%	4%

Ms. Frances Maroni
Page 5

FOOTNOTES
for page 4

September 02, 1993
PACE Project Number: 430827515

Client Reference: BP Station # 11104

MDL Method Detection Limit
ND Not detected at or above the MDL.
RPD Relative Percent Difference

CHAIN-OF-CUSTODY RECORD
Analytical Request

Client: HYDRO ENVIRONMENTAL
Address: 2363 MAUNIER SQ DR
LAUREL, IL 61801
Phone: 510-521-2684

Report To: EMERSON
Bill To: BROILCO
P.O. # / Billing Reference:
Project Name / No. 9-038

Phase Client No.:
Phase Project Manager RML
Phase Project No. 430827.515
*Requested Due Date:

Sampled By (PRINT):
DRAYTON MASON
Sampler Signature: DRAYTON MASON Date Sampled: 8/20/00

NO. OF CONTAINERS	PRESERVATIVES			ANALYSES REQUEST
	UNPRESERVED	H ₂ SO ₄	HNO ₃	
				<u>ANALYST</u>

ITEM NO.	SAMPLE DESCRIPTION	TIME	MATRIX	PAGE NO.	NO. OF CONTAINERS	PRESERVATIVES	ANALYSES REQUEST	REMARKS
1	RW-1A	6p	Air	14189.5			X	
2	RW-1-B	6p	Air	14199.3			X	
3								
4								
5								
6								
7								
8								

COOLER NOS.	BAILERS	SHIPMENT METHOD	ITEM NUMBER	RELINQUISHED BY / AFFILIATION	ACCEPTED BY / AFFILIATION	DATE	TIME
		OUT / DATE RETURNED / DATE		<u>DRAYTON MASON</u>	<u>DRAYTON MASON</u>	<u>8/27/00</u>	<u>1100</u>

Additional Comments: cc/ms 3

SEE REVERSE SIDE FOR INSTRUCTIONS