HAGEMAN-AGUIAR, INC.
Environmental & Water Resources Engineering
Groundwater Consultants

June 4, 1998

Larry Seto
Alameda County Environmental Health
1131 Harbor Bay Pkwy
Alameda, CA 94502

STID 1211

RE: Pacific Cryogenic Company
2311 Magnolia Street, Oakland, CA
RWQCB LUST Case File No. 01-0833

Dear Mr. Seto:

Please find enclosed two copies of the "*Health-Based Risk Assessment and Recommendation for UST Case Closure*", by Hageman-Aguiar, Inc., dated June 3, 1998. This report 1) presents a summary and analysis of all data collected to date in terms of subsurface contamination beneath the subject property, 2) presents the results of a sensitive receptors survey in order to assess the potential for impact upon beneficial uses of surface water and groundwater in the area, and 3) provides the results of a health-based risk assessment that is consistent with ASTM Standard E 1739, *Risk-Based Corrective Action Applied at Petroleum Release Sites*.

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We have made every effort to provide all of the information required for closure of the site, and would expect a timely response from the County in terms of formal case closure and subsequent authorization to decommission the six existing monitoring wells in the near future.

If you have any questions, or require any further information, please call me at (510)620-0891.

Sincerely,

Gary Aguiar

Principal Engineer

HAGEMAN-AGUIAR, INC.
Environmental & Water Resources Engineering
Groundwater Consultants

HEALTH-BASED RISK ASSESSMENT

AND

RECOMMENDATION FOR UST CASE CLOSURE

PACIFIC CRYOGENIC COMPANY
2311 Magnolia Street
Oakland, California

RWQCB LUST File No. 01-0833

June 3, 1998

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I. INTRODUCTION

The subject property is the historic location of Pacific Cryogenic Company at 2311 Magnolia Street in Oakland, California. The location of the subject property is shown on Figure 1 (Site Location Map).

The layout of the subject property is shown in Figure 2 (Site Plan). The locations of the existing shallow groundwater monitoring wells are shown in this figure, along with the current layout of the facility. All underground tanks and associated underground piping have been removed from the subject property.

The following report 1) presents an analysis of all data collected to date in terms of subsurface contamination beneath the subject property, 2) assesses the potential for impact upon beneficial uses of groundwater in the area, 3) assesses the risk of future physical occupation of the subject property, and 4) provides recommendations for future activities at the subject property. The scope of work is consistent with ASTM Standard E 1739, *Risk-Based Corrective Action Applied at Petroleum Release Sites.*

FIGURE 1.
Site Location Map

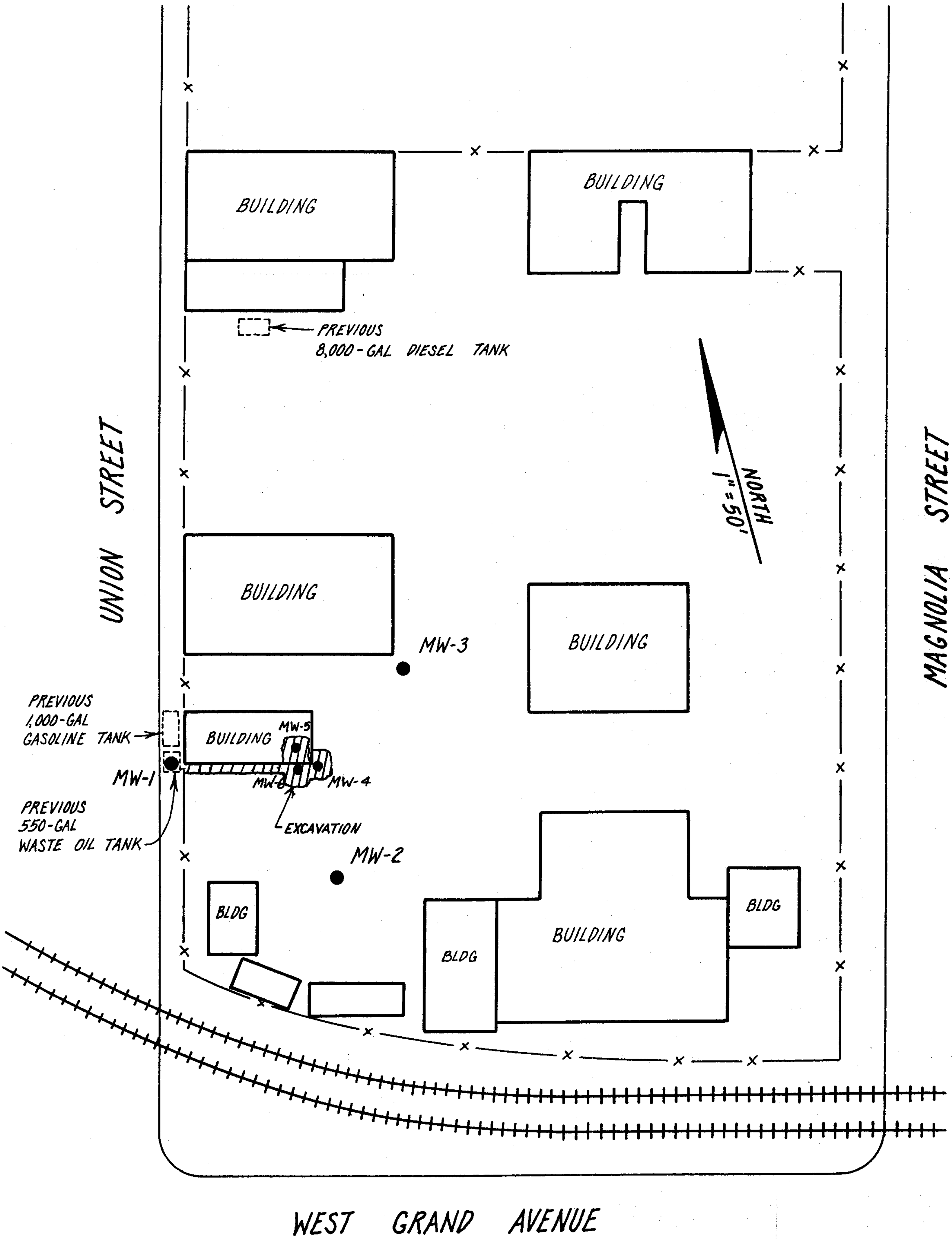


FIGURE 2.

Site Plan

II. SITE CHRONOLOGY

June 30 & July 12, 1989

Geo-Environmental Technology removes three underground storage tanks from the subject property: one 8,000-gallon underground Diesel tank, one 1,000-gallon underground Gasoline tank, and one 550-gallon underground Waste Oil tank. The locations of the three underground storage tanks are indicated on Figure 2 (Site Plan).

October 16, 1990

Due to the detection of obvious subsurface contamination in the vicinity of the Gasoline and Waste Oil underground storage tanks, Geo-Environmental Technology installs shallow groundwater monitoring well MW-1 within the tank pit area. Geo-Environmental Technology samples shallow groundwater monitoring well MW-1.

The results of the groundwater sampling indicate the presence of Diesel at a concentration of 5,400 μg/L (ppb). Benzene, Toluene, Ethylbenzene, and Total Xylenes are detected at concentrations of 1,200 μg/L (ppb), 18 μg/L (ppb), 7.1 μg/L (ppb) and 37 μg/L (ppb), respectively. The results of the sampling are presented in the *Progressive Report, Groundwater Investigation*, by Geo-Environmental Technology, dated November 20, 1990.

→ TPH(g) was not tested for

Sometime in 1991

Following the installation and sampling of monitoring well MW-1, two additional shallow groundwater monitoring wells are installed on the subject property (wells MW-2 and MW-3). No data regarding these well installations are available at the present time.

March 4, 1992

Monitoring wells MW-1, MW-2 and MW-3 are sampled by Bernabe and Brinker, Inc. It should be noted that 590 μg/L (ppb) and 360 μg/L (ppb) of Diesel reported by Bernabe and Brinker for this round of sampling are qualified by McCampbell Analytical, Inc., as containing "oil range compounds together with Gasoline range compounds". These results may reflect a quantification of the higher boiling point components of Gasoline, and may also be indicative of the presence of older, weathered Gasoline.

April 3, 1992

Monitoring wells MW-1, MW-2 and MW-3 are sampled by Hageman-Aguiar, Inc., for dissolved petroleum constituents. This sampling represents a follow-up "round" of sampling following groundwater sampling conducted by Bernabe and Brinker, Inc., on March 4, 1992.

Gasoline is detected in the groundwater samples collected from wells MW-1 and MW-3 at concentrations of 300 μg/L (ppb) and 5,200 μg/L (ppb), respectively. In addition, Benzene is detected in the groundwater samples collected from wells MW-1 and MW-3 at concentrations of 21 μg/L (ppb) and 120 μg/L (ppb), respectively. For this round of shallow groundwater sampling, no detectable concentrations of Diesel are found in any of the samples.

November 12-18, 1992

On November 12, 1992, the underground piping running between the previous Gasoline and Waste Oil underground storage tanks and the previous dispenser pedestal are removed by Hageman-Aguiar, Inc.

Subsequent to the piping removal, an additional excavation is conducted on November 18, 1992. The excavation extends to a depth of approximately 15 feet below ground surface and is conducted in order to mitigate the apparent surface Gasoline contamination. All soil sample collection is conducted in the presence of Jennifer Eberle of the Alameda County Environmental Health Services. Several holes were noted in the waste oil and the gasoline underground pipelines (11-23-92 report)

Analyses of soil samples demonstrate that elevated Gasoline concentrations remain in the native soil at the full extents of the excavation. The excavation is backfilled, with the casings for monitoring wells MW-4, MW-5, and MW-6 placed inside the open excavation prior to the backfilling procedure.

report dated 11-23-92 Significant gasoline contamination is still remaining at the areal limits of the excavation (up to 1,600 PPM TPH(g) and 2.4 PPM benzene in sample SP-9) To facilitate future in-situ treatment, 3 backfill wells were installed MW-4, MW-5 and MW-6

October 8, 1993

The report entitled *Proposed Workplan for Subsurface Investigation* by Hageman-Aguiar, Inc., is prepared and subsequently submitted to Alameda County Environmental Health Services. This workplan proposes the collection of "grab" groundwater samples from a number of on-site "hydropunch" locations.

November 2, 1993

Verbal approval of the proposed workplan is issued by Jennifer Eberle of the Alameda County Environmental Health Services.

November 5, 12, and 23, 1993

At fifteen on-site locations, "hydropunch" probes are driven to an approximate depth of 20 feet below ground surface and "grab" shallow groundwater samples are subsequently collected.

The results of the subsurface investigation are presented in the *Quarterly Groundwater Sampling Report and Report of Subsurface Investigation* by Hageman-Aguiar, Inc., dated December 8, 1993. Gasoline and Benzene were detected in the "grab" groundwater samples at concentrations of up to 29,000 μg/L (ppb) and 20 μg/L (ppb), respectively. No detectable concentrations of Diesel are found in any of the samples. Results of this investigation indicate that no detectable concentrations of any petroleum hydrocarbons as either Gasoline, Diesel, or BTEX are moving off-site from the subject property.

III. HYDROGEOLOGY

Regional Hydrogeology

A portion of a USGS topographic map showing surface features and local surface water drainage in the vicinity of the subject property is illustrated in Figure 3. As shown on this map, this portion of West Oakland has a surface elevation of approximately 10 feet MSL. The subject property is approximately 1.25 miles east of the Oakland Outer Harbor, 1.75 miles north of the Oakland Inner Harbor, and approximately 6.0 miles west of the Berkeley Hills.

On this portion of the low-lying Bay Plain in close proximity to San Francisco Bay, the soils beneath the subject property consist primarily of fine grain soils (silts and clays). The near surface soils are described as younger alluvium, mainly stream and channel deposits interbedded with beach and dune sand, and marine terrace deposits (Geologic Map of California, San Francisco Sheet, State of California Division of Mines and Geology, 1980). The majority of shallow groundwater movement occurs in the thin sand and gravel layers and/or "stringers". Bedrock is likely to occur at a depth of greater than 50 feet beneath the subject property.

FIGURE 3.

Topographic Map.

On-Site Hydrogeology

Based upon the data obtained from the various soil borings and monitoring well installations that have been conducted, the subject property is underlain by fine-grained alluvial deposits, the major portion of which appear to consist of clay and clay-silt mixtures. During on-site excavation work, the shallow groundwater was typically encountered within a thin layer of clayey sand at a depth of approximately 12 feet below ground surface. The static shallow groundwater table elevation beneath the site has historically been on the order of 8 to 10 feet below the ground surface.

Figure 4 presents the shallow groundwater table contour map, based upon the most recent data collected on November 15, 1996. As shown in this figure, the shallow groundwater flow is in the easterly direction.

Table 1 presents the results of all water level measurements collected between April 3, 1992, and the present time. As shown by the data in Table 1, the shallow groundwater flow direction has historically been in the easterly to southeasterly direction. This groundwater flow toward Lake Merritt rather than directly toward San Francisco Bay, is consistent with other groundwater monitoring sites in this portion of Oakland.

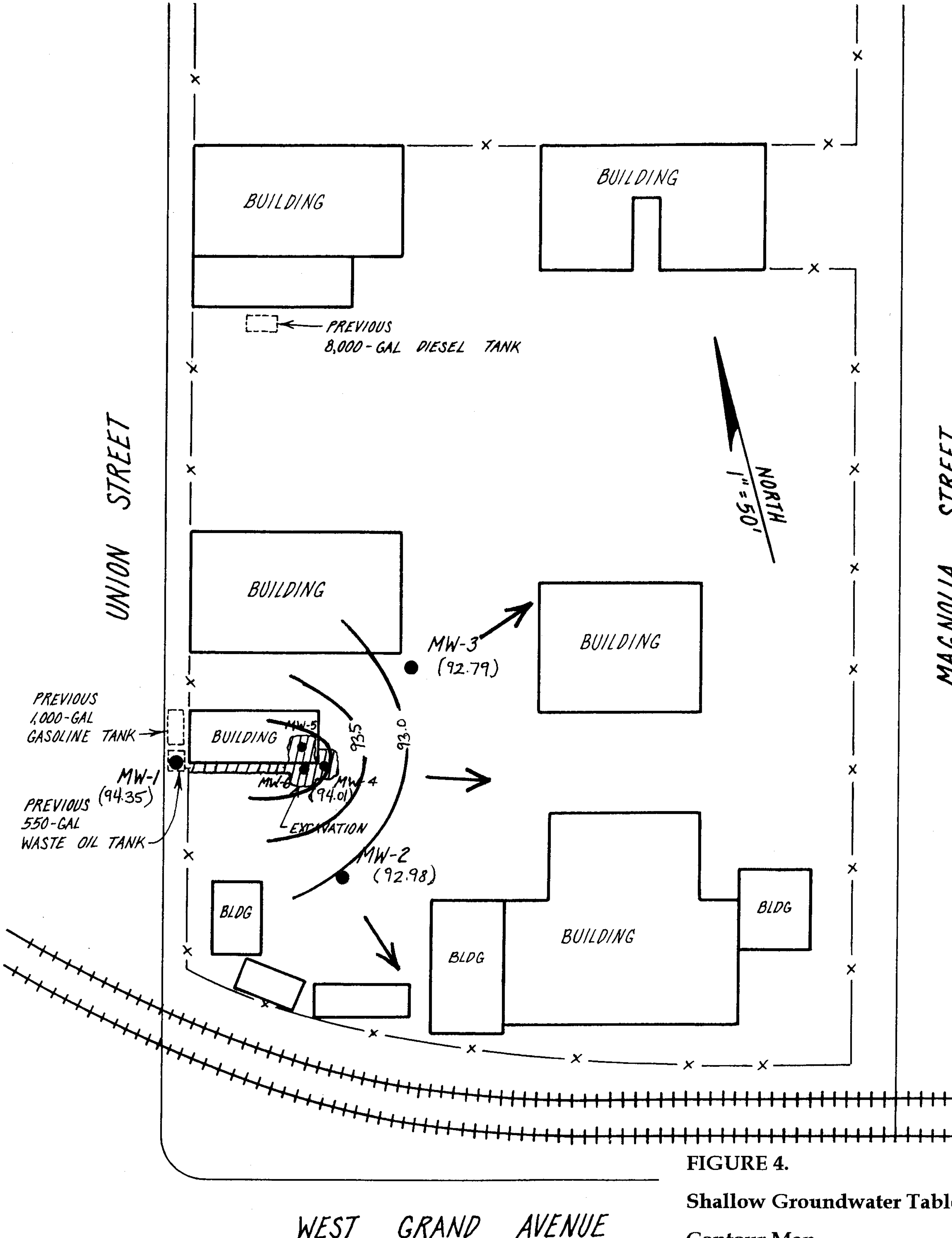


FIGURE 4.

Shallow Groundwater Table Contour Map, measured on February 20, 1997.

TABLE 1.

Historical Water Table Elevations
(feet)

Well	Date of Measurement								
	4-3-92	6-16-92	10-8-92	1-7-93	4-23-93	7-16-93	11-8-93	2-2-94	5-2-94
MW-1	95.58	92.01	91.11	97.17	95.17	92.07	91.78	94.42	93.55
MW-2	93.25	91.60	90.83	94.24	92.69	91.46	91.04	92.55	92.19
MW-3	92.52	91.87	90.65	94.43	92.64	91.21	91.14	92.21	91.94
MW-4	---	---	---	---	---	91.48	91.16	92.67	92.37
Flow Direction	SE	SE	E	SE	SE	E	SE	E	E

Well	Date of Measurement								
	8-3-94	11-4-94	3-14-95	8-23-95	5-8-96	8-12-96	11-15-96	2-20-97	
MW-1	---	90.96	96.33	91.70	93.72	91.96	---	94.35	
MW-2	91.25	90.77	95.08	91.30	92.64	91.55	91.09	92.98	
MW-3	91.00	90.57	94.96	91.10	92.84	91.21	90.84	92.79	
MW-4	91.26	90.74	95.60	91.38	93.28	91.72	91.18	94.01	
Flow Direction	E	E	E	E	E	E	E	E	

IV. REMEDIATION ACTIVITIES

Underground Tank Removals

On June 30 and July 12, 1989, Geo-Environmental Technology removed three underground storage tanks from the subject property: one 8,000-gallon underground Diesel tank, one 1,000-gallon underground Gasoline tank, and one 550-gallon underground Waste Oil tank.

Due to the detection of subsurface contamination in the vicinity of the Gasoline and Waste Oil tanks, shallow groundwater monitoring well MW-1 was installed by Geo-Environmental Technology at the previous tank locations. The results of shallow groundwater sampling on October 26, 1990, indicated the presence of Diesel at a concentration of 5,400 μg/L (ppb). In addition, Benzene, Toluene, Ethylbenzene, and Total Xylenes were detected at concentrations of 1,200 μg/L (ppb), 18 μg/L (ppb), 7.1 μg/L (ppb), and 37 μg/L (ppb), respectively. Subsequent to the installation and sampling of monitoring well MW-1, two additional shallow groundwater monitoring wells were installed on the subject property (wells MW-2 and MW-3). No data regarding these well installations are available.

Piping Removal and Soil Excavation

On November 12, 1992, the underground piping running between the previous Gasoline and Waste Oil underground tanks and the previous dispenser pedestal were removed by Hageman-Aguiar, Inc. During the removal process, several holes were noted in both the Waste Oil and the Gasoline underground pipelines. At one location, significant Gasoline contamination was apparent in the soil (based upon odor and color).

Subsequent to the piping removal, additional excavation was conducted on November 18, 1992. The excavation extended to a depth of approximately 15 feet below ground surface and was conducted in order to mitigate the apparent subsurface Gasoline contamination. All soil sample collection was conducted in the presence of Jennifer Eberle, Alameda County Environmental Health.

Obvious Gasoline contamination was present at the limits of the excavation. The Gasoline contamination appeared to coincide with the capillary fringe above the water table, and appeared to potentially be of considerable lateral extent. Considering 1) the unknown lateral extent of the subsurface contamination, 2) the structural integrity of the existing building, 3) the successful removal of the primary subsurface contamination from beneath the source (piping leak), and 4) general site safety considerations, the decision was made to backfill the excavation in its entirety as soon as possible.

Excavation Backfill and Backfill Well Installations

Upon completion of the excavation activities, three backfill monitoring wells were installed. The locations of backfill monitoring wells MW-4, MW-5 and MW-6 are shown in Figure 5. Upon completion of the soil excavation, three 4-inch well casings were suspended inside the excavation, with the bottoms located within the lower trench section. Each well casing consisted of 10 feet of 4-inch PVC slotted screen pipe (0.02" slots), and were each completed up to the ground surface with 4-inch PVC blank casing. The total depth of each well is 15 feet below ground surface.

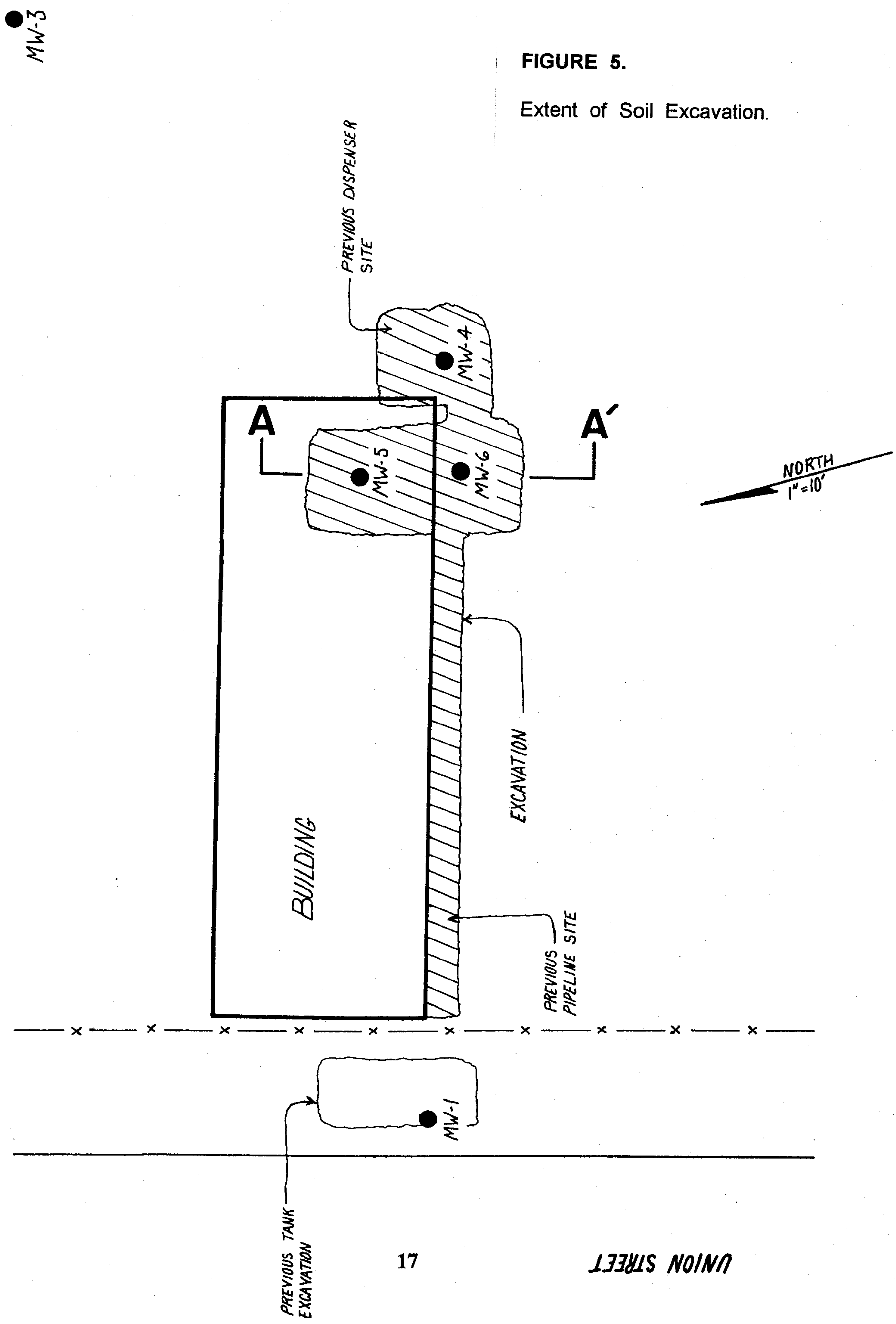
The excavation was subsequently backfilled around each well casing with 3/8" pea gravel. Approximately 2 to 3 feet of compacted Class II baserock was placed on top, followed by approximately 8 inches of Portland cement concrete. The well constructions and excavation backfill are illustrated in Figure 6 (generalized geologic cross-section).

Excavated Soil Disposal

All spoils from the excavation were covered with plastic sheeting and stockpiled on-site until a suitable plan for disposal could be developed. As the result of the soil excavation in the vicinity of the apparent underground piping leak, approximately 140 cubic yards of contaminated soil were stockpiled. On December 7, 1993, the stockpiled contaminated soil was transported to the Vasco Road Sanitary Landfill operated by Browning Ferris Industries (BFI), and subsequently disposed of as a special non-hazardous waste. This Class III landfill is located at 4001 Vasco Road in Livermore, California.

FIGURE 5.

Extent of Soil Excavation.



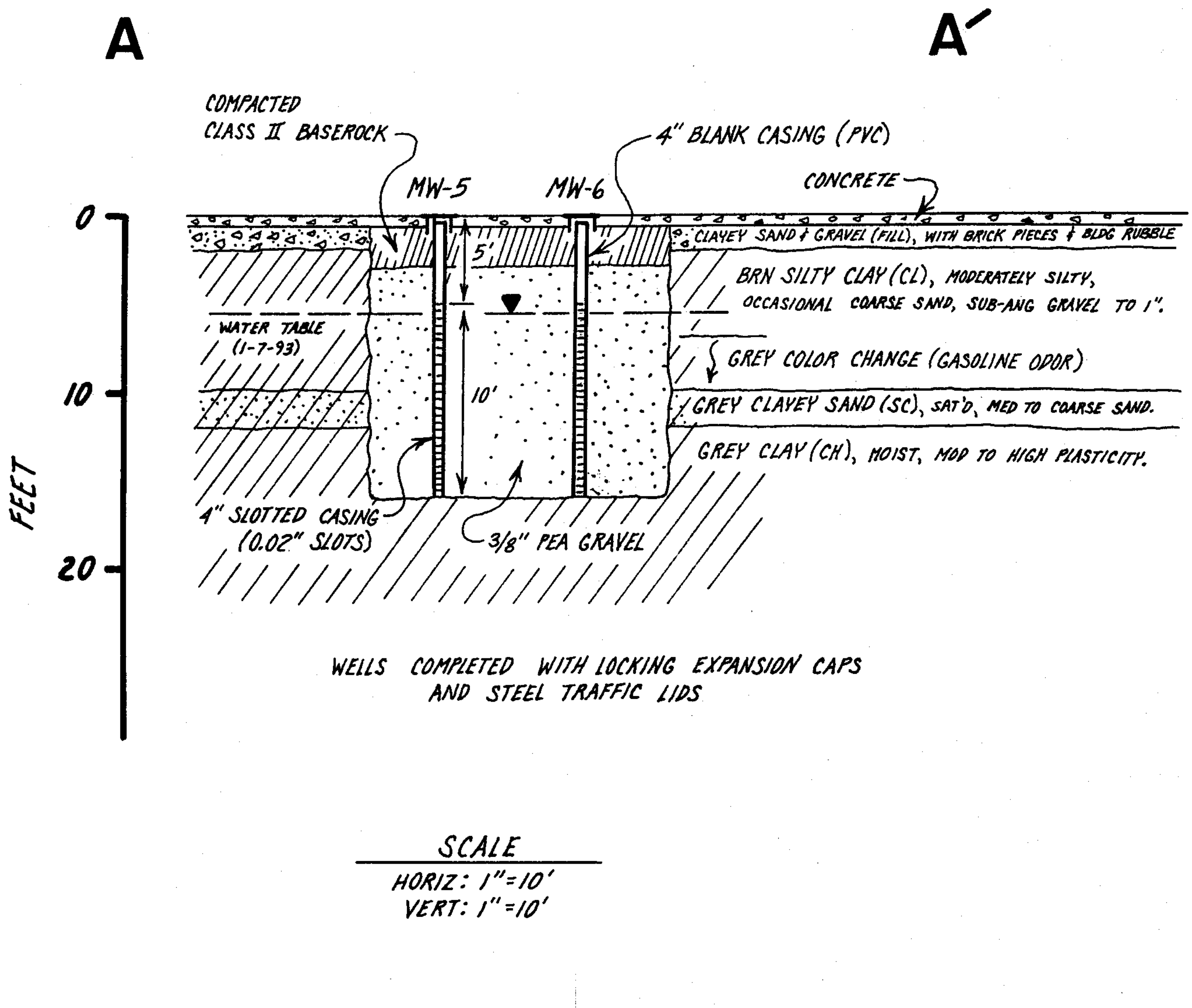


FIGURE 6.

Generalized Geologic Cross-Section A-A'.

V. EXTENT OF HYDROCARBON PRESENCE ON-SITE

Residual Soil Concentrations

Final excavation soil sampling locations are shown in Figure 7. As shown by the laboratory results in Table 2, elevated concentrations remained in the native soil at the limits of the excavation. The Gasoline contamination appeared to coincide with the capillary fringe above the water table, and appeared to potentially be of considerable lateral extent. The contamination was evident as a relatively thin gray-colored band on each of the four excavation sidewalls. As shown in Table 2, residual Gasoline concentrations remaining in the soil beneath the subject property appear to be less than 2,000 mg/kg (ppm).

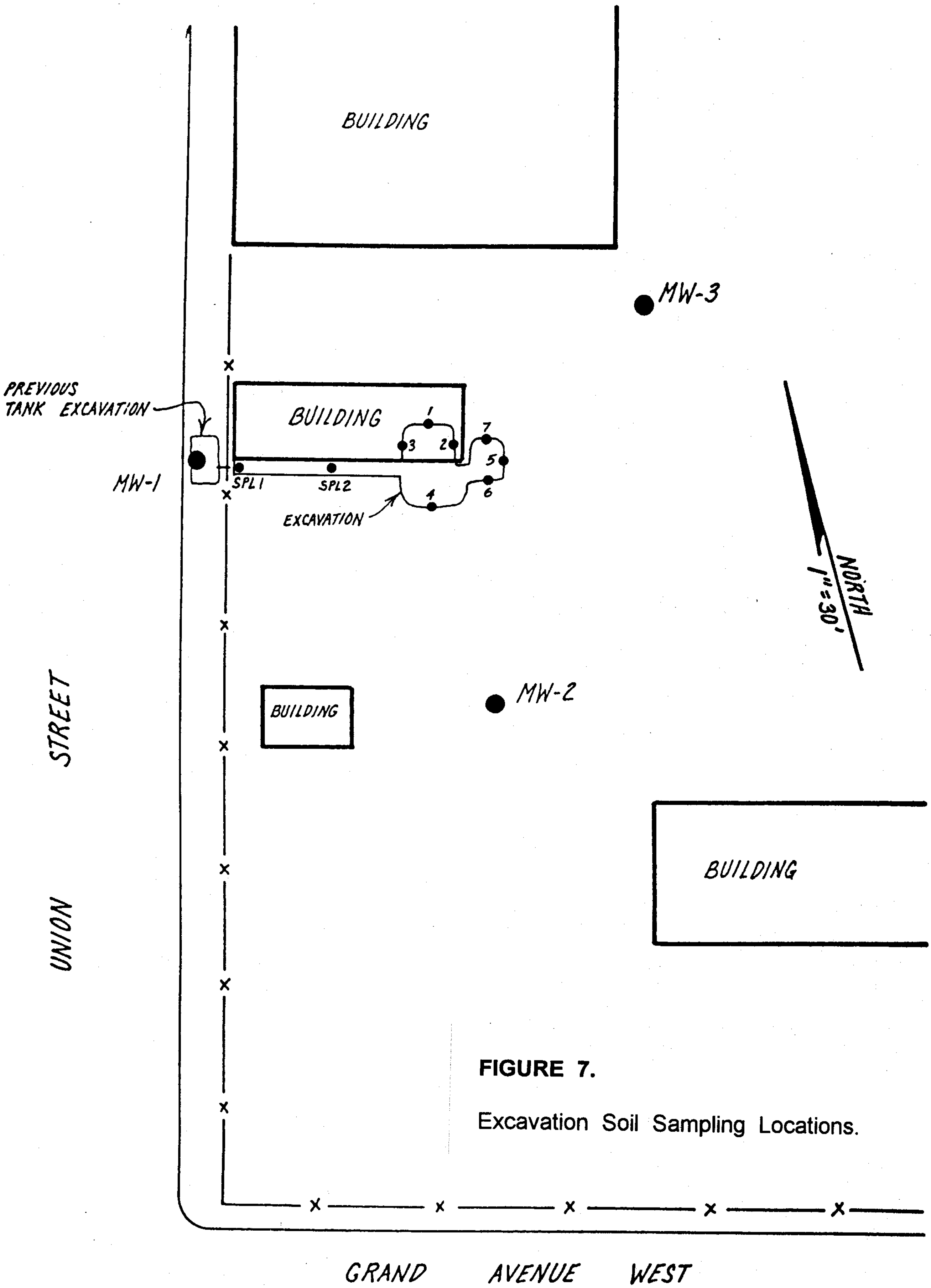


FIGURE 7.

Excavation Soil Sampling Locations.

Sampled on 11-18-92

TABLE 2.
Excavation Soil Sampling Results

Sample	Date	Depth (feet)	TPH as Gasoline (mg/Kg)	TPH as Diesel (mg/Kg)	Benzene (ug/Kg) ppb	Toluene (ug/Kg)	Ethyl-benzene (ug/Kg)	Total Xylenes (ug/Kg)	Oil & Grease (mg/Kg)	Motor Oil (mg/Kg)	VOCs (ug/Kg)
PL 1	11-12-92	7	ND	ND	ND	ND	ND	ND	1,400	1,100	ND
PL 2	11-12-92	7	ND	ND	ND	ND	ND	ND	16	13	ND
1 A	11-18-92	6	28	ND	22	19	33	86	ND	ND	ND
1 B	11-18-92	9	670	2.3	870	1,400	1,800	6,600	22	24	ND
2 A	11-18-92	6	310	ND	480	760	1,100	3,500	20	18	ND
2 B	11-18-92	9	400	ND	550	940	1,300	4,000	11	ND	ND
3 A	11-18-92	6	29	ND	25	21	34	92	ND	ND	ND
3 B	11-18-92	9	1,600	ND	2,400	2,800	3,300	18,000	19	ND	ND
4 A	11-18-92	6	28	ND	26	20	31	89	ND	ND	ND
4 B	11-18-92	9	420	ND	520	1,400	1,600	5,300	64	38	ND
5 A	11-18-92	6	26	ND	23	18	35	83	ND	ND	ND
5 B	11-18-92	9	1,100	10	2,000	2,500	3,000	16,000	29	22	ND
6 A	11-18-92	6	8.7	ND	11	8	27	29	ND	ND	ND
6 B	11-18-92	9	150 ~~4.7~~	ND	18	120 ~~40~~	21	70 ~~54~~	ND	ND	ND
7 A	11-18-92	6	27	ND	28	24	38	85	14	ND	ND
7 B	11-18-92	9	350	1.2	580	950	1,800	4,200	30	25	ND
Detection Limit			1.0	1.0	5.0	5.0	5.0	5.0	10.0	10.0	5.0

ND = not detected

Residual Shallow Groundwater Concentrations

Table 3 presents the results of the laboratory analysis for petroleum hydrocarbons of the groundwater samples collected from monitoring wells MW-1, MW-2, MW-3, and MW-4. Due to the close proximity of MW-4, MW-5, and MW-6 in the pea gravel backfill, only samples from MW-4 have been historically collected for laboratory analysis. As shown in Table 3, the highest concentrations of Gasoline and Benzene that have most recently been detected are 4,900 μg/L (ppb) and 66 μg/L (ppb), respectively. It should be noted that these elevated concentrations are found in well MW-3, located immediately down-gradient of the previous soil excavation.

TABLE 3.
Shallow Groundwater Sampling Results

Well	Date	TPH as Gasoline (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl-benzene (ug/L)	Total Xylenes (ug/L)	MTBE (ug/L)
MW-1	10-26-90	---	1200	18	7.1	37	---
	03-04-92	460	120	9.0	16	44	---
	04-03-92	300	21	6.0	15	36	---
	06-16-92	220	54	17	29	73	---
	10-09-92	ND	ND	ND	ND	ND	---
	01-07-93	210	0.7	3.7	4.4	9.6	---
	04-23-93	280	0.9	1.3	2.9	6.2	---
	07-16-93	110	ND	ND	0.5	1.1	---
	11-08-93	ND	ND	ND	ND	ND	---
	01-28-94	190	5.7	4.9	6.7	21	---
	05-02-94	ND	ND	ND	ND	ND	---
	08-03-94	ND	ND	ND	ND	ND	---
	11-04-94	ND	ND	ND	ND	ND	---
	03-14-95	ND	ND	ND	ND	ND	---
	08-23-95	ND	ND	ND	ND	ND	---
	05-08-96	110	1.0	ND	ND	2.8	---
	08-12-96	---	---	---	---	---	---
	11-15-96	---	---	---	---	---	---
	02-20-97	---	---	---	---	---	---
Detection Limit		50	0.5	0.5	0.5	0.5	0.5

ND = Not Detected

TABLE 3. (continued)
Shallow Groundwater Sampling Results

Well	Date	TPH as Gasoline (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl-benzene (ug/L)	Total Xylenes (ug/L)	MTBE (ug/L)
MW-2	03-04-92	ND	ND	ND	ND	ND	---
	04-03-92	ND	ND	ND	ND	ND	---
	06-16-92	ND	ND	ND	ND	ND	---
	10-09-92	ND	ND	ND	ND	ND	---
	01-07-93	ND	ND	ND	ND	ND	---
	04-23-93	ND	ND	ND	ND	ND	---
	07-16-93	ND	ND	ND	ND	ND	---
	11-08-93	ND	ND	ND	ND	ND	---
	01-28-94	ND	ND	ND	ND	ND	---
	05-02-94	ND	ND	ND	ND	ND	---
	08-03-94	ND	ND	ND	ND	ND	---
	11-04-94	ND	ND	ND	ND	ND	---
	03-14-95	ND	ND	ND	ND	ND	---
	08-23-95	ND	ND	ND	ND	ND	---
	05-08-96	ND	ND	ND	ND	ND	---
	08-12-96	---	---	---	---	---	---
	11-15-96	---	---	---	---	---	---
	02-20-97	---	---	---	---	---	---
Detection Limit		50	0.5	0.5	0.5	0.5	0.5

ND = Not Detected

TABLE 3. (continued)
Shallow Groundwater Sampling Results

Well	Date	TPH as Gasoline (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl-benzene (ug/L)	Total Xylenes (ug/L)	MTBE (ug/L)
MW-3	03-04-92	14,000	6,200	60	110	740	---
	04-03-92	5,200	120	32	57	180	---
	06-16-92	6,000	180	45	82	190	---
	10-09-92	11,000	87	49	94	200	---
	01-07-93	4,200	3.3	13	44	92	---
	04-23-93	21,000	23	43	49	130	---
	07-16-93	16,000	19	21	25	78	---
	11-08-93	10,000	4.3	5.7	7.9	35	---
	01-28-94	7,500	8.5	10	50	95	---
	05-02-94	22,000	69	39	60	110	---
	08-03-94	2,500	35	12	27	25	---
	11-04-94	2,900	4.0	8.1	18	27	---
	03-14-95	2,500	9.5	3.0	4.6	8.3	---
	08-23-95	12,000	35	8.2	14	20	---
	05-08-96	19,000	57	17	32	56	---
	08-12-96	8,900	47	7.6	14	16	---
	11-15-96	4,900	66	13	33	41	ND
	02-20-97	1,100	68	21	18	23	ND
Detection Limit		50	0.5	0.5	0.5	0.5	0.5

ND = Not Detected

TABLE 3. (continued)
Shallow Groundwater Sampling Results

Well	Date	TPH as Gasoline (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl-benzene (ug/L)	Total Xylenes (ug/L)	MTBE (ug/L)
MW-4	01-07-93	4,800	6.4	25	60	110	---
	04-23-93	2,700	8.3	11	31	59	---
	07-16-93	3,000	3.7	4.2	4.9	15	---
	11-08-93	1,400	0.6	0.8	1.1	4.8	---
	01-28-94	830	8.5	10	12	27	---
	05-02-94	900	7.3	3.2	0.5	14	---
	08-03-94	1,000	22	0.7	8.0	7.4	---
	11-04-94	160	0.6	ND	1.9	2.9	---
	03-14-95	120	3.6	ND	ND	3.7	---
	08-23-95	ND	ND	ND	ND	ND	---
	05-08-96	ND	ND	ND	ND	ND	---
	08-12-96	ND	ND	ND	ND	ND	ND
	11-15-96	320	19	3.2	5.6	15	ND
	02-20-97	ND	ND	ND	ND	ND	ND
Detection Limit		50	0.5	0.5	0.5	0.5	0.5

ND = Not Detected

"Grab" Groundwater Sampling

On November 5, 12, and 23, 1993, a subsurface investigation was conducted on the site. At fifteen on-site locations, "hydropunch" probes were driven to an approximate depth of 20 feet below ground surface and "grab" shallow groundwater samples were subsequently collected. The locations were selected based upon 1) the known shallow groundwater flow direction, 2) known concentrations of dissolved petroleum constituents at the three existing on-site monitoring wells, and 3) what was believed to be good spacing between data points in order to achieve reasonable plume definitions of any contaminates that may be present in the shallow groundwater. The various "hydropunch" locations are shown in Figure 8.

The results of the subsurface investigation were presented in the *Quarterly Groundwater Sampling Report and Report of Subsurface Investigation* by Hageman-Aguiar, Inc., dated December 8, 1993. Table 4 presents the results of the laboratory analysis for petroleum hydrocarbons of the "grab" groundwater samples collected from the fifteen "hydropunch" locations.

Figures 9 and 10 show lines of equal concentration for Gasoline and Benzene in the shallow groundwater. As shown by these plots, the data generated from both the monitoring well sampling and the "hydropunch" sampling have provided a relatively complete definition of the on-site shallow groundwater contamination. The chemical concentration contours indicate that the present source of dissolved Gasoline concentrations are centered somewhere around the area between the previous excavation and the location of monitoring well MW-3. The contours are indicative of residual subsurface contamination still remaining in the soil in the vicinity of the previous underground piping leak.

FIGURE 8.

"Hydropunch" Groundwater Sampling Locations.

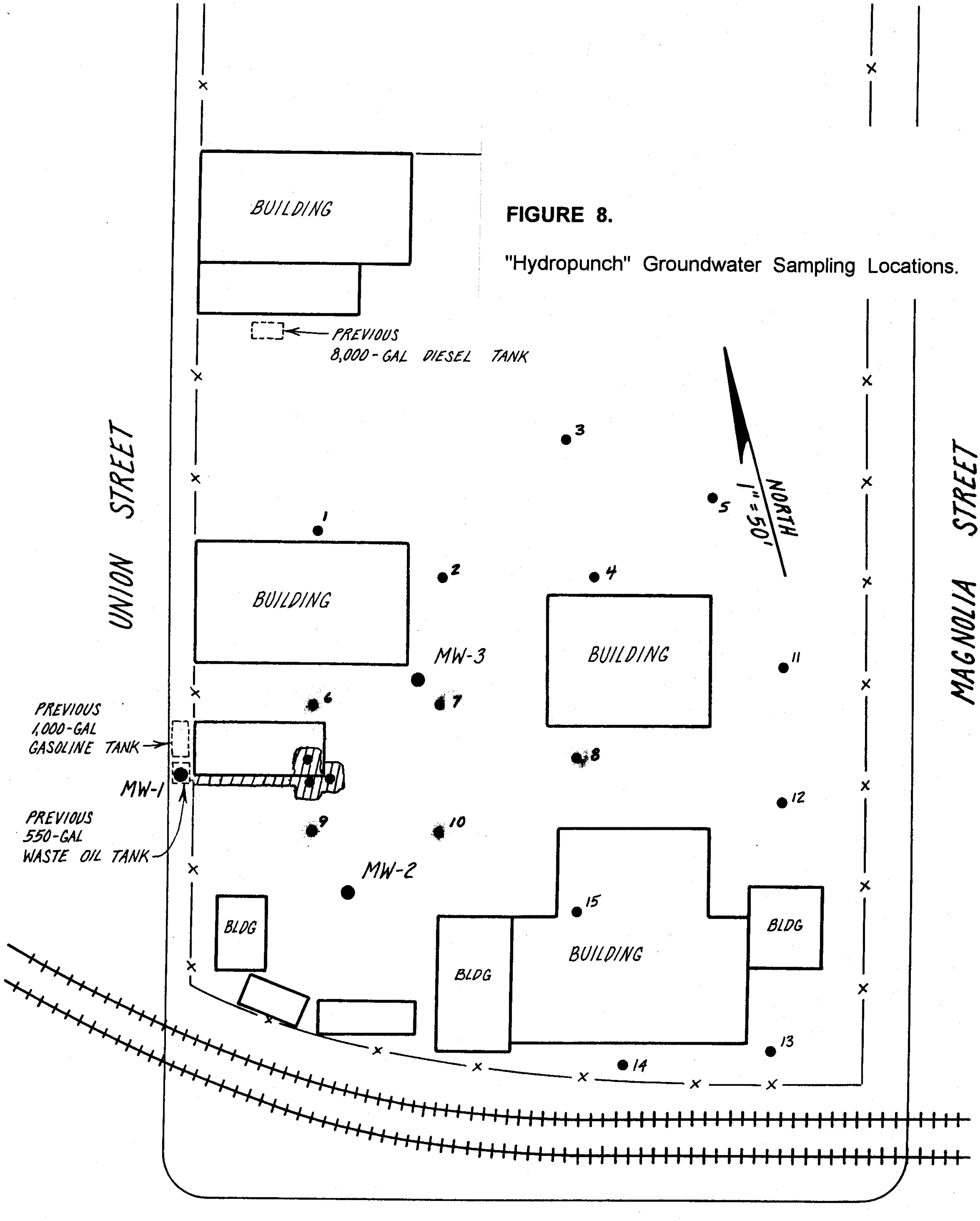


TABLE 4.

Shallow "Grab" Groundwater Sampling Results

Sampling Location	TPH as Gasoline (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl-benzene (ug/L)	Total Xylenes (ug/L)	TPH as Diesel (ug/L)
#1	ND	ND	ND	ND	ND	---
#2	ND	ND	ND	ND	ND	---
#3	ND	ND	ND	ND	ND	---
#4	ND	ND	ND	ND	ND	---
#5	ND	ND	ND	ND	ND	ND
#6	29,000	20	28	36	110	---
#7	9,100	6.2	8.7	11	34	---
#8	12,000	8.2	11	15	45	---
#9	330	ND	0.7	0.9	3.2	---
#10	2,500	1.7	2.4	3.1	9.4	ND
#11	ND	ND	ND	ND	ND	---
#12	ND	ND	ND	ND	ND	ND
#13	ND	ND	ND	ND	ND	ND
#14	ND	ND	ND	ND	ND	ND
#15	ND	ND	ND	ND	ND	ND
Detection Limit	50	0.5	0.5	0.5	0.5	50

ND = not detected

FIGURE 9.

Lines of Equal Concentration of Gasoline in ug/L (ppb) in the Shallow Groundwater. (November 1993)

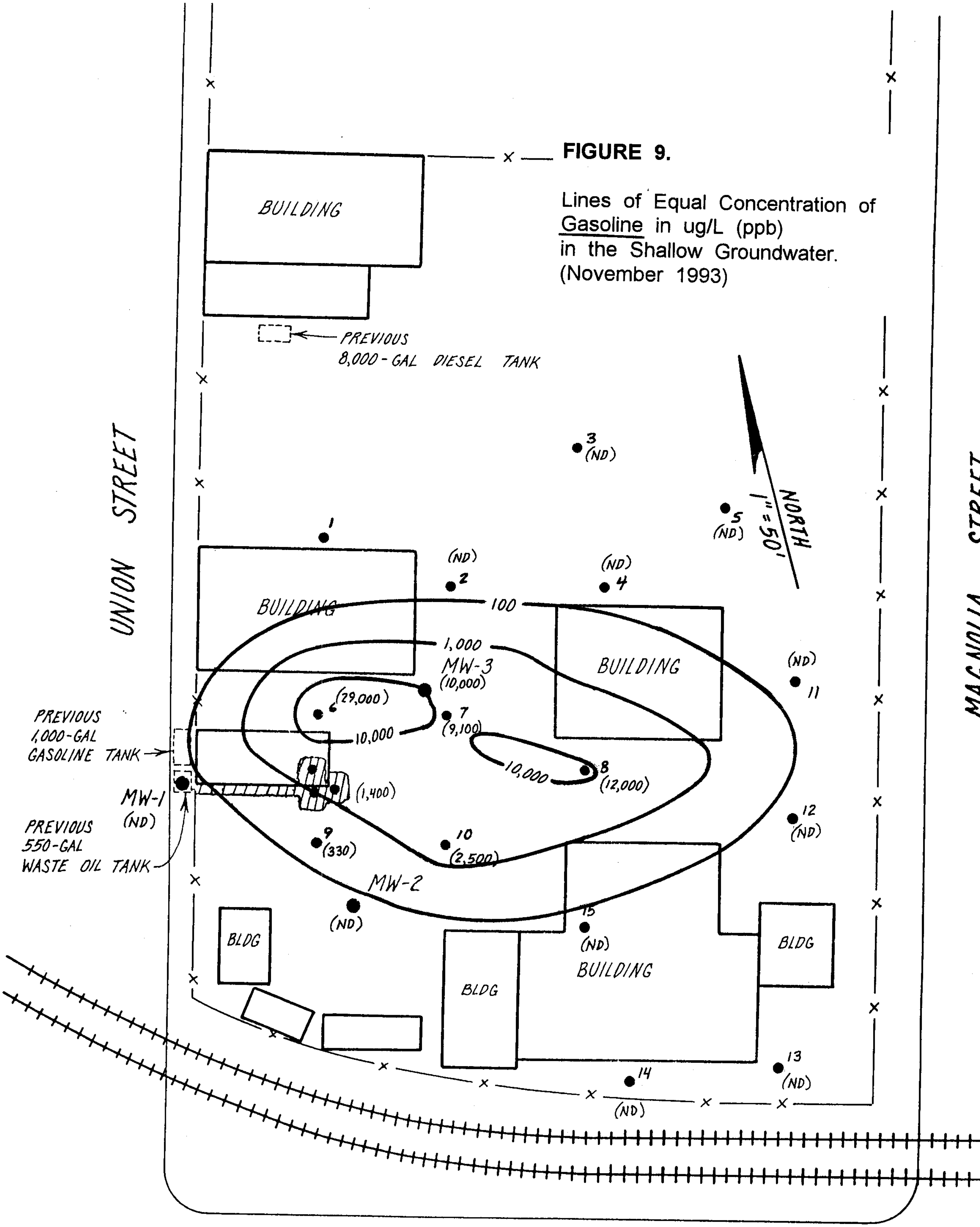
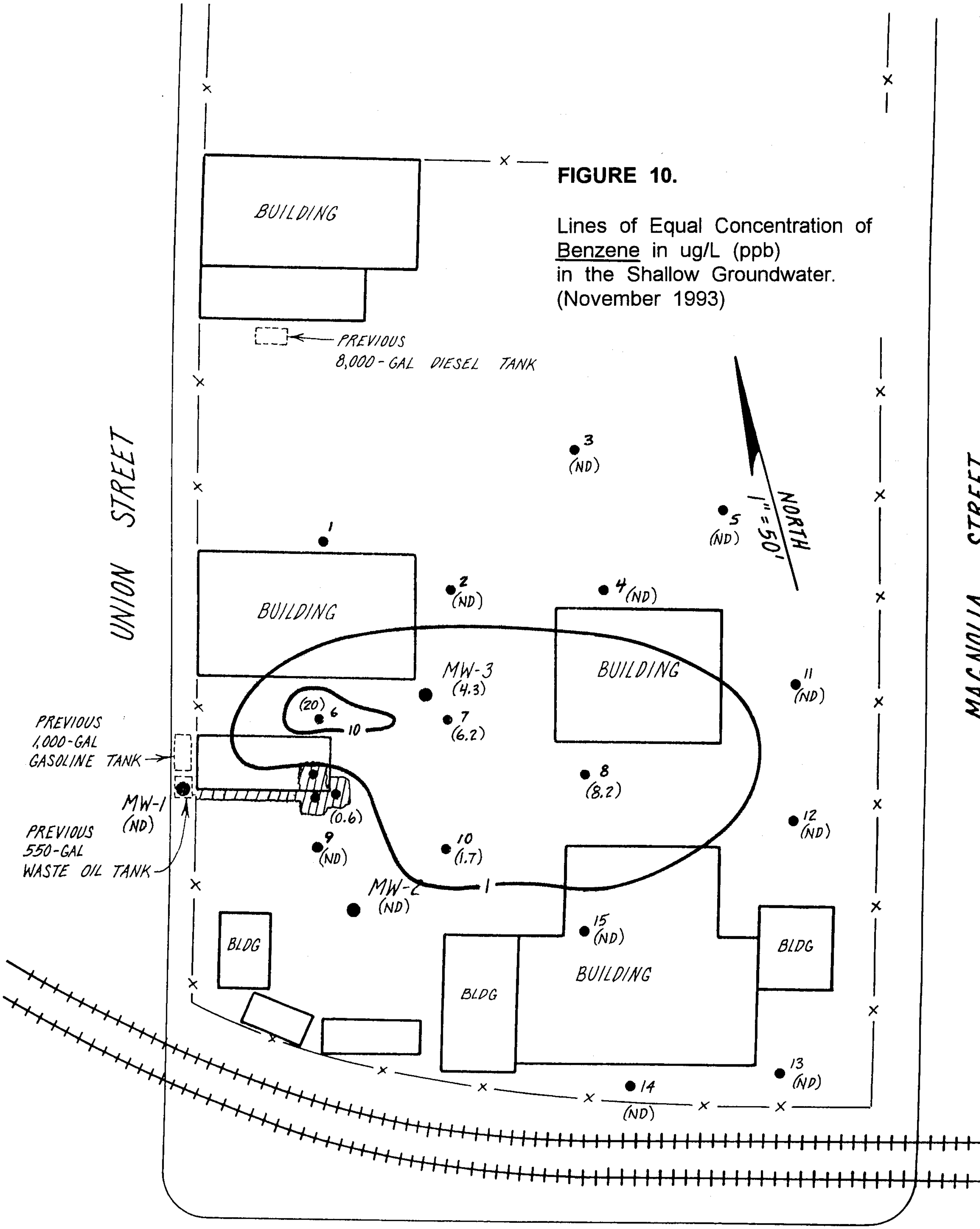


FIGURE 10.

Lines of Equal Concentration of <u>Benzene</u> in ug/L (ppb) in the Shallow Groundwater. (November 1993)



The chemical concentration contours indicate that the present dissolved Gasoline and Benzene plumes are elongated in an east-west orientation that is consistent with the measured shallow groundwater flow direction. Most importantly, the contours indicate that **no detectable concentrations of any petroleum hydrocarbons as either Gasoline, Diesel, or BTEX are moving off-site from the subject property**. Such concentration attenuation is consistent with dilution due to hydrodynamic dispersion in the longitudinal direction of flow.

VI. BENEFICIAL USES OF GROUNDWATER

Well Inventory

An inventory of nearby water wells has been conducted. The results of this study are presented in Figure 11 (Well Location Map) and in Table 5 (Well Inventory Data). The average depth of the wells in the well survey is 26 feet. **None of these wells are used for domestic purposes**. One well, at a depth of 55 feet, is utilized for irrigation purposes.

Domestic Wells

As shown by the data in Table 5, there are no domestic wells in the area.

Agricultural Wells

As shown in Table 5, only one irrigation well is located southwest of the subject property. The well, constructed in 1915, is approximately 55 feet deep, and is owned and maintained by Nabisco Brands, Inc.

Fire Protection

As shown in Table 5, no wells are utilized for emergency fire protection.

LEGEND

▲	Park		Interstate Highway
	Interstate, Turnpike		State Route
	Population Center		Railroad
	Street, Road		Open Water
	Hwy Ramp		
	Major Street/Road		

Scale 1:10,938 (at center)

1000 Feet

200 Meters

FIGURE 11.

Well Location Map.

Table 5. Area Well Survey - Pacific Cryogenic Company - 2311 Magnolia Street, Oakland, California

Map Code	Tr-Section	Well Number	Address	Company	Well Designation	Drilling Date	Total Depth	Diameter	Usage
1	1S/4W-27G	2	2311 Magnolia Street	Aldo Guidotti	MW-4	11/92	15	4	Destroyed
1	1S/4W-27G	3	2311 Magnolia Street	Aldo Guidotti	MW-5	11/92	15	4	Destroyed
1	1S/4W-27G	4	2311 Magnolia Street	Aldo Guidotti	MW-6	11/92	15	4	Destroyed
2	1S/4W-27A	3	1218 24Th Street	Tim Williams		3/89	30	2	Monitoring Well
2	1S/4W-27A	4	1218 24Th Street	Northwestern Blind		3/89	25	2	Monitoring Well
2	1S/4W-27A	5	1218 24Th Street	Northwestern Blind		10/89	26	2	Monitoring Well
2	1S/4W-27A	6	1218 24Th Street	Northwestern Blind		10/89	26	2	Monitoring Well
3	1S/4W-27H		2311 Adeline Street	Ned Clyde Construction		1/89	17	8	Monitoring Well
3	1S/4W-27H	1	2311 Adeline Street	Ned Clyde Construction		1/89	17	8	Monitoring Well
3	1S/4W-27H	2	2311 Adeline Street	Ned Clyde Construction		3/89	30	2	Piezometer
3	1S/4W-27H	3	2311 Adeline Street	Ned Clyde Construction		3/89	16	2	Piezometer
3	1S/4W-27H	4	2311 Adeline Street	Ned Clyde Construction		3/89	16	2	Piezometer
3	1S/4W-27H	5	2311 Adeline Street	Ned Clyde Construction		4/89	21	2	Piezometer
3	1S/4W-27H	6	2311 Adeline Street	Ned Clyde Construction		5/89	15	2	Piezometer
3	1S/4W-27H	7	2311 Adeline Street	Ned Clyde Construction		5/89	20	2	Piezometer
3	1S/4W-27H	8	2311 Adeline Street	Ned Clyde Construction		5/89	20	2	Piezometer
3	1S/4W-27H	9	2311 Adeline Street	Ned Clyde Construction		5/89	18	2	Piezometer
3	1S/4W-27H	10	2311 Adeline Street	Ned Clyde Construction		5/90	65	2	Monitoring Well
4	1S/4W-27A	2	2452 Magnolia	Bonta Collins		9/89	21	2	Monitoring Well
5	1S/4W-26E	7	2400 Filbert Street	Cal West	MW-1	10/91	20	2	Monitoring Well
5	1S/4W-26E	14	2400 Filbert Street	Cal West	MW-2	12/92	25	2	Monitoring Well
6	1S/4W-27A	1	2736 Magnolia	Holly Meat		?/26	135	unk	Abandoned
7	1S/4W-27B	10	2525 Cypress Street	Kantor's Furniture	MW1	9/92	25	2	Monitoring Well
7	1S/4W-27B	11	2525 Cypress Street	Kantor's Furniture	MW2	9/92	25	2	Monitoring Well
7	1S/4W-27B	12	2525 Cypress Street	Kantor's Furniture	MW3	9/92	25	2	Monitoring Well
8	1S/4W-22Q	8	2717 Peralta Street	C. E. Toland & Son	MW-1	3/90	25	4	Monitoring Well
8	1S/4W-22Q	9	2717 Peralta Street	C. E. Toland & Son	MW-2	3/90	25	4	Monitoring Well
8	1S/4W-22Q	10	2717 Peralta Street	C. E. Toland & Son	MW-3	3/90	25	4	Monitoring Well
9	1S/4W-27B	1	2730 Peralta Street	Custom Alloy Scrap Sales		5/90	20	unk	Monitoring Well
9	1S/4W-27B	2	2730 Peralta Street	Custom Alloy Scrap Sales		5/90	20	unk	Monitoring Well
9	1S/4W-27B	3	2730 Peralta Street	Custom Alloy Scrap Sales		5/90	20	unk	Monitoring Well
9	1S/4W-22R	2	2730 Peralta Street	Custom Alloy Scrap Sales		10/90	19	4	Monitoring Well
9	1S/4W-22R	3	2730 Peralta Street	Custom Alloy Scrap Sales		10/90	18	4	Monitoring Well
10	1S/4W-22Q	11	2850 Poplar Street	Linford Construction	MW1	4/93	22	2	Monitoring Well
10	1S/4W-22Q	12	2850 Poplar Street	Linford Construction	MW2	4/93	20	2	Monitoring Well
10	1S/4W-22Q	13	2850 Poplar Street	Linford Construction	MW3	4/93	20	2	Monitoring Well

Table 5. Area Well Survey - Pacific Cryogenic Company - 2311 Magnolia Street, Oakland, California

Map Code	Tr-Section	Well Number	Address	Company	Well Designation	Drilling Date	Total Depth	Diameter	Usage
11	1S/4W-23N	1	990 28Th Street	Oakland Towel Co.		?/27	146	8	Abandoned
12	1S/4W-26D	5	958 28Th Street	AraTex Service Inc.		3/90	25	2	Monitoring Well
12	1S/4W-26D	6	958 28Th Street	AraTex Service Inc.		3/90	30	4	Monitoring Well
12	1S/4W-26D	7	958 28Th Street	AraTex Service Inc.		3/90	30	4	Monitoring Well
12	1S/4W-26D	8	958 28Th Street	AraTex Service Inc.	MW-4A	7/91	27	4	Monitoring Well
12	1S/4W-26D	9	958 28Th Street	AraTex Service Inc.	MW-7	7/91	30	4	Monitoring Well
13	1S/4W-26E	1	889 W. Grand Avenue	ARCO Products		5/91			Destroyed
13	1S/4W-26E	2	889 W. Grand Avenue	ARCO Products	A-1	3/92	30	3	Monitoring Well
13	1S/4W-26E	3	889 W. Grand Avenue	ARCO Products	A-2	3/92	27	3	Monitoring Well
13	1S/4W-26E	4	889 W. Grand Avenue	ARCO Products	A-3	4/92	30	3	Monitoring Well
13	1S/4W-26E	5	889 W. Grand Avenue	ARCO Products	A-4	4/92	30	3	Monitoring Well
13	1S/4W-26E	6	889 W. Grand Avenue	ARCO Products	AR-1	4/92	30	6	Monitoring Well
13	1S/4W-26E	8	889 W. Grand Avenue	ARCO Products	AR-1	6/92	29	6	Monitoring Well
13	1S/4W-26E	9	889 W. Grand Avenue	ARCO Products	AV-1	6/92	14	6	Monitoring Well
13	1S/4W-26E	10	889 W. Grand Avenue	ARCO Products	AV2	6/92	14	6	Monitoring Well
13	1S/4W-26E	11	889 W. Grand Avenue	ARCO Products	AV3	6/92	14	6	Monitoring Well
13	1S/4W-26E	12	889 W. Grand Avenue	ARCO Products	A-5	2/93	30	6	Monitoring Well
13	1S/4W-26E	13	889 W. Grand Avenue	ARCO Products	A-6	2/93	29	6	Monitoring Well
14	1S/4W-26M	1	850 W. Grand	Chevron USA		10/84	30	8	Monitoring Well
14	1S/4W-26M	2	850 W. Grand	Chevron USA		10/84	25	8	Monitoring Well
14	1S/4W-26M	3	850 W. Grand	Chevron USA		10/84	24	8	Monitoring Well
14	1S/4W-26M	4	850 W. Grand	Chevron USA		4/89	25	11	Monitoring Well
14	1S/4W-26M	5	850 W. Grand	Chevron USA		4/89	25	11	Monitoring Well
14	1S/4W-26M	6	850 W. Grand	Chevron USA		7/90	22	2	Monitoring Well
14	1S/4W-26M	7	850 W. Grand	Chevron USA		7/90	27	2	Monitoring Well
14	1S/4W-26M	8	850 W. Grand	Chevron USA		12/90	24	4	Monitoring Well
14	1S/4W-26M	9	850 W. Grand	Chevron USA	MW-7	10/92	24	2	Monitoring Well
15	1S/4W-27J	1	1919 Market Street	Scott Co.	MW-1	7/92	22	4	Monitoring Well
15	1S/4W-27J	2	1919 Market Street	Scott Co.	MW-2	7/92	22	4	Monitoring Well
15	1S/4W-27J	3	1919 Market Street	Scott Co.	MW-3	7/92	22	4	Monitoring Well
15	1S/4W-27J	4	1919 Market Street	Scott Co.	MW-4	7/92	24	4	Monitoring Well
15	1S/4W-27J	5	1919 Market Street	Scott Co.	MW-5	7/92	25	4	Monitoring Well
16	1S/4W-22Q	2	2792 Cypress Street	L & B Arrighi Investments		12/89	20	4	Monitoring Well
16	1S/4W-22Q	3	2792 Cypress Street	L & B Arrighi Investments		12/89	15	4	Monitoring Well
16	1S/4W-22Q	4	2792 Cypress Street	L & B Arrighi Investments		12/89	20	4	Monitoring Well
17	1S/4W-27C	1	1735 24 Th Street	Pacific Supply Company		9/88	20	2	Monitoring Well

Table 5. Area Well Survey - Pacific Cryogenic Company - 2311 Magnolia Street, Oakland, California

Map Code	Tr-Section	Well Number	Address	Company	Well Designation	Drilling Date	Total Depth	Diameter	Usage
17	1S/4W-27C	3	1735 24 Th Street	Pacific Supply Company		9/88	20	2	Monitoring Well
17	1S/4W-27C	8	1735 24 Th Street	Pacific Supply Company		12/89	17	2	Monitoring Well
17	1S/4W-27C	9	1735 24 Th Street	Pacific Supply Company		12/89	19	2	Monitoring Well
17	1S/4W-27C	10	1735 24 Th Street	Pacific Supply Company	VEW1	6/92	9	2	Extraction
18	1S/4W-27C	11	1700 W. Grand Avenue	Raymond Robideaux	MW1	5/92	15	2	Monitoring Well
19	1S/4W27C	12	1699 W. Grand Avenue	Jorgensen S?. & Alum	MW1	11/92	14	2	Monitoring Well
20	1S/4W-27C	1	1700 20Th Street	Anheuser-Busch Co.		9/87	30	2	Monitoring Well
20	1S/4W-27C	2	1700 20Th Street	Anheuser-Busch Co.		9/87	30	2	Monitoring Well
20	1S/4W-27C	3	1700 20Th Street	Anheuser-Busch Co.		9/87	30	2	Monitoring Well
21	1S/4W-27C	4	2230 Willow Street	Mead Corp.		7/89	14	unk	Monitoring Well
21	1S/4W-27C	5	2230 Willow Street	Mead Corp.		7/89	14	unk	Monitoring Well
21	1S/4W-27C	6	2230 Willow Street	Mead Corp.		7/89	20	unk	Monitoring Well
21	1S/4W-27C	7	2230 Willow Street	Mead Corp.		7/89	14	unk	Monitoring Well
22	1S/4W-27L	2	1800 Peralta Street	Architectural Emphasis		6/88	10	2	Monitoring Well
22	1S/4W-27L	3	1800 Peralta Street	Architectural Emphasis		6/88	18	2	Monitoring Well
23	1S/4W-27L		1310 14Th Street	Carnation Dairy Facility	This facility has 173 wells associated with a remediation and extraction project. The wells were installed in 1989 and 1990, and range in depth from 7 feet to 57 feet.				
24	1S/4W-27B	4	1340 Cypress Street	Coca-Cola Enterprises		3/91	30	4	Monitoring Well
24	1S/4W-27B	5	1340 Cypress Street	Coca-Cola Enterprises		3/91	27	2	Monitoring Well
24	1S/4W-27B	6	1340 Cypress Street	Coca-Cola Enterprises		3/91	27	unk	Monitoring Well
24	1S/4W-27B	7	1340 Cypress Street	Coca-Cola Enterprises		3/91	27	unk	Monitoring Well
24	1S/4W-27B	8	1340 Cypress Street	Coca-Cola Enterprises		3/91	27	unk	Monitoring Well
24	1S/4W-27B	9	1340 Cypress Street	Coca-Cola Enterprises		3/91	27	unk	Monitoring Well
25	1S/4W-27Q	2	1267 W. 14th Street	Nabisco Brands Inc.		4/90	22	2	Monitoring Well
25	1S/4W-27Q	3	1267 W. 14th Street	Nabisco Brands Inc.		4/90	22	2	Monitoring Well
25	1S/4W-27Q	4	1267 W. 14th Street	Nabisco Brands Inc.		4/90	22	2	Monitoring Well
25	1S/4W-27Q	5	1267 W. 14th Street	Nabisco Brands Inc.		11/90	30	2	Monitoring Well
25	1S/4W-27Q	1	1267 W. 14th Street	Nabisco Brands Inc.		?/15	55	unk	Irrigation

Shallow Groundwater

Table 6 presents the various physical parameters for water samples that were recorded following the purging of the on-site monitoring wells prior to sample collection. As shown in this table, slightly elevated specific conductance measurements have been indicated. In terms of suitability for drinking water, a comparison can be made with the corresponding Secondary Maximum Contaminant Levels (MCL) for drinking water, per California Code of Regulations, Title 22, Division 4, Environmental Health, Section 64449:

Most Recent Conductance Measured On-Site (μmhos/cm)	California Recommended MCL (μmhos/cm)	California Upper MCL (μhos/cm)
557 to 1,350	900	1,600

As shown by these data, **the shallow groundwater is not ideally suitable for drinking**, since the conductance fluctuates to levels well above the California Recommended MCL for drinking water. In addition, based upon a factor of 0.6 (Hem 1979), a Total Dissolved Solids (TDS) concentration of up to 810 mg/L (ppm) is indicated beneath the subject property. This groundwater would exhibit obvious mineral characteristics, and would certainly be less than ideal for a domestic drinking water supply.

TABLE 6.

Physical Parameters of Water Samples Following Purging

Shallow Groundwater Monitoring Wells

Well	Date	Temp (deg C)	Specific Conductance (umhos)	pH
MW-1	04-03-92	20.5	850	7.0
	06-16-92	19.4	1,000	7.2
	10-09-92	18.0	1,150	7.2
	01-07-93	16.9	800	7.1
	04-23-93	17.8	550	7.2
	07-16-93	20.3	500	7.2
	11-08-93	19.6	700	7.1
	01-27-94	19.5	380	6.4
	05-03-94	18.5	340	6.7
	08-03-94	---	---	---
	11-04-94	19.0	750	6.7
	03-14-95	19.2	810	6.7
	08-23-95	20.9	960	6.8
	05-08-96	20.5	750	7.2
	08-12-96	---	---	---
	11-15-96	---	---	---

TABLE 6. (CONTINUED)

Physical Parameters of Water Samples Following Purging

Shallow Groundwater Monitoring Wells

Well	Date	Temp (deg C)	Specific Conductance (umhos)	pH
MW-2	04-03-92	21.5	1,200	8.3
	06-16-92	18.5	1,400	7.3
	10-09-92	19.6	1,500	7.4
	01-07-93	17.9	1,150	7.2
	04-23-93	17.1	1,050	7.3
	07-16-93	18.9	1,100	7.3
	11-08-93	18.5	800	7.0
	01-28-94	17.5	650	6.9
	05-03-94	18.5	600	6.8
	08-03-94	19.3	392	7.0
	11-04-94	17.8	1,350	7.0
	03-14-95	17.7	1,530	7.0
	08-23-95	20.4	1,680	6.9
	05-08-96	18.9	1,350	7.1
	08-12-96	---	---	---
	11-15-96	---	---	---

TABLE 6. (CONTINUED)

Physical Parameters of Water Samples Following Purging

Shallow Groundwater Monitoring Wells

Well	Date	Temp (deg C)	Specific Conductance (umhos)	pH
MW-3	04-03-92	21.0	1,530	8.1
	06-16-92	18.9	1,200	7.1
	10-09-92	20.7	1,200	7.2
	01-07-93	17.9	950	6.9
	04-23-93	17.9	700	7.2
	07-16-93	21.8	700	7.1
	11-08-93	19.5	650	6.7
	01-28-94	20.2	550	6.7
	05-03-94	18.6	650	6.9
	08-03-94	20.1	480	7.0
	11-04-94	19.1	850	6.6
	03-14-95	17.6	1,140	6.7
	08-23-95	20.6	1,300	6.8
	05-08-96	18.8	1,150	6.9
	08-12-96	21.4	690	7.1
	11-15-96	19.7	557	7.1

TABLE 6. (CONTINUED)

Physical Parameters of Water Samples Following Purging

Shallow Groundwater Monitoring Wells

Well	Date	Temp (deg C)	Specific Conductance (umhos)	pH
MW-4	01-07-93	16.4	900	7.3
	04-23-93	17.1	700	7.2
	07-16-93	21.1	750	6.9
	11-08-93	20.3	550	6.6
	01-28-94	19.5	380	6.4
	05-03-94	18.9	390	6.5
	08-03-94	20.7	290	7.0
	11-04-94	20.1	675	6.6
	03-14-95	18.5	800	6.7
	08-23-95	20.5	720	6.8
	05-08-96	18.7	860	7.1
	08-12-96	20.6	400	7.2
	11-15-96	19.7	371	6.7

Another consideration in the analysis of beneficial use of shallow groundwater is the actual depth at which this groundwater occurs. The shallow groundwater table is encountered at a depth of approximately 12 feet below ground surface. Water well standards for the State of California (DWR, 1981) require the following minimum depths of sanitary seals:

Types	Minimum Depth of Seal
Community Water Supply Wells	50 feet
Individual Domestic Wells	20 feet
Industrial Wells	50 feet
Agriculture Wells	20 feet

Based upon this information, **shallow groundwater beneath the subject property could not be legally utilized for either drinking water or agricultural purposes on the basis of the required depth of well seal.**

VII. CONTAMINANT FATE AND TRANSPORT

Constituents of Concern

Constituents detected in soil at the Pacific Cryogenic Company property during previous investigation have included Benzene, Toluene, Ethylbenzene, Total Xylenes (BTEX) and Gasoline. These five petroleum compounds are considered to be the primary constituents of concern for the subject site.

Gasoline exhibits significant differences from BTEX, in that it is a complex mixture of petroleum-derived hydrocarbons with 4 to 11 carbon atoms in their molecular structures. When Gasoline enters the soil, changes in its composition, referred to as "weathering", begin immediately. Volatilization of the lighter compounds occurs at a higher rate than heavier compounds, resulting in a shift in the composition of the weathered Gasoline toward heavier compounds. The solubilities of the heavier hydrocarbons generally are lower and the adsorption characteristics are stronger than those of the lighter fuel compounds. These heavier compounds tend to remain adsorbed to soil organic matter for longer periods of time, while the more soluble components partition into soil moisture more quickly and/or more completely. Rates of biotransformation also are different. Short-chain alkanes generally are biodegraded more readily than aromatics, cycloalkanes, and heavier alkanes.

The net result of the weathering processes with respect to analytical data is that the Gasoline concentrations reported will reflect a greater proportion of the heavier petroleum hydrocarbon components than for fresh Gasoline. These heavier components are comprised largely of cycloalkanes and straight- and branched-chain alkanes.

For the purposes of the health risk modeling described in this report, the fate and transport characteristics of Gasoline are compared to those of n-Hexane, although n-Hexane, a comparatively toxic, short-chained hydrocarbon, only reportedly comprises 0.24 percent to 3.5 percent by weight of fresh Gasoline. Using n-Hexane as a surrogate compound to describe the fate and transport behavior of weathered Gasoline in soil represents a conservative approach, because n-Hexane is soluble and volatile, if not more soluble and volatile than most of the heavier hydrocarbons. It has been shown that the toxicity and mobility of hydrocarbons generally decreases as the chain length increases. Therefore, n-Hexane, a 6-carbon chain hydrocarbon, is expected to be the most toxic and most mobile component of the represented Gasoline mixture.

Contaminant Migration in Shallow Groundwater

The results of recent sampling has indicated that some residual petroleum hydrocarbon concentrations remain in the shallow groundwater beneath the subject property. Gasoline, Benzene, Ethylbenzene, Toluene and Total Xylenes appear to be present beneath the center of the subject property at concentrations of 4,900 μg/L (ppb), 66 μg/L (ppb), 13 μg/L (ppb), 33 μg/L (ppb), and 41 μg/L (ppb), respectively.

Residual petroleum hydrocarbon concentrations carried down-gradient in the shallow groundwater can be expected to become quickly diluted below detection limits by hydrodynamic mixing (dispersion) in the longitudinal direction of groundwater movement. The results of the previous "hydropunch" investigation are consistent with this scenario, and have clearly demonstrated that **no detectable concentrations of any petroleum hydrocarbons have migrated off-site**.

Future Groundwater Contamination Remediation

Based upon 1) the successful removal of the major portion of the source of shallow groundwater contamination (soil excavation), 2) the apparent lack of domestic use of shallow groundwater in the vicinity of the subject property, 3) the relatively low concentrations of petroleum hydrocarbons currently present in the shallow groundwater beneath the site, and 4) the demonstration that no detectable concentrations of any petroleum hydrocarbons have migrated off-site, **no future remediation of the shallow groundwater is warranted.**

VIII. HEALTH RISKS

Exposure Routes

The risks associated with exposure to constituents detected at the subject property are a function of the inherent toxicity of the constituents and the exposure dose. In terms of the actual potential exposure dose, the following possible exposure routes were considered at the subject property:

- Exposure of adult occupant via direct ingestion of chemicals in soil or groundwater.

- Exposure of adult occupant via direct dermal contact with chemicals in soil or groundwater.

- Exposure of adult occupant via incidental inhalation of fugitive dust emissions.

- Exposure of adult occupant via inhalation of volatile chemicals originating from subsurface soil and intruding into outdoor air.

- Exposure of adult occupant via inhalation to volatile chemicals originating from subsurface soil and intruding into overlying building.

Since the residual subsurface contamination at the subject property exists in soil at depths greater than approximately 9 feet below ground surface, **the only exposure route to be considered is that due to vapor intrusion**. **Direct contact with contaminated soil or groundwater is not possible**.

Migration of chemical constituents into the air from soil occurs via volatilization, which is the mass transfer of an organic compound from a specific medium (i.e., water or soil) to the air. The ability for this mass transfer or migration to occur will depend on other competing processes which could hinder this migration. For example, if a constituent is highly soluble and dissolved in water, or strongly sorbed to soil, it will be less likely to volatilize into the air even though it may also have a high vapor pressure. Environmental factors that affect constituent volatilization and transport through soil include the soil temperature, porosity, water content, and the depth to impacted soil.

Vapors that may migrate upward through the soil diffuse into ambient air when they reach the surface. These vapors that may be released into the ambient air are subject to dispersion by prevailing winds and diffusion into the atmosphere. Vapors originating from subsurface soil can, however, enter on-site buildings through cracks in building foundations. These vapors are subject to limited dispersion and diffusion forces and may accumulate in indoor air.

The following vapor intrusion modeling and subsequent development of Health-Based Goals for soil considers the more conservative exposure route of vapor accumulation in the existing on-site buildings. The potential for contact with vapors in outdoor air can be considered to be much less due to transport and dispersion by prevailing winds.

Vapor Intrusion Modeling: Health-Based Goals for Soil

It was assumed that receptors could hypothetically be exposed to vapors diffusing from the soil, migrating upwards, and entering on-site air spaces where the potential exists for the accumulation and inhalation of vapors. A vapor intrusion model was used to calculate a soil Health-Based Goal (HBG) for each constituent of concern. The vapor intrusion model, developed by Daugherty (1991), was modified through the use of site-specific assumptions to more accurately represent site-specific exposure conditions. A description of the vapor intrusion model is presented in Attachment A.

The result of the Daugherty (1991) volatilization and vapor diffusion model is a constituent-specific indoor air concentration potentially resulting from soil. This air concentration then can be used in exposure calculations to estimate the potential exposure for hypothetical occupants of the modeled building and subsequently to develop HBG's. Comparison of reported residual soil concentrations to the HBG's will identify if further remediation may be required. Site-specific information was used whenever possible in place of default assumptions. Site-specific environmental factors accounted for in the model include moisture content of soil, bulk density of soil, total soil porosity, and depth to impacted soil beneath the building. Site-specific values for these parameters were obtained from previous investigations at the subject property and from judgment based on known site conditions, such as soil type. For site-specific parameters for which values were uncertain, such as soil bulk density, conservative estimates were developed using information collected in previous investigations. Building air exchange rates and infiltration rates were estimated based on default values for standard residential buildings.

To calculate the HBG's, acceptable risk levels had to be targeted. The "target" cancer risk for the one potential carcinogen (Benzene) was conservatively set at 1×10^{-6}. The "target" hazard quotient (HQ) for non-cancer risk for constituents with different critical effects was set at 1 (one). However, Ethylbenzene and Toluene both exert effects on the liver and kidney, so the target HQ were set at 0.5.

Generally, organic constituents with high vapor pressures (greater than 10 mm Hg) or high Henry's Law Constants (greater than 10^{-3} atm-m^3/mol) and molecular weights less than 200 g/mol are expected to volatilize readily from soil and water. BTEX and n-Hexane have Henry's Law Constants greater than 10^{-3}, with the highest value being 0.77 atm-m^3/mol for n-Hexane (the surrogate compound used to represent TPH-Gasoline). Using this high Henry's Law Constant to assess the volatilization potential of TPH-Gasoline is conservative since the TPH-Gasoline petroleum mixture at the subject property is believed to be weathered and composed of mostly heavier, much less volatile compounds.

The calculated Health-Based Soil Goals for the Pacific Cryogenics site are presented in Table 7. This model assumes occupation of the subject property by adults for only 8 hours per day, 260 days per year.

As shown in Table 7, the calculated Health-Based Soil Goal for each constituent of concern is compared to the respective maximum residual concentration remaining in the soil. This residual concentration is based upon an average of the results of the sidewall sampling that was conducted during the previous soil excavation activities.

TABLE 7.
Health-Based Soil Goals.

Property Use: Industrial

Constituent	Calculated Health-Based Soil Goals for an Adult (mg/kg)	Maximum On-Site Residual Concentration (mg/kg)
Benzene	13.0	2.4
Toluene	52,900	2.8
Ethylbenzene	170,000	3.3
Total Xylenes	14,500,000	18.0
TPH-gasoline	3,372	1,600

(*) value is greater than one million parts-per-million, and therefore is not itself a concentration goal, but indicates that concentrations below saturation are health-protective.

(**) n-Hexane used as a surrogate for TPH-gasoline.

NOTES:

1) On-Site Residual Concentration is average of all 14 sidewall samples that were collected during soil excavation.

2) Model assummes that adult is on-site for 8 hours each day, 260 days per year.

Commercial

IX. CONCLUSIONS

1) Based upon 1) the successful removal of the major portion of the source of shallow groundwater contamination (soil excavation), 2) the apparent lack of domestic use of shallow groundwater in the vicinity of the subject property, 3) the relatively low concentrations of petroleum hydrocarbons currently present in the shallow groundwater beneath the site, and 4) the demonstration that no detectable concentrations of any petroleum hydrocarbons have migrated off-site, **no future remediation of the shallow groundwater is warranted.**

2) Based upon vapor intrusion modeling and the subsequent development of Health-Based Soil Goals, As demonstrated by the data presented in Table 7, **there appear to be no health risks associated with occupation of the subject property for commercial/industrial use, and no further remediation of any residual subsurface contamination is waranted.**

X. RECOMMENDATIONS

The results of this recent compilation of site data and subsequent health-based risk assessment clearly indicate that no further remediation of residual petroleum hydrocarbon contamination in either the soil or shallow groundwater is warranted. It is therefore recommended that the Alameda County Environmental Health Department and the Regional Water Quality Control Board (RWQCB) 1) declare the Pacific Cryogenics site to be a "low-risk" case, 2) provide regulatory closure of the LUST case, and 3) assign a status code of "9" (case closed) on the Leaking Underground Storage Tanks Information System Database.

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HEALTH-BASED RISK ASSESSMENT

AND RECOMMENDATION FOR LUST CASE CLOSURE

PACIFIC CRYOGENIC COMPANY

2311 Magnolia Street, Oakland, California

June 3, 1998

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ATTACHMENT A

VAPOR INTRUSION MODELING:

HEALTH-BASED SOIL GOALS

VAPOR INTRUSION MODEL

Pacific Cryogenics Company

2311 Magnolia Street, Oakland, CA

A vapor intrusion model was used to calculate indoor exposure to Benzene, Toluene, Ethylbenzene, Total Xylenes and TPH-Gasoline, assuming these constituents volatilize from soil and enter into an occupied building. The conceptual model consists of estimating the concentration of the constituent in soil air and the subsequent movement of the vapor phase constituent upward to the atmosphere, and then estimating concentrations of the constituent in indoor air. The calculation follows the mathematical model developed by Daugherty (1991).

The vapor intrusion model is based upon several assumptions. The model considers only diffusive flux, not pressure or convection driven flow. The constituent is assumed to be present as a non-diminishing steady state source. Biodegradation and other attenuation forces are expected to occur in subsurface soils over time, and therefore, this is a conservative assumption. The system is assumed to be at equilibrium and exposure to a constituent above equilibrium levels due to shutdown of the building ventilation system is assumed to be trivial in terms of lifetime exposure. It is assumed that flux occurs only through infiltration areas such as cracks in the building slab and/or surface pavement and that flux through the asphalt or concrete itself is insignificant.

The vapor intrusion model was proposed as a method to calculate concentrations of constituents in indoor air based upon specified constituent concentrations in soil gas. For the analysis at this site, an acceptable constituent concentration in indoor air was determined based upon target risk levels. The model was then applied in a backward direction and the acceptable indoor air concentration was used to derive the target concentration in soil gas and then the soil Health-Based Goal (HBG).

Physical parameters such as moisture content, dry soil density, porosity, and effective air permeability affect the rate at which the vapors from a volatile compound may migrate through the soils. Site-specific values for these soil parameters were used where available. Conservative default values were identified based upon known site characteristics for parameters that were not measured directly. The area of infiltration was determined to include only that portion of the building that overlies portions of the property known to contain subsurface soil concentrations of the constituents of concern.

A maximum acceptable vapor phase flux ($mg/cm^2/sec$), given the indoor air concentration derived from target risk levels, was calculated by dividing the product of the indoor air concentration, building air exchange rate and building volume, by the area of infiltration:

$$\mathbf{F} = \frac{\mathbf{Ci \times AER \times V}}{\mathbf{A \times UC2 \times UC3}}$$

where:

A Area of infiltration (m^2)

AER Building air exchange rate (volumes/hour)

Ci Indoor air concentration (mg/m^3)

UC2 Unit conversion (100,000 cm^2/m^2)

UC3 Unit conversion (3600 sec/hr)

V Volume of building (m^3)

The volatilized constituent diffuses upward through the soil. The rate of diffusion through soil is determined by the soil characteristics and the constituent characteristics. If it is assumed that diffusion through the soil is primarily vapor-phase diffusion (neglecting diffusion through the soil moisture), than effective diffusivity (De) can be approximated as:

$$De = \frac{Di \times (Pt-[M \times B])^{3.33}}{Pt^2}$$

Where:

B Bulk density of soil (g/cm^3)

De Effective diffusion coefficient (cm^2/sec)

Di Diffusivity (cm^2/sec)

M Moisture content of soil (cm^3/g)

Pt Total soil porosity (unitless).

The target concentration of constituent in soil gas was calculated by dividing the product of the maximum acceptable flux and depth to groundwater by the effective diffusion coefficient:

$$Csg = \frac{F \times X}{De}$$

where:

Csg Concentration in soil gas (mg/cm^3)

De Effective diffusion coefficient (cm^2/sec)

F Flux (mg/cm^2/sec)

X Depth to groundwater (cm).

Residual concentrations of petroleum constituents at the site were relatively low. It was therefore assumed that these constituents were dissolved in soil pore water. Thus, the target concentration of constituent in soil gas was used to determine the target concentration in soil pore water based upon the Henry's Law Constant for the constituent dissolved in water:

$$Cpw = \frac{Csg}{UC1 \times Ho}$$

where:

Cpw Concentration in soil pore water (mg/L)

Csg Concentration in soil gas (mg/cm^3)

Ho Unitless Henry's Law Constant

UC1 Unit conversion ($0.001\ L/cm^3$)

The target concentration of constituent in soil pore water was then used to determine the soil Health-Based Goal (HBG):

$$HBG = Cpw \times F_{oc} \times f_{oc}$$

where:

Cpw Concentration in soil pore water (mg/L)

f_{oc} Fraction of organic carbon (unitless)

HBG Health-based goal (mg/L)

K_{oc} Organic carbon partition coefficient (L/kg)

The result of this application of the vapor intrusion model is a concentration of constituent in soil that is expected to result in exposure of receptors at or below the target risk levels.

HEALTH-BASED GOAL FOR SOIL
Daugherty Vapor Intrusion Model

Pacific Cryogenic Company
2311 Magnolia St, Oakland, CA

Constituent: **BENZENE**
Receptor: **ADULT**
Effects: **CANCER**
Property Use: **COMMERCIAL/INDUSTRIAL**

Formula Symbol		Value	Units	Comments
TCR	=	1E-06	---	target carcinogenic risk
BW	=	70	(kg)	body weight
AP	=	25550	(days)	averaging period
CPFi	=	0.10000	(kg-day/mg)	cancer potency factor for inhala
BR	=	0.6	(m3/hr)	breathing rate
EF	=	260	(days/yr)	exposure frequency
ED	=	30	(years)	exposure duration
ET	=	8	(hrs/day)	exposure time
AER	=	0.5	(vol/hr)	bldg air exchange rate
V	=	410	(m3)	volume of building
Af	=	100	(m2)	area of foundation over contam.
IR	=	0.0005	---	infiltration ratio
A	=	0.05	(m2)	area of infiltration
UC2	=	10000	(cm2/m2)	unit conversion
UC3	=	3600	(sec/hr)	unit conversion
Di	=	0.0932	(cm2/sec)	diffusivity
Pt	=	0.35	---	total soil porosity
Pw	=	0.1	---	water-filled porosity
X	=	275	(cm)	depth to impacted soil
UC1	=	0.001	(l/cm3)	unit conversion
H	=	0.00548	(atm-m3/mol)	Henry's Law Constant
Ho	=	0.228	---	unitless Henry's Law Constant
Koc	=	74.5	(l/kg)	organic carbon partition coef
foc	=	0.02	---	fraction of organic carbon

Maximum Allowable
Indoor Air Concentration
Ci = 0.00048 (mg/m3)

Flux
F = 5.44E-08 (mg/cm2/sec)

Effective diffusion coefficient
De = 0.0075 (cm2/sec)

Concentration in Soil Gas
Csg = 0.00 (mg/cm3)

Concentration in Soil Pore Water
Cpw = 9 (mg/L)

HEALTH-BASED SOIL GOAL

HBG = 13.0 (mg/kg)

HEALTH-BASED GOAL FOR SOIL
Daugherty Vapor Intrusion Model

Pacific Cryogenic Company
2311 Magnolia St, Oakland, CA

Constituent: **ETHYLBENZENE**
Receptor: **ADULT**
Effects: **NON-CANCER**
property use: **COMMERICAL/INDUSTRIAL**

Formula Symbol		Value	Units	Comments
THI	=	0.5	---	target hazard index
BW	=	70	(kg)	body weight
AP	=	10950	(days)	averaging period
RfDi	=	0.29	(mg/kg/day)	inhalation reference dose
BR	=	0.6	(m3/hr)	breathing rate
EF	=	260	(days/yr)	exposure frequency
ED	=	30	(years)	exposure duration
ET	=	8	(hrs/day)	exposure time
AER	=	0.5	(vol/hr)	bldg air exchange rate
V	=	410	(m3)	volume of building
Af	=	100	(m2)	area of foundation over conta
IR	=	0.0005	---	infiltration ratio
A	=	0.05	(m2)	area of infiltration
UC2	=	10000	(cm2/m2)	unit conversion
UC3	=	3600	(sec/hr)	unit conversion
Di	=	0.06667	(cm2/sec)	diffusivity
Pt	=	0.35	---	total soil porosity
Pw	=	0.1	---	water-filled porosity
X	=	275	(cm)	depth to impacted soil
UC1	=	0.001	(l/cm3)	unit conversion
H	=	0.00868	(atm-m3/mol)	Henry's Law Constant
Ho	=	0.361	---	unitless Henry's Law Constant
Koc	=	177.5	(l/kg)	organic carbon partition coef
foc	=	0.02	---	fraction of organic carbon

Maximum Allowable
Indoor Air Concentration
Ci = 2.97 (mg/m3)

Flux
F = 0.00034 (mg/cm2/sec)

Effective diffusion coefficient
De = 0.0054 (cm2/sec)

Concentration in Soil Gas
Csg = 17.28 (mg/cm3)

Concentration in Soil Pore Water
Cpw = 47,845 (mg/L)

HEALTH-BASED SOIL GOAL

HBG = 169,851 (mg/kg)

HEALTH-BASED GOAL FOR SOIL
Daugherty Vapor Intrusion Model

Pacific Cryogenic Company
2311 Magnolia St, Oakland, CA

Constituent: **n-HEXANE**
Receptor: **ADULT**
Effects: **NON-CANCER**
property use: **COMMERICAL/INDUSTRIAL**

Formula Symbol		Value	Units	Comments
THI	=	1	---	target hazard index
BW	=	70	(kg)	body weight
AP	=	10950	(days)	averaging period
RfDi	=	0.057	(mg/kg/day)	inhalation reference dose
BR	=	0.6	(m3/hr)	breathing rate
EF	=	260	(days/yr)	exposure frequency
ED	=	30	(years)	exposure duration
ET	=	8	(hrs/day)	exposure time
AER	=	0.5	(vol/hr)	bldg air exchange rate
V	=	410	(m3)	volume of building
Af	=	100	(m2)	area of foundation over contam.
IR	=	0.0005	---	infiltration ratio
A	=	0.05	(m2)	area of infiltration
UC2	=	10000	(cm2/m2)	unit conversion
UC3	=	3600	(sec/hr)	unit conversion
Di	=	0.07461	(cm2/sec)	diffusivity
Pt	=	0.35	---	total soil porosity
Pw	=	0.1	---	water-filled porosity
X	=	275	(cm)	depth to impacted soil
UC1	=	0.001	(l/cm3)	unit conversion
H	=	0.77	(atm-m3/mol)	Henry's Law Constant
Ho	=	32.030	---	unitless Henry's Law Constant
Koc	=	890	(l/kg)	organic carbon partition coef
foc	=	0.02	---	fraction of organic carbon

Maximum Allowable
Indoor Air Concentration
Ci = 1.17 (mg/m3)

Flux
F = 0.0001329 (mg/cm2/sec)

Effective diffusion coefficient
De = 0.0060 (cm2/sec)

Concentration in Soil Gas
Csg = 6.07 (mg/cm3)

Concentration in Soil Pore Water
Cpw = 189 (mg/L)

HEALTH-BASED SOIL GOAL

HBG = 3,372 (mg/kg)

HEALTH-BASED GOAL FOR SOIL
Daugherty Vapor Intrusion Model

Pacific Cryogenic Company
2311 Magnolia St, Oakland, CA

Constituent: **TOLUENE**
Receptor: **ADULT**
Effects: **NON-CANCER**
property use: **COMMERICAL/INDUSTRIAL**

Formula Symbol		Value	Units	Comments
THI	=	0.5	---	target hazard index
BW	=	70	(kg)	body weight
AP	=	10950	(days)	averaging period
RfDi	=	0.11	(mg/kg/day)	inhalation reference dose
BR	=	0.6	(m3/hr)	breathing rate
EF	=	260	(days/yr)	exposure frequency
ED	=	30	(years)	exposure duration
ET	=	8	(hrs/day)	exposure time
AER	=	0.5	(vol/hr)	bldg air exchange rate
V	=	411	(m3)	volume of building
Af	=	100	(m2)	area of foundation over contam.
IR	=	0.0005	---	infiltration ratio
A	=	0.05	(m2)	area of infiltration
UC2	=	10000	(cm2/m2)	unit conversion
UC3	=	3600	(sec/hr)	unit conversion
Di	=	0.07828	(cm2/sec)	diffusivity
Pt	=	0.35	---	total soil porosity
Pw	=	0.1	---	water-filled porosity
X	=	275	(cm)	depth to impacted soil
UC1	=	0.001	(l/cm3)	unit conversion
H	=	0.00674	(atm-m3/mol)	Henry's Law Constant
Ho	=	0.280	---	unitless Henry's Law Constant
Koc	=	132.5	(l/kg)	organic carbon partition coef
foc	=	0.02	---	fraction of organic carbon

Maximum Allowable
Indoor Air Concentration
Ci = 1.13 (mg/m3)

Flux
F = 0.00013 (mg/cm2/se

Effective diffusion coefficient
De = 0.0063 (cm2/sec)

Concentration in Soil Gas
Csg = 5.59 (mg/cm3)

Concentration in Soil Pore Water
Cpw = 19,954 (mg/L)

HEALTH-BASED SOIL GOAL

HBG = 52,878 (mg/kg)

HEALTH-BASED GOAL FOR SOIL
Daugherty Vapor Intrusion Model

Pacific Cryogenic Company
2311 Magnolia St, Oakland, CA

Constituent:	**TOTAL XYLENES**
Receptor:	**ADULT**
Effects:	**NON-CANCER**
property use:	**COMMERICAL/INDUSTRIAL**

Formula Symbol		Value	Units	Comments
THI	=	1	---	target hazard index
BW	=	70	(kg)	body weight
AP	=	10950	(days)	averaging period
RfDi	=	2.0	(mg/kg/day)	inhalation reference dose
BR	=	0.6	(m3/hr)	breathing rate
EF	=	260	(days/yr)	exposure frequency
ED	=	30	(years)	exposure duration
ET	=	8	(hrs/day)	exposure time
AER	=	0.5	(vol/hr)	bldg air exchange rate
V	=	411	(m3)	volume of building
Af	=	100	(m2)	area of foundation over contam.
IR	=	0.0005	---	infiltration ratio
A	=	0.05	(m2)	area of infiltration
UC2	=	10000	(cm2/m2)	unit conversion
UC3	=	3600	(sec/hr)	unit conversion
Di	=	0.07164	(cm2/sec)	diffusivity
Pt	=	0.35	---	total soil porosity
Pw	=	0.1	---	water-filled porosity
X	=	275	(cm)	depth to impacted soil
UC1	=	0.001	(l/cm3)	unit conversion
H	=	0.0063	(atm-m3/mol)	Henry's Law Constant
Ho	=	0.262	---	unitless Henry's Law Constant
Koc	=	854	(l/kg)	organic carbon partition coef
foc	=	0.02	---	fraction of organic carbon

Maximum Allowable
Indoor Air Concentration
Ci = 40.95 (mg/m3)

Flux
F = 0.00467461 (mg/cm2/sec)

Effective diffusion coefficient
De = 0.0058 (cm2/sec)

Concentration in Soil Gas
Csg = 222.29 (mg/cm3)

Concentration in Soil Pore Water
Cpw = 848,228 (mg/L)

HEALTH-BASED SOIL GOAL

HBG = 14,487,732 (mg/kg)