PES Environmental, Inc.
Engineering & Environmental Services

A Report Prepared For:

Alameda County Environmental Health Services
1131 Harbor Bay Parkway, Suite 250
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Attention: Mr. Barney Chan

WORKPLAN
SOIL AND GROUNDWATER REMEDIATION
PACIFIC ELECTRIC MOTOR COMPANY
1009 66TH AVENUE
OAKLAND, CALIFORNIA

MARCH 22, 2001 #565

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1.0 INTRODUCTION

This report has been prepared by PES Environmental, Inc. (PES) on behalf of Pacific Electric Motor Company (PEM) for the property located at 1009 66th Avenue in Oakland, California (Plate 1). In a August 29, 2000 letter to PEM, Alameda County Environmental Health Services division (ACEHS) requested that a workplan be prepared for remediation of soil and groundwater affected with petroleum hydrocarbons, including methyl tert-butyl ether (MTBE), a gasoline additive. ACEHS agreed with the findings of PES' Evaluation of Groundwater Remediation Options, presented in the First Quarter 2000 Groundwater Monitoring Report for the site (PES, 2000). The evaluation noted that because monitored natural attenuation might require more than 5 years and therefore be unacceptable to ACEHS, utilizing oxidation techniques to expedite the remediation appeared to be appropriate. ACEHS requested that PES further evaluate injection of oxidizing chemicals, preferably using hydrogen peroxide or Fenton's Reagent.

This report summarizes site environmental conditions (including UST removal and various investigations), evaluates remediation technology (as requested by ACEHS), and describes the recommended scope of work involving soil excavation, disposal and placement of oxygen-releasing compound (ORC).

2.0 SUMMARY OF ENVIRONMENTAL CONDITIONS

A description of the site and a discussion of the characteristics of site contaminants are presented below.

2.1 Site Description

The subject site is located in a residential and light industrial area of Oakland, California and is presently used to repair large electric motors. PEM formerly operated a 2,000-gallon steel gasoline underground storage tank (UST) and dispenser on the east side of the warehouse building (Plate 2). The tank was reportedly installed in approximately 1975 (ENVIRON, 1997).

2.2 Investigation History

In February 1995, the UST was removed by W. A. Craig, Inc. (WAC). Observations at the time of removal indicated that the tank was in good condition and no holes were evident. However, free-phase gasoline product was observed on the water surface in the tank excavation. Soil samples collected from the UST excavation and associated piping trenches detected total petroleum hydrocarbons as gasoline (TPH-g) at concentrations up to 10,000 milligrams per kilogram (mg/kg).

In April 1995, WAC performed a soil investigation consisting of nine soil borings (GP1 through GP9) to delineate the lateral and vertical extent of the petroleum hydrocarbons in soil

(WAC, 1995). Sampling locations are shown on Plate 2. Benzene and TPH-g were detected in soil samples at concentrations up to 1,900 mg/kg (GP2 at 8 feet bgs) and 16 mg/kg (GP7 at 8 feet bgs), respectively (Table 1).

On the basis of the results of the soil investigation, WAC prepared and implemented a remediation program to remove soil affected by petroleum hydrocarbons (WAC, 1997). WAC excavated affected soil from the vicinity of the UST and dispenser island to depths of up to 24 feet below ground surface (bgs). Approximately 1,500 cubic yards of soil were excavated and stockpiled onsite, and 116,000 gallons of petroleum hydrocarbon-affected water were pumped from the excavation and disposed. Residual concentrations of TPH-g and benzene in confirmation soil samples reportedly ranged up to 930 mg/kg and 7.4 mg/kg, respectively; however, at sampling location 11-TB, TPH-g and benzene were detected at concentrations of 2,800 and 18 mg/kg, respectively (Table 1 and Plate 2). No additional soil excavation was performed in the vicinity of 11-TB.

ENVIRON, Inc. (ENVIRON) installed and sampled three shallow monitoring wells (MW-1, MW-2, MW-3) in June 1997 to evaluate groundwater conditions in the vicinity of the former UST (Plate 2). The well installation program, associated soil sampling, and the first round of quarterly groundwater monitoring were summarized in the ENVIRON report *Soil and Ground Water Investigation, Summary Report, Pacific Electric Motor Co., 1009-66th Avenue, Oakland, California*, dated July 17, 1997 (ENVIRON, 1997). ENVIRON concluded that the remediation performed had successfully removed the source of the petroleum hydrocarbons (i.e., the former UST), and that residual concentrations of petroleum hydrocarbons in soil and groundwater were present only in the immediate vicinity of the former UST.

PES conducted three additional quarterly monitoring events through late 1997 and early 1998, as directed in an August 19, 1997 ACEHS letter to PEM. After completion of the fourth quarter of groundwater monitoring, PES prepared an evaluation of residual health risks. The evaluation utilized historical soil data collected by WAC and groundwater data from the March 1998 sampling event (PES, 1998). These data indicated that concentrations were decreasing and there was no health risk from residual petroleum hydrocarbons.

After review of the health risk evaluation report, ACEHS indicated that it was not satisfied with site characterization and in a May 13, 1998 letter to PEM, requested further soil and groundwater sampling in the vicinity of the former UST (ACEHS, 1998a). Two soil borings (SB-1 and SB-2) were drilled within the backfill of the former UST excavation, and one monitoring well (MW-4) was installed downgradient of the former UST. Petroleum hydrocarbons were generally not detected in the excavation backfill, although groundwater samples collected from both soil borings indicated the presence of MTBE. At well MW-4, elevated concentrations of petroleum hydrocarbons were found in soil (TPH-g up to 660 mg/kg, and benzene up to 2.8 mg/kg) and in groundwater (TPH-g up to 170,000 micrograms per liter [µg/L], benzene up to 26 µg /L, and MTBE up to 26 µg /L). A soil sample collected from 5 feet bgs during installation of MW-4, approximately 24 feet southwest of 11-TB, detected concentrations of TPH-g (21 mg/kg) and benzene (0.085 mg/kg); no MTBE was detected in this sample. At GP6, located approximately 40 feet

south of GP2, no petroleum hydrocarbons were detected in soil samples. The additional investigation was summarized in the PES report *Results of Additional Soil and Groundwater Investigation, 1009 66th Avenue, Oakland, California*, dated November 11, 1998 (PES, 1998).

2.3 Quarterly Groundwater Monitoring

A quarterly groundwater monitoring program, which began in June 1997, is ongoing. Sampling results for the four monitoring wells from the most recent sampling event in October 2000 indicate that elevated concentrations of petroleum hydrocarbons are present in groundwater at monitoring wells MW-1 and MW-4. Benzene and MTBE were detected in water samples from MW-4 at concentrations of 6,700 and 68,000 µg/L, respectively. However, no petroleum hydrocarbons were detected in wells MW-2 and MW-3 located downgradient of the former UST location with respect to observed groundwater flow direction. Table 2 presents current and historical groundwater analytical data.

2.4 Site Hydrogeology

Soils encountered during drilling were fine-grained sediments consisting primarily of silts and clays typical of the margin of San Francisco Bay. No readily-transmissive water-bearing units were observed. The fine-grained silts and clays result in low hydraulic conductivities and therefore the rate of groundwater flow and dissolved chemical migration is low. Further, the high organic carbon content typically found in the Bay sediments retards migration of dissolved chemicals.

Based on water-level elevations and placement of well screens in monitoring wells, groundwater appears to occur under semi-confined to unconfined conditions. PES observed saturated conditions during drilling at depths ranging from 7 to 10 feet bgs. The potentiometric surface in the four monitoring wells typically ranges from approximately 2.9 to 6.5 feet bgs.

Water-level elevation data collected from monitoring wells at the site indicate that groundwater flow is at a nearly flat gradient to the south to southwest, toward Lion Creek. A stable plume of dissolved petroleum hydrocarbons associated with the former UST is limited in area and is not migrating off the site. Further, the low conductivity and high organic carbon content of the Bay Mud water bearing zone limits the potential for the plume to migrate. Petroleum hydrocarbons have generally not been detected in groundwater monitoring wells located near the downgradient edge of the property.

2.5 Recommended Cleanup Concentrations

A previously-prepared Corrective Action Plan (CAP) presented the results of a Risk-Based Corrective Action (RBCA) evaluation of risks to human health (PES, 1999). The RBCA evaluation compared the maximum concentrations of benzene, toluene, ethylbenzene, xylenes, and MTBE detected in soil and groundwater to calculated concentrations that would be protective of human health under various exposure scenarios. The exposure scenarios included

volatilization of chemicals from the subsurface into outdoor and indoor air. The RBCA evaluation suggested that concentrations of benzene in groundwater exceed human health-based cleanup levels for both outdoor and indoor air exposures, and toluene concentrations exceed health-based cleanup levels in an indoor air exposure scenario. Though no structures overlie the area of groundwater contamination and therefore no indoor air exposure scenario currently exists, PES recommended that conservative cleanup levels of 150 μg/L and 25,000 μg/L be established for benzene and toluene, respectively, under an indoor air exposure scenario. A cleanup level of 25,000 μg/L for benzene in groundwater would appear to be appropriate based on the RBCA evaluation for an outdoor air exposure setting. ACEHS has indicated that remediation is required to reduce MTBE concentrations in groundwater below 10,000 μg/L (ACEHS, 2000). PES recommends that this level be adopted as the target cleanup level for MTBE in groundwater.

2.6 Remediation Objectives

Based on the observed concentrations of residual petroleum hydrocarbons in subsurface soils and groundwater, the remediation objectives for this site are to: (1) reduce the mass of residual contaminants in the subsurface soils, and (2) expedite the degradation of contaminant levels in groundwater to meet the recommended cleanup concentrations (refer to Section 2.5). For this site, PES evaluated: (1) injecting hydrogen peroxide/Fenton's Reagent, (2) additional source area removal, and (3) enhanced in-situ bioremediation of groundwater. An evaluation of the feasibility of these remediation options, followed by a selection of the preferred remedial approach, is presented in Sections 3.0 and 4.0, respectively.

3.0 EVALUATION OF RECOMMENDED REMEDIAL MEASURES

3.1 Injection of Hydrogen Peroxide/Fenton's Reagent

Based on PES' experience and understanding of the successful use of injecting hydrogen peroxide/Fenton's Reagent to remediate petroleum hydrocarbons in the subsurface, the ideal lithology consists of soils with a grain size of fine sand or coarser materials of relatively high hydraulic conductivity, low organic content, and a soil pH between 2 and 4. As discussed above, the subsurface soils at this site are primarily low hydraulic conductivity silts and clays, which are not conducive to successful remediation by these injection techniques.

Attempts at using a high-pressure injection system to deliver oxidants to target depths at a site with similar fine-grained soil, resulted in very limited success. The remediation contractor at that site, FASTEK Engineering Support Services, concurred that this injection technology would not likely be appropriate for the PEM site because of the fine-grained soil. This assessment of the feasibility of using oxidant injection technology at sites containing fine-grained soil was also mirrored in interviews with Mr. Chuck Headlee of the Regional Water Quality Control Board, San Francisco Bay Region, and Ms. Donna Drogos and Mr. Lane Davis of the Santa Clara Valley Water District. These regulators have had direct experience

observing injection of hydrogen peroxide and Fenton's reagent at petroleum hydrocarbon sites within the San Francisco Bay area.

Therefore, remediation of soil and groundwater using injection of oxidizing chemicals is not an optimal solution for the PEM site.

3.2 Additional Source Area Removal

Elevated concentrations of petroleum hydrocarbons were left in place in the vadose zone at sampling location 11-TB. As described above, TPH-g and benzene were detected at concentrations of 2,800 and 18 mg/kg, respectively, in a soil sample from 6 feet bgs at this location, near the southwest corner of the former tank excavation. MTBE was not analyzed during excavation activities. Additionally, at boring GP2, TPH-g was detected at a concentration of 1,900 mg/kg (8 feet bgs). South and west of the area between 11-TB and GP2, petroleum hydrocarbon concentrations in vadose zone soils decrease significantly.

These data suggest that a significant mass of petroleum hydrocarbons, including BTEX and MTBE, are present in vadose zone and capillary fringe soils over a limited area. Removal of contaminant mass from soils in contact with groundwater would reduce the mass of chemicals dissolving in water and result in the reduction of TPHg, BTEX and MTBE concentrations in groundwater downgradient of the former UST location. Excavation and disposal of affected soils is readily implementable, cost-effective and proven.

3.3 Enhanced In-Situ Bioremediation of Groundwater

PES previously recommended enhanced passive in-situ bioremediation of groundwater at the PEM site (PES, 1999). Bioremediation involves stimulating native bacteria through the addition of oxygen and possibly nutrients to the affected zone, which results in the accelerated degradation of petroleum hydrocarbons by these microbes. This remedial technology has been previously approved by the RWQCB and implemented at similar sites in California.

ORC is an oxygen-releasing product manufactured by Regenesis of San Clemente, California and is an established application of this technology. ORC is a powder form of time-release magnesium peroxide. The ORC product contains both magnesium oxide and magnesium peroxide (the active ingredient). Essentially, ORC is "oxygenated magnesia" and releases the oxygen upon contact with water. The spent magnesium peroxide is converted to magnesium hydroxide (a suspension of magnesium hydroxide in water is ordinary "milk of magnesia"). ORC releases of oxygen have been documented to enhance microbial growth in both soil and groundwater, and in turn, accelerate biodegradation rates of petroleum hydrocarbons.

Several technical bulletins prepared by Regenesis documenting the results of ORC in conjunction with cleanup of petroleum hydrocarbons are included in Appendix A.

4/4/01
Conv w/ S. Germanes / W. Mast

Question's:

- How was the amt of ORC to be added to excavation & slurry injected calculated?
- How much water will be removed? at least 2 excavation worth 1000 gallons
  will sample GW.
- Reuse 1ppm total BTEX not just B.
- did they consider adding enhanced bio-compds / nutrients · micro organisms · surfactants } to
- How about adding observation/extraction well in the excavation for sampling or addition of (*)?

4.0 SELECTED REMEDIAL ACTIONS–SOIL EXCAVATION AND ENHANCED BIOREMEDIATION

Removal of additional petroleum hydrocarbon-affected soil south of the former UST excavation, coupled with enhanced bioremediation, is the recommended remediation approach. Source area removal and replacement with clean, imported fill materials will reduce leaching of petroleum hydrocarbons in groundwater.

4.1 Soil Excavation

The hydrocarbon-affected soils between the southern limit of the UST excavation, well MW-4 and boring GB2 will be excavated, profiled and disposed offsite at an appropriately licensed disposal facility. Based on historical data, the hydrocarbon-affected soil is generally present between approximately 5 and 10 to 13 feet bgs. Soil will be excavated from a 30 by 70 foot area (Plate 3). To minimize the amount of water to be pumped and disposed from the excavation, soil excavation will generally extend to a depth of approximately 10 feet. ?

A qualified contractor using a backhoe will conduct the excavation. The asphalt surface will be removed and segregated for recycling/disposal. The vadose zone soil to a depth of approximately 5 feet bgs will be removed and segregated through field screening and characterized to evaluate offsite disposal/recycling and reuse alternatives. Hydrocarbon-affected soil (typically present below 5 feet bgs) will be stockpiled separately and covered until disposal arrangements are completed. Offsite disposal of the hydrocarbon-affected soil will be conducted based on the soil stockpile analytical results and in accordance with applicable Federal, State, and local regulations. 10'

will the excavate to GW? or to what depth?

Confirmation soil samples will be collected from the sidewalls of the excavation using a hand sampler and the backhoe. The sidewall soil samples will be collected within the capillary fringe "smear zone" at depth intervals corresponding to the depth of previously-collected soil samples exhibiting elevated concentrations of petroleum hydrocarbons. In general, the backhoe bucket will not be decontaminated between sampling locations; however, in order to avoid cross contamination of samples, soil samples will be collected from soil that does not come in direct contact with the bucket surface.

Following collection, each soil sample liner will be sealed with Teflon tape, polypropylene end caps and silicon tape. The soil samples will be labeled, and stored in an iced cooler for delivery to a California Department of Heath Services-approved laboratory for chemical analysis. Confirmation soil samples will be analyzed for TPHg using EPA Test Method 8015 modified, and for BTEX and MTBE using EPA Test Method 8260. The analyses will be performed utilizing a 5-day turn-around time.

Groundwater is expected to be encountered during the excavation. Accumulated water will be evacuated and temporarily stored in tanks. Samples of extracted groundwater will be collected and analyzed to evaluate disposal options.

Once completed, the excavation will be backfilled using segregated overburden material and clean, imported fill. The 1999 RBCA evaluation calculated that benzene at a concentration of 1.8 mg/kg in subsurface soil did not present a risk to human health. PES proposes to use a threshold of 1.0 mg/kg for benzene and 100 mg/kg for TPH-g for determining the suitability of overburden soil used as backfill material. Excavated soil with detected concentrations above these criteria will be disposed off of the site.

The portion of the excavation below the saturated zone (expected to be approximately 6 feet bgs) will be backfilled using coarse gravel and geotextile fabric. ORC will be mixed with the gravel to assist in the natural biodegradation of petroleum hydrocarbons (refer to Section 4.2). Fine-grained silts and clays will be placed above the rock backfill, from 6 feet bgs to within 6 inches of the ground surface). The fine-grained fill material will be placed in 8 to 12 inch lifts, and compacted to 90 percent relative maximum density. The subgrade and asphalt pavement will be replaced to match the thickness and grade of the existing materials.

4.2 Passive In-Situ Bioremediation System

The in-situ bioremediation system will consist of ORC placed within saturated coarse rock backfill materials. In addition, because ORC in the excavation backfill will only reach a portion of the affected saturated zone, ORC slurry will be injected using direct-push technology in the area south of the UST excavation.

Excavation Backfill

An estimated 200 pounds of palletized ORC will be mixed with gravel and placed in the excavation to a depth of 6 feet bgs. The ORC in the saturated portion of the excavation backfill will provide a continuous supply of oxygen to shallow groundwater.

ORC Slurry Injection

ORC will be injected into the saturated zone as a slurry using direct-push drilling methodology. On the basis of the site lithology consisting primarily of silts and clays, and the relatively flat water table, a grid spacing of approximately 10 feet will provide adequate density to release oxygen over the plume area. PES estimates that the borings will cover a 50-foot by 80-foot area between the former UST excavation area and the south property line. The area of application is superimposed on the Fourth Quarter 2000 water-level elevation map (Plate 3).

ORC Filter Sock Placement

ORC filter socks will be placed in wells MW-1 and WAC-1 (Plate 3). The ORC Filter Socks will provide a continuous supply of oxygen, and will be replaced when they no longer maintain elevated dissolved oxygen concentrations. No sock will be placed in well MW-4.

Groundwater samples from this well will be used to evaluate the effectiveness of the overall source removal (excavation) and ORC application program

4.3 Quarterly Groundwater Monitoring

A quarterly groundwater monitoring program will be performed concurrently with passive in-situ bioremediation. The current groundwater monitoring program, in progress since 1997, will continue to evaluate the effectiveness of the remediation program. The quarterly monitoring program includes the collection and analysis of groundwater samples from wells MW-1 through MW-4 for TPHg, BTEX, and MTBE. In addition, groundwater samples will be analyzed in the field for dissolved oxygen to demonstrate that biological degradation of petroleum hydrocarbons is occurring.

Initially, following installation of the ORC filter socks, dissolved oxygen measurements will be collected once per month to determine an initial rate of consumption of ORC. PES estimates that the ORC will be replaced after approximately every three months of use. (socks)

4.4 Schedule of Corrective Action Implementation, Monitoring, and Reporting

Upon ACEHS approval, the corrective action will be implemented. The remediation program will consist of the following elements: (1) soil excavation; (2) confirmatory sidewall soil sampling; (3) removal of groundwater from the excavation; (4) testing of soil and groundwater for waste characterization purposes; (5) excavation backfilling and ORC placement; (6) waste disposal; (7) reporting; and (8) continuation of quarterly groundwater monitoring. PES anticipates that tasks 1 through 5 can be completed within a 4-week period following receipt of approval to proceed. Task 6 can be completed within 2 weeks of completion of field activities. The report summarizing the work completed can be submitted to ACEHS within 2 weeks following offsite disposal of wastes. The groundwater monitoring program will continue on the current quarterly schedule.

5.0 SUMMARY AND CONCLUSIONS

PES has evaluated site data and additional remediation alternatives, as requested by ACEHS. The results of this assessment indicate that residual petroleum hydrocarbons are still present in saturated soils just south of the former UST excavation. These affected soil result in concentrations of benzene and toluene in groundwater that exceed risk-based screening levels, and corrective action for petroleum hydrocarbon affected soil and groundwater is warranted.

Due to the fine-grained clayey and silty soils that comprise the water-bearing zone at the site, PES recommends additional source removal (soil excavation) and passive in-situ bioremediation of groundwater as the most technically feasible, implementable and cost-effective remedial approach.

The results of quarterly groundwater monitoring indicate that dissolved concentrations of petroleum hydrocarbons do not appear to be migrating off the PEM site. To evaluate the effectiveness of the recommended remediation program, PES recommends continued quarterly groundwater monitoring.

6.0 REFERENCES

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American Society for Testing and Materials (ASTM), 1995. *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.* ASTM E 1739-95.

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Table 1. Summary of Historical Analytical Results for Soil Samples
Pacific Electric Motor Company
1009 66th Avenue, Oakland, California

Sample Location	Date Sampled	Depth	TPH-g	Benzene	Toluene	EB	Total Xylenes	MTBE
1995 WAC Investigation[1]								
GP1	8/24/95	5	130	0.33	3.1	2.2	13	--
	8/24/95	10	1100	13	72	28	150	--
	8/24/95	17	ND	ND	ND	ND	ND	--
GP2	8/24/95	8	1900	ND	6	40	220	--
	8/24/95	13	530	ND	12	1.4	53	--
	8/24/95	18	ND	ND	0.005	ND	0.012	--
	8/24/95	23	5.2	0.01	0.083	0.034	0.14	--
GP3	8/24/95	4.5	ND	ND	ND	ND	ND	--
	8/24/95	11	ND	ND	ND	ND	ND	--
	8/24/95	15.5	ND	ND	ND	ND	ND	--
	8/24/95	20	ND	ND	ND	ND	ND	--
GP4	8/24/95	5	1.3	0.024	0.007	0.006	0.18	--
	8/24/95	10.5	970	11	47	23	130	--
	8/24/95	15.5	ND	ND	0.006	ND	0.013	--
	8/24/95	20	ND	ND	ND	0.007	0.008	--
GP5	8/24/95	5	ND	ND	0.006	0.006	0.049	--
	8/24/95	12.25	230	0.97	10	4.9	27	--
	8/24/95	20	ND	ND	ND	ND	ND	--
GP6	8/25/95	5	ND	ND	ND	ND	ND	--
	8/25/95	10.5	ND	ND	ND	ND	ND	--
	8/25/95	15.5	ND	ND	ND	ND	ND	--
	8/25/95	20	ND	ND	ND	ND	ND	--
	8/25/95	25	ND	ND	ND	ND	ND	--
GP7	8/25/95	8	1300	16	99	31	170	--
	8/25/95	14	260	1.5	8.9	5.1	27	--
	8/25/95	19	ND	ND	ND	ND	ND	--
	8/25/95	24	6.5	0.03	0.18	0.086	0.44	--
	8/25/95	29	ND	ND	0.017	ND	0.012	--
GP8	8/25/95	5	ND	ND	0.012	ND	0.023	--
	8/25/95	12	ND	ND	ND	ND	ND	--
	8/25/95	19	ND	ND	ND	ND	ND	--
GP9	8/25/95	5	1.2	0.16	ND	0.1	0.17	--
	8/25/95	10	1300	14	75	28	160	--
	8/25/95	15	32	1.5	2.2	0.85	4.4	--
	8/25/95	19.5	1.3	0.011	0.02	0.027	0.13	--
1995 WAC UST Excavation Limits[2]								
11-TB-0-W	4/11/95	6	2,800	18	150	72	420	--
1 SWN	8/24/95	11	260	4.4	10	8.1	38	--
2 SWN	8/24/95	20	ND	ND	ND	ND	ND	--
3 SWN	8/24/95	10	530	6.6	41	14	82	--
4 SWN	8/24/95	14	51	0.37	0.11	2.3	0.21	--

Table 1. Summary of Historical Analytical Results for Soil Samples
Pacific Electric Motor Company
1009 66th Avenue, Oakland, California

Sample Location	Date Sampled	Depth	TPH-g	Benzene	Toluene	EB	Total Xylenes	MTBE
(continued)								
5 SWN	8/24/95	21	300	1.4	1.1	0.52	0.33	--
6 PBN	8/24/95	22	300	2.3	1.2	3.2	0.96	--
7 PBN	8/24/95	24	58	0.98	0.1	0.86	0.35	--
8 SWN	8/24/95	13	930	7.4	50	19	110	--
9 SWN	8/24/95	20	1.7	0.026	0.02	0.034	0.13	--
10 PBS	8/24/95	21	93	0.75	0.33	0.55	1.5	--
11 PBS	8/24/95	12	320	0.71	1.1	5.9	7.9	--
12 SWE	8/24/95	21	120	1.6	0.61	2.1	1.5	--
1-82595	8/25/95	23	ND	ND	ND	ND	ND	--
4-82595	8/25/95	9	ND	ND	ND	ND	0.014	--
5-82595	8/25/95	3	1.2	ND	0.005	ND	0.04	--
6-82595	8/25/95	5	ND	ND	ND	ND	0.012	--
1-SW-SSW	8/29/95	13	690	22	22	16	90	--
3-PB-N	8/29/95	24	ND	ND	ND	ND	ND	--
PBSE	11/8/95	19	ND	ND	ND	ND	ND	ND
PBSM	11/9/95	19	ND	ND	ND	ND	ND	ND
PBSW	11/10/95	14	ND	ND	ND	ND	ND	ND
PSSW	11/10/95	13	ND	ND	ND	ND	ND	ND
1997 ENVIRON Investigation[3]								
MW-1	6/10/97	16	480	1.4	0.71	11	35	--
MW-2	6/10/97	16	<1.0	<0.0050	<0.0050	<0.0050	<0.0050	--
MW-3	6/10/97	10	<1.0	<0.0050	<0.0050	<0.0050	<0.0050	--
1998 PES Investigation[4]								
SB-1	9/14/98	5.5	<1.0	<0.005	<0.005	<0.005	0.012	<0.05
SB-2	9/14/98	5.5	<1.0	<0.005	<0.005	<0.005	<0.005	<0.05
MW-4	9/14/98	5	21	0.085	0.28	0.23	1.7	<0.25
	9/14/98	10.5	660	2.8	34	13	70	<0.25
	9/14/98	15.5	3.9	0.77	0.037	0.10	0.31	3.8

Notes:
All results in milligrams per kilogram (mg/kg)
TPH-g = Total petroleum hydrocarbons quantified as gasoline
EB = Ethyl benzene
MTBE = Methyl tert-butyl ether
-- = Not analyzed
ND = Not detected at or above laboratory reporting limit (not provided in W.A. Craig reports)
<1.0 = Not detected at or above laboratory reporting limit indicated
[1] = W.A. Craig, May 16, 1995
[2] = W.A. Craig, May 12, 1997
[3] = ENVIRON, July 9, 1997
[4] = PES, November 11, 1998

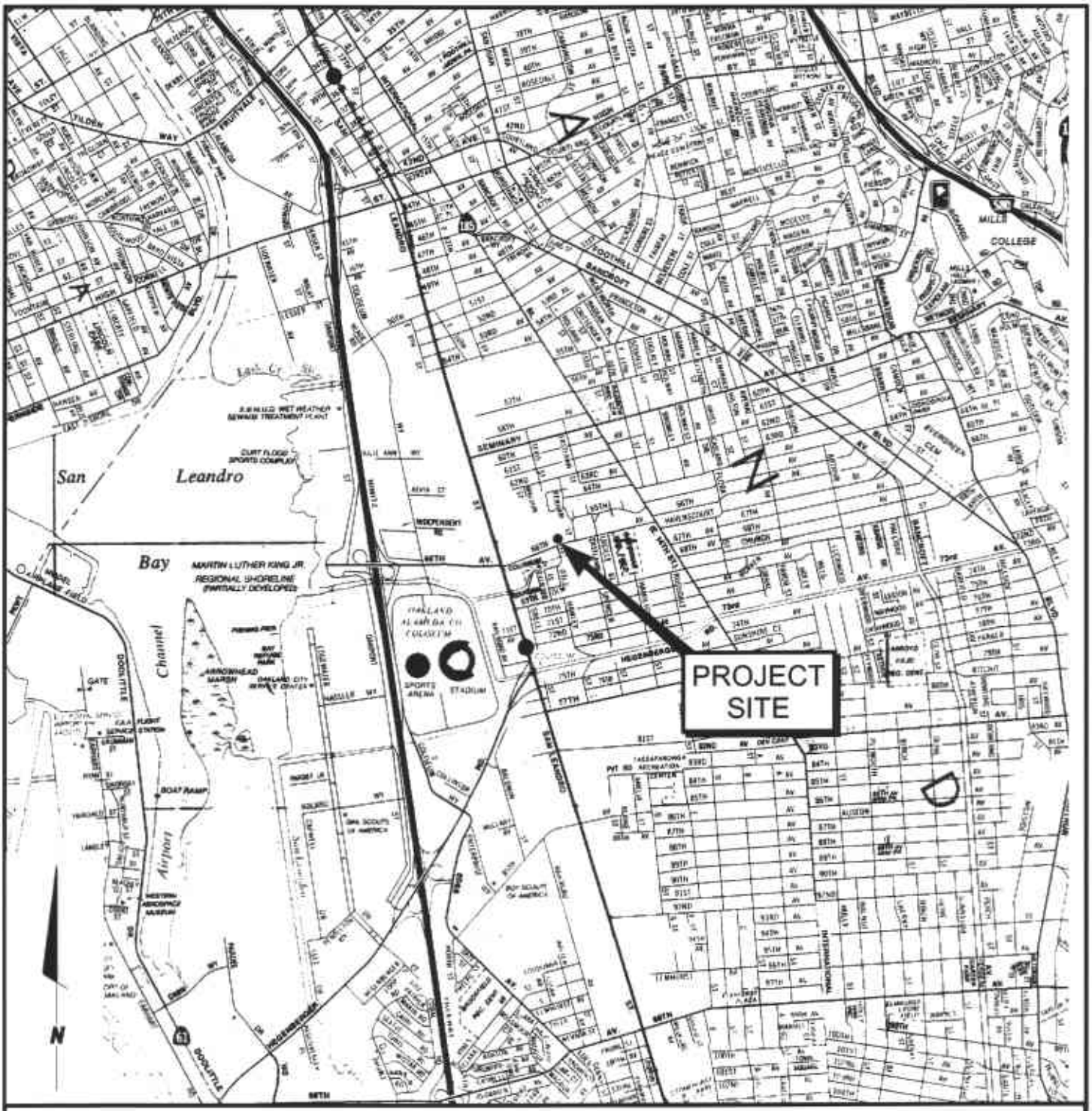
Table 2. Summary of Historical Analytical Results for Groundwater Samples
Pacific Electric Motor Company
1009 66th Avenue, Oakland, California

Sample Location	Date Sampled	Sampled By	TPH-g (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes (µg/L)	MTBE EPA 8020 (µg/L)	MTBE EPA 8260 (µg/L)
MW-1	6/19/97	ENVIRON	18,000	3,300	200	1,100	4,900	<250	--
	9/29/97	PES	29,000	4,800	<25	2,000	3,500	<250	--
	12/16/97	PES	<50	1.3	<0.5	0.6	0.7	<5	--
	3/10/98	PES	190	2.0	<0.5	5.7	1.7	<5	--
	1/19/99	PES	1,000	40	<0.5	18	68	8.3	6.9
	4/15/99	PES	<50	0.92	0.9	0.7	0.87	<5.0	--
	7/30/99	PES	1,400	60	<0.5	63	120	13	<5.0
	11/15/99	PES	3,600	120	<0.5	150	620	<5.0	--
	3/24/00	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	5/18/00	PES	1,300	10	1.2	38	130	8.6	<5.0
	7/26/00	PES	6,400	100	7.4	260	680	<5.0	NA
	10/30/00	**PES**	**6,000**	**130**	**14**	**330**	**950**	**<100**	**NA**
MW-2	6/19/97	ENVIRON	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	9/29/97	PES	<50	<0.5	<0.5	<0.5	<0.5	<5	--
	12/16/97	PES	<50	<0.5	<0.5	<0.5	<0.5	<5	--
	3/10/98	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	1/19/99	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	<5.0
	4/15/99	PES	<50	0.75	0.64	<0.5	0.74	<5.0	--
	7/30/99	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	11/15/99	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	3/24/00	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	5/18/00	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	7/26/00	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	10/30/00	**PES**	**<50**	**<0.5**	**<0.5**	**<0.5**	**<0.5**	**<5.0**	**--**
MW-3	6/19/97	ENVIRON	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	9/29/97	PES	<50	<0.5	<0.5	<0.5	<0.5	<5	--
	12/16/97	PES	<50	<0.5	<0.5	<0.5	<0.5	<5	--
	3/10/98	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	1/19/99	PES	<50	0.78	<0.5	<0.5	<0.5	8.7	<5.0
	4/15/99	PES	<50	5.4	3.9	1.7	5.6	23	25
	7/30/99	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	11/15/99	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	3/24/00	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	5/18/00	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	7/26/00	PES	<50	<0.5	<0.5	<0.5	<0.5	<5.0	--
	10/30/00	**PES**	**<50**	**<0.5**	**<0.5**	**<0.5**	**<0.5**	**<5.0**	**--**

Table 2. Summary of Historical Analytical Results for Groundwater Samples
Pacific Electric Motor Company
1009 66th Avenue, Oakland, California

Sample Location	Date Sampled	Sampled By	TPH-g (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes (µg/L)	MTBE EPA 8020 (µg/L)	MTBE EPA 8260 (µg/L)
MW-4	9/15/98	PES	170,000	26,000	32,000	2,900	18,000	26,000	--
	1/19/99	PES	2,600	1,700	3.8	25	29	13,000	16,000
	4/15/99	PES	210,000	28,000	15,000	3,700	19,000	52,000	67,000
	7/30/99	PES	91,000	16,000	7,500	2,300	8,500	68,000	67,000
	11/15/99	PES	63,000	8,500	2,400	1,400	4,000	57,000	58,000
	3/24/00	PES	95,000	16,000	13,000	2,500	12,000	44,000	NA
	5/18/00	PES	91,000	15,000	10,000	2,200	9,600	64,000	77,000
	7/26/00	PES	130,000	11,000	6,400	1,700	6,500	80,000	NA
	10/30/00	PES	59,000	6,700	2,200	750	3,100	68,000	68,000*

Notes:
TPH-g = Total petroleum hydrocarbons quantified as gasoline (EPA 8015M).
MTBE = Methyl tert-butyl ether (EPA 8020; detected concentrations were confirmed by EPA 8260.)
µg/L = Micrograms per liter.
<50 = Not detected at or above the indicated laboratory reporting limit.
* = MTBE result confirmed but not requantified by EPA Method 8260.



Oakland Map, California State Automobile Association, 1997

PES Environmental, Inc.
Engineering & Environmental Services

Site Location Map
Pacific Electric Motor Company
1009 66th Avenue
Oakland, California

PLATE
1

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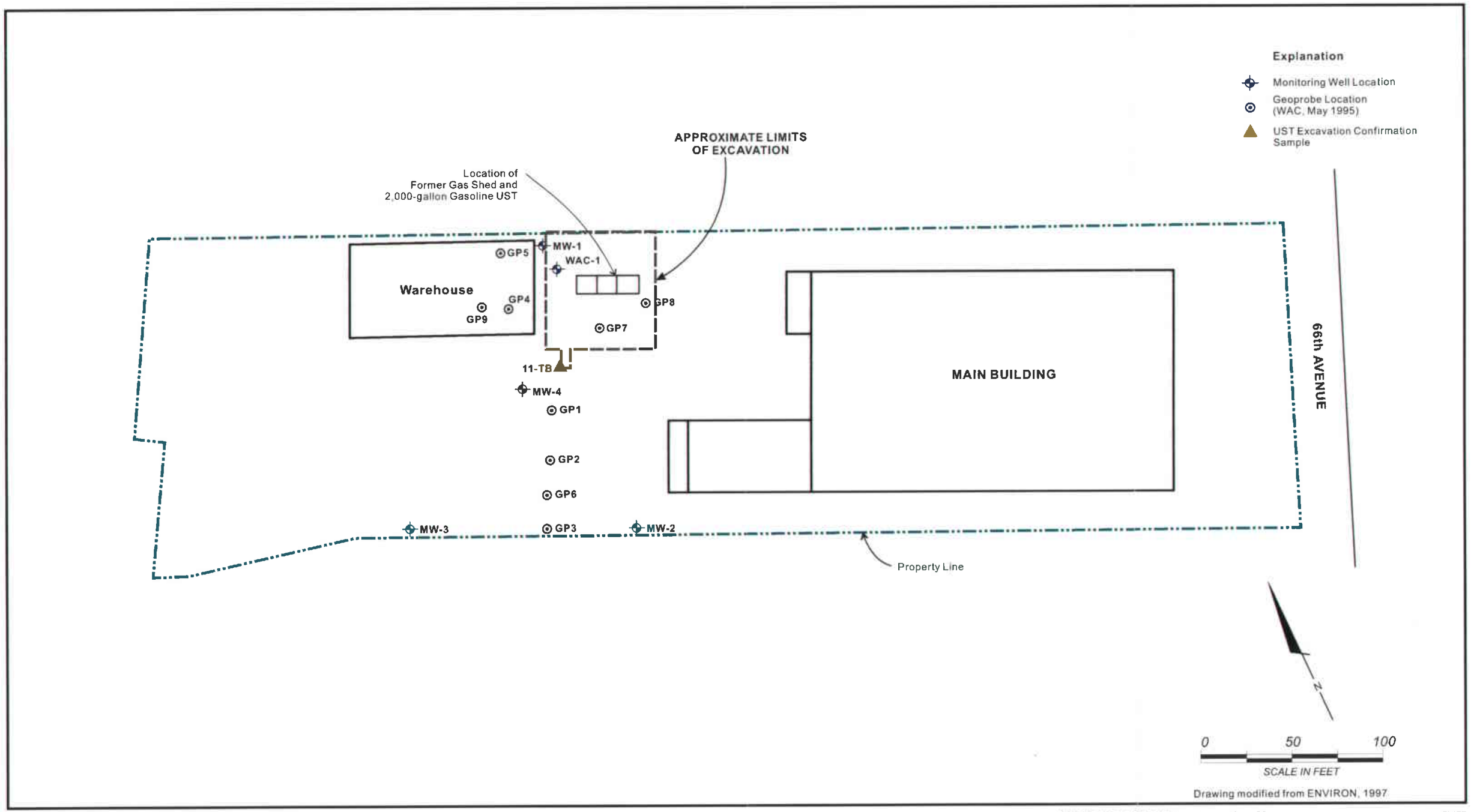
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE



Drawing modified from ENVIRON, 1997

PES Environmental, Inc.
Engineering & Environmental Services

Site Plan and Sampling Location Map
Pacific Electric Motor Company
1009 66th Avenue
Oakland, California

PLATE 2

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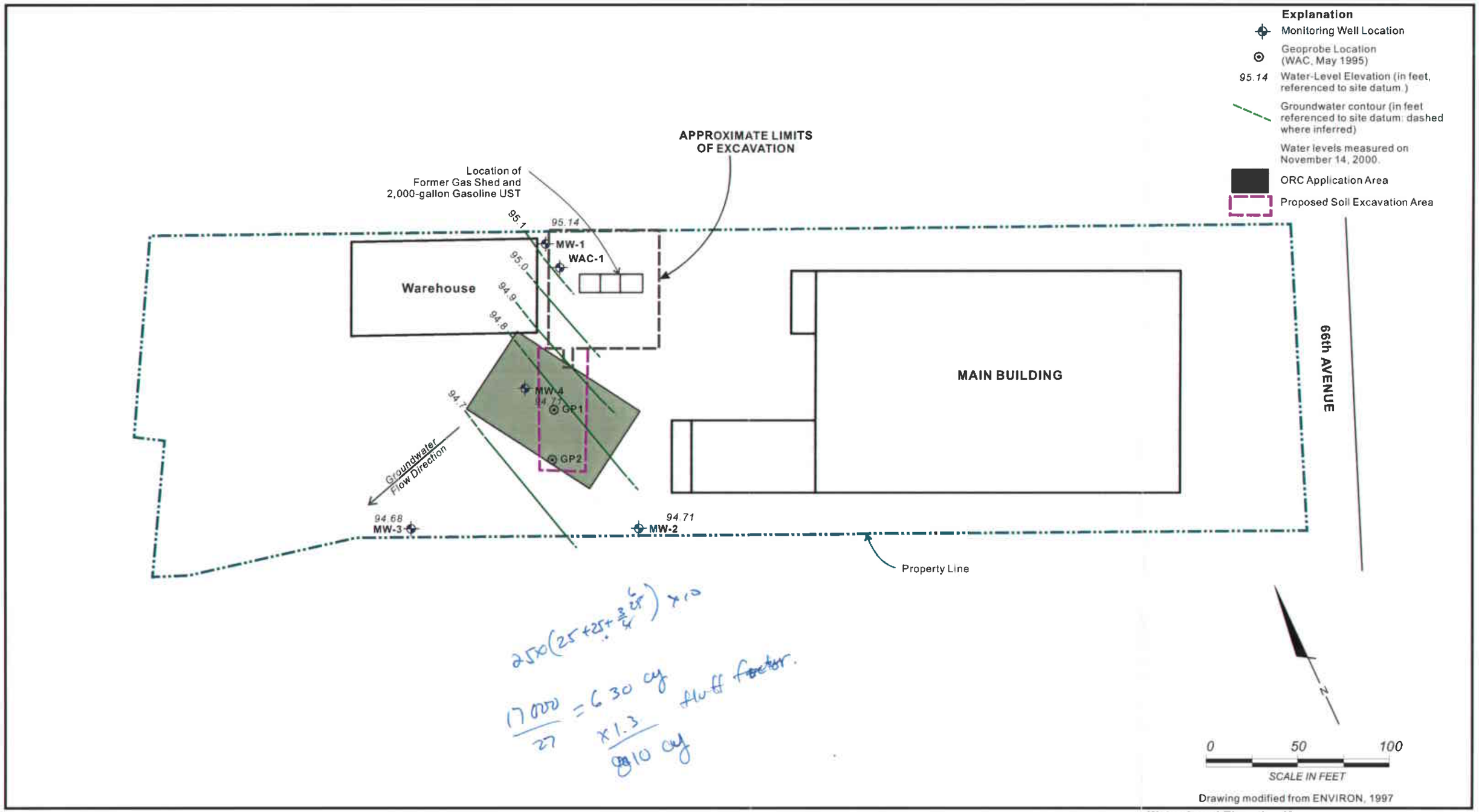


$250\left(25+25+\frac{3}{4}25\right)\times 10$

$\frac{17000}{27} = 630$ cy

630×1.3 fluff factor.

819 cy

PES Environmental, Inc.
Engineering & Environmental Services

Water-Level Elevation Map and Proposed Remediation Areas
Pacific Electric Motor Company
1009 66th Avenue
Oakland, California

PLATE 3

618.001.02.009	61800102009_wp2-01-03.cdr	SC	3/01
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE

APPENDIX A

SELECTED REGENESIS TECHNICAL BULLETINS

ORC TECHNICAL BULLETIN #2.2.3.1

Potential for the Bioremediation of Methyl Tertiary Butyl Ether (MTBE)

The Problem:

The gasoline oxygenate, methyl tertiary butyl ether (MTBE), presents a serious complication in the remediation and closure of properties contaminated with fuel hydrocarbons. Several factors contribute to this complexity:

1. MTBE degrades very slowly under aerobic conditions.
2. MTBE is not recognized as an anaerobically degradable compound.
3. Unlike BTEX, MTBE is highly soluble and does not retard on the aquifer matrix. The compound in therefore capable of rapid and pervasive dispersion in groundwater.
4. The toxicity and carcinogenicity of MTBE have not been established.
5. Taste and odor thesholds for MTBE are very low.
6. Although MTBE is extremely volatile, when dissolved in water it is difficult to strip which complicates sparging and pumping options. In the latter case pumped water may have to be treated in bioreactors.

Just when a coherent and manageable protocol for BTEX remediation is being formed by consultants and regulators (Risk Based Corrective Action - RBCA), the MTBE "wild card" has threatened to change the tenor of the issue. In the words of one national clean-up manager for a major oil company, "We have come so far in managing thousands of our sites and now I feel like I'm back to square one with the MTBE problem."

A Solution in Development - ORC Enhanced Bioremediation

About a year ago, Regenesis began to notice that in wells containing ORC socks MTBE was disappearing at an unusually high rate. Data was sparse as MTBE was rarely measured and reported, however, an intriguing trend was emerging. In some cases the removal rates for MTBE, presumed to be a function of biological degradation, were extremely high. The literature reports aerobic degradation rate constants in a range of .0231 to .0038 (half-life of 30 to 182 days). In the Regenesis data from 11 wells across three diverse oil company sites (CA, MI and NJ), degradation rate constants were in a range of .1447 to .0112 (half-life of 5 to 61 days). The question then became - "What is the role of ORC in this process?"

Figures 1 to 3 present examples of BTEX and MTBE degradation in a single representative well for each of the three sites referenced above. Each example also reflects a low, moderate and high background level of BTEX. We believe that the presence of background hydrocarbons can interfere with the metabolism of MTBE by competent microorganisms. Thus, the documented impact of ORC on BTEX is an important factor in MTBE bioremediation.

This important hypothesis evolved as a result of sharing the data with other researchers in the field. Regenesis has since gathered evidence that supports the concept that in a mixed contaminant system

BTEX is consumed preferentially to MTBE. This is not a competitive inhibition—in that different enzyme systems are responsible for the metabolism of each compound—but rather is a pattern of preferential consumption (BTEX> MTBE). It can be clearly seen in Figures 2 and 3 that there is a lag in degradation of MTBE relative to BTEX. In Figure 1, where BTEX is almost non-existent, MTBE is readily degraded from the outset.

Follow-up laboratory experiments further clarified the issue. Using microbial isolates that use MTBE as a sole carbon source, Regenesis has shown the metabolism of MTBE can be largely inhibited by the addition of BTEX - causing it to fall behind in the preferential sequence of degradation. Furthermore, MTBE metabolism can be predictably modulated by the BTEX, such that when BTEX is removed from the culture MTBE degradation resumes.

Regenesis is now in the process of funding more involved column bioreactor studies which will elucidate the inhibition of MTBE by background hydrocarbons. More importantly, this work will establish a mass balance for the process and identify other important co-factors that may be operating in the system. The first experiments will correlate an increase in CO_2 with a decrease in MTBE to establish that bioremediation is the primary mechanism of removal. Subsequent experiments will employ radioactively labeled MTBE and follow the appearance of various intermediates.

Figure 1

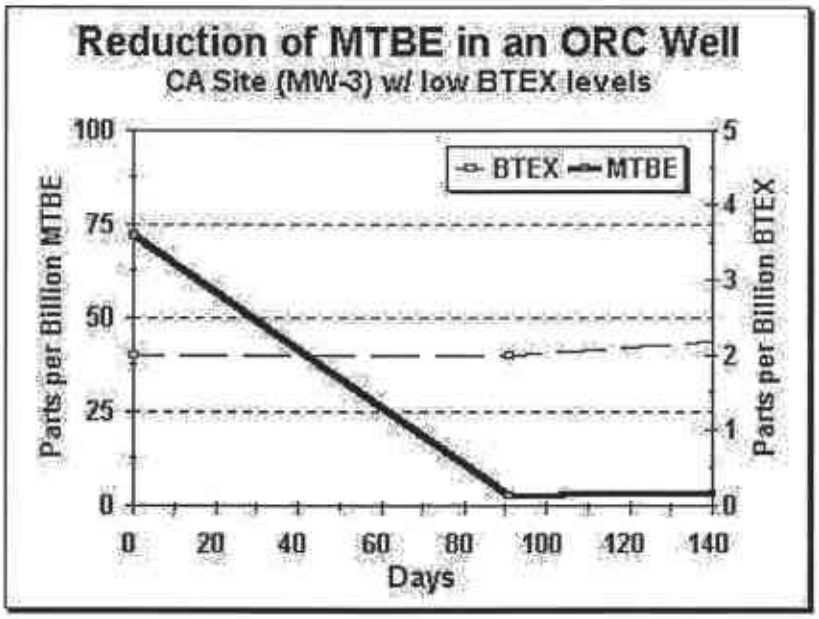


Figure 2

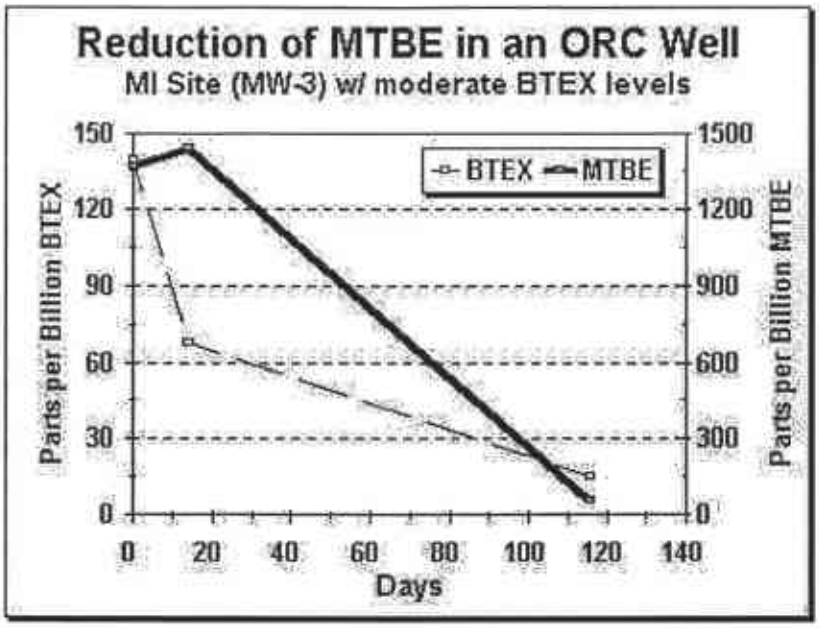
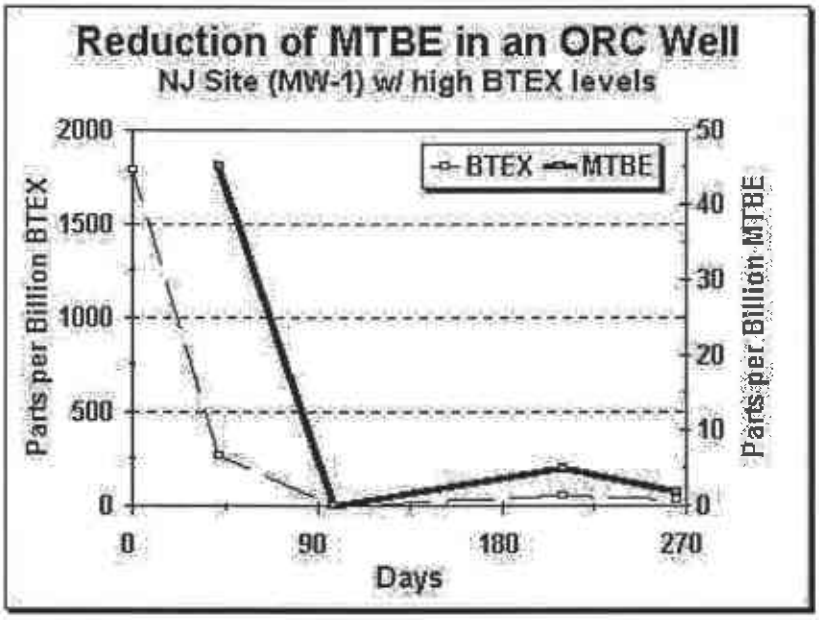


Figure 3



In addition to the commercial features of the project, establishing the relationship between ORC and MTBE bioremediation, the isotope study will also be fundamental to the basic science of MTBE degradation pathways as very little is known about the subject at this time.

Another possible explanation for the higher degradation rates is that MTBE degrading microorganisms, normally slow to metabolize the substrate, do so at greater efficiency in higher oxygen concentrations. This theory will also be tested in the bioreactor experiments. There are examples in the literature, specifically with PCP degrading fungi, that establish a relationship

between high oxygen concentrations and high rates of degradation. This is important because ORC, as a pure oxygen source, is capable of generating dissolved oxygen levels in excess of those achieved by air saturation.

Encouraging results were obtained from a recent data set showing MTBE degradation outside an area that was source treated with ORC slurry injections. In Wisconsin, after about four months, the degradation rate in a well five feet downgradient of the treated area was .0434 (half-life of 25 days). This is presented in Figure 4. Note that these are not measurements from a well with ORC socks; the well is downgradient from an ORC source injection zone and was exposed to oxygenated groundwater derived from the injection array.

Earlier we stated that the biological degradation mechanisms were putative. Several other abiotic explanations must be considered and systematically eliminated; the following dialogue is intended to anticipate the appropriate questions.

Q. Is MTBE being absorbed by ORC? Does ORC chemically destroy MTBE?

A. No. Experiments in the laboratory have shown that there is no chemical or physical reaction between ORC and MTBE. This eliminates the possibility that any type of absorption by ORC or direct chemical oxidation is occurring.

ORC particles are insoluble and, when applied in filter socks, will not migrate from the application well. Groundwater samples were collected by standard purge methods (three to five casing volumes). Any chemical reactions occurring on the surface of ORC particles in the source well would therefore be diluted out, particularly on the sites in question which have low ground water velocity.

Furthermore, the new data show positive results at a distance from the ORC source wells. The fact that oxygen is slowly diffusing from ORC, which in turn is stimulating bioremediation of MTBE and competing species such as BTEX, remains the most the likely mechanism of action.

Q. Is the MTBE being volatilized from the well?

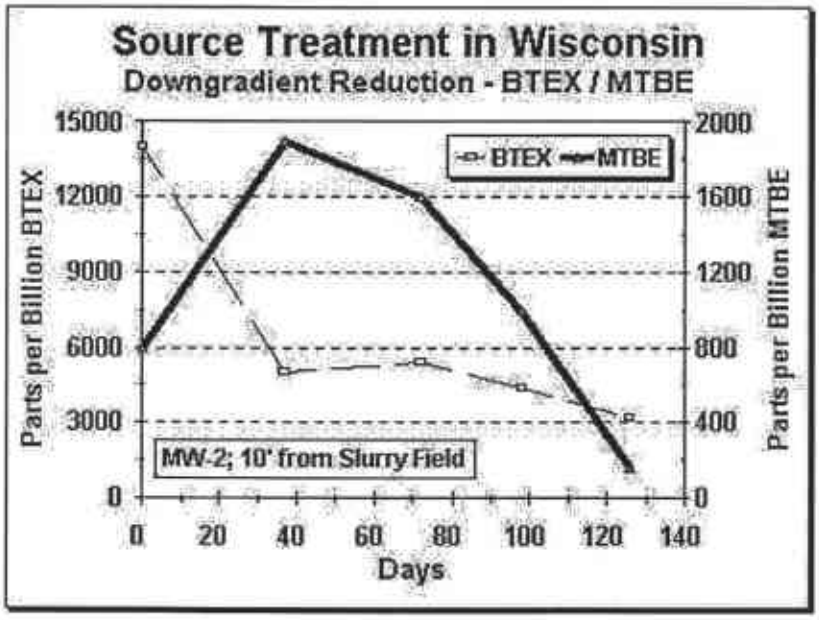
A. This is highly unlikely, although experiments are being planned to account for this. For the moment, one must realize that MTBE does not readily strip and that the release of oxygen from ORC is not forceful like air sparging. If MTBE were being stripped from a well volume, that stripped groundwater would experience the previously mentioned dilution in sampling. In addition, the results in Figure 4, which were derived from a downgradient monitoring point, provide good initial evidence that that MTBE is not being stripped.

Q. Is the MTBE moving through the well zone over time and only appear to be degrading?

A. The fact we have seen the same pattern in multiple wells makes this explanation unlikely. Also, if the rates of MTBE degradation were as dramatic as illustrated in Figures 1-4, then MTBE plumes would become infinitely diluted in short period of time which obviously is not the case.

In conclusion, it appears that MTBE is biodegradable and the application of ORC may be an approach to enhance the bioremediation of MTBE. Given the fact that an MTBE plume will move farther downgradient than the more highly retarded BTEX components, barriers of different configurations are likely required. A tight series of direct push injections to form an ORC "slurry wall," in combination with the use of MTBE degrading microorganisms, will soon be the subject of an investigation by a major oil company. Oxygen barriers using ORC filter socks in wells are also a reasonable approach to cutting off the leading edge of an MTBE plume. Otherwise, standard direct push injections in the core of the plume will address the problem at the source.

Figure 4



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ORC TECHNICAL BULLETIN #3.1.9

ORC Barrier MTBE Remediation in New Jersey

Contaminants	Application Method	Soil Type	Groundwater Velocity
MTBE, BTEX	ORC Barrier	Coarse Gravel	0.04 ft/day

An industrial site in New Jersey was contaminated with benzene and MTBE. The site had 13 USTs which were either abandoned in place or excavated and removed. The contaminant plume area was approximately 275 feet in width and 8 feet thick. Ground water flow direction is to the north at a velocity estimated to be approximately 0.04 foot per day.

Based on the contaminant type and the hydrogeological conditions of the site, an ORC barrier was selected as the best remedial alternative. The barrier was constructed within a trench. In order to enhance the microbial degradation process at the barrier, ORC socks were placed into two rows of 4 inch diameter wells spaced 12 feet on center within the trench. A single row of five wells was installed along the upgradient edge of the trench to oxygenate groundwater immediately as it flowed into the trench. A second row of five wells was installed in offset locations to supply supplemental oxygen. A map of the site detailing the ORC placement wells and monitoring well locations is presented in Figure 1.

Two wells (MW-1 and MW-3) were used to monitor the reduction of benzene and MTBE. Six months after application of ORC, with a changeout of socks occurring at three months, the concentration of benzene dropped from 1,940 to 1,470 ppb and the concentration of MTBE dropped from 1,570 to 1,160 ppb in MW-1 (Figure 2). In MW-3, the concentration of benzene decreased from 329 to 90 ppb and the concentration of MTBE decreased from 1,070 to 9 ppb (Figure 3).

NOTE: The data set represented in the following graphs shows that BTEX levels decrease before MTBE levels. The ORC Technical Bulletin entitled "Potential for the Bioremediation of Methyl Tertiary Butyl Ether (MTBE)" discusses this mechanism in more detail, pointing out that the presence of background hydrocarbons (i.e. BTEX) may interfere with the metabolism of MTBE. Thus, the impact of ORC on BTEX is an important secondary factor in MTBE bioremediation.

Figure 1

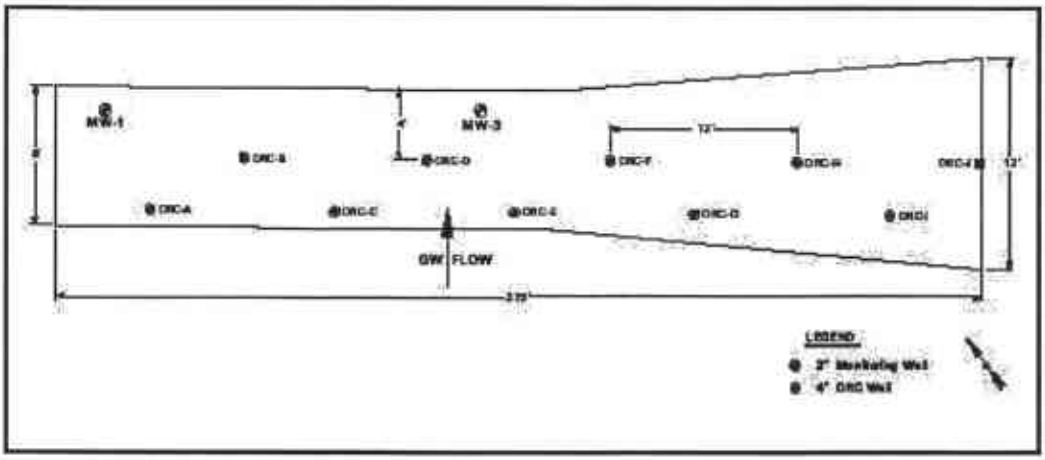


Figure 2

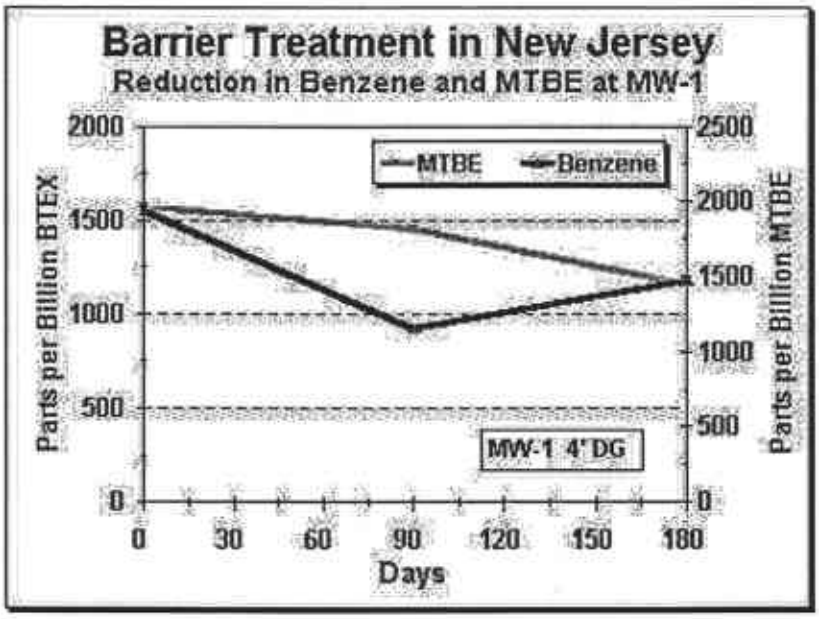
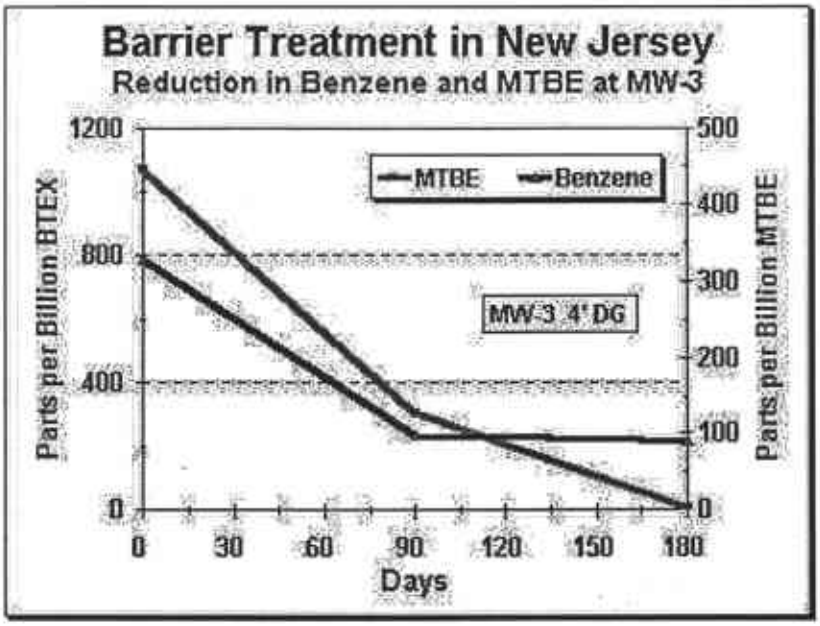


Figure 3



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ORC TECHNICAL BULLETIN #3.1.11

Slurry Injection MTBE Remediation in Wisconsin

Contaminants	Application Method	Soil Type	Groundwater Velocity
MTBE, BTEX	Slurry Injection	Sand	0.2 ft/day

High levels of MTBE and BTEX were detected in the groundwater at a service station in Wisonsin. The contamination was largely due to underground storage tank (UST) leakage at the site. The contaminant plume had MTBE concentrations ranging up to 800 ppb and BTEX concentrations ranging up to 14,000 ppb in a sandy aquifer. The groundwater flow direction is to the east northeast at a velocity of 0.2 foot per day.

Following UST removal and remedial excavation of contaminated soil, ORC slurry was applied into the backfill excavation via Geoprobe® injection. A total of 1,700 pounds of ORC powder were injected in the form of a slurry at the site. Monitoring wells MW-2 and MW-3 were used to monitor the reduction of BTEX and MTBE levels over time. A map of the site detailing the treatment area and monitoring well locations is presented in Figure 1. Following approximately nine months of treatment with ORC, both MTBE and BTEX levels decreased dramatically at MW-2 and MW-3. The decrease in contaminant levels is graphically represented in Figures 2 and 3.

Figure 1

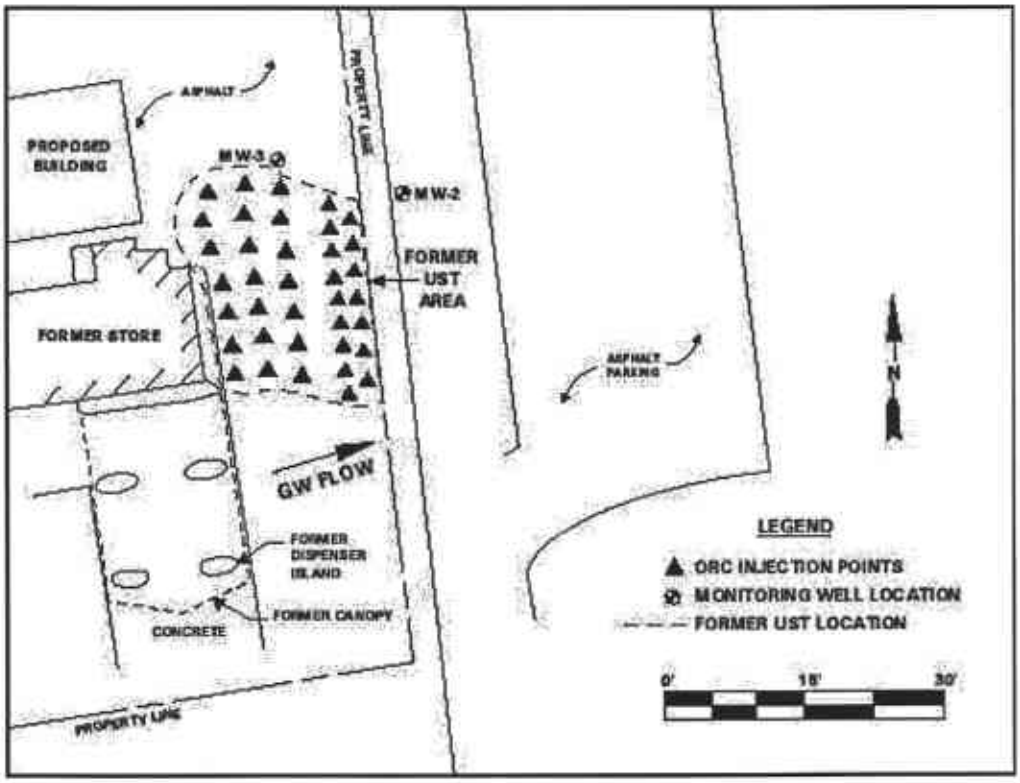


Figure 2

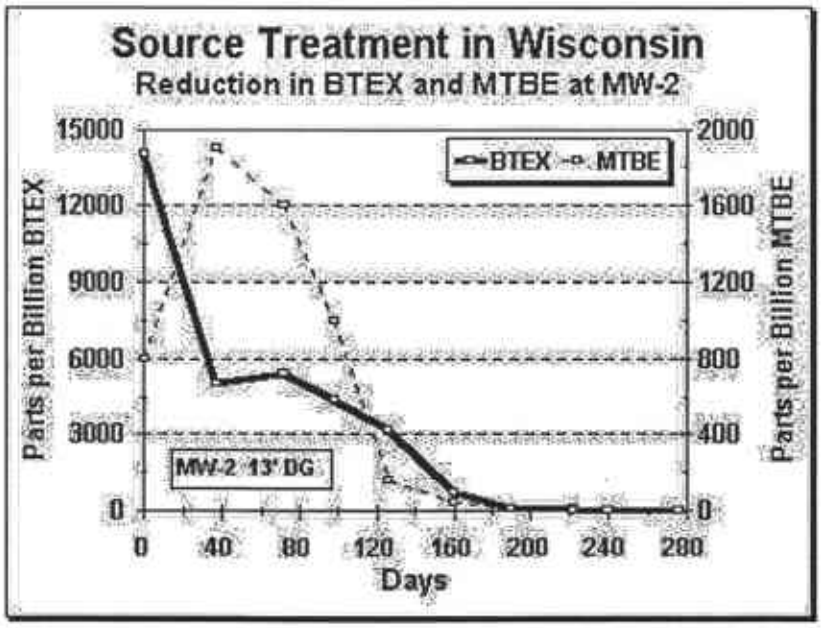
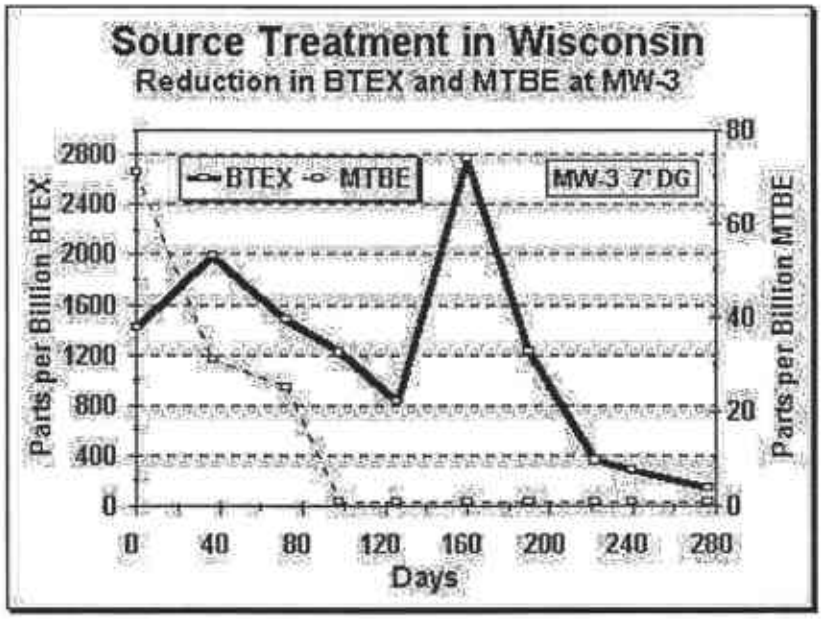


Figure 3



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ORC TECHNICAL BULLETIN # 3.1.13

Slurry Injection BTEX & MTBE Remediation in California

Contaminants	Application Method	Soil Type	Groundwater Velocity
BTEX/MTBE	Slurry Injection	Sandy Silt	Undetermined

A service station in Oakland, California was contaminated with high levels of BTEX and MTBE. Groundwater contamination was the result of leaking underground storage tanks. The aquifer material consists of sandy silt with intermittent clayey silt and silty sand. The depth to groundwater is approximately 7 feet below ground surface. Although aquifer conditions are poorly understood, plume dimension and extent indicate groundwater flow is to the north at an undetermined velocity.

On May 30 and June 24, 1997, a total of 2,550 pounds of ORC were injected as a slurry via Geoprobe along the northern and eastern sides of the existing underground storage tanks. Existing well MW-5 was used to monitor the reduction of BTEX and MTBE. A map of the site detailing the treatment area, groundwater flow direction, and monitoring well location is presented in Figure 1. The reduction of BTEX and MTBE is graphically presented in Figures 2 and 3. Six months following the installation of ORC, BTEX was reduced 99% and MTBE was reduced 30%. Based on these results, this site has been submitted for closure.

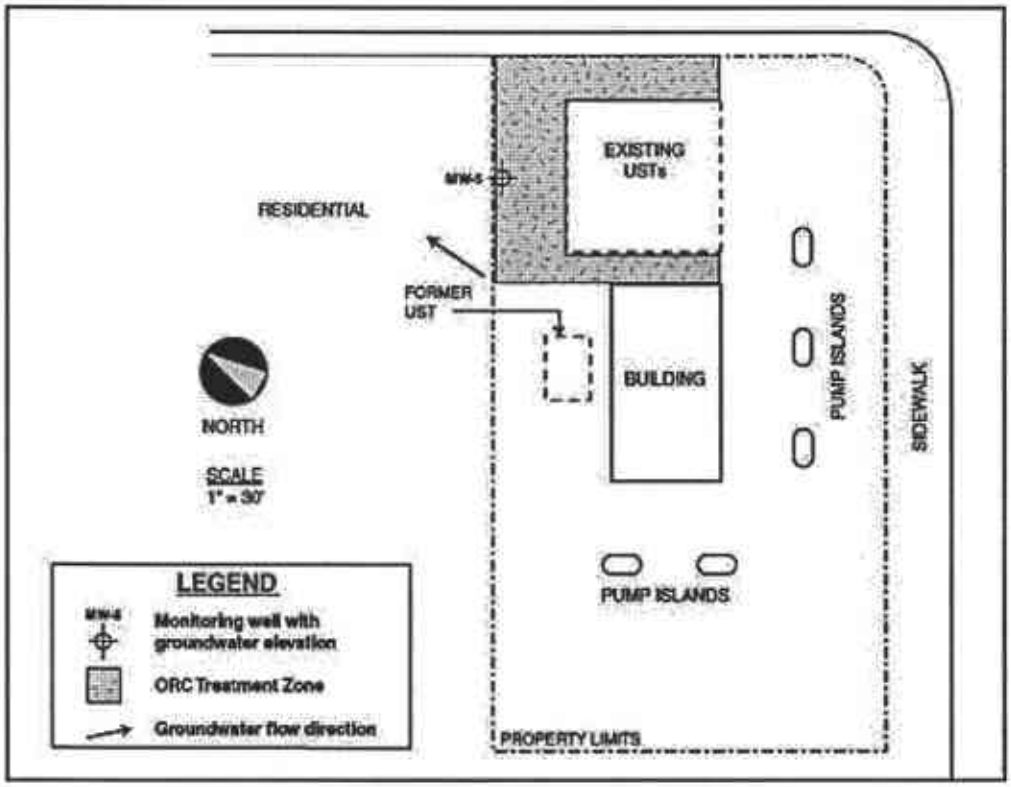

Figure 1

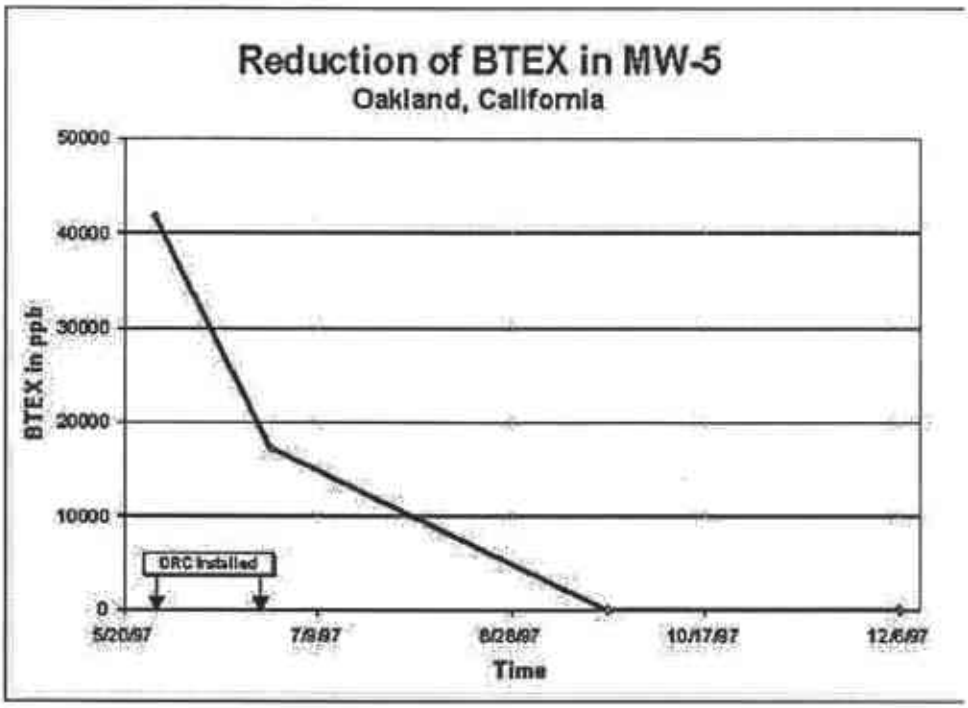

Figure 2

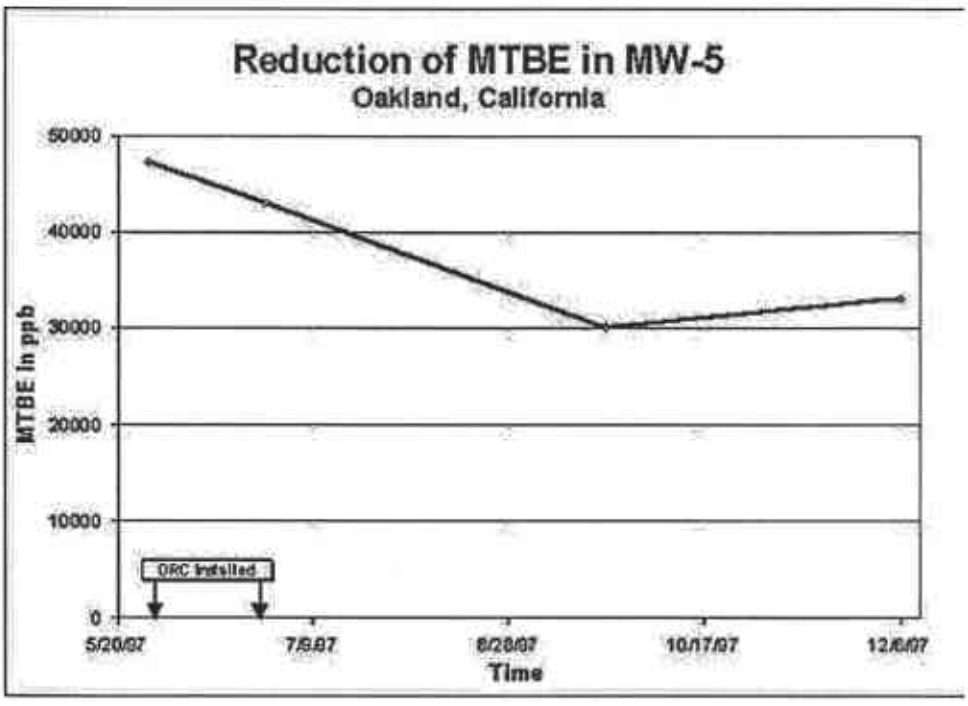

Figure 3

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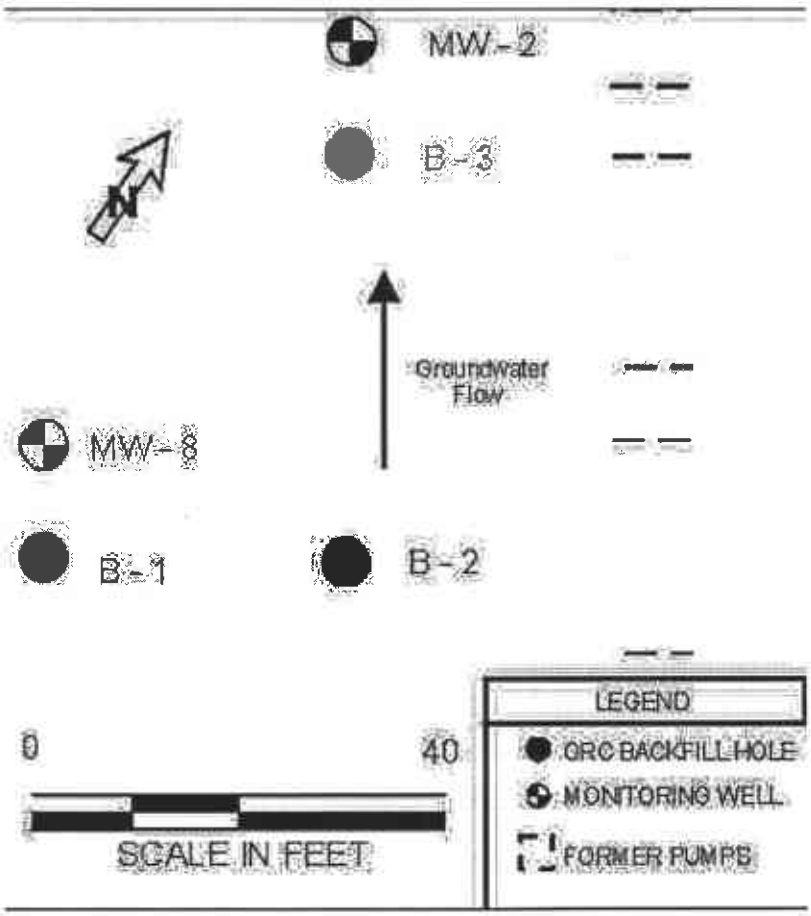
ORC TECHNICAL BULLETIN #3.2.8

Slurry Backfill BTEX, MTBE, and Naphthalene Remediation in Florida

Contaminants	Application Method	Soil Type	Groundwater Velocity
BTEX, MTBE, Naph.	Slurry Backfill	Sand	0.5-5.0 ft/day

An active gas station site in Florida was impacted with a dissolved phase hydrocarbon plume and after conventional high-cost remedial activity some pockets of contamination remained. To correct this residual problem three bore holes were prepared and backfilled with ORC in order to affect the problem areas represented by two monitoring wells (MW-2 and MW-8). Contaminants on the site included BTEX, naphthalene and MTBE.

Site Description and Remedial Design



The groundwater flow direction is towards the North under a gradient of 0.005. The water table is between 4 and 8 feet below ground surface. Groundwater velocity is estimated to be between 0.5 and 5 feet per day in the sandy aquifer.

Three bore holes, each 3 inches in diameter, were augered in at the points shown above. B-1 and B-3 are 5 feet upgradient of MW-8 and MW-2, respectively, and would be expected to have the most influence on those wells. A 7 foot column of ORC slurry containing about 21 pounds of ORC was applied to each of the three bore holes. The total ORC cost was $614. The bore holes were completed with bentonite and cement.

Results

The ORC was installed April 10, 1996; no baseline data was obtained at this time. The first measurements were taken on May 6 (Day 26) and the most recent data set was taken on July 16 (Day 97). It is likely, based on groundwater flow rates, that oxygen reached the monitoring wells and impacted the hydrocarbons before Day 26, such that the levels at Day 0 were probably higher. By Day 97 the results of bioremedial activity are clear. Dramatic reductions are noted in the Figures below.

MW-8 was taken to non-detect for all BTEX components and naphthalene was reduced 88%. There was no MTBE in MW-8.

At MW-2, toluene and MTBE were taken to non-detect and the other components were reduced as follows: xylenes were reduced 95%, ethylbenzene was reduced 93%, benzene was reduced 54% and naphthalene was reduced 66%. Only benzene and naphthalene were slightly above standard, however, these results were only at the mid-point of the average ORC longevity cycle and only within the first application.

Figure 1

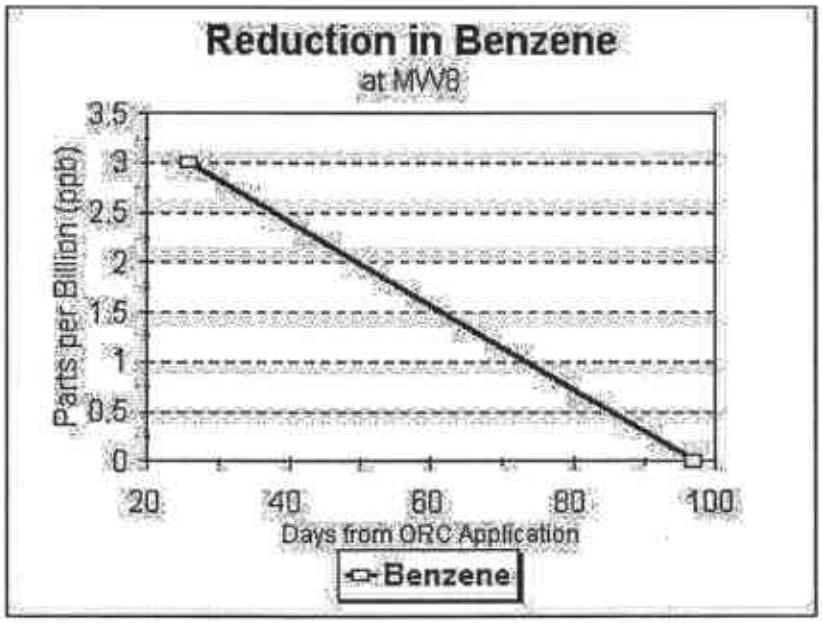


Figure 2

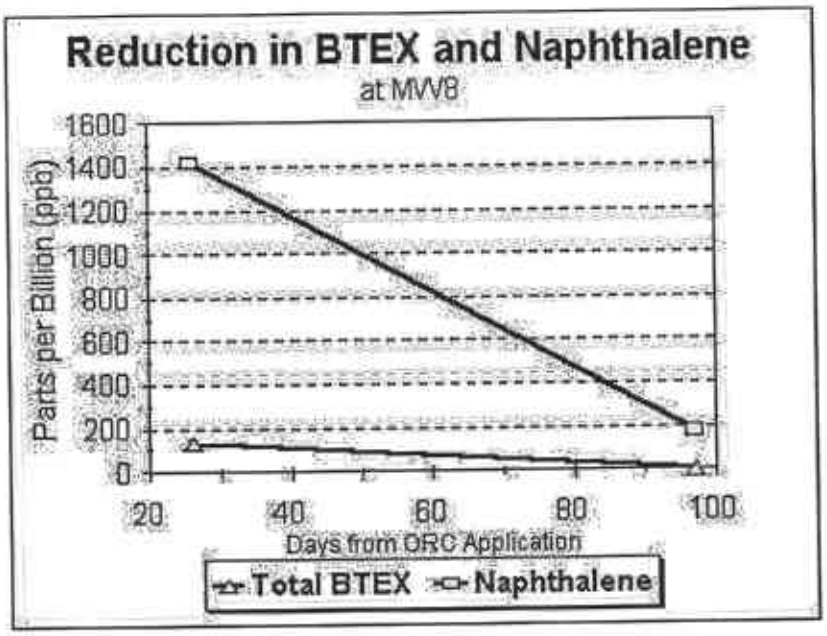


Figure 3

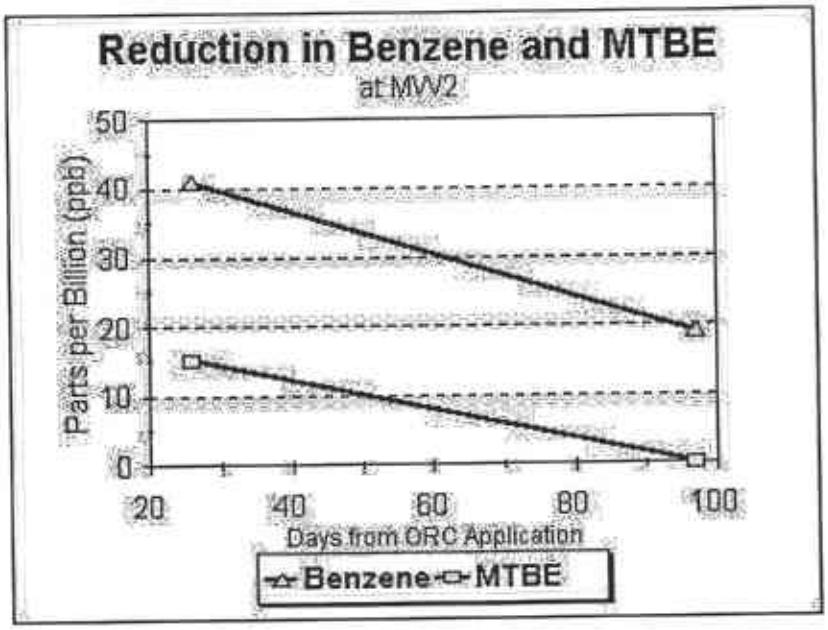
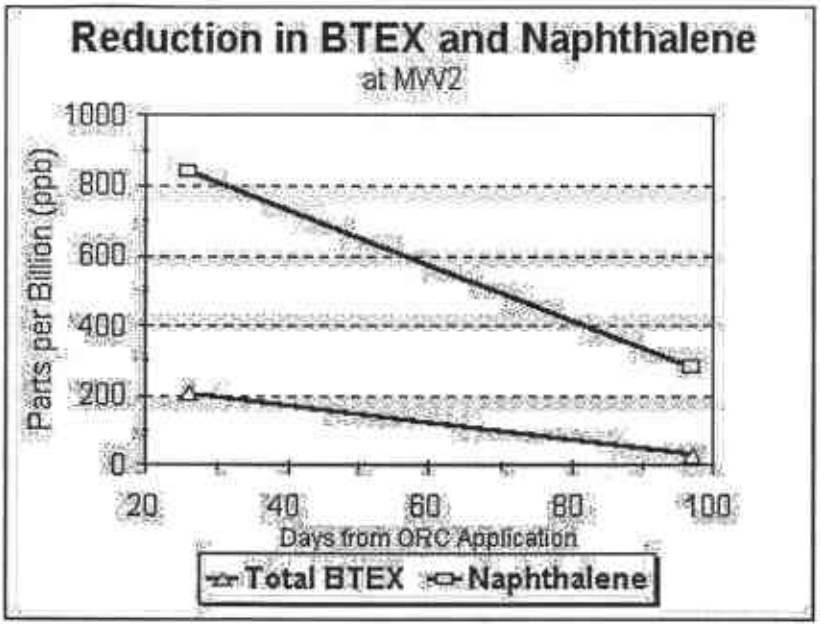


Figure 4



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